



# Biofuels Research Gap Analysis



**Final report to the Biofuels Research  
Steering Group**

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AEA  
329 Harwell  
Didcot  
Oxfordshire  
OX11 0QJ

t: 0870 190 8441  
f: 0870 190 5545

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<b>Author</b>	Name	Pat Howes (AEA), Judith Bates (AEA), Craig Jamieson (AEA), Susan O'Brien (AEA), J Webb (AEA) Nick Barker (AEA), Todd Sajwaj (AEA), Alison Pridmore (AEA). Steve Wiggins (ODI), Henri Leturque (ODI), Nick Dale (Metroeconomica). Thanks to Jeremy Woods (Themba/Porter Alliance), Mairi Black (Themba/Porter Alliance) Jess Chalmers (Winrock), Nigel Mortimer (North Energy) Daniel Kindred (ADAS) and Angela Johnson (RICARDO) for their contributions to the project.
<b>Approved by</b>	Name	Sujith Kollamthodi
	Signature	
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## Biofuels research programme scoping study

Biofuel production is one of the options that governments have to help them develop more sustainable transport and meet international environmental targets. Research has shown that biofuels can reduce carbon emissions, yet they are currently a controversial area of science. Insufficient data exists to fully understand the impact of biofuel production on communities and the environment; and, whilst biofuels could be a powerful tool in reducing carbon emissions, they must be produced in a sustainable manner if they are not to do more harm than good.

This study has identified a number of issues that need to be addressed in order for the Government to develop policies that will move the UK towards sustainable biofuel production. Its key findings are:

### **An improved understanding is needed of the indirect impacts of biofuels, particularly indirect land-use change (ILUC), including:**

- modelling frameworks for ILUC.
- the definition of “alternative” lands (idle, marginal, and degraded land) and “alternative” feedstocks (wastes, by-products and residues) and their contribution to reducing indirect effects.
- the potential contribution of improvements in yield and productivity to decreasing indirect effects.
- the potentially beneficial impact of biofuel co-product use on land-use pressures.

### **An improved understanding is needed of the environmental, socio-economic and supply-chain impacts of biofuels, including:**

- modelling the impacts of expanded biofuel production on commodity markets.
- monitoring the potential harm to poor and vulnerable people in developing countries arising as a result of higher prices for food on international markets, and from localised effects on access to land and working conditions of marginalised people resulting from domestic development of biofuel industries in the developing world.
- assessing the promising potential of some developing countries with underused land to establish biofuel industries serving local, national and export markets.
- understanding the direct effects of biofuels crops on soil and water resources.

### **There is a need for research into developing vehicle, production and infrastructure technologies to meet longer-term biofuel and sustainability targets, including:**

- understanding the benefits of second-generation technologies and identifying which advanced technologies are most suited to the UK.
- understanding the impact of higher biofuel targets on vehicle performance.
- developing skills and training to support the biofuels industry.
- researching vehicle compatibility issues.
- understanding the impact of using biofuels in rail, air and sea transport.
- developing knowledge transfer mechanisms between research and industry.
- providing funding for new biofuels infrastructure overseas in regions which could be important for the development of biofuels for import into the UK.

### **There are a number of cross-cutting research gaps that need to be addressed in order to support the development of a UK biofuels policy, including:**

- obtaining improved data to support modelling, analysis and policy development across a wide range of areas.
- understanding the wider impacts of biofuels policies on markets.
- research into “grandfathering provisions” (these allow for existing companies/organisations/plants/machinery to be temporarily outside incoming legislation).

## Executive Summary

Biofuels are one of a number of options that governments have to enable us to develop more sustainable transport. Biofuels provide governments with the potential to address a number of important policy issues – they can help to reduce CO<sub>2</sub> emissions from the transport sector; they provide an opportunity to improve security of supply for transport fuels in many areas; and they offer options to support rural development. Based on these potential benefits, governments worldwide have set targets for the inclusion of biofuels in transport fuels. However, over the last couple of years, life-cycle analysts have begun to have concerns about some of the direct and indirect impacts from the cultivation of biofuels. In particular, the following questions arose:

- ***What changes in soil carbon levels occur as a result of planting biofuels?***
- ***What happened to crops that were displaced as a result of planting biofuels?***
- ***Did demand for these crops drop or did it switch to another commodity?***
- ***Or were crops planted elsewhere on land that had not been used before for agriculture and what were the carbon implications of this?***

Furthermore, there were concerns that setting biofuels targets merely meant that industry would seek the cheapest form of biofuel grown on the cheapest land. Such actions might lead to the destruction of habitats such as tropical rainforest or drainage of peatland, with a resultant release of carbon as these habitats were destroyed. The net impact could be additional carbon releases into the atmosphere - a perverse, unintended consequence of the action governments were taking to decrease carbon emissions.

The truth is that the jury is still out on a lot of these issues. We do not understand if these impacts happen, mainly because we do not have the underlying data to prove anything one way or the other for certain. Consequently, biofuels are currently a controversial topic area, and it is difficult to move forward in such circumstances.

What we do know is that, in the right circumstances, biofuels can be a powerful tool in our battle to reduce carbon emissions, but that we must take care to produce them in a sustainable manner. That is, due regard must be taken of the land-use changes caused by an expansion of the market for biofuels, and of the other direct and indirect effects that a rapid increase in biofuels can have on the markets for other agricultural commodities.

With these factors in mind, the UK Government commissioned this analysis to understand the areas where there are currently gaps in the scientific understanding of the impacts of biofuels. By carrying out this gap analysis, we have been able to identify and prioritise the areas that should be the focus of future research on biofuels. In carrying out this analysis, the following questions were used to help focus our work on the key issues related to biofuels:

1. ***Where do we need to be in terms of our understanding of biofuels?*** The Government has developed a set of key questions for research relating to biofuels; the ability to answer these questions will allow the UK to develop a robust, evidence-based biofuels policy.
2. ***What do we know now?*** There is plenty of research being carried out worldwide on the topic of biofuels, but we need to know the focus of this research and how effectively the outputs from ongoing research will address the Government's questions.

3. ***Where are the gaps in our knowledge?*** In assessing where we need to be and what we know now, we have identified the gaps in our understanding of the impacts of biofuels, and we have made recommendations on the topic areas where new research is needed to fill these gaps.
4. ***How should we address the gaps in knowledge?*** The identified research gaps, which are set out below, may be addressed in a number of ways. We have made recommendations on the routes, mechanisms and partnerships that could be used to best deal with the various gaps.

It should be stressed that the main purpose of the gap analysis was not to answer these questions, but to use these questions as a means of identifying whether current global research activities are sufficient to enable the development of robust biofuels policies or whether new research is required.

## Key findings

The main focus of this work has been to identify the key research gaps that need to be addressed to move sustainable biofuels forward in the UK. However, prior to presenting these gaps, we have set out some high-level observations established during the course of this analysis.

- **It is unlikely that the UK or EU will be able to supply all of their biofuels from within Europe; a significant proportion will need to be imported. As a result, there is a fundamental need for work to be conducted on an international basis and for information to be available internationally.** International working has additional benefits: it allows the UK to leverage its funding for any one research area; it allows better access to information and information exchange; and it allows the UK to build on foundations developed elsewhere. There are good existing mechanisms for international work which could be used, including the European Commission's Framework programme, Intelligent Energy Europe, the European Environment Agency and Joint Research Council programmes, the International Energy Agency Bio-energy Agreement, the Global Bio-Energy Partnership (GBEP) and UN initiatives. The UK may also wish to consider bilateral agreements for work with the USA and Brazil, along with aid initiatives or other international initiatives to work with Sub-Saharan Africa or South America.
- **Some issues are also international in impact.** These include modelling of indirect land-use change (ILUC), the development of sustainability criteria and certification and standards for fuels. For these areas, international harmonisation is important and the UK has strong international links with relevant organisations that it can use to participate in this international effort (e.g. GBEP, the Roundtable on Sustainable Biofuels, the UN, OECD, the IEA and international standards bodies (CEN in Europe)).



- **Issues relevant to the sustainability of biofuels must not be seen in isolation.** ILUC and land-use change have impacts on greenhouse gas (GHG) life-cycle analysis and overlap with many other issues, such as crop yields, biodiversity, and the use of soil and water resources. All of these areas require more monitoring, data collection and resolution between satellite imagery and on-the-ground monitoring. We have identified that there are gaps in knowledge that are common to a number of different research issues. However, work on these different topics is often carried out by researchers in different disciplines and organisations. We recommend the creation of a framework whereby communication and information exchange can be encouraged to ensure that the area as a whole moves forward at the pace needed to achieve policy aims. We also identified a gap in access to information. In particular, the requirement to publish in peer-reviewed journals tends to result in information being dispersed over a wide range of sources. A central database of such information would enable rapid access and good information exchange.
- **There is a need for roadmaps.** This is particularly the case for advanced conversion technologies, potentially for the examination of socio-economic impacts, and for agricultural research. These roadmaps should build on current initiatives within the Research Councils, the Low Carbon Vehicle Partnership, the Renewable Fuels Agency, the Carbon Trust, the National Non-Food Crops Centre (NNFCC) and Government departments.

The results of this gap analysis have been grouped into four key findings, each of which relates to a major topic area where we believe that further research is required in order to support the development of robust, evidence-based biofuels policies. A high-level summary of the main findings of the gap analysis is presented in the box below.

- **Key finding 1: We need to improve our understanding of the indirect impacts of biofuels, particularly indirect land use change (ILUC), with a specific focus on developing and agreeing a framework for ILUC modelling.**
- **Key finding 2: We need to improve our knowledge of the environmental, socio-economic and supply-chain impacts of biofuels.**
- **Key finding 3: There is a need for new research to examine the evolution of the production, infrastructure and vehicle technologies necessary to enable us to meet longer-term biofuels targets for transport and for improving the sustainability of biofuels.**
- **Key finding 4: There are a number of cross-cutting research gaps that need to be addressed in order to support the development of biofuels policy.**

For each of the four key findings outlined in the box above, a more detailed summary of the findings from the gap analysis is set out below.

**Key finding 1: We need to improve our understanding of the indirect impacts of biofuels, particularly indirect land-use change (ILUC)**

ILUC happens when land-use changes occur not just where biofuel crops are planted, but as a result of displacement of the previous land use elsewhere (including in other countries, which can be some distance from the original crops). This process is not well understood at present. ILUC may ultimately lead to pressure for deforestation or conversion of grasslands or peat land to agriculture, as well as loss of biodiversity in these habitats. We need research to help us understand ILUC better in order to develop indirect sustainability criteria. The key ILUC research gaps are as follows:

- **There is no current agreed framework for ILUC modelling.** In the absence of data, modelling is the best way to understand the impacts that biofuels may have and how to address these impacts. Modelling can help us develop better biofuels policies in future, with the aim of ensuring sustainable biofuels and minimising ILUC. This modelling framework should be developed, taking into account best practice in current approaches to ILUC modelling internationally. Current ILUC modelling work is international in nature and the UK cannot develop an approach in isolation; it will be essential for us to work with other organisations developing ILUC approaches at the European or international level. Currently, there are different approaches to constructing ILUC models; we need to understand the rationale for each approach, and the assumptions that have been used in order to compare the advantages and disadvantages of each approach. Research will be required to understand whether the different modelling approaches are complementary or whether elements from selected approaches can be combined. Selected modelling methodologies currently being put forward (for example, the Öko Institute's risk adder approach and the US GTAP models) may have an important role as short term, 'stop-gap' approaches to calculating the impact of ILUC. Further research in this area is required to guarantee the validity and appropriateness of such methodologies. Additional information is also necessary to be able to model ILUC, including the impacts of crop price on crop yields, the impacts of land prices on land use, and the inclusion of peatlands in computable global equilibrium (CGE) models. Modelling techniques also need to be refined to take into account the important role that biofuel co-products can play in potentially reducing the effects of ILUC. It is our view that these research gaps need to be addressed in the short term.
- **Further research is required to improve our understanding of what is meant by 'alternative' lands (idle, marginal, and degraded land) and 'alternative' feedstocks (wastes, by-products and residues) that could be used for biofuels.** The use of idle, marginal and degraded lands for the production of biofuel crops has been identified as a potential way of producing biofuel crops that will not compete with food crops or lead to land expansion onto natural habitats. Furthermore, crop residues, wastes and by-products could potentially be a sustainable source of bioenergy without needing to set land aside for additional crop production, or expend additional energy and resources for its production (although the current uses of these materials need to be taken into account). A key research gap for 'alternative' lands is the need to reach a global consensus on the terminology and definitions used when referring to idle, marginal and degraded land. This will help to ensure that the lands are genuinely available for biofuels use, and provide an understanding of the amount of land available. Without this consensus, there is a risk that lands are used where the negative environmental or social impacts outweigh any benefits.
- **Research to understand the advantages and disadvantages of using alternative land types for growing biofuel feedstocks is also required.** Growing certain types

of biofuel crops on degraded land can improve the quality of land, but there is the potential that marginal and degraded land may not be economically attractive to producers due to potentially poor crop yields. A more comprehensive understanding of these issues would help to ensure that better policy decisions are made with respect to encouraging the use of idle, marginal and degraded land.

- **Research is required to understand how biofuel crop production can be incentivised so that it takes place on alternative lands.** Given that alternative lands could play an important role in reducing ILUC impacts, it is important to understand how the use of these lands for growing biofuel crops could be incentivised in the future. It is equally important to develop robust methods for monitoring and verifying that, once incentivised, biofuel crop production actually does happen on these types of land, and brings benefits.
- **A better understanding of the indirect effects of using waste, by-products and residues as feedstocks for biofuels is required.** It is necessary to understand the indirect effects of diverting these feedstocks from other forms of production, including the foregone agricultural benefits in the case of residues. A more complete understanding of the competing uses for these materials is also required, and the impacts (negative and positive) of supporting their use in producing biofuels. These competing uses include heat and power, the use of tallow by the oleochemicals industry, the use of food processing residues as animal feed and the use of crop residues to improve soil fertility and structure. With regard to the last of these competing uses, new methods, including the possible use of biochar, could substitute for crop residues as a method for improving soil quality. It is recommended that longer-term research on the potential impacts of biochar is required. As with many of the research gaps identified in this report, it is essential that the production of biofuels is not seen in isolation.
- **Further research is required to understand the potential contribution of improvements in yield and productivity and to undertake work to achieve these improvements.** Improvements in yield and productivity, which lead to increased efficiency in land use, are important for minimising ILUC. Further research in this area must include work on high yield crops, both for biomass and food. It must also consider varieties that have reduced input requirements to help ensure that the total footprint does not increase. A better understanding is needed of crop physiology (to increase carbohydrate assimilation). These are topics for long-term research and it is important that this work starts now. In the short term, research should be focused on how yield improvements could be incentivised through the use of indirect sustainability criteria. In the longer term, R&D activities are required to understand how improvements in productivity can avoid ILUC. This is one area where work on biofuels overlaps with research in other areas, for example with research being undertaken by the agricultural community and that being undertaken on perennial energy crops for heat and power.
- **Additional work is required to better understand the potentially beneficial impact of biofuel co-product use on land use pressures.** The use of biofuels co-products by other industries (for example in animal feed and oleochemicals) could potentially decrease ILUC by reducing the land area required by these industries. Whilst research is already underway in this area, further work is required to improve our understanding of the potential benefits of co-products. This work should aim to develop an agreed methodology to account for the use of co-products in life-cycle analysis and ILUC modelling.

- **For ILUC there is also the requirement for better resolution between satellite imagery and data on the ground.** To improve the data we have on land use changes and potential ILUC from biofuels, we need to improve our basic understanding of land use. Currently, information from many parts of the world is only available through satellite imagery and is subject to a high degree of uncertainty. To decrease this uncertainty there needs to be a better resolution between satellite imagery and on-the-ground data. This is the only way that we can be certain of the long-term impacts of biofuels.
- **Understanding the wider impacts of ILUC.** There are a number of potential wider impacts associated with ILUC, including non-GHG issues such as biodiversity, ecosystem services and local social impacts. These all have potential long-term consequences that cannot be ignored, but this study found that there are large gaps in our understanding of such factors. As with all ILUC impacts, the role of biofuels is not clear and long-term studies are required that will provide us with baseline data and information on changes to ensure that biofuels are produced sustainably.

**Key finding 2: Improving our knowledge of the environmental, socio-economic, and supply-chain impacts of biofuels will be important.**

The goal of sustainable development is to enable all people throughout the world to satisfy their basic needs and enjoy a better quality of life, without compromising the quality of life of future generations. The Government has developed five key principles for sustainable development, all of which must apply to policies if we are to ensure that they are sustainable. These principles are “living within environmental limits”, “ensuring a strong, healthy, and just society”, “achieving a sustainable economy”, “using sound science responsibly” and “promoting good governance”. On this basis, it is clear that direct environmental, social and economic impacts play a key role in determining how sustainable biofuels are. These direct impacts are much better understood than the indirect effects described in Key finding 1. However, there are still significant research gaps which could have major implications in determining how sustainable biofuels are. These gaps have been split into three sub-groups: environmental impacts; social and economic impacts; and sustainability and the supply chain.

**Environmental impacts.** The potential environmental impacts of biofuels are the same as those of any agricultural crops. They include impacts on soil carbon storage, on natural resources (e.g. water use, water pollution and soil fertility) and on ecosystems. There are also tailpipe emissions from the combustion of biofuels in vehicle engines. These impacts need to be encompassed, as far as is possible, within life-cycle analysis methodologies. Specific issues that we identified in this gap analysis were as follows:

- **A better understanding of direct land use change impacts is required.** We need to understand more completely the levels of carbon emissions due to land use change, particularly from soils. We also need to monitor land use change in the longer term. This research should include work to understand differences in the direct land use impacts of perennial crops compared to energy crops, and the soil quality impacts of irrigation and fertiliser treatment.
- **The use of life-cycle analysis for examining the environmental impacts of biofuels.** Further work is required to develop a framework for life-cycle analysis (LCA), and to provide data for input into LCAs (e.g. on fugitive emissions from biogas vehicles and emissions from high percentage blend biofuels). If co-products are dealt with by substitution, more work is required to accurately define what will be

substituted, and what the GHG impacts of co-products are. All of this research needs to be used to develop good practice guidance on LCA methodology.

- **Improving the knowledge-base on tailpipe emissions associated with the use of biofuels.** Research is required to improve our understanding of the non-CO<sub>2</sub> GHG tailpipe emissions and local air pollutant tailpipe emissions associated with the combustion of biofuels. Previous research has shown that emissions of methane and nitrous oxide (N<sub>2</sub>O) from low percentage blend biofuels were comparable to those from conventional fossil fuels, but more data are required on N<sub>2</sub>O emissions from high percentage blend ethanol, and on emissions of particulate matter from high percentage biodiesel blends. Furthermore, emissions of methane from biogas vehicles and the potential interactions between biodiesel tailpipe emissions and abatement technologies used in vehicles for controlling emissions of local air pollutants need to be investigated.
- **More research is required to understand the impacts of biofuels on natural resources and ecosystems.** Data are required on where biofuels are being planted (including on idle, marginal and degraded land) and on the impacts of biofuels on the local environment. These impacts include soil, water and air impacts, as well as impacts on biodiversity and ecosystem services. Further work is needed to understand the environmental implications of large-scale deployment of energy crops in terms of their impacts or benefits on natural resources including soil, water and other ecosystems. This research should include an examination of the impacts of biofuels grown in poor soil. Work is also required to monitor, and minimise impacts on ecosystem services, as well as to understand the economic and social impacts of agricultural mitigation techniques for ecosystem services. Non-biofuel-specific research on mapping biodiverse ecosystems, and to develop methods for monitoring agricultural impacts are also required.

**Social and economic impacts.** The social and economic impacts of biofuels can be categorised as: (i) impacts on international markets for feedstocks and other agricultural commodities in terms of prices and trade; (ii) impacts on national economies; and (iii) impacts on households and enterprises. For the latter two impacts, the gap analysis focused largely on developing countries where there are major concerns. This study has identified that there is already much ongoing research on categories (i) and (ii), and that most of the research gaps relate to impacts on households and enterprises. The key gaps are as follows:

- **Understanding the impacts of biofuels on food and other commodity prices in the medium term, taking into account expected concurrent climate change.** Although several models have been developed and adapted to address this issue, there is scope to refine these so that more precise, detailed and reliable projections can be made.
- **Monitoring the potential harm to poor and vulnerable people in developing countries from the expanded biofuels production.** The impact of higher food prices on poor people is imperfectly understood: most analyses so far use models whose projections need to be compared to actual observed outcomes. As the results of field studies of the impact of the 2007/08 food price spike become available, they need to be synthesised. Similarly, there are concerns that growing biofuel feedstock in developing countries can result in poor and marginalised groups, including women farmers, losing land or being hired in poor working conditions. To date, reports are isolated case studies that need to be more systematically registered and synthesised to establish under what conditions such abuses arise, and how they may be countered. A wider point is that such research on impacts on households and

individuals would be facilitated if there were more regular nationally representative surveys of poverty and hunger in the developing world.

- **Assessing the potential for developing countries to encourage biofuels production for local, national and export markets.** Some countries in the South, especially in Africa, Latin America and South-East Asia, have underused land that might be used to grow feedstock, thereby creating new incomes for farmers, and jobs in the chain of biofuel production and marketing. Preliminary studies, plus the experience of Brazil, suggest that successful industries could be established that contribute strongly to poverty production. Additional and more thorough studies are needed to examine: the economics of growing feedstock on farms, and producing biofuel at the factory level; the institutional arrangements needed to develop biofuel industries, and within this, the sustainability criteria that governments might apply; the potential of individual countries to develop biofuels; and the comparative insights from those national assessments already carried out so that general lessons and guidelines can be derived.

**Sustainability and the supply chain.** The development of sustainability criteria, including the certification of sustainable biofuels production practices, is one of the main tools available for implementing sustainability policies for biofuels. Work has already been carried out at the European level to define sustainability criteria and reporting requirements, but further research is still required. The key research gaps relate to the following issues:

- **Building a common, international approach to ensuring that biofuels are sustainable.** There is a need to harmonise international efforts on sustainability, to further develop certification for biofuels and to develop methodologies that demonstrate compliance. A number of tools are being developed in support of policy needs, such as GHG life-cycle analysis and certification. We need to ensure that the verification process is robust and that there is feedback into the development of policies and procedures. An overarching issue is the need to review proposals for the adoption of sustainability criteria, and identify the key indicators that will be used to measure these criteria. We must also understand how to monitor these indicators. In terms of minimising negative socio-economic impacts, consideration of the needs of smallholders is necessary; rules that do not exclude or disadvantage small producers or suppliers are therefore required.
- **Avoiding unintended side effects.** For the biofuels supply chain, further research is required to ensure that positive policy aims associated with introducing certification and verification processes are translated into good practice on the ground, and that there are no unintended side effects (for example, on smallholders or producers in developing countries).

**Key finding 3: There is a need for new research to examine the evolution of the production, infrastructure and vehicle technologies necessary to enable us to meet longer-term biofuels targets for transport and for improving the sustainability of biofuels.**

The evolution of technology covers the production, infrastructure and use of biofuels and the skills required to ensure take up. New technologies will be required to support the development, production and deployment of advanced future biofuels, and modifications to vehicle technologies may be required in order that high-percentage blend fuels can be successfully used without performance and durability problems occurring. The following key points were identified during the gap analysis:

- **The UK needs to have a better understanding of which potential second generation technologies will deliver quantified benefits and be sustainable for the UK.** A first step towards this is the development of a roadmap for second-generation biofuels in the UK. This will need to build on current initiatives in second-generation technologies in the UK and examine how to leverage UK research effort and funding with that available within the EU. Furthermore, there needs to be a clear understanding of the scale and likely contribution that second generation biofuels will make in achieving reductions in GHG emissions (and other potential benefits), based on improved data from current demonstration projects. In addition, infrastructure needs such as those that would be required for biogas should be considered. The roadmap will help inform knowledge on the commercial availability of second-generation biofuels from a UK perspective.
- **For the UK, there needs to be research and development on advanced biofuel production technologies.** Such research would build on the proposed UK roadmap described above, and on work being done elsewhere in the EU. Taking forward the key areas identified by the NNFFC this includes:
  - Proving pyrolysis technology
  - Commercialisation of anaerobic digestion
  - Gasification

This will allow a better understanding of the potential of these technologies in terms of their contribution to the domestic production of biofuels and ensure their contribution to future biofuels targets.

- **Building a better understanding of the UK's future biofuels infrastructure requirements.** The types of biofuels in use at present are ones that fit easily into the current infrastructure for distribution of vehicle fuels. However, the use of advanced second generation technologies and high blend fuels required to meet future higher targets (in order to meet, for example, the RED 10% target) will require new infrastructure. A further understanding of these needs is required for both domestically produced and imported fuels. With the latter, this research should build on work undertaken in the USA, much of which is directly applicable to the UK situation. One key area of UK relevant research is the infrastructure requirements for the use of biogas as a transport fuel. Biogas has tremendous potential in the UK for use in the transport sector as well as in the heat and power sectors, but its effective use for transport will require investment in the appropriate infrastructure for refuelling vehicles.
- **Funding for new biofuels infrastructure overseas.** Biofuels for the UK could also be imported from developing nations. However, many of these countries are currently restricted by a lack of infrastructure. Research into the most appropriate forms of funding to remove these restrictions is required.
- **Understanding the impacts of increasing the biofuels targets on vehicle technologies and performance.** First generation biofuels are, in the main, limited to 5% blends. Steps to move us towards higher targets (for example the RED 10% target) are therefore required. For first generation biofuels the main research gaps associated with the use of higher percentage blends are technical concerns. For example, fuel quality standards for high percentage blends are required, and work is also needed to understand the impacts of high percentage blends on vehicle component performance. We also need to understand the ability of the future vehicle fleet to use these fuels, as well as the impacts of these fuels on older vehicles and long-term impacts.



- **Vehicle compatibility issues.** Vehicle compatibility does not appear to be a significant research priority outside of industry as the technical issues associated with current biofuels are relatively well understood, and current work is focused on addressing the existing limitations and fuel quality issues. For ethanol, the technical vehicle compatibility issues are the same for both current and advanced biofuels, whilst for biodiesel, advanced future fuels are anticipated to have far fewer, or no limitations compared to conventional biodiesel. In order to maximise the benefits of advanced future biofuels, collaborative research between fuel suppliers and the automotive industry is required. Whilst there are signs that this is beginning to happen, it may be beneficial to encourage further research activities. Finally, only limited research on the performance and potential of Hydrotreated Vegetable Oil (HVO) biodiesel fuels was identified and this may be an area for further work.
- **Understanding the impacts of expanding the use of biofuels to non-road modes of transport.** A number of research gaps have been identified for the use of biofuels in other modes of transport. These include the need for evidence on the impacts on other biofuel sectors, for example on prices and on the sustainability of potential fuels. For the marine sector there are research gaps on the ability of fuels to be used in the sector and, correspondingly, for demand in this sector.
- **Developing the skills and training required to support the development of the biofuels industry.** Ensuring we can achieve increased deployment of biofuels in the UK also requires the development of skills. Although there is support for training by the research councils and companies also train staff on the job, there will need to be long-term investment to raise the profile of biofuels professionally and to ensure that skills are available. The extent to which these skills will be needed will depend on whether future UK targets are met through imports or whether targets are achieved by UK industry (domestic production). In the latter case, engineering and biofuel plant management skills will be required. This could be facilitated through an increase in relevant higher education courses and research groups as well as professional development to facilitate the uptake of biofuels. There is also a need to ensure procurement managers are aware of the opportunities that biofuels can offer and to understand the implications for their vehicle fleets. On-site training will need to be provided.
- **Adopting a multi-disciplinary approach to biofuels deployment.** To ensure future targets are achieved in a timely and cost-effective manner, movement towards a truly multi-disciplinary approach is necessary. This means that improved co-operation between different research disciplines is required, as well as better co-ordination of Government programmes on biofuels.
- **Mechanisms to ensure knowledge transfer between research and industry are required.** Currently, there are many different sources of information on biofuels, published across a wide range of scientific journals, conference proceedings, Government and international websites etc. It would be more useful for one organisation to act as a central database of information, providing a central focus for information transfer.



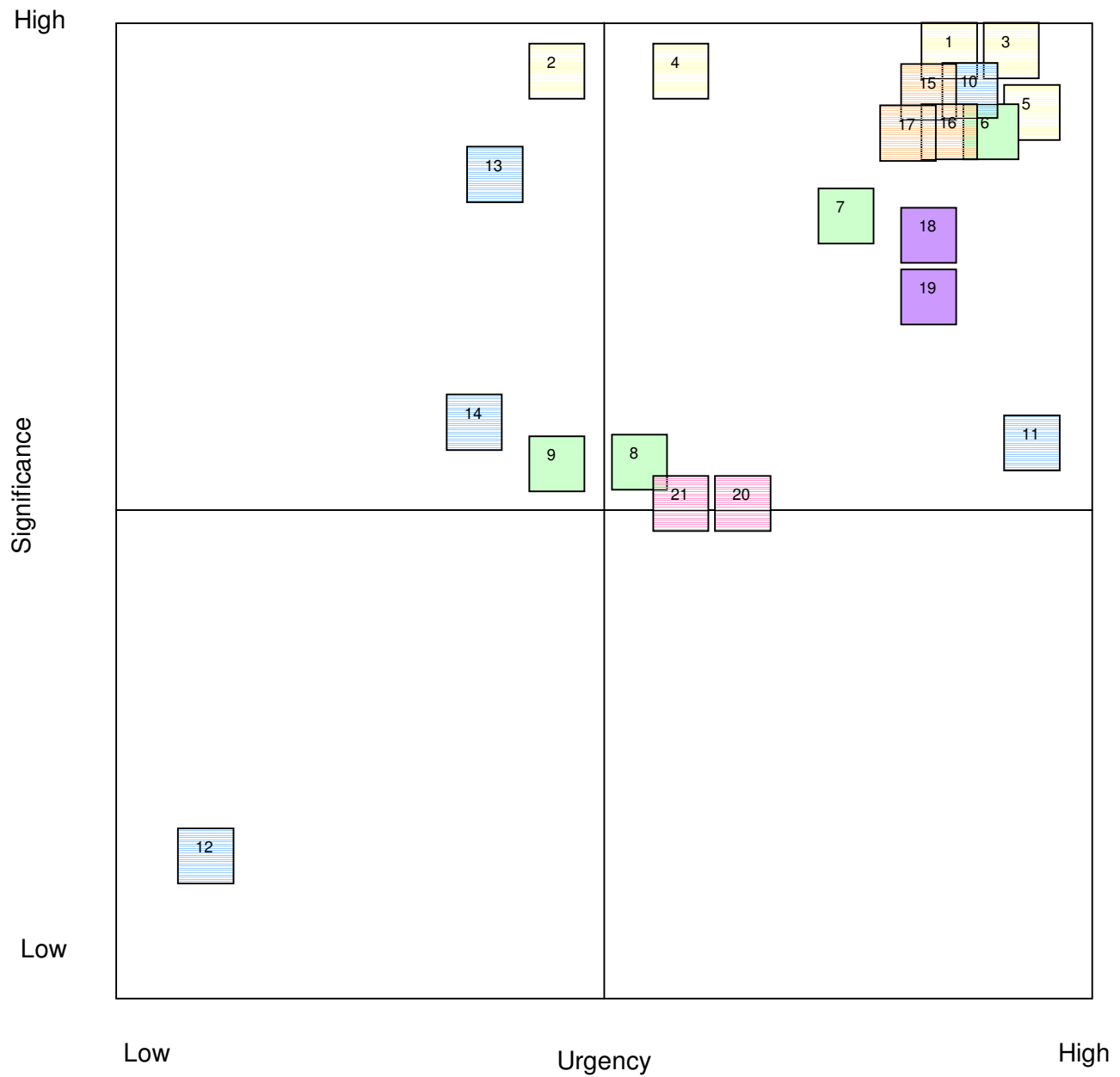
**Key finding 4: There are a number of cross-cutting research gaps that need to be addressed in order to support the development of biofuels policy.**

The gap analysis has identified a number of important, high priority issues that have implications for all aspects of biofuels policy and deployment, but also for policy areas outside the biofuels arena.

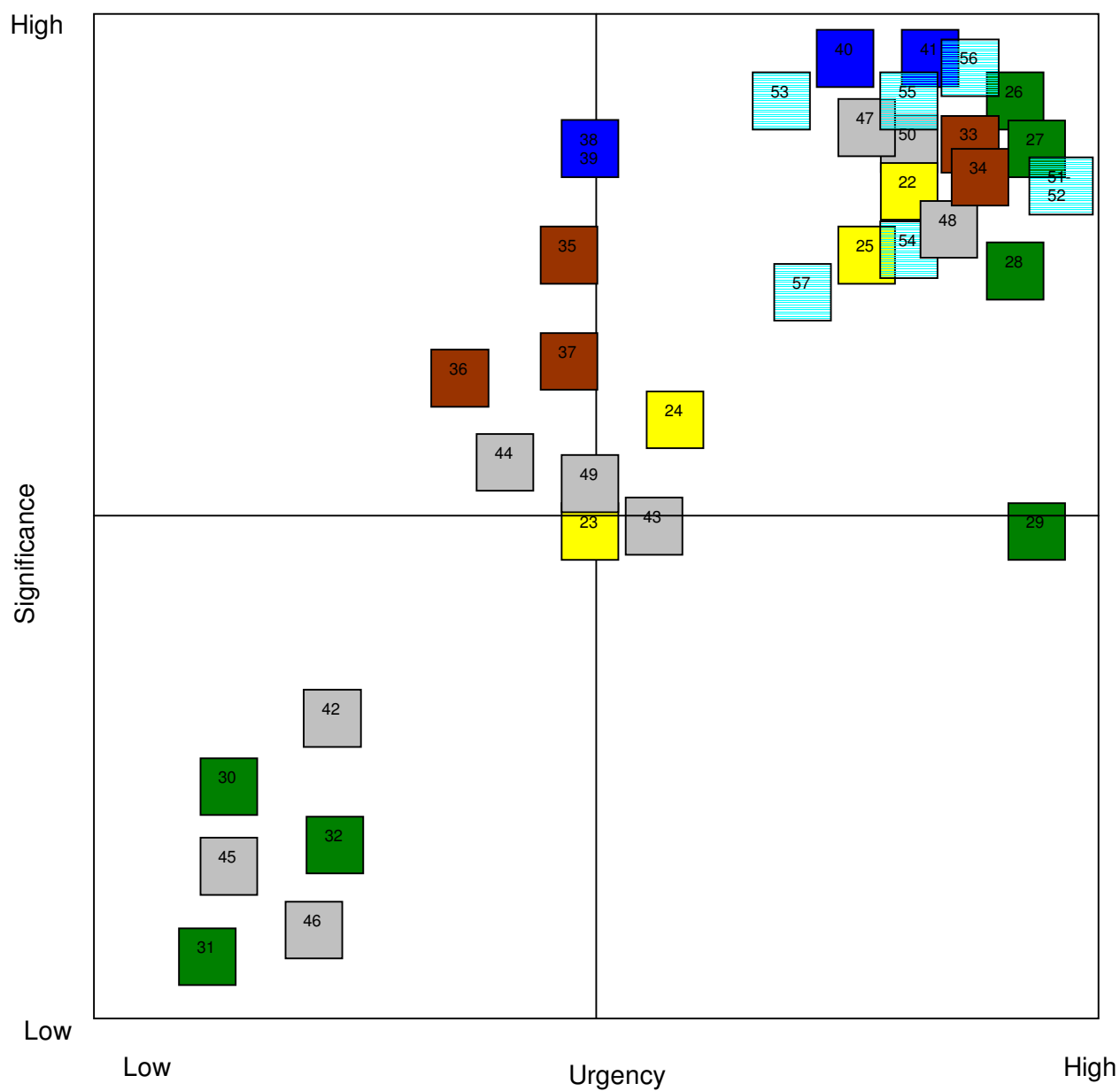
- **Improved data is required to support modelling, analysis and policy development across a wide range of areas.** The availability of high quality data on the impacts of biofuels is critical if we are to develop robust policies that support the sustainable uptake of these types of fuels. Better data are required on where biofuel crops are grown in order that we can improve our understanding of the direct and indirect land use change impacts associated with the increased use of biofuels. Better datasets are also required on the impacts of biofuels on the natural environment, on the global economy, and on society.
- **Understanding the impacts of biofuels policies on markets.** A better understanding is needed of the investment and market issues which influence both the effectiveness of policy measures and how biofuels targets will be met. Research gaps in this area centre on the impacts of biofuel policy decisions on: (i) market and investment decisions according to scenarios for trajectories to targets; (ii) market and investment decisions according to scenarios for the design and introduction of sustainability requirements; (iii) trade in biofuels and feedstocks; and (iv) scenarios for the development of technologies. There is also the need to understand the impacts of other factors (including economic slowdown and oil prices) on market and investment decisions. It is important that these research gaps are considered together rather than in isolation.
- **Research into grandfathering provisions.** Grandfathering provisions allow for existing companies/organisations/plants/machinery to be temporarily outside incoming legislation. Research into a number of areas is required, including identifying how grandfathering provisions may impact on (i) investment in biofuel production and (ii) technology and sustainability. There is also the need for an increased understanding of the potential misuse of grandfathering, a comparison of different grandfathering regimes or proposals, and the possibility of modelling the optimum level of grandfathering. There is the potential for this research to be incorporated into other research projects.

This gap analysis has been used to develop a comprehensive understanding of the areas where there is a need for further research to support the development of robust, evidence-based biofuels policies. The four key findings from this gap analysis set out the priority areas that we believe should be the main focus of the planned cross-government research and development strategy on sustainable biofuels.

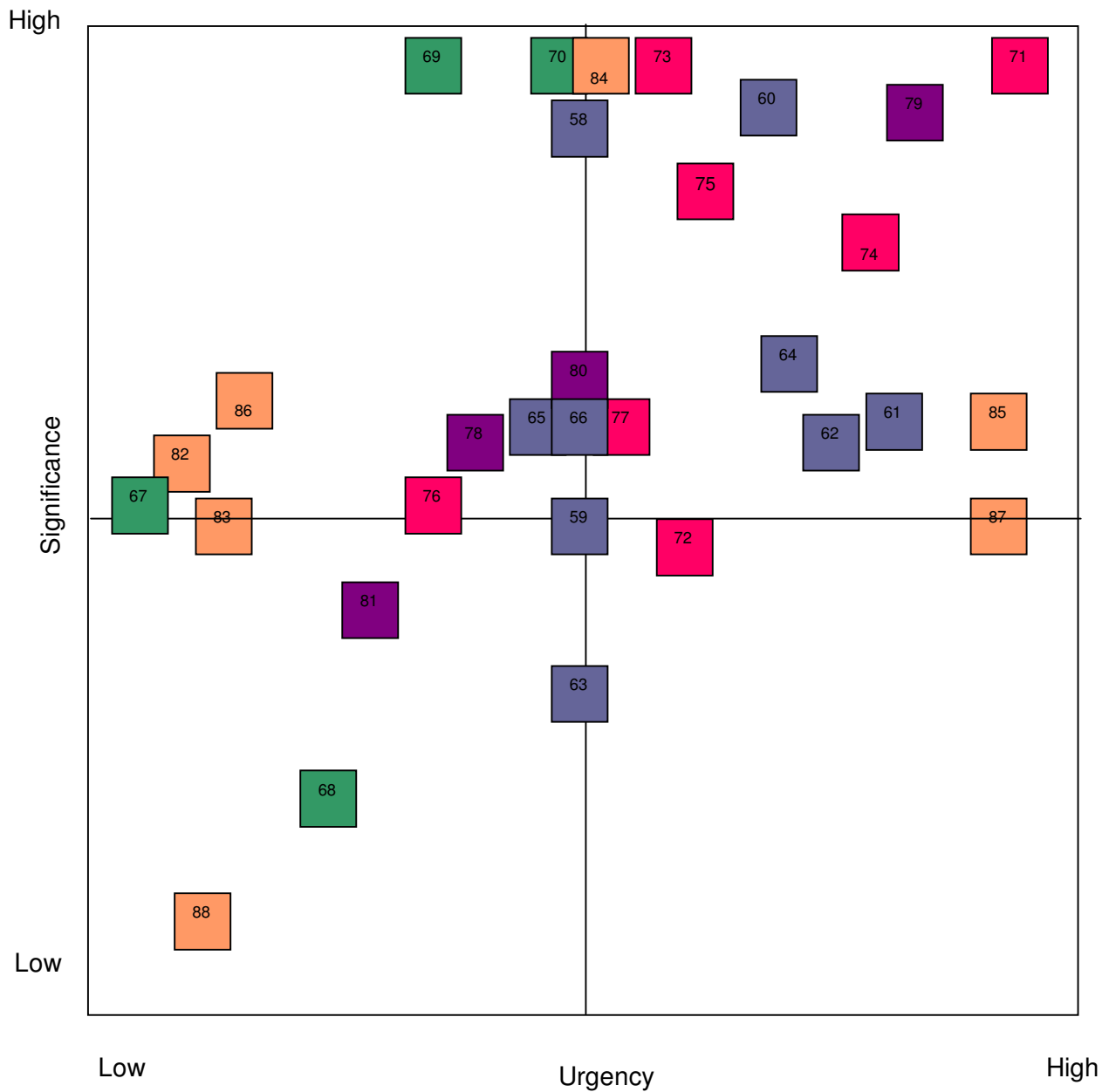
**Key finding 1: We need to improve our understanding of the indirect impacts of biofuels, particularly indirect land use change (ILUC), with a specific focus on developing and agreeing a framework for ILUC modelling.**



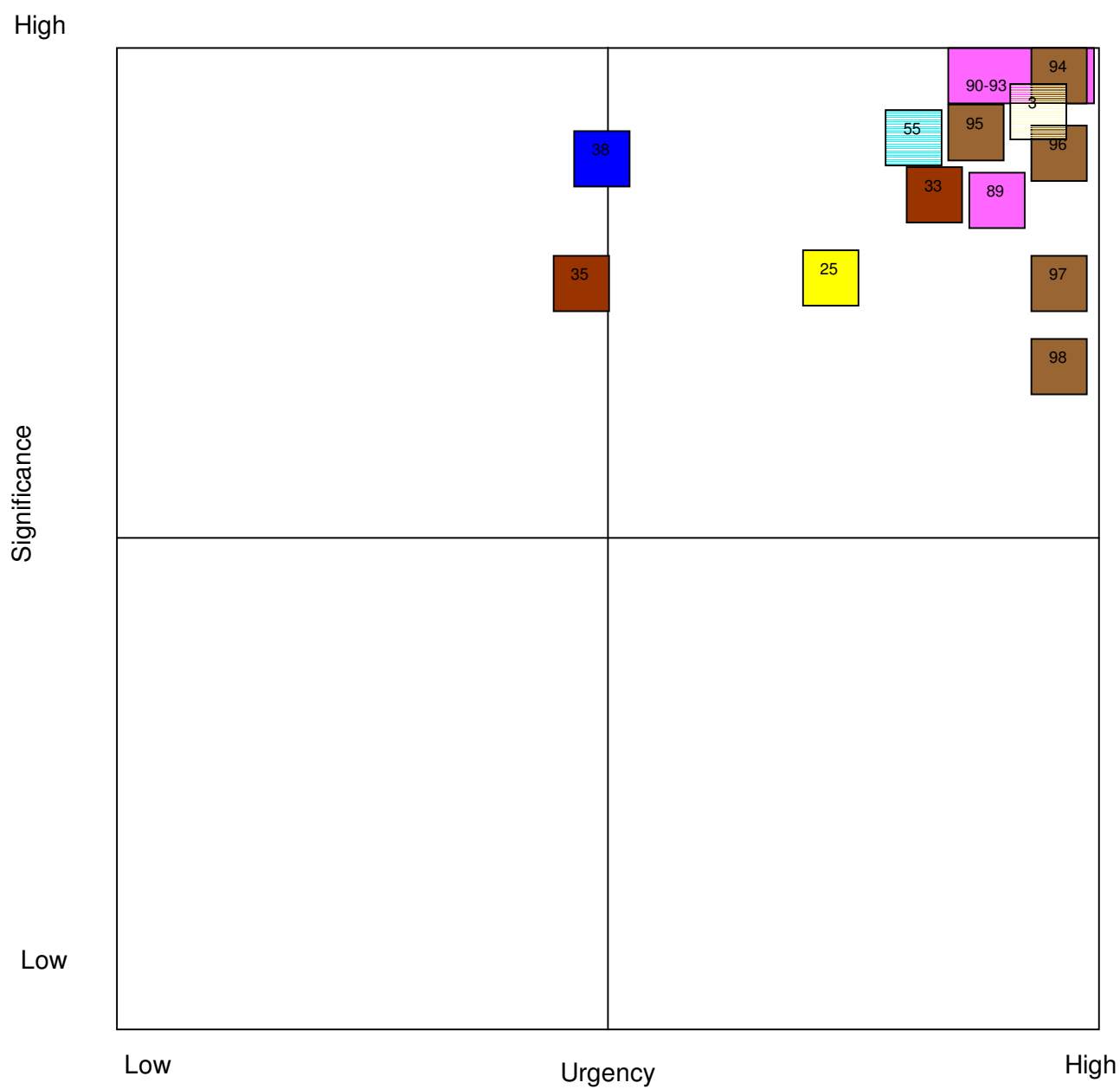
**Key finding 2: Improving our knowledge of the environmental, socio-economic, and supply-chain impacts of biofuels will be important.**









**Key finding 3: There is a need for new research to examine the evolution of the production, infrastructure and vehicle technologies necessary to enable us to meet longer-term biofuels targets for transport and for improving the sustainability of biofuels.**














**Key finding 4: There are a number of cross-cutting research gaps that need to be addressed in order to support the development of biofuels policy**





# Key

	<p>Indirect land Use Change</p> <ol style="list-style-type: none"> <li>1) Review of ILUC modelling from UK perspective</li> <li>2) Allocation of ILUC between different causal factors</li> <li>3) Research on key data gaps</li> <li>4) Resolution between satellite imagery and data on the ground</li> <li>5) Role of alternative solutions</li> </ol>
	<p>Idle and Marginal Land / Degraded Land</p> <ol style="list-style-type: none"> <li>6) Internationally agreed definitions</li> <li>7) Methodologies for monitoring and verification</li> <li>8) EU influence in productions</li> <li>9) For degraded land – value in reclaiming land</li> </ol>
	<p>Wastes, by-products and residues</p> <ol style="list-style-type: none"> <li>10) Effects of biofuels on competing uses</li> <li>11) Removal of residues from land</li> <li>12) Potential of biochar</li> <li>13) Comparison of use for heat and power</li> <li>14) Monitoring benefits of use of biofuels</li> </ol>
	<p>Increases in yield/ productivity</p> <ol style="list-style-type: none"> <li>15) R &amp; D on high yield crops</li> <li>16) Research into increasing yield, without increasing total footprint, of conventional crops</li> <li>17) R &amp; D on fundamental crop physiology to increases carbohydrate assimilation</li> </ol>
	<p>Co-products</p> <ol style="list-style-type: none"> <li>18) Continued research on the effect of co-product use on land pressures</li> <li>19) Agreed methodology to account for use of co-products</li> </ol>
	<p>Other indirect effects</p> <ol style="list-style-type: none"> <li>20) Identification of other (non land use) indirect effects</li> <li>21) Research into whether it should be included in the sustainability criteria</li> </ol>

	<p>Direct land use Change</p> <p>22) Further research into carbon emissions of LUC 23) Further research into responses of soils to LUC 24) Long term monitoring of land use change 25) Datasets</p>
	<p>Greenhouse Gas Life-cycle Analysis</p> <p>26) Good practice guidance on LCA methodology 27) Comparison of default values 28) Co-products: understanding impact of approaches 29) Co-products: definition of substituted products</p> <p>Vehicle emissions</p> <p>30) Emissions from high % blends 31) CH<sub>4</sub> emissions from biogas 32) Impacts of blends on SCR</p>
	<p>Local environment/ natural resources</p> <p>33) Monitoring and data collection on soil, water and air impacts 34) Data linking biofuels with impacts 35) Data on yields of specific crops, under different conditions 36) Data on the impact of large scale deployment linked to good practice guidance 37) Policy framework to ensure best practice is adopted</p>
	<p>Biodiversity</p> <p>38) And 39) Baseline data on ecosystem services and monitoring 40) Impacts of biofuels on ecosystem services 41) Assessment of biofuels targets within ecosystem services sustainability</p>
	<p>Economic and social effects of biofuels production</p> <p>42) Economic modelling of biofuels and world prices 43) Studies of national potential in low income developing countries 44) Comparative analysis of national potential across countries 45) Impacts of the price spike on poor and vulnerable people 46) National statistics on poverty and hunger 47) Institutional approaches and value chains for biofuels in the South 48) Economics of biofuels enterprises 49) Sustainability criteria for biofuels in developing countries 50) Monitoring the impact on local livelihoods</p>

	<p>Sustainability and supply chain</p> <ul style="list-style-type: none"> <li>51) Implementation of RED: Definition of RED criteria and measures to implement them: development of RTFO and reporting requirements for RED</li> <li>52) Implementation of RED: Assistance to developing nations to develop sustainability guidance</li> <li>53) Verification: Development of a robust process</li> <li>54) Verification: Consideration of needs of small holders</li> <li>55) Monitoring and data collection</li> <li>56) Feedback on development of policy and procedures</li> <li>57) Monitoring: Linking compliance to benefits</li> </ul>
	<p>Vehicle engines and flex fuel vehicles</p> <ul style="list-style-type: none"> <li>58) Future fleet capability</li> <li>59) Resource time need to move to high blends</li> <li>60) Fuel quality standards for high blends</li> <li>61) Fuel quality and cylinder pressure sensing</li> <li>62) Lubricant interaction with bio-content</li> <li>63) Impacts of biofuels on older vehicles</li> <li>64) Long term impacts of biofuels</li> <li>65) Impacts of advanced biofuels on future engine technology development</li> <li>66) Impact of wider availability of sustainable bioethanol on future engine technology development</li> </ul>
	<p>The extension of biofuels for use in other modes of transport</p> <ul style="list-style-type: none"> <li>67) Barriers to using biofuels in the marine sector</li> <li>68) Potential demand for biofuels in the aviation and marine sectors</li> <li>69) Sustainability issues of extending biofuel use to other transport modes</li> <li>70) Impacts on other biofuels sectors, such as prices</li> </ul>
	<p>Advanced/second generation biofuel technologies</p> <ul style="list-style-type: none"> <li>71) Impact on sustainability</li> <li>72) Quantifying benefits</li> <li>73) Overarching road map for development of advanced biofuel technologies in UK</li> <li>74) Hydrolysis technology for alcohols from lignocellulose</li> <li>75) Demonstration of gasification routes</li> <li>76) Proving of pyrolysis routes</li> <li>77) Commercialisation of anaerobic digestion</li> </ul>
	<p>Infrastructure</p> <ul style="list-style-type: none"> <li>78) Understanding infrastructure needs for high blends and second generation biofuels for local authority fleets</li> <li>79) Examination of infrastructure for biogas</li> <li>80) Assistance for infrastructure in developing countries</li> <li>81) Grants for ports facilities and for regional development</li> </ul>
  AEA	<p>Skills</p> <ul style="list-style-type: none"> <li>82) Continuation of funding for fundamental research groups</li> <li>83) Higher education courses</li> <li>84) Professional development</li> <li>85) Technical training 'on the job'</li> <li>86) Knowledge transfer</li> <li>87) Co-operation in research</li> <li>88) Continue to improve common understanding/removing barriers</li> </ul>



	<p>Impact of policy decisions on investment and market forces</p> <ul style="list-style-type: none"><li>89) Trajectories to targets</li><li>90) Sustainability requirements</li><li>91) Trade</li><li>92) Development of technologies</li><li>93) Other market factors</li></ul>
	<p>Grandfathering</p> <ul style="list-style-type: none"><li>94) Investment/financial impacts</li><li>95) Technological and sustainability impacts</li><li>96) Potential for misuse of grandfathering</li><li>97) Comparison of different grandfathering regimes</li><li>98) Modelling of optimum level of grandfathering</li></ul>

**Table of Contents**

<b>Executive Summary.....</b>	<b>vii</b>
<b>1 Introduction .....</b>	<b>1</b>
1.1 Overview.....	1
1.2 Approach to the study .....	1
1.3 Approach to the report.....	2
1.4 Format of the report .....	3
<b>2 Indirect Effects .....</b>	<b>6</b>
2.1 Introduction .....	6
2.2 Indirect Land Use Change.....	7
2.3 Idle and marginal land.....	29
2.4 Degraded land .....	39
2.5 Wastes, by-products and residues .....	48
2.6 Increases in yield/productivity.....	58
2.7 Co-products .....	69
2.8 Other indirect effects .....	77
<b>3 Other Environmental Issues.....</b>	<b>85</b>
3.1 Introduction .....	85
3.2 Direct land use change.....	86
3.3 Greenhouse Gas Life-cycle Analysis.....	94
3.4 Local environment /natural resources.....	107
3.5 Biodiversity.....	119
<b>4 Economic and Social Effects of Biofuels Production.....</b>	<b>132</b>
4.1 Introduction .....	132
4.2 International markets.....	133
4.3 National economies.....	144
4.4 Households and Enterprise .....	153
<b>5 Market Forces/Trade .....</b>	<b>175</b>
5.1 Introduction .....	175
5.2 Impacts of policy decisions on investment and market forces.....	176
5.3 Sustainability and supply chain .....	194
5.4 Grandfathering .....	213
<b>6 Vehicle Capability .....</b>	<b>221</b>
6.1 Vehicle engines and flex fuel vehicles .....	221
6.2 The extension of biofuels for use in other modes of transport.....	237
<b>7 Advanced/second generation biofuel technologies.....</b>	<b>250</b>
<b>8 Infrastructure.....</b>	<b>276</b>

<b>9 Skills.....</b>	<b>289</b>
<b>References .....</b>	<b>300</b>
<b>Abbreviations.....</b>	<b>314</b>



# 1 Introduction

## 1.1 Overview

The UK's Gallagher Review<sup>1</sup>, published in June 2008, identified major uncertainties in the evidence surrounding the production and use of biofuels. In response, the Government set up a cross-Government steering group - the Biofuels Research Steering Group (BRSRG) - to develop a research programme that would address gaps in the existing knowledge and evidence about biofuels in order to inform the Government's future policy. The BSRG will enable the UK to make evidence-based contributions to further international policy discussions, specifically the potential introduction of indirect sustainability criteria into the EU's Renewable Energy Directive (RED) in 2010, and the European Commission's review of aspects of the RED's 10% renewable transport target, which is due by 2014.<sup>2</sup>

This report provides the outcomes of a gap analysis, which set out to identify and better understand these research gaps. The objective of the study was to highlight current research work being carried out across Government, industry, academia and NGOs in the UK, the European Union and internationally and to identify the outcomes. The study has used this evidence to determine gaps in the research work and knowledge in this field. The outputs from the study will be used to inform the development and scope of the planned BSRG biofuels research programme.

## 1.2 Approach to the study

The study has been undertaken by AEA, Metroeconomica, Overseas Development Institute (ODI), Themba/Porter Alliance, Winrock, North Energy, ADAS and Ricardo on behalf of the BRSRG.

The study approach involved the identification of relevant research groups and organisations; the development of a questionnaire; the contacting of key research groups (agreed with the BRSRG) with a request to complete the questionnaire and the opportunity for a telephone interview<sup>3</sup>.

In total, more than **190 organisations** responded. These include:

- UK Government including:
  - Department of Energy and Climate Change (DECC)
  - Department for Environment, Food and Rural Affairs (DEFRA)
  - Department for Transport (DfT)
- Research Centres including:
  - UK Energy Research Centre (UKERC)
  - Biotechnology and Biological Sciences Research Council (BBSRC)
  - Engineering and Physical Sciences Research Council (EPSRC)

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<sup>1</sup> Commissioned by the Government's Renewable Fuels Agency to investigate the indirect effects of biofuels production

<sup>2</sup> By the end of 2014 the commission will undertake a review of, amongst others: the cost-efficiency of the measures to be implemented to achieve the 10% target and; the feasibility of meeting the target sustainably. This will be referred to throughout this study as the 2014 review, or review clause

<sup>3</sup> A more detailed methodology is provided in Annex 1

- US Government including:
  - United States Department of Energy (USDOE)
  - United States Department of Agriculture (USDOA)
- Academia including
  - The European Union's Joint Research Centre (JRC)
  - University of Leeds
  - University of Cambridge
  - University of Aberdeen
- NGOs including
  - Oxfam
  - World Wildlife Fund (WWF)
- Industry including
  - British Petroleum (BP)
  - The Virgin Group
  - British Sugar
  - Ensus

Analysis of the responses and initial thinking on key gaps was presented by the study teams at an International Expert Workshop on biofuels research, held in February 2009. Feedback from the workshop has been incorporated into the final findings of the study.

## 1.3 Approach to the report

The structure of this report is as follows:

**Chapter 2** – considers Indirect Land use Change (ILUC) and the measures, which may reduce the potential for this. These measures include the use of: idle and marginal land; degraded land; wastes by-products and residues; increasing yield and productivity; and co-products. Other indirect effects (non-ILUC) are also given consideration. Research gaps in these areas are identified.

**Chapter 3** – considers direct environmental effects of biofuels production and use. The research gaps associated with direct land use change; greenhouse gas (GHG) life-cycle assessment (LCA); local environment/natural resources and biodiversity (which also addresses the impacts on ecosystem services) are examined.

**Chapter 4** – considers the economic and social effects of biofuels production. The research gaps associated with the impacts of biofuels on: international markets, national economies and households and enterprises are examined.

**Chapter 5** – considers market forces and trade. The research gaps associated with the impacts of policy decisions on investment and market forces; issues around sustainability and the supply chain, and grandfathering rights are examined.

**Chapter 6** – considers vehicle capability. The research gaps associated with the potential for biofuels use in current and flex fuel vehicles and the extension of biofuels for use in other modes of transport are examined.

**Chapter 7** – considers advanced / second generation technologies for biofuels. The research gaps around the role of these technologies in meeting future biofuel use targets and what Government / EU action is required to encourage uptake are considered.

**Chapter 8** – considers the importance of infrastructure. The research gaps around immediate and future infrastructure and what is required for increased production/consumption of the different biofuel technologies are examined.

**Chapter 9** – considers skills and knowledge transfer. The gaps around skills and requirements to meet future biofuels targets and the mechanisms for knowledge transfer which currently exist are examined.

## 1.4 Format of the report

The format of each chapter is as follows:

- a matrix – which presents a preliminary assessment of the research gaps for the topic area (guidance is provided on the following page)
- an Executive Summary
- the context of the issue
- key research questions on the topic area
- research in the area – current and planned
- research gaps – mapped against the key research questions
- summary and conclusions and a table illustrating key findings

Please note that a list of abbreviations is provided in a separate report.

## Representation of results – guidance on matrices

Matrices representing a preliminary assessment of the research gaps have been developed for each of the areas included in this report. These matrices represent an initial high-level analysis only and are intended to summarise the study's findings. They do not represent an in-depth analysis of the relative priorities of the research areas or provide recommendations on which areas of biofuels research the UK Government should fund.

In these matrices an indication has been provided of:

- 1) The urgency of the work – i.e. the timescale over which this work needs to be done taking into consideration UK policy needs, the dependency on other research, current research in the area and the need for a specific issue to be addressed.
- 2) The significance of the work – i.e. its importance in terms of answering the research questions identified for each area. If a piece of work is ranked as highly significant, this indicates that it is vital in answering the relevant question(s) for that area.
- 3) 'Size of gap' – this represents a consideration of the *amount and complexity* of the work, including:
  - a) The amount of work involved, which is a reflection of:
    - i) the current 'state of the art' research on the topic and whether or not it is building on a good foundation or forging new work;
    - ii) the cost of the work e.g. does it involve construction of expensive equipment or a simple desk study? and
    - iii) the number of different issues and areas that need to be investigated to address the knowledge gap.
  - b) The skills available, i.e. whether the UK currently has the skills to do this work (therefore a small gap) or if it needs to develop new skills (i.e. large gap)
- 4) The need to interact internationally, i.e. leveraging UK funds with international funds to address the issue, which would be ranked as a large gap. If the work can be done on a UK only basis, this would be ranked as a smaller gap, and the criteria in (a) and (b) above may influence the size of the gap more significantly in this case.





# Biofuels Research Gap Analysis

## Chapter 2 – Indirect Effects



**Final report to the Biofuels Research  
Steering Group**

ED45917  
Issue Number 3  
30<sup>th</sup> July 2009

## 2 Indirect Effects

### 2.1 Introduction

The following chapter considers Indirect Land use Change (ILUC) and the measures which may reduce the potential for this. These measures include the use of: idle and marginal land; degraded land; wastes by-products and residues; increasing yield and productivity; and co-products. Other indirect effects (non-ILUC) are also given consideration, and research gaps in these areas are identified.

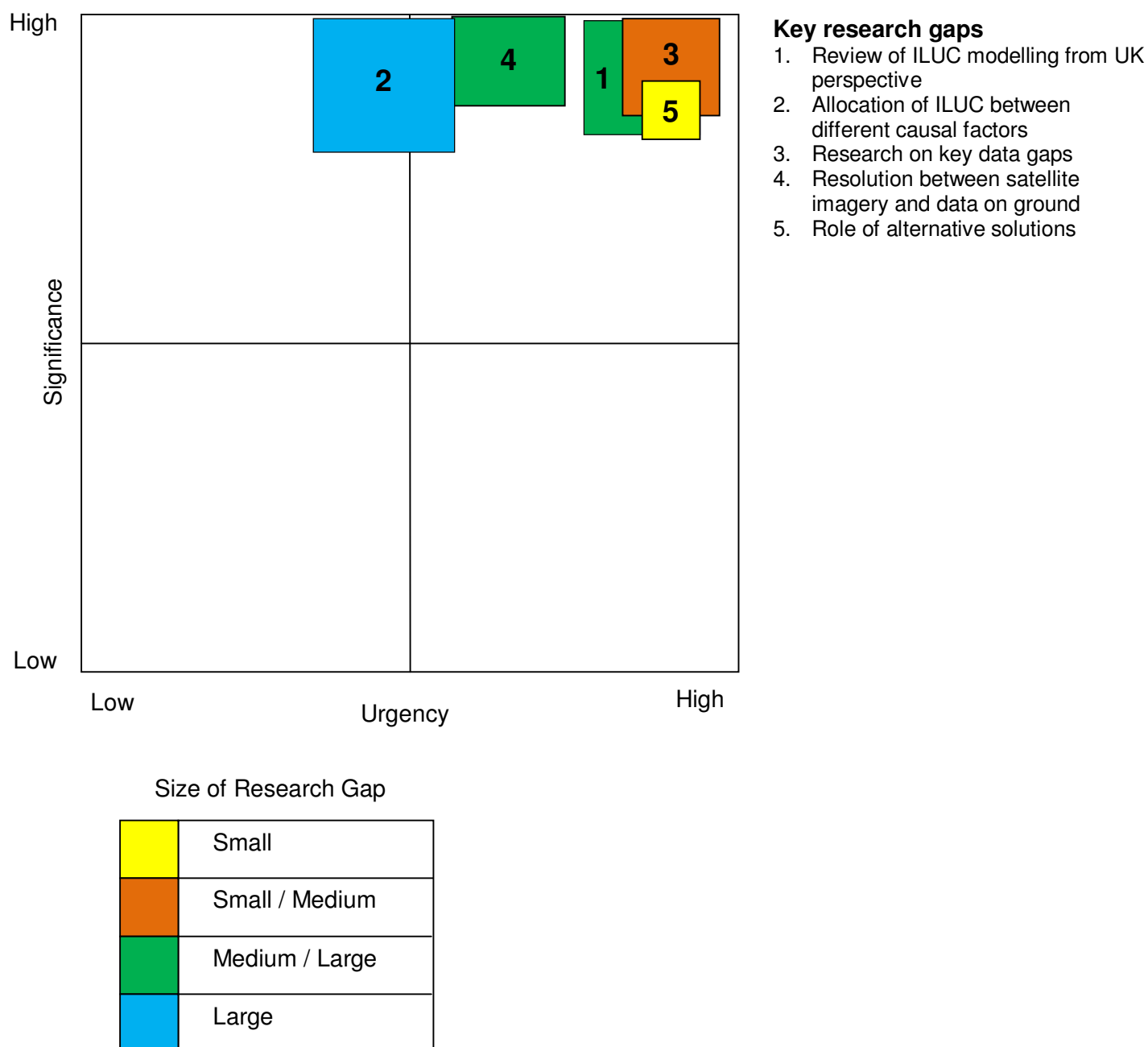
ILUC happens when land use changes occur not just where the biofuels crop is planted, but as a result of displacement of the previous land use elsewhere (including in other countries, which can be some distance from the original crop). The main concern is that this may ultimately lead to pressure for deforestation or conversion of grasslands or peat land to agriculture. Such habitats represent considerable carbon stocks and their conversion to agriculture leads to the destruction of the carbon stocks in and above ground, resulting in an immediate increase in greenhouse gas emissions, which may outweigh the greenhouse gas (GHG) benefit from the use of some biofuels. In addition, there are other impacts of ILUC, such as loss of biodiversity in these habitats.

This chapter considers whether and how the potential for ILUC can be reduced. For example, the Gallagher Review recommended that to help avoid ILUC, policies must be focused on ensuring that agricultural expansion to produce biofuel feedstock is directed towards suitable idle, marginal or degraded land or utilises appropriate wastes, residues or other non-crop feedstock. In addition, increasing yields and productivity through ensuring that land is used more efficiently and the use of biofuel co-products (including glycerol and low CV feeds) to substitute for crop production (and therefore land take) are also sometimes suggested as potential ILUC reducing measures.

These issues impact on a wide range of issues as well as those considered here. These issues also impact more widely, and this Chapter must therefore be considered alongside other relevant chapters including Chapter 3 on Other Environmental Issues and Chapter 4 on the Economic and Social Effects of biofuels production.

## 2.2 Indirect Land Use Change

**Figure 2-1 Matrix prioritising key research gaps for Indirect land use change**



## 2.2.1 Executive Summary

*What evidence exists which we can build on to allow us to, a) develop indirect sustainability criteria, and; b) inform our position on the 2014 review of the RED target?"*

Indirect Land Use Change (ILUC) encompasses the potential for land use change to occur not just where the biofuels crops are planted, but as a result of displacement of the previous land use elsewhere. Given the global nature of the agricultural commodities market, ILUC can occur in other countries, which may be some distance from the original crop. ILUC is a concern because it can result in negative impacts associated with biofuels, particularly with respect to GHG emissions and impacts on local ecosystems.

We need research to help us understand ILUC better in order to develop indirect sustainability criteria. The European Commission will review aspects of the 10% transport target by 2014 (including the feasibility of reaching the target sustainably), and by then we will need to understand the impact of this target on ILUC.

Our analysis has revealed that there are gaps in our understanding of ILUC, and these need to be filled if we are to develop indirect sustainability criteria and inform our position on the Commission's review.

The key research gaps identified were:

Research Gap 1: There are a number of different approaches to ILUC modelling, each complex and each with its own strengths and weaknesses. It is important to have a full appreciation of how these models are developing and which are most suited to UK needs. There is a need to review these approaches with the aim of understanding why there is a wide range of results, what factors the models are most sensitive to, what are the constraints for each approach and how accurately the models are able to represent the different sectors. This needs to be done on all proposed methodologies for modelling ILUC, including the global equilibrium models and the simpler modelling approaches (i.e. the static modelling approaches). It should take the work of the EC, US EPA and US DoE into account. The outcome of this work should be a clear understanding of global approaches to ILUC, an indication of the most appropriate approach for modelling of ILUC for UK biofuels, an indication of the most important gaps in data and an assessment of how any approach for the UK can build on the work that has already been done. It should also examine whether the models being used could be better tailored to biofuels and if so, how; and develop good practice guidance for ILUC modelling.

Research Gap 2: ILUC is not the result of expansion of a single sector, but often the end result of a complex interaction of a number of pressures. There is a need to examine how this is expressed in modelling.

Research Gap 3: There is a need to address key gaps not included in the modelling at present. These include the potential for the use of co-products to decrease the impact of ILUC; the impact of price on yield and of land prices on land use; and the inclusion of peatlands in CGE models.

Research Gap 4: The need to improve our understanding of real changes in land use through on the ground monitoring linked to satellite imagery.

Research Gap 5: The role of other solutions including development of sustainability certification and the exclusion of specific important ecosystems from agricultural development need to be considered.

Work is being done on an international scale and any work supported by the UK will also need to be international in outlook. In this area there are advantages to acting at both European and international level and the UK needs to consider how it will do this.

### 2.2.2 Context

This section provides supporting information about the indirect effects of biofuels production on land use change, generally referred to as Indirect Land Use Change or 'ILUC', which then provides context for analysing the research gaps. Other indirect effects are examined in later stages of this chapter and related issues such as biodiversity and socio-economic impacts are examined in later chapters.

ILUC encompasses the potential for land use change to occur not just where the biofuels crop itself is planted, but also, if the biofuels replace established agricultural commodities, the resultant displacement of the previous land use elsewhere, which can be some distance from the original crop, including in other countries. For ILUC to happen, demand for the original crop/commodity must be driven by market need that does not decrease because the crop has been replaced by biofuel. Essentially it considers that if land is switched from food crop (or other agricultural commodity) production to biofuel crop production the displaced crop will need to be planted elsewhere as demand for this crop, presumably, does not decrease. Alternatively, another crop may be substituted, but this crop will also need to be grown somewhere. This amounts to a "knock-on" effect, with the result that it is possible for land use change to occur in a number of locations as an indirect consequence of biofuels crop production.

Furthermore, it is possible for a 'chain' of displaced land use to occur. For example, expansion of sugar cane production for bioethanol in South America might result in displacement of a crop previously grown on this land (such as soy) elsewhere. In turn, this might displace another land use (e.g. cattle ranching) to virgin rain forest, resulting in the release of carbon from the destruction of the existing forest. In general, it is difficult to prove the chain of displacement of historical land use; and apportioning the final land use change among all the contributory factors is complex and often controversial.

The GHG savings from biofuels are assessed using life-cycle assessment (LCA) techniques. The indirect impacts of biofuels and how far reaching these issues are is a problem that has vexed researchers working on biofuels GHG LCAs for some time. Interest in this issue grew beyond the LCA community in 2008 with the publication of the results of theoretical modelling of the potential GHG emissions implications of ILUC (of displacing corn production in the US) by Searchinger (2008). While there are a number of critiques of this research and the applicability of its conclusions outside of the USA, there is general agreement among researchers that GHG emissions from ILUC can be significant and need to be factored into any assessment. There is, however, wide debate on the specific treatment of the topic and it is clear that there is a significant need for improved data to feed into ILUC modelling, to improve our understanding of land use and to improve our understanding of the impact that production of biofuels has on agricultural commodity markets. Such work is fundamental to our long term understanding of the impact of Government policy on biofuels on emissions from ILUC.

The nature of ILUC means that it will be a long time before it can be assessed using real data, and this may not actually ever be possible. This is because the intricate patterns of cause and effect, and the many inter-relationships with other variables, are simply too manifold to draw together. Yet in the meantime there is considerable risk of carbon emissions should we ignore the issue. Thus, policy makers are reliant on modelling for estimation of ILUC. There is currently no agreed method for accounting for ILUC in life-cycle assessment of GHG emissions for biofuels. Most developing techniques use a number of models linked together to provide an indication of how much ILUC may occur and an estimation of the GHG consequences of this ILUC. This complex modelling is discussed in more detail in the recent EPA documentation on its approach to ILUC (EPA 2009) and in presentations at a GBEP conference (GBEP 2009), but will be briefly discussed here.

A number of methodologies are being developed for modelling of ILUC. These generally develop an estimate of ILUC and associated GHG emissions, which can then be incorporated into LCA models. The models to estimate ILUC can be complex (e.g. GTAP) or simpler, static approaches (e.g. the Öko-Institute's Risk Adder approach or the work by Ensus). The complex approaches use modelling of trade in agricultural economics to provide an estimation of crop substitution and land use change occurring as a result of the planting of biofuels crops. Examples of this include the approach taken by the California Air Resources Board (CARB) for the Low Carbon Fuel Standard (LCFS); and the recent EPA examination of the issue for the US Renewable Fuel Standard (RFS). In addition, EU and Dutch work on bioenergy crops are taking a similar route. The models involved are discussed below.

The simpler approaches also frequently use trade data, but without the dynamic modelling. For example, the Öko Institute in Europe uses information on trade in agricultural commodities to develop an estimate of the risk of potential ILUC that can be added to GHG LCA. Ensus, a British based bioethanol producer, have also examined a static approach to ILUC modelling, using historical data on changes in natural vegetation and land use for crops. These approaches are also described below.

The concept of ILUC as applied to biofuels is still relatively novel. As a result, clarity has not yet emerged on a number of critical issues relating to land use. This includes the lack of consensus on land classification and underlying definitions of land use or status. In order to develop the means to "measure" or attribute GHG emissions and sustainability criteria to ILUC in a global context, the harmonisation of descriptive terms for land use and land use classification will be necessary.

### **Brief description of methodologies for estimating carbon emissions from ILUC**

As indicated above, the current approach to ILUC generally involves the use of combinations of trade, environment (land use) and LCA models to examine potential scenarios for ILUC, based on current biofuels production practices:

- The trade models are used to provide an indication of substitution of agricultural products using real economic trade data, which indicate where commodities are produced and which regions trade these commodities (although often only bilateral trade is considered).
- The environment models provide information on current land use and are often supplemented with estimates of carbon emissions from soils when land use change happens (usually the IPPC estimates are used).
- The results from above are used to provide an estimate of emissions that can be attributed to ILUC from biofuels, so that they can be used to allow a factor for ILUC to be included in LCAs of biofuels production systems.

These models use estimates of carbon emissions from the predicted land use change to provide an indication of the impact of ILUC on total GHG emissions from biofuels.

Such models output a representation of what might happen, given a set of assumptions. Analysts are quite aware of the uncertainty surrounding some key issues on which these assumptions are based (e.g. land use, yield, carbon emissions due to land use change and substitution of one commodity for another) and the lack of data in other areas (e.g. where biofuels crops might be grown and what they might displace). As a result, they tend to use conservative estimates, examine ranges of inputs rather than specific numbers and undertake scenario analysis to test extremes of data and different potential consequences. The results are therefore broad and associated with uncertainty, but they provide a representation of what could happen as a result of increased planting of biofuels, which allows an ILUC factor to be developed and added into the LCA of biofuels use. For their part, regulatory agencies using these ILUC factors generally demand transparency in the analysis to allow the biofuels sector to understand where the figures come from and to challenge these figures if more detailed information is available for specific cases.

The modelling approaches all have at their core a number of steps on which they are based:

1. First an estimation of the area planted with biofuels crops (including which crops and where they are planted) is required. This provides an indication of the direct land use that is displaced.
2. The information from (1) is used to provide an estimate of the need to substitute any crops that were displaced by the biofuels plantation. It is assumed that there is either a continued market demand for this crop or for a substitute for the crop or commodity and estimation is made of the area of land needed for these crops elsewhere.
3. The next step is to define where this planting takes place, how much land use is required and whether this leads in turn to displacement of other crops (i.e. the displaced indirect land use). This will be influenced by factors such as socio-economics, yields, costs and other factors that may influence the choice of substituted commodity.
4. Once the land use changes are defined an estimation of the greenhouse gas emissions from this ILUC can be made. This figure will depend on the land change that happens, that is what type of plant ecosystem is cultivated for the substituted crop. Because of general uncertainties surrounding substitution at present modellers often assume a range of different habitats are used, and the final emission provided represents a range of habitat displacements. This figure can then be fed into a GHG LCA for the biofuel crop.

The level of uncertainty in the modelling depends on the biofuels system being examined and the availability of data on the biofuel crop; data on potential substitution crops (including where they may be grown, costs and yields); and on carbon emissions from land use change. Unfortunately, good quality data on current land use and the impact of land use change is not available in many parts of the world (e.g. Sub Saharan Africa and South America) that may be important areas for ILUC related to biofuels. This leads to disagreement between the modellers and the biofuels sector about the land use displacement and the influence of factors such as potential intensification of farming, particularly in areas where farming is currently extensive. Thus, there is a great need for improvements in data and our understanding of both current land use and the consequences of land use change. In addition, by their nature, most of these models work in a macro level and so can only be applied on a site basis if ILUC factors derived from them are used. Nevertheless the modelling provides important insights into the changes that could occur and an indication of ILUC due to these changes; and they provide the best approach at present.

### **Key modelling tools**

This section provides a brief summary of key modelling tools, as a background to the assessment of further R&D required.

**Life-cycle assessment (LCA)**

LCA is an analytical method used to examine the life-cycle impacts of a particular process and there are many LCA tools available (e.g. the RTFO default emissions for biofuels are based on an LCA developed for the UK Renewable Fuels Agency). LCA can be used at individual site level or for a specific commodity. The models work essentially by summing the GHG emissions at all levels of a production, use and disposal chain, i.e. they attribute carbon emissions from each stage within the LCA. For estimation of the GHG savings from renewable energy, these emissions are compared with those from the conventional energy source replaced to provide an indication of the GHG savings from substitution of renewable energy for fossil energy. LCA of GHG emissions for biofuels is relatively advanced but the LCA community does not have an agreed methodology for including ILUC, although they are aware of the issue. LCA is a technique that captures life-cycle changes. Current methodologies need to be extended to incorporate ILUC. To do this it is important to have a clear idea of what the ILUC changes are before they can be incorporated into the LCA. Two ways have been proposed to incorporate these changes into LCA and these are categorised as consequential and attributional changes. Box 2-1, taken from EPA (2009), describes these terms in more detail.

**Box 2-1 Definition of Attributional and Consequential LCA (from EPA 2009)**

**Attributional LCA** focuses on describing the environmentally relevant physical flows to and from a life cycle and its sub-systems. Attributional analyses are based on the direct suppliers of the necessary inputs to production; co-products are handled by allocation. This means that the environmental impacts from biofuels production are simply split between the fuel and its co-products, using average data to determine the allocation shares. Therefore an attributional LCA of corn ethanol would account for the direct impacts of increased corn production (e.g. fertiliser and pesticide use) but would ignore the indirect/marginal impacts of shorting crop patterns, such as decreased soy production, that would also result. Attributional analysis also requires a choice about the basis for allocation among co-products (e.g. mass, energy content, market displacement), which can lead to significantly different results.

**Consequential LCA** captures indirect/marginal impacts that are not explicitly included in attributional analyses. Consequential analyses account for activities within and outside the life cycle that are affected by an incremental change within the life cycle of the product under investigation. In other words, consequential life-cycle analyses study the consequences of changes in production or consumption from a market-based perspective, utilising economic modelling to identify the ultimate impacts of a decision such as a policy or a single project. This often implies the use of marginal data and co-product allocation is typically avoided through system expansion. In other words, consequential analyses include alternative uses of constrained production factors and marginal supply and demand on affected markets. Some researchers have concluded that the consequential approach provides more precise results but with inherent blind spots that lead to less accurate results.

**Economic modelling tools**

To provide an estimate of what crops are likely to be substituted and where they will be grown, a number of modellers have turned to economic data on trade in agricultural commodities. The key economic modelling tools that have been used to predict the changes that result from biofuels policies are the Global Trade Analysis Project (GTAP), FAPRI (the Food and Agricultural Policy Research Institute) and FASOM (Forest and Agricultural Sector Optimisation model) in the USA and the LEITAP and IMAGE modelling in Europe. In the EU JRC are also developing an approach. These have been used in association with various LCA models, notably GREET (and CA\_GREET) in the USA. More information on these models is provided in Box 2-2.



**Box 2-2. Description of key models used in assessment of ILUC**

**GTAP** is a computable general equilibrium (CGE) model developed in the early 1990s for the analysis of trade policy issues in the USA and elsewhere. It is coordinated by a team in the Agricultural Economics Department at Purdue University and used by researchers world wide. A CGE model comprises a detailed database and a series of equations that describe model variables. They are designed to seek equilibrium when a change is introduced and to predict the impacts of that change. For GTAP the main database comprises economic data from (currently) 113 regions of the world and for 57 sectors. The current version uses 2004 as its base year. For use for modelling climate change issues GTAP has been linked to other databases; for land use the FAO/IIASA agro-ecological zones are used, backed up by recent FAO datasets. GTAP has been used in many ways, including the modelling of agricultural price volatility. For modelling ILUC it provides predicted land use change impacts aggregated by affected land use type (e.g. forest). It is a key tool in the modelling of ILUC from biofuels in the USA where both CARB and the EPA use GTAP as a basis of their modelling for ILUC. For further information on GTAP see the GTAP web site:

<https://www.gtap.agecon.purdue.edu/default.asp> and the California Low Carbon Fuel Standard Regulation Staff Report (Chapter 4), which provides detail of the GTAP model and a list of inputs and parameters ([http://www.arb.ca.gov/fuels/lcfs/030409lcfs\\_isor\\_vol1.pdf](http://www.arb.ca.gov/fuels/lcfs/030409lcfs_isor_vol1.pdf)).

The **FAPRI** model is a partial equilibrium model that can provide data on the impact of changes in biofuel demand and land use in the countries included in its database; it does not include the USA. The FAPRI model predicts how much crop land will change in other countries but does not predict what type of land such as forest or pasture will be affected. For further information see: [www.fapri.iastate.edu/](http://www.fapri.iastate.edu/)

The **FASOM** model is similar to a partial equilibrium model and covers (only) the USA. It models the response of forestry and agriculture in the USA to policy changes and provides an indication of technical, economic and environmental (including GHG) impacts. For further information see: [http://www.epa.gov/sequestration/greenhouse\\_gas.html](http://www.epa.gov/sequestration/greenhouse_gas.html)

The Dutch Agricultural Economics Research Institute (LEI) together with the NL Environmental Assessment Agency have been examining ILUC from biofuels using a modified version of GTAP ('LEITAP') together with the **IMAGE** model. LEITAP is used to calculate agricultural production, trade and consumption of food crops and bioenergy crops over the time period 2000-2030. Its projects are then passed to the IMAGE model, which allocates land use and calculates the resulting environmental impacts, GHG balances and climate change under various scenarios developed as part of the EURuralis project. For further information see: Stehfest et al 2009.

The **Öko Institute** in Germany have developed a simple 'risk adder' approach to modelling ILUC (Fritsche 2009). This is intended to be an illustrative approach only and was developed as part of a continuing discussion about ILUC. The approach assumes potential release of CO<sub>2</sub> from direct LUC caused by displacement is a function of land used to produce agricultural commodities (i.e. the displacement is a function of trade flows). Using FAO data on trading of agricultural commodities it estimates which land use change takes place and where. It then uses IPCC emission factors coupled with regional land use shares for each agricultural commodity to provide an average CO<sub>2</sub> emission factor per ha of displaced land, discounted over 20 years. This is used to calculate a theoretical global average ILUC factor (which represents a maximum risk) and examines ILUC due to bioenergy for three scenarios: low (25% biofuels subject to theoretical full ILUC); medium (50% subject to theoretical full ILUC factor) and maximum (75% biofuel feedstock subject to full theoretical factor) to provide a "risk" factor for ILUC in the GHG emissions calculations.

**Approaches to modelling ILUC.**

The most advanced approaches to modelling ILUC are the US EPA work to underpin the revised Renewable Fuel Standard and the work on the LCFS by CARB. In Europe the Dutch Government has funded work and the EC is supporting work at the JRC. In addition industry has also contributed to the development of methodologies.

*US EPA approach*

The US EPA has developed a methodology to estimate GHG emissions from biofuels, including ILUC (EPA 2009). Their approach involves a series of relevant models linked through their outputs/inputs to examine both life-cycle analysis and market impacts. The EPA used data analyses provided by Winrock International to estimate what land types will be converted into crop land in each country and the GHG emissions associated with the land conversions. Two scenarios are examined: a business as usual case and one that examines technological advances including crop yield improvements. The EPA is also evaluating its models using GTAP.

The EPA states that the indirect, international emissions component of their analysis is the area associated with the highest level of uncertainty. They go on to say:

“For example, identifying what type of land is converted internationally and the emissions associated with this land conversion are critical issues that have a large impact on the GHG emissions estimates. We address this uncertainty by using sensitivity analyses to test the robustness of the results based on different assumptions. We also identify areas of additional work that will be completed prior to the final rulemaking. For example, while we utilized an approach using comprehensive agricultural sector models and recent satellite data to determine the GHG emissions resulting from international land use impacts, we are also considering an alternative methodology (the analyses using GTAP) that estimates changes in land use based on the relative land use values of cropland, forest, and pastureland. Additionally, we are considering country-specific information which may allow us to better predict specific trends in land use such as the degree to which marginal or abandoned pasture land will need to be replaced if used instead for crop production. Another approach to examining these uncertainties is to identify variables with the greatest impact on the overall results and apply sensitivity analysis. This is the approach we have taken, for example, looking at a range of ethanol plant types, as well as ranges of land use change factors. In this way we bound the results with high and low cases. The challenge in a complicated analysis with so many variables, of course, is to ensure that we have identified the most significant factors influencing GHG emissions, and that our choices of low and high cases accurately encompass the range of possible outcomes. **We note that further research on key variables will allow for a more robust assessment of these impacts in the future.**”

Research related to ILUC has been supported by the US EPA at Argonne National Laboratory (ANL) and Purdue University (Hertel et al, Tyner et al 2009); Purdue University<sup>4</sup> (Taheripour et al 2008).

*California Air Resources Board (CARB) Low Carbon Fuel Standard*

CARB have supported development of GTAP and GREET to provide them with defaults for ILUC. This work is ongoing, but they anticipate having a full set of results by the end of 2009. The work is intentionally transparent so that industry can understand the assumptions made and examine the modelling work. Further information on the CARB is provided by O'Hare (2009) and CARB (2009).

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<sup>4</sup> Purdue have examined the impact that use of co-products may have on land use change.

O'Hare indicates that the key parameters influencing ILUC are: fuel yield, price elasticity of yield, productivity of new land, cultivation period, carbon stock data, carbon recapture (time and amount) and discount rate. In addition the preliminary figures released by CARB have been subject to scrutiny by the biofuels sectors. For example, the response of UNICA to the defaults proposed by CARB provides a critique of the underlying assumptions on ILUC as applied to sugar cane ethanol production in Brazil, including the assumptions regarding trends in intensification of cattle on pasture land, yields of sugar cane, carbon emissions from land use change and the absence of carbon uptake for crops when they replace pasture (UNICA 2009).

### *Europe*

The European Commission is examining ILUC as part of its work on the Renewable Energy Directive. The 2009 Biofuels Thematic Programme focuses on the definition, analysis and testing of sustainability criteria for biofuels production and use. Questions of land use and ILUC associated with biofuel production and associated GHG emissions will have priority (JRC 2009). This work will be overseen by the Institute for Energy as part of the 7<sup>th</sup> Framework programme and the approach presented is similar to that used in the USA by CARB and the US EPA.

In the NL the LEITAP model is being developed to examine ILUC. The model is linked with the IMPAGE land use database. Further work is proposed on this model to include co-product modelling and modelling of agricultural and forestry residues. Also in the EU IASA are proposing a bottom up approach to modelling biofuels on a geographically explicit basis using a combination of partial equilibrium and biophysical models. This work includes detailed modelling of land intensive sectors, modelling of co-products and examination of the availability of land under different scenarios. The results will include an indication of ILUC.

### *Other models*

Modelling of ILUC is not restricted to Government regulators. Industry and NGOs have looked at this issue. Most well-known of these are:

- Friends of the Earth commissioned Scott Wilson to examine ILUC. They use a spreadsheet approach and currently assume that 10% of demand growth is met by land area growth; and that land displacement occurs globally in equal proportions across six key biomes/habitats (FoE 2009).
- Greenergy have supported work by Ecometrica who have used allocation and attribution of responsibility, in which direct and indirect emissions are estimated. Historical data is used to estimate GHG emissions associated with land use change from increases in commercial agriculture. Assuming that the observed land use change includes direct and indirect land use change, emissions from direct land use change is then progressively attributed to various sectors and crops, leaving emissions from ILUC. This is then used to calculate an ILUC penalty per unit mass of crop.
- ENSUS, whose approach includes examination of the avoided GHG from the use of co-products. Ensus have taken a static approach to the modelling of ILUC, examining natural vegetation changes resulting from changes in land requirements historically to provide an indication of likely future changes resulting from biofuels production. They assume that co-products from biofuels plants can be used for animal feed in the EU and displace a mixture of wheat and soy meal to maintain metabolisable energy and digestible protein. They then calculate the land area not required for soy for animal feed as a result of this substitution.

Further information on research in this area is provided in Table 2-1.

## Summary

ILUC remains a complicated area, and the methodologies described above attempt to reduce highly complex and uncertain issues to a default value that can be added to GHG LCAs that were originally developed to measure direct impacts. This approach needs to be examined in detail to assess its strengths and weaknesses and its applicability to UK biofuels.

The defaults proposed by the EPA and CARB have been subjected to extensive comment by the biofuels industry (e.g. UNICA 2009). The uncertainty in some of the fundamental assumptions (such as where ILUC occurs, what land use is displaced, assumed yields, etc) allows for critical analysis of the results. Nevertheless, in summarising the work for CARB, O'Hare (2009) stresses the importance of understanding not only what we think the GHG intensity of biofuels are, but also the cost of getting this wrong – and ILUC is a big issue in this equation.

A number of the researchers working in the area have also expressed concerns about ILUC. Typical of these are O'Hare (2009), Gnansounou *et al* (2008), Dale (2009) and Woods (2009). In summary these authors point out that:

- ILUC is not caused by biofuels alone.
- Co-products are often not taken into account in the modelling.
- There is a very large amount of uncertainty in the scale and spatial dispersion of future land use change.
- Some aspects may be too difficult / complex to adequately cover in systems models.

Additionally there is some concern that the models and assumptions are driven by hypothetical scenarios and thus only provide predictions of what might occur given that set of hypothetical conditions.

Boxes 2-3 and 2-4 provide further extracts from Gnansounou *et al* (2008) and Dale (2009) that consider the approaches being used for ILUC.

Wood (2009) lists some of the options to improve the situation including increasingly complex (scale/resolution and methodology) global land use models coupled to market models coupled to atmospheric models; and development and implementation of 'sustainability criteria' implemented through assurance and certification. Fritsche (2009) says 'in the long term the only solution is to strengthen global conventions to cap ILUC effects on GHG and biodiversity'.

### **Box 2-3. Approaches to quantification of ILUC in current modelling** Gnansounou *et al* (2008)

Quantification of ILUC is characterised at present by:

- Economic modelling of demand for land in a general / partial equilibrium approach.
- Modelling of global ILUC by relocation of activities on a worldwide scale.
- Worst case assumptions.
- The subjective choice of land to allocate displaced activities.
- Being restricted to cropland relocation.
- Being restricted to land-use due to biomass-use substitution and avoided crop rotation.
- Being modelled as decreased supply in producing country / increased production in other producing country of the same commodity.
- Displaced land-use not currently being modelled.

**Box 2-4. Weakness of the approaches to ILUC (Dale 2009)**

- Price increases drive models and LUC, therefore:
  - Any increase in agricultural prices is “bad”.
  - Conservation programs that take land out of production are “bad” because they raise prices.
  - Ag land should never be converted into forest/grassland.
  - Agricultural communities should stay poor forever.
- Global economic forecasts 10 years + from now?
- Models omit unused land (~400 million ha).
- Competing ILUC models give different results.
- ILUC makes domestic industries responsible for the environmental performance of competitors.
- Destroys value of real life-cycle analysis.
- Assumes all land use change worldwide is driven by agricultural expansion - clearly untrue.

Both CARB and the US EPA show that they are aware of these arguments and have done (and are continuing to) work to address them: as the US EPA says, ‘further work is needed on key variables to allow for a more robust assessment of these impacts in the future’.

**2.2.3 Key research questions**

The key research questions relating to ILUC include: What evidence exists which we can build on to allow us to a) develop indirect sustainability criteria and b) inform our position on the 2014 review?

This is underpinned by the following questions:

- 1) What are the different approaches to modelling indirect land use change, and how do they differ? How synchronised are the models, and are there gaps in the models?
- 2) Does the modelling assess the impact on:
  - GHG?
  - Natural resources?
  - Biodiversity?
  - Food prices?
  - Other issues?
- 3) What are the risks/probability ranges in the modelling?
- 4) What are the data gaps?
- 5) Are there solutions being identified?
- 6) Are the solutions site/producer specific, or macro?

**2.2.4 Research in the area**

As indicated above research is being undertaken on ILUC at two different levels, although in reality the distinction between the two is blurred:

- 1) Modelling Methodology

Modelling work is examining methodologies for inclusion of ILUC in GHG LCAs and through the use of complex modelling. This is high-level work, often being supported by national (or State) administrations. In answer to some of the results achieved by the work, industry has also begun to commission its own analysis. This work is described in the context section above.

## 2) Environmental Impacts

The results of modelling are restricted in value by the uncertainties in the fundamental data required for the modelling. In the ILUC area one of the key variables is land use and land use change and it is fair to say that there are not completely understood, particularly in some areas of the world. This is one of the fundamental areas that results in most controversy in ILUC modelling (Woods 2009). To improve the data input into the ILUC modelling and decrease the uncertainties in the data and the results, we need to have a better fundamental understanding of land use and all of the factors that result in land use change.

Research is being undertaken on the environment and its response to change in order to provide fundamental data on how and why land use change occurs. This work is being supported by research-funding organisations and is an attempt to understand land availability, current land use and the impact of land use on a local and national scale. This is highly complex multi-disciplinary research often involving more than one research group and taking some time to complete.

## 1) Modelling of ILUC in GHG LCAs of biofuels

The work being supported in these areas is summarised in Table 2-1.

**Table 2-1 Research on the modelling of ILUC**

<b>Funding or research organisation and budget where available</b>	<b>Current status and R&amp;D</b>
<b>UK</b>	
Department of Energy and Climate Change (DECC)	DECC have supported work on the ILUC impact of using for palm kernel etc. versus its use as an animal feed.
Defra	Supporting a short term project: Bioenergy Crops - Indirect Land Use Effects (December 2008 - June 2009) which is being undertaken by Central Science Labs.
Department for Business Innovation and Skills (BIS) (formally DIUS)	Has supported work at the Edinburgh Centre for Carbon Management and will be supporting the Foresight Global Food and Farming Futures project, which will include biofuels.
LowCVP	Development of an ILUC factor with Government/industry/academic/NGO consensus on how to derive ILUC, Collaborative with RFA, building on work by Ensus and others. Work will include collaboration with other international initiatives.
Greenenergy	Have supported Ecometrica to assess approaches to modelling ILUC. Research involves: <ul style="list-style-type: none"> <li>• comparison of outputs / results</li> <li>• comparison of assumptions and underlying data</li> <li>• boundaries and gaps</li> <li>• development of practical approaches to deal with ILUC</li> </ul>

Funding or research organisation and budget where available	Current status and R&D
<b>Europe</b>	
European Commission	The DGTREN and DG ARGRI are supporting work on approaches to ILUC, including modelling. The work of the JRC is central to the EC approach to this area.
Joint Research Centre (JRC)	The JRC is modelling ILUC as part of a large coordination between groups. They are not making new models but rather coordinate existing models to use the same baseline scenarios so that they are comparable. The JRC is also coordinating internationally including holding a major workshop earlier this year ( <a href="http://re.jrc.ec.europa.eu/biof/html/iluc_bioenergy_policies_paris.htm">http://re.jrc.ec.europa.eu/biof/html/iluc_bioenergy_policies_paris.htm</a> ). The JRC is working towards developing robust methodology for measuring, monitoring and reducing ILUC - including production-specific ILUC factors, and approaches and assessing models required to determine impacts of ILUC. In addition they are examining factors that impact ILUC, such as use of idle and marginal land and improvements in yield.
Öko-Institute & IFEU, Germany	The Öko-Institute and IFEU have done work to develop a simplified model of ILUC in GHG LCA models (Fritsche 2008), which allows ranking and exploration of the impacts, although it is sensitive to the assumptions made about land types chosen.
Meo-consulting, Germany	Meo Consulting is developing a certification system for sustainability, which will consider a methodology to estimate ILUC for the German International Sustainability and Carbon Certification (ISCC) project ( <a href="http://www.iscc-project.org/index_eng.html">http://www.iscc-project.org/index_eng.html</a> ). This is due to be completed early 2010.
Dutch Government	The Dutch Government delayed the inclusion of ILUC until 2011, although the Cramer Commission (2007) did propose a methodology for estimating GHG emission from ILUC.
IIASA	IIASA are examining a bottom up approach to land use and availability using the GLOBIOM (Global Biomass Optimisation Model) and other models (such as FAPRI and FASOM). This model builds up information on land use and land use change from basic data on land use to examine the impact of various levels of bioenergy demand and various scenarios on bioenergy trade on global deforestation. (See: Havlik et al 2009).
LEI/IMAGE	Examination of indirect land use change using the LEITAP model in combination with the IMAGE land use database.
EPFL, Switzerland	École Polytechnique Fédérale de Lausanne has reviewed work being undertaken on ILUC.
<b>US</b>	
Californian Air Resources Board (CARB)	CARB has developed defaults for ILUC in its Low Carbon Fuel Standard (LCFS). The CARB methodology has recently been published (CARB 2009), with a preliminary set of defaults. Further work will be done on both the modelling approach and on other biofuels pathways, which is

Funding or research organisation and budget where available	Current status and R&D
	anticipated to be completed by the end of 2009.
US EPA	The US EPA has developed a methodology for estimating ILUC from biofuels. Further work is planned to improve the methodology and data.
US DoE	US\$1.8 million in FY08/09 on ILUC research, including refining models to help study ILUC issues due to growth of biofuels.
German Marshall Fund	Biofuels project: This has included funding some of Searchinger's research on ILUC for biofuels and will continue to support work in this area.
Other US work	Other key US researchers in this area are: T. Searchinger (Princeton), Michael Wang (ANL), Bruce Dale (Michigan State University) R Lal (Ohio State University) and J. Fargione (The Nature Conservancy Council).
<b>International</b>	
UNEP and FAO	UNEP and FAO are providing datasets on land use worldwide through their global land cover network.
OECD	The OECD are examining biofuel related land use change effects using their Aglink model, which is the OECD's market model for the agricultural sector.
Brazil	Work is being undertaken by the Institute for International Trade Negotiations (ICONE), <a href="http://www.iconebrasil.org.br">www.iconebrasil.org.br</a> . This work is examining specifically sugar cane expansion and using a partial equilibrium model to project land allocation for agricultural activities at macro-regional level. The work focuses mainly on land use issues in Brazil (Nassar et al 2008) and includes land use information from CANASAT to provide an indication of direct land use change and ILUC ( <a href="http://www.dsr.inpe.br/canasat">www.dsr.inpe.br/canasat</a> ). Future land use is projected using partial equilibrium modelling. The Brazilians are also working with the US Government to improve modelling in FAPRI, FASOM and GTAP.
<b>Industry</b>	
ENSUS	ENSUS (2008 a, b) have worked on preventing ILUC from the use of DDGS as a protein feed for cattle, substituting for soy. They are continuing this work and have written a number of papers on the topic, which are in publication.
Greenergy	Greenergy (2008) are working on a practical solution to the issue of ILUC. This work is due for completion in 2009.
Other industry	Many companies are consultees or participants in the UK, Dutch and German biofuels sustainability initiatives.



Other	
Friends of the Earth (FoE)	Have developed a tool for the calculation of carbon dioxide emissions due to ILUC from biofuel production (FoE 2009)

## 2) Collection of data on the environment and its response to change

One of the criticisms of the modelling approach to ILUC is that it estimates and assumptions to model future land use. Outcomes from the models suggest that Government policies on biofuels will lead to land use changes. However, it is not always true that farmers will shift their behaviour in response to market conditions, particularly in the short term, unless there are significant changes (Mitchell 2009). There is a need to ensure that realistic and good quality data on land use and agricultural economics are available to allow us to monitor changes that happen.

This issue underlines the concern that there is not yet hard data on how the agricultural community will react to targets for biofuels (e.g. which crops will be planted). In addition for some crops (e.g. sweet sorghum, jatropha, switch grass) data is lacking on their interaction with the local environment, how and where they will be planted and what land use they will displace.

These are important gaps in data which make modelling of the consequences of biofuels policy difficult. More work is needed to understand the impact that biofuels policy will have on the ground: what crops are planted, where they are planted, what impact this has on local agricultural economics and if it results in expansion of agriculture elsewhere. In reality this work needs to be done on an international basis, with national and regional work feeding into international initiatives, such as those supported by UNEP and FAO.

**Table 2-2 Summary of work being done to gather data which will allow better understanding of the indirect land use impacts of biofuels**

Funding or research organisation and budget where available	Current status and R&D
<b>UK</b>	
Defra	Supports work on the consequences of agriculture in general, particularly on the impacts of set aside and on the impact of removing set aside.
DIUS	Foresight Global Food and Farming Futures Project will include biofuels. This Project will look to 2050 and take a global view of the food system, considering issues of demand, production and supply as well as broader environmental impacts and important issues such as changes in land-use for bio fuels.
NERC	Examining land bioenergy resources, impact of bioenergy and supply and demand. Supports work at Rothamsted on the environmental implications of increasing rural land use under energy crops. TSEC-Biosys examines land use and land management,
BBSRC	Key funding agency for the Sustainable Bioenergy Centre (BSBEC). Work of BBSRC includes optimisation of biomass yield and composition for sustainable biofuels.

<b>Funding or research organisation and budget where available</b>	<b>Current status and R&amp;D</b>
University of Aberdeen	Land use modelling and the effects of biofuel crop development.
<b>Europe</b>	
European Commission	Supporting relevant work under the Framework Programmes: e.g. BEE, <sup>5</sup> COMPETE, REFUEL <sup>6</sup> and work at the JRC under Luisa Marelli. Supports work on CARENSA, <sup>7</sup> a network aimed at South African sugar cane production, which is examining the sustainable production of sugar cane in South Africa.
IIASA	Work on land use and land use management: Mapping of land use. Participation in REFUEL.
University of Utrecht, NL	Work on land use and land use management and bioenergy resources and supply and demand: Participation in REFUEL, COMPETE and BEE. Work for FAO in food security.
WIP, Germany	Working on the sustainable production of biofuels feedstocks in South America (through LAMNET and BIO-TOP). Experience of biofuels crops production in Africa.
Chalmers University	Work on biomass trade and environmental impact of biofuels.
<b>International</b>	
UNEP	Has led work on assessments and guidelines for sustainable liquid biofuels production in Developing Countries. Executing agents FAO and UNIDO. Developing an evidence base on the relationship between biofuels, climate change mitigation and biodiversity (expected publication June 2009), supported by the Global Environment Facility. <sup>8</sup>
US MIT Joint Program on the Science and Policy of Global Change	Has supported work on land use implications of a global biofuels industry, completed in 2008.
USDA	Funding work on agriculture and its consequences and land use in the USA, including examination of biofuels crops and the value of land put aside under the Cropland Reserve Program.
FAO	Examining impact of agriculture and of biofuels. See: <a href="http://www.fao.org/nr/ben/befs">www.fao.org/nr/ben/befs</a>
SCOPE	SCOPE: Scientific Committee on Problems of the Environment. Aim of biofuels work: comprehensive, systematic and comparative analysis of the environmental benefits and costs of biofuel technologies. Funding includes UNEP, The German Research Foundation and Cornell University.
US – The Nature Conservancy Council	Has undertaken work on the impact of human activity on land use and biodiversity and on the impact of agriculturally driven global environmental change.

<sup>5</sup> The EU BEE project aims to harmonise biomass resource assessments focussing on EU and neighbours. 2008-11. Funding and dates for all EC FP7 and FP6 relevant to this study is presented in Annex 1

<sup>6</sup> See [www.refuel.eu](http://www.refuel.eu) - this project assessed biomass potentials for biofuel feedstock production in Europe. The work was undertaken by IIASA and partners and supported by The EC Intelligent Energy Europe programme. It was completed in 2008.

<sup>7</sup> EU funded Cane Resources Network for Southern Africa – work includes environmental impacts of different production strategies

<sup>8</sup> GEF provides grants for work on environmental land use issues. Has and is supporting biofuels work in developing countries

Funding or research organisation and budget where available	Current status and R&D
Indian Institute of Science	Involved in the Scope project and also being funded by the GDF to look at biofuels sustainability. Also involved in Indian funded research on biofuels land use.

### 2.2.5 Research gaps

We have considered research gaps in relation to the key research questions.

#### 1) **What are the different approaches to modelling indirect land use change, and how do they differ? How synchronised are the models, and are there gaps in the models?**

ILUC is a function of many different factors and full analysis requires a thorough understanding of these factors. Biofuels are not the only factor resulting in ILUC - other pressures on development of land will also result in ILUC. Consideration needs to be given to how all of these pressures interact to result in the ILUC impact and how ILUC should be assigned across the various sectors causing the indirect change.

Currently no model exists that allows such analysis; and the R&D needs to address it are extensive, covering all aspects of ILUC resulting from agriculture, other potential land use pressures and datasets on carbon stocks for the land where ILUC takes place. Clearly such models will be difficult to achieve in the near future. However, as indicated in the context section, a number of research funders are examining the ILUC from biofuels, including the EC, US EPA, CARB and US DoE.

Unfortunately, this has resulted in different modelling approaches that produce different results. This is mainly because the approaches differ in their core assumptions, leading to a lack of synchronicity. Furthermore, these uncertainties can result in a lack of confidence in the figures produced. Consequently, there is a need to provide improved models to ILUC, but this needs to build on the foundation already in place.

Research Gap 1: There are a number of different approaches to ILUC modelling, each complex and each with its own strengths and weaknesses. It is important to have a full appreciation of how these models are developing and which are most suited to UK needs. There is a need to review these approaches with the aim of understanding why there is a wide range of results, what factors the models are most sensitive to, what are the constraints for each approach and how accurately the models are able to represent the different sectors. This needs to be done on all proposed methodologies for modelling ILUC, including the global equilibrium models and the GHG LCA work. It should take the work of the EC, US EPA and US DoE into account. The outcome of this work should be a clear understanding of global approaches to ILUC, an indication of the most appropriate approach for modelling of ILUC for UK biofuels, an indication of the most important gaps in data and an assessment of how any approach for the UK can build on the work that has already been done. It should also examine whether the models being used could be better tailored to biofuels and if so, how; and develop good practice guidance for ILUC modelling.

Research Gap 2: ILUC is the result of expansion of a single sector, but often the end result of a complex interaction of a number of pressures. There is a need to examine how this is expressed in modelling.

## **2) Does the modelling assess the impact on: a) GHG; b) Natural resources; c) Biodiversity; d) Food prices; e) other issues?**

The modelling attempts to assess the impact of ILUC on GHG emissions; however, further research and development is required to gather basic data, given that at present the modelling involves a large number of assumptions.

There is limited assessment of the impact on natural resources and biodiversity and food prices in the ILUC modelling, although some global models do include agro-ecological zones, which give an indication of impacts at the level of these zones; and a number of these global models can be used to predict the impact of biofuels on food prices at regional level.

Indirect socio-economic effects are not covered and this is an area where further research and development is required (see Chapter 4 for more information on this).

Other issues, to a certain extent, may be considered in the modelling; for example LCA can be used to assess the impacts of alternative uses of biofuel raw material.

## **3) What are the risks/probability ranges in the modelling?**

There are large risks and probability ranges in the current modelling approach. This is due to the assumptions that have to be made for input data and to the number of differing scenarios that are modelled, which lead to a large range in the results presented. The consequence is that the results can appear to be dependent on assumptions. In addition, the models do not always take real differences in agricultural practices into account (e.g. yield improvements, the use of additional inputs, particularly if crops are grown in marginal land, improvements in technology etc).

R&D is needed to address these concerns and to ensure that any default value adopted for ILUC represents a more realistic situation and allows the objective of reduction in carbon emissions to be achieved. This work needs to be transparent; and there is a need for consensus on the methodologies. Without this any methodology chosen to support policy will remain open to criticism and may not be easily enforceable. Work is ongoing in the SA, Brazil and EU and by industry to try to decrease the risks/probability ranges in the modelling.

## **4) What are the data gaps?**

The risks and probability ranges in the modelling are in part due to a large number of data gaps, which include:

- Limited data on land use, agricultural practices and real-life data on crops.
- Limited information on the markets (biofuels or other) that crops are sold into (for example there is information on oilseed rape and palm oil trade but not always on their final use, which might be food, non-food or biofuels use).
- A 'real' understanding of the factors that result in land use change, of which biofuels are just one.
- An understanding of the impact of the use of co-products in mitigating land use change.

- A 'real' understanding of actual carbon stocks in land.

Research Gap 3: There are key gaps that are not included in the modelling at present:

- The potential for the use of co-products to bring beneficial changes in ILUC.
- The impact of price on yield and of land prices on land use.
- Peatlands are frequently not included in the global equilibrium models, even though drainage of peatland for agriculture has significant GHG emissions.

Work is already ongoing in some of these areas. For example, ENSUS (2008 a, b) are looking at the use of co-products and the US EPA are also examining how co-products can be included in their modelling.

Research Gap 4: The need to improve our understanding of real changes in land use through on the ground monitoring linked to satellite imagery.

Data on land use changes, which provides basic information on ILUC processes, is obtained from global datasets. These datasets are built up through a combination of satellite imagery and on the ground monitoring (often being done at national level or through FAO sponsorship). Such data provides the basis for calculation of GHG emissions from land use change due to biofuels; but if the fundamental data is uncertain, then the results to modelling ILUC will also be uncertain. For example, data on current land use in some of the key regions where ILUC from biofuels is likely to be important is lacking, particularly for Sub Saharan Africa and South America. We do not have specific data on the carbon emissions from land use change in some of these areas. Furthermore we do not understand farming systems in some of these areas, including potentials for yield improvement or for intensification of extensive farming techniques and the constraints on agriculture (water availability or low fertility soils). Consequently the estimate of deforestation resulting from biofuels or the estimate of carbon emissions due to LUC may be based on assumptions that are not necessarily correct. There remains a need to improve these datasets through expansion of on the ground monitoring linked to improved resolution satellite imagery. Much of this work has to be done internationally. Some work has been done to more clearly divide the world into agro ecological zones, which can be used to provide regional assessment of potentials for agriculture and specific crops. In addition the UN supports work through FAO, and in areas such as Brazil further work is being supported by national and regional government. It is not clear that a UK-only initiative could add to this, but UK support for acceleration of current international initiatives would be useful.

## **5) Are there solutions being identified?**

The study found that there is research going on and that solutions are being identified. The current work to establish a series of defaults for ILUC from biofuels is summarised in the context section and in Table 2-1.

However, it is likely that beyond the immediate establishment of ILUC defaults a more long-term requirement for data, to improve the default values and increase confidence in the concept and methodologies, will remain. In addition, the future development of methodologies is required to enable the inclusion of more sophisticated models which take real agricultural practice, the use of co-products and technology improvements into account. This research suggests that more work needs to be carried out on providing data for GHG LCAs on advanced / second generation biofuels and a more equal approach to be taken towards fossil fuels and to other agricultural crops.

It is also important to be realistic about the limitations of the application of life-cycle assessment techniques to the issue of ILUC. There is a need to understand what the drivers for land use are – and how significant biofuels are among these drivers (i.e. the consequential land use changes). The current approach appears to be too simplistic. The differentiation of LCA into ‘attributional’ and ‘consequential’ methodological approaches is helpful but further work is required to understand the benefits and limitations of these two methodologies.

As part of research gap 1 the applicability of the modelling solutions being proposed to the UK will need to be considered.

Research Gap 5: The role of other solutions, including development of sustainability certification and the exclusion of specific important ecosystems from agricultural development, need to be considered.

## **6) Are the solutions site/producer specific, or macro?**

Whether or not the solutions are site/producer specific or macro depends on specific needs. Individual producers attempting to improve their own practice and to model GHG emissions using LCA techniques need to act on a site/producer specific level; and they need to be able to see how their practice affects their individual plant carbon balance. Site by site data like this can provide good information on which to base best practice.

However, to gain the greatest benefits work on ILUC needs to be undertaken at the macro level. This will allow complex land use chains to be modelled across large areas and for different economies; and it will allow more than one factor to be examined for its impact on land use change globally. There are disadvantages to this approach, however, if we concentrate just on the macro level modelling (e.g. through GTAP) then we can only make judgements at macro level; and we are limited by the model and the assumptions/scenarios it can handle. In addition, as Greenenergy (2009) point out, the models result in the attribution of changes to remote ‘actors’, which may ‘impede the development of local standards and controls’. Thus it is important that these models are not seen as an end in themselves, but as a start to a process which also includes an understanding of all of the factors that control land use change, and that the results are fed back into best practice guidance.

### **2.2.6 Summary and conclusions**

In conclusion, ILUC is an area where comprehensive research is currently taking place, particularly to support policy in the US and in Europe. One danger is that there will be different approaches in different countries leading to confusion, which leads us to conclude that there is a need to review the current modelling initiatives, to understand their application to UK biofuels and to understand where (and if) the UK needs to develop work on ILUC modelling further. This research gap is a medium to large, reflecting the limitations with the current state of the art, the cost and the importance of interacting internationally.

However, it is not in itself an end to the process, but a beginning. There is also a need to understand all of the factors that lead to land use change and to understand the complex interactions between them, so that the role of biofuels can be put into context and so that complex land use changes are not attributed solely to biofuels. This is longer term work, but it is also urgent and will be significant in addressing the research questions listed above.

Furthermore, the CGE models currently being used to predict ILUC for biofuels were not developed for biofuels, but were adopted from other uses. There is a need to develop these models to ensure that they are better tailored to the needs of biofuels. Although urgent, this is a longer term project that will require funding over the next 1-3 years to ensure that the models are more appropriate to needs and to allow for improved datasets to be incorporated. Any work that is done in this area should take the large US DoE and EPA and EU programmes into account. The results of this work will be significant in answering the fundamental research questions posed in this study, because they are likely to begin to decrease uncertainty in the models.

In general there is also a need to ensure that good practice guidance is provided for ILUC modelling. There is great concern from industry and arguments amongst researchers on the approach to modelling – these critiques need to be answered by ensuring that best practice is developed and adopted (on an international basis). Although this is not a large project in itself, it has been assessed as a large research gap because of the level of consensus needed internationally.

The fifth research gap identified encompasses key gaps that are not included in the modelling at present:

- The potential for the use of co-products to bring beneficial changes in ILUC.
- The impact of price on yield and of land prices on land use.
- Peatlands are frequently not included in the global equilibrium models, even though drainage of peatland for agriculture has significant GHG emissions.

All of these are important issues that need to be considered, although smaller projects than those mentioned above. Nevertheless their inclusion in the modelling will add to the confidence that the models are reflecting a situation closer to reality. This is an urgent gap that will need to be addressed over the near future.

Underlying all of the above work is a need for real data on land use changes – what changes are happening and why. This is a significant and ongoing gap, which will need a significant amount of resources to address it.

The final research gap identified is to examine the role of solutions other than modelling of ILUC. This work will be international in context as the solutions may need to be implemented outside of the UK and through international agreement. This is an urgent gap, which will need first to be reviewed and then implemented; and it is likely to be developed over a period of years.

Table 2-3 Key research gaps

Research Gap	1. Review of modelling of ILUC and applicability to UK	2. Allocation of ILUC between different causal factors	3. Research on key gaps e.g. co-products, peatland, agricultural practice	4. Methodology for specific needs and resolution between satellite imagery and data on ground	5. Role of alternative solutions to ILUC
Key related work	JRC Öko-Institute CARB USEPA US DoE	FAO, IIASA, EC, UN, individual Governments	ENSUS	FAO, IASA, NERC, BBSRC, Defra, Brazilian Government	EU
Complexity	***	***	*	***	**
Time scale	*	**	**	***	***
Potential costs	***	***	**	***	***
National or international?	International				
Availability of data	Data available	Need for more data	Need more data	Need more data	
Availability of skill sets	***	**	***	***	***

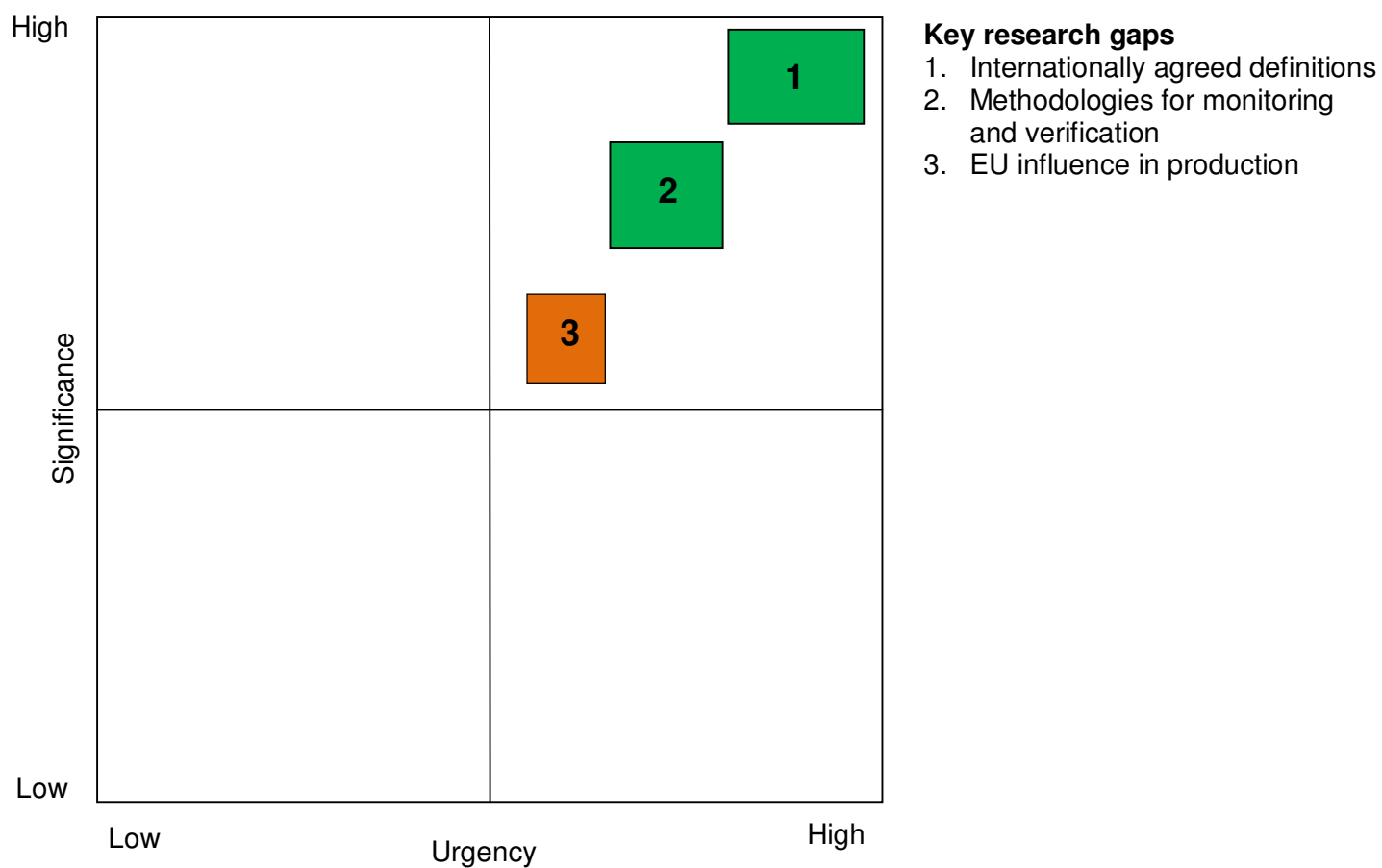
**Key**

<b>Significance</b> – please see matrix	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k * <£100k	<b>National or international</b> i.e. can the work be done in the UK or would it be better done internationally?
<b>Availability of data</b> This will refer to the IPR/availability of R&D already ongoing in the area (e.g. Commercial – restricted; or published/available)			<b>Availability of skill sets</b> *** a number of organisations working in area ** availability restricted to a few groups or only on international scale * skills gap, significant training required	



## 2.3 Idle and marginal land

**Figure 2-2 Matrix prioritising key research gaps for Idle and Marginal Land**



**Size of Research Gap**

	Small
	Small / Medium
	Medium / Large
	Large

### 2.3.1 Executive Summary

*What evidence is there to suggest that directing biofuel production onto idle, marginal land could be a) incorporated into the indirect sustainability criteria and b) a sustainable and viable way of achieving the 10% target without causing indirect land use change?*

Idle land can include former or current agricultural land<sup>9</sup> that will not otherwise be used for food production while marginal land can include land that is unsuitable for food production<sup>9</sup> for example due to poor soils or harsh weather environments. The use of idle, marginal lands for the production of biofuel crops has been identified as a way of producing biofuel crops, which will not compete with food crops and/or lead to land expansion onto natural habitats. However, several issues have been raised which address concerns about the value of lands which are not currently used for the production of agricultural crops e.g. the social value of lands (for communal grazing; small scale cultivation and local harvest of raw materials) and its biodiversity/environmental value.

This chapter considers current and future research in this area in order to identify the research gaps, which must start to be filled before degraded land can be incorporated into the indirect sustainability criteria and before we can be sure they can be a sustainable and viable way of achieving the 10% target without causing indirect impacts.

The key research gaps identified were:

Research Gap 1: Internationally agreed definitions. Descriptive terminologies for land such as idle and marginal have different meanings and connotations in different situations. Using these terms too generically can lead to confusion and the potential for misinterpretation as to which lands are being promoted for biofuel use. In order to promote growth of biofuel crops on land, which is currently “not-used” for agriculture, there must be global consensus on terms used to describe land.

Research Gap 2: Methodologies for monitoring and verification. Assessing and understanding the impacts of using marginal/idle land must be an on-going process. There will be a need to verify that the land used meets the internationally agreed definition and that marginal and idle land is being used appropriately for biofuels production.

Research Gap 3: EU influence in production. Research is required to help understand how the EU can influence production on these lands and ensure that sustainability objectives are met.

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<sup>9</sup> Examples provided in the Gallagher Review

### 2.3.2 Context

Agricultural land is classed as 'idle' because it is not currently being used for agriculture, where such use is feasible. So, for example, in the EU set-aside land is often also referred to as idle land. Marginal land is marginal for a number of reasons that include factors such as water scarcity, poor soil, erosion (or potential for erosion), slope, poor drainage and a number of other factors that make it economically marginal to farm (including distance from market). Poor management practices may also lead to land being marginal.

The Gallagher review identified the use of idle, marginal lands for the production of biofuel crops as a potential way of producing biofuel crops that will not compete with food crops and/or lead to land expansion onto natural habitats. However, several issues have been raised which address concerns about the value of lands which are not currently used for the production of agricultural crops e.g. the social value of lands (for communal grazing; small scale cultivation and local harvest of raw materials) and biodiversity/environmental value.

One area of debate, which strongly affects the efficacy of targeting biofuel crop production to particular land types, is the underlying definition of those land types, which needs to encompass what currently happens to the land and its value for biodiversity, ecosystem services and subsistence agriculture.

### 2.3.3 Key research questions

The key research questions include: What evidence is there to suggest that directing biofuel production onto idle, marginal land could be a) incorporated into the indirect sustainability criteria and b) a sustainable and viable way of achieving the 10% target without causing indirect land use change.

These are underpinned by the following questions:

- 1) Does it include an assessment of practicality of defining these concepts, including the difference between the two?
- 2) Does it research the practical issues that might be encountered in using this land for biofuel production?
- 3) Does it look at where "marginal/idle land" is likely to be found, and how much there is?
- 4) Does it look at yield and economic issues, which might affect attractiveness?
- 5) Does it include an analysis of the interaction between set-aside land and marginal/idle land?
- 6) Does it include an assessment of the impact of using marginal land upon biodiversity, natural resources, social issues (etc)?
- 7) Are there (direct or indirect) benefits from producing from idle/marginal land?

### 2.3.4 Research in the area

Research in the area is set out in Table 2-4.

**Table 2-4 Research in the area of Idle and Marginal land**

<b>Funding or research organisation and budget where available</b>	<b>Current status and R&amp;D on idle and marginal land</b>
<b>UK</b>	
CSL Funded through DECC/DEFRA £110 k	Indirect effects of growing bioenergy crops on marginal or idle land in the UK (includes LCA). Work covers definition of idle and marginal land, summary of land available and how much biomass could be produced. The work should be completed in March 2009.
DECC	DECC are considering following up the work on economic analysis of marginal land to look at issues such as the alternative uses of marginal land in order to understand the relative impacts of different options.
RFA	Over the next 12 months the RFA are considering work on definition of idle and marginal land and the potential for intensification – this work would include case studies on avoidance of ILUC.
BBSRC, ESRC, NERC and DFD	Potentially relevant work includes - the ERA ARD Net (ERA - European Research Area, ARD - Agricultural Research for Development) Call theme is “Bioenergy – an opportunity or threat to the rural poor”. BBSRC will be the lead organisation for the management of the UK dimension of the call which will consist of funding from BBSRC, ESRC, NERC and DFID. Two successful applications are due to be funded in the coming months.
Defra – work on set aside.	Set aside may be classed as idle land in the UK (and EU) and ideal for biofuels production. Defra have recently funded work on the benefits of set aside and on the impacts of the loss of set aside (e.g. ADAS 2008, IEEP 2008). This includes work on biodiversity, on plants, birds, mammals and insects, as well as water quality and soils. Defra also monitor the amount of set aside and uncropped land in England.
NERC, Imperial College London	QUEST: Quatermass project. Assessing the global potential of sustainable forestry and agriculture for bioenergy supply and climate change mitigation may be relevant.
Land use Policy Group (at JNCC)	Examination of the benefits of set aside (LUPG 2007).
RSPB and Birdlife International	Have supported work on the value of set-aside in UK and EU.

<b>Europe</b>	
JRC	JRC will use the output of ILUC modelling to look at where production will take place, including the use of idle/marginal and degraded land. JRC will use maps of land based suitability, taking into account LUC, cultivation and will use the maps to evaluate GHG emissions, c stock, LULUCF, N2O.
EEA	Produced report on how much biomass the EU can produce without harming the environment. Monitors land use and land use changes in EU.
<b>US</b>	
PURDUE University	Impact of Biofuels Production on Marginal Lands – modelling approaches.
Argonne US Office of Biomass Department of Energy	Evaluation of the sustainable production of bioenergy crops through the use of marginal land and impaired water. Considered Nebraska and Illinois.
Ohio University	Involved in land classification.
Stanford University	Modelling work, which will make a more detailed assessment of the opportunities and pitfalls, associated with an array of possible biofuels development scenarios (e.g. using different crops for biofuels production, using marginal land vs. highly productive land, etc).  Research on global estimates of abandoned land.
The Ecosystem Centre	Working on land definitions and a series of questions about “suitable” lands using existing land definitions.
Energy Bioscience Institute, the University of California, Berkeley	Research includes: work on quantifying abandoned and marginal lands available for energy crops; what crop species are most suitable on these lands; ecological impact socio-economic impact.
The Nature Conservancy	Research on defining idle/marginal land us land under the Conservation Reserve Programme (CRP). As such the scope is mostly national (USA).  Work on the issues of sustainability and idle/ marginal land – see below
PRBO Conservation Science, the Nature Conservancy and the Department of Applied Economics	Research into the impacts on biodiversity of the use of retired croplands for biofuels production.
USDA and USDOE	The joint solicitation from the USDA and the USDOE covers: the assessment of the potential of Federal land resources to increase the production of feedstocks for biofuels and bio-based products, consistent with the integrity of soil and water resources and with other environmental considerations.

<b>International</b>	
FAO	Global land use models from the FAO, NASA, UNEP-WCMC are widely relied on and initiatives such as the FAO/IIASA Global Agro-Ecological Zoning work provides much of the data which is universally used.
India	India has a policy decision to try to grow biofuels crops on marginal (and degraded) land. To do this the Indian government has undertaken its own national AEZ work through the Indian Institute for Science. The data from the Indian study is currently available.
Brazil	The Brazilian Government has undertaken its own national AEZ work. The results of the Brazilian study are expected to be made available in 2009.
South Africa Kuazulu Natal University	Idle or marginal land research done with GIS on land use.
The Gaia Foundation, Biofuelwatch, the African Biodiversity Network, Salva La Selva, Watch Indonesia and EcoNexus	Policy briefings on marginal lands.
ICRISAT	ICRISAT's BioPower Strategy, work on making the bio-energy opportunity work for the dryland poor.

### 2.3.5 Research gaps

We have considered research gaps in relation to the key research questions set out in 2.3.3

#### 1) Does it include an assessment of practicality of defining these concepts, including the difference between the two?

There is research considering the definition of idle/marginal land. The RFA are considering undertaking work on the definition of idle and marginal land. Defra is monitoring the use of agricultural land in the UK, including the extent of set aside; in the EU the EEA bring such data together. The Nature Conservancy are undertaking research on defining idle/marginal land us land under the Conservation Reserve Programme (CRP). As such the scope is mostly national (USA). The Ecosystem Centre are currently working on land definitions and developing a series of questions about "suitable" lands using existing land definitions.

However, many of the commentators in this area are not doing research, but merely expressing concern that the definitions are not clear and that such land is not always 'idle' but has important ecosystem and sometimes socio-economic functions. Descriptive terminologies for land such as idle, and marginal have different meanings and connotations in different situations. Concerns about existing definition are that they do not describe the background or land history that has led to these descriptions. The terms also do not express any timescale or degree/extent of idleness, marginality or degradation. Further concerns are that the terms also do not link biophysical properties with socio-environmental properties. Using these terms too generically can then lead to confusion and the potential for misinterpretation as to which lands are being promoted for biofuel use.

In order to promote growth of biofuel crops on land, which is currently "not-used" for agriculture, there must be global consensus on terms used to describe land. This is currently not the case and land use classification systems often differ by location/country. The means of physically measuring or quantifying land uses also vary (e.g. inventory methods may be ground-up based on practical data collection or top-down using satellite imaging) and there is a need to develop consensus between the two approaches. The problem of assessing the properties of land areas, which fall under certain terminologies, is also problematic in real terms as land areas may be inaccessible. Current guidelines such as those of the IPCC, describe land use in very broad categories for the purposes of GHG emission inventories. These categories are defined by both land cover and land use classes.

There is therefore the need to build on current research and agree international definitions for idle and marginal land.

Research Gap 1: There is a need for internationally agreed definitions for idle and marginal land.

## **2) Does it research the practical issues that might be encountered in using this land for biofuel production?**

The CSL are undertaking research to identify UK areas of idle land or land of currently marginal economic production value that could be used to grow energy crops while minimising competition with existing food crop production and ensuring that any associated land use change does not have a significant impact on the anticipated GHG saving, or any other significant detrimental environmental impact. The research aims to identify the key factors (including economic and environmental factors) that will influence whether such land could potentially convert to bioenergy cropping.

Argonne are undertaking an evaluation of the sustainable production of bioenergy crops through the use of marginal land and impaired water, this is using 'real life' examples in Nebraska and Illinois.

In India and Brazil there is work ongoing on defining agro-ecological zones to better classify land use. In India marginal lands are being specifically targeted for biofuels crops (Rajagopal 2008). Rajagopal and Zilberman question the use of marginal lands in a paper for the World Bank (2007). There is also some work undertaken through aid organizations or the UN or FAO, which examines the current uses of marginal land.

It is clear that work is needed to understand the impact of the use of such land on a country or regional basis and to consider its current versus its potential use from a number of angles.

**3) Does it look at where “marginal/idle land” is likely to be found, and how much there is?**

The CSL work will identify, on a spatial scale, the areas of idle and marginal land in the UK that could potentially convert to energy crop production, comparing current and potential use for energy production on the basis of suitability and estimated economic returns. It is likely that the EEA could include marginal and idle land within its land classifications for the EU.

Work at the global level includes the BIOSAFOR project which has examined saline soils around the world and their potential for bioenergy production; UNCTAD have done research on land availability for bioenergy internationally and identified projects for Jatropha planting on unused land in Indonesia, Mozambique and Mali; while Stanford University are currently undertaking research into global estimates of abandoned land.

**4) Does it look at yield and economic issues which might affect attractiveness?**

The CSL study (once it has identified and defined types of idle and marginal land in England and Wales) will identify the key factors (including economic and environmental factors) that will influence whether such land could potentially convert to bioenergy cropping.

The study will then identify appropriate annual and perennial bioenergy crops that could viably be grown taking into account the yield potential and the economic return that may accrue to growers as an alternative to the existing land use (where managed).

It is likely that the USA, India and China will also undertake studies on the yield and economic issues that will affect attractiveness of biofuels on marginal or idle land. Rajagopal and Zilberman comment on this issue in their 2007 World Bank paper.

**5) Does it include an analysis of the interaction between set-aside land and marginal/idle land?**

Birdlife International has conducted research into the implications for developing set-aside land in relation to the threat to birdlife and biodiversity. In response to the European Commission's proposal to reduce set-aside rates to 0%, Birdlife International highlighted the importance of set-aside land for biodiversity.

Birdlife Austria have conducted research which suggests set-aside land to be the single most important factor determining the density of wintering raptors, the diversity of farmland birds and the densities of several threatened or declining species (such as the great bustard and grey partridge). Their research notes the importance of set-aside land as a lifeline for many species and argues that using this land for large-scale conversion to energy crops would threaten the EU's chance of achieving the Gothenburg target of restricting biodiversity decline across Europe. Additionally, researchers in the UK have observed that when the set-aside area was halved in the 1990s, the number of farmland birds showed a serious decline.

Defra have recently funded work on the benefits of set aside and on the impacts of the loss of set aside (e.g. ADAS 2008, IEEP 2008). This includes work on biodiversity, on plants, birds, mammals and insects, as well as water quality and soils. Defra also monitor the amount of set aside and uncropped land in England.



**6) Does it include an assessment of the impact of using marginal land upon biodiversity, natural resources, social issues (etc)?**

The CSL will consider environmental factors in their study. Work by PRBO Conservation Science, the Nature Conservancy and the Department of Applied Economics has considered the impacts on biodiversity of the use of retired crop land.

The Roundtable on Sustainable Biofuels (RSB) is also considering the impact of the use of marginal/degraded land on social issues. Research is highlighting that land rights are complex. Furthermore RSB work on High Nature Value Classifications may also be of benefit.

NGO groups are also considering the impacts of growing biofuels on marginal land.

Research Gap 2: Methodologies for monitoring and verification are needed to ensure that marginal and idle land is being used appropriately for biofuels production.

Research Gap 3: Taking into account the above there is a need for an overarching research/policy gap considering how the EU could influence production on appropriate lands.

### 2.3.6 Summary and conclusions

In conclusion, idle and marginal land is an area where research is starting to take place.

A key issue is the need for internationally agreed definitions on idle and marginal land and the research to underpin this. This is a gap of high significance and reflecting the timescales for the RED is of high urgency. It is a medium to large sized research gap reflecting that although the skills sets are in place and data is available there needs to be international cooperation. Methodologies for monitoring and verification are a research gap of high significance and medium to high urgency. It is a medium to large sized gap reflecting that while the skills sets are in place it needs to take place on a longer timescale and involve international cooperation.

The role of the EU in influencing production is a research and policy gap of medium to high significance and urgency. It is a small to medium sized gap reflecting that the data and skill sets are in place.

**Table 2-5 Key research gaps**

Research Gap	1) Internationally agreed definitions on idle and marginal land	2) Methodologies for monitoring and verification	3) EU influence in production
Key related work	The Nature Conservancy The Ecosystem Centre Potentially the RFA	RSB	RTFO RED Directive
Complexity	***	***	**
Time scale	**	***	**

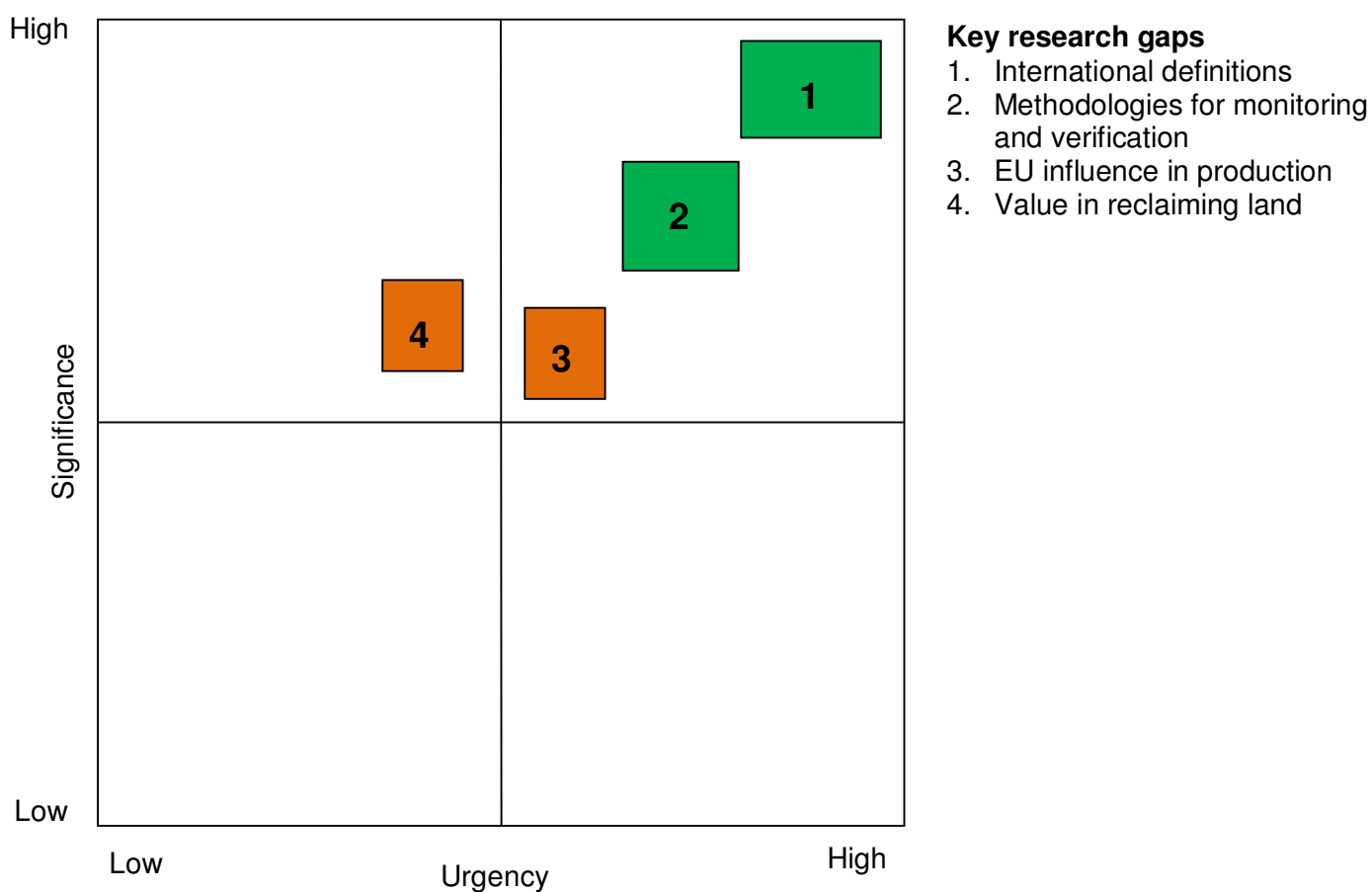
Research Gap	1) Internationally agreed definitions on idle and marginal land	2) Methodologies for monitoring and verification	3) EU influence in production
Potential costs	**	**	*
National or international?	International	International	International
Availability of data	Data available	Some data available	Some data
Availability of skill sets	***	**	***

### Key

<b>Significance</b> – please see matrix	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k * <£100k	<b>National or international</b> i.e. can the work be done in the UK or would it be better done internationally?
<b>Availability of data</b> This will refer to the IPR/availability of R&D already ongoing in the area (e.g. Commercial – restricted; or published/available)			<b>Availability of skill sets</b> *** a number of organisations working in area ** availability restricted to a few groups or only on international scale * skills gap, significant training required	

## 2.4 Degraded land

Figure 2-3 Matrix prioritising key research gaps for degraded land



Size of Research Gap

	Small
	Small / Medium
	Medium / Large
	Large

## 2.4.1 Executive Summary

*What evidence is there to suggest that directing biofuel production onto degraded land could be a) incorporated into the indirect sustainability criteria and b) a sustainable and viable way of achieving the 10% target without causing indirect land use change?*

Degraded land is 'lower quality' land not currently used for agriculture. It can include heavily contaminated land or land which has been degraded by poor agricultural practice.

Studies (for example Gallagher) have suggested that a way to avoid indirect land use change is to use degraded lands for the production of biofuel crops. However, several issues have been raised which address concerns about the value of lands which are not currently used.

The European Commission, through the RED, has proposed that a bonus of 29 gCO<sub>2</sub>eq /MJ should be attributed to biofuels if 'evidence is provided that the land: was not in use for agriculture or any other activity in January 2008; and falls in to the categories for severely degraded, including land that was formerly in agricultural use or heavily contaminated land'.

This chapter considers current and future research in this area in order to identify the research gaps that must start to be filled before degraded land can be incorporated into the indirect sustainability criteria and before we can be sure they can be a sustainable and viable way of achieving the 10% target without causing indirect impacts.

The key research gaps identified were:

Research Gap 1: Internationally agreed definitions. Descriptive terminologies for land such as idle and marginal have different meanings and connotations in different situations. Using these terms too generically can then lead to confusion and the potential for misinterpretation as to which lands are being promoted for biofuel use. In order to promote growth of biofuel crops on land, which is currently "not-used" for agriculture, there must be global consensus on terms used to describe land.

Research Gap 2: Methodologies for monitoring and verification. Assessing and understanding the impacts of using marginal/idle land must be an on-going process. There will be a need to verify that the land used meets the internationally agreed definitions.

Research Gap 3: EU influence in production. Research is required to help understand how the EU can influence or incentivise production on these lands and ensure that sustainability objectives are met.

Research Gap 4: The value of reclamation of degraded land needs to be better understood. While it is thought that production of biofuels on degraded land may have benefits in terms of reclaiming the land, little has been practically proven. More work, therefore is needed to demonstrate the value of reclamation of degraded land by biofuels crops.

### 2.4.2 Context

The classification of land as “degraded” faces similar challenges to classifications such as idle and marginal. Land may be marginally productive as a result of inaccessibility due to naturally occurring physical constraints or as a result of constraints that occur due to land or soil degradation. The extent of land degradation may then define its marginality and the problems of defining land use and quantifying land that might be available for biofuel crop production is emphasised.

The UN/FAO define degraded land generally in terms of a temporary or permanent decline in the productive capacity of the land. Usually this is land that has been degraded due to poor management or over intensive use (although natural disasters such as land slides and earthquakes can also induce temporary land degradation). Thus irrigated land can become salinated; over grazed land can be eroded; and poorly managed land may be subject to issues such as wind erosion. In addition, over extraction of water supply can also result in land degradation; and pollution can lead to degradation of land. This land then becomes ‘marginal’ in terms of its economic value for agriculture; and the extent to which this occurs will be impacted on by other factors that induce marginal agricultural economics, such as constraints on the land, water constraints or inaccessibility. It is these factors that make it difficult to classify. This makes degraded land a subset of marginal land in some cases. The same issues apply to degraded land as marginal and idle land – i.e. it may have a current use and it may provide an ecosystem or social benefit which needs to be accounted for (although perhaps to a lesser extent than idle or marginal land). However, it has been proposed that biofuels can be beneficial to degraded land, particularly those crops (such as perennial energy crops and those crops that can tolerate arid conditions) that add organic matter to soil, improve soil structure and help combat erosion or desertification.

The main source of information on degraded land is GLASOD (the Global Assessment of Human Induced Soil Degradation), which was produced in 1990. In addition, there have been some regional studies, a world atlas on desertification, a study to assess land degradation in drylands, plus several country specific studies (UN 2004).

### 2.4.3 Key research questions

Key research questions include: What evidence is there to suggest that directing biofuel production onto degraded land could be a) incorporated into the indirect sustainability criteria, and; b) a sustainable and viable way of achieving the 10% target without causing indirect land use change.

These are underpinned by the following questions:

- 1) Does it include an assessment of practicality of defining and using degraded land?
- 2) Does it look at where degraded land is likely to be found, and how much there is?
- 3) Does it look at yield and economic issues that might affect attractiveness?
- 4) Does it include an assessment of the impact of using degraded land upon biodiversity, natural resources, social issues (etc)?
- 5) Are there (direct or indirect) benefits from producing from degraded land?

#### 2.4.4 Research in the area

Research in the area is set out in Table 2-6.

**Table 2-6 Research in the area of degraded land**

<b>Funding or research organisation and budget where available</b>	<b>Current status</b>
<b>Europe</b>	
Öko Institute	Options for sustainable use of degraded lands, and the geospatial-referenced identification of such lands.  Interim results from work on biodiversity mapping/degraded lands (especially case studies for China and South Africa) will be presented at July 2009 workshop in Paris (to be held jointly with CI, DG-ENV, FAO, IUCN, UNEP, WWF and others). Final reports at the end of 2009.
Utrecht University	Creating a global map of degraded land looking at where, how, to what extent, how it overlaps with existing agricultural lands and yields.  The project may also potentially look at economics of production and GHG performance. Completion Sept. 2009.
<b>US</b>	
Ohio State University	Lal R 2006. Land area for establishing biofuel plantations, Energy for Sustainable Development,
Stanford University	Research on the global potential of Bioenergy on Abandoned Agricultural lands
<b>International</b>	
UN	Research on land degradation processes is well advanced and has been occurring over the last 30 decades at least. It is well characterised by the UN Food and Agriculture Organisation and through the Convention to Combat Desertification ( <a href="http://www.unccd.int/">http://www.unccd.int/</a> ), and at the regional level by the European Environment Agency, for example.  Despite this, it remains un-clear how national or regional policies developed specifically to regulate biofuels can successful direct the production of relevant feedstocks onto degraded lands around the world.
University of KwaZulu Natal South Africa	COMPETE – Competence Platform on Energy Crop and Agroforestry Systems for Arid and Semi-Arid Ecosystems – Africa  Research into the potential for sustainable bioenergy from degraded lands.
The Ecosystem Centre	Working on land definitions and a series of questions about “suitable” lands using existing land definitions.

Funding or research organisation and budget where available	Current status
University of Science and Technology Beijing Tsinghua University Beijing	Research into the potential for sustainable bioenergy from degraded lands.
Tanzania Traditional Inanely Development and Environment Organisation	Research into the potential for sustainable bioenergy from degraded lands.
Embrapa – Brazil	Research into the potential for sustainable bioenergy from degraded lands.
Roundtable Sustainable Biofuels	Research into social issues around degraded and marginal lands.
ICRISAT ICAR, IFAD, EC and private sector members in the consortia. GTZ, private entrepreneurs, Government of India and Government of Andhra Pradesh.	Research on Jatropha and Pongamia and degraded lands. Research started five years ago.

## 2.4.5 Research gaps

### 1) Does research include an assessment of practicality of defining and using degraded land?

Öko Institute have summarised and identified issues with definitions:

1. Land degradation is a long-term loss of ecosystem function and services, caused by disturbances from which the system cannot recover unaided (UNEP 2007).
2. Land degradation is a long-term decline in ecosystem function and productivity and measured in terms of net primary productivity (Bai/Dent 2006).
3. Land degradation is the decline of natural land resources, commonly caused by improper use of the land (Bergsma et al. 1996).

A consensus on degraded land and marginal land has been reached through the Indian AEZ activity as being that marginal lands are those lands which are not “naturally” suitable for agricultural crop growth whilst a degraded land is a land area which was once productive agriculturally but which has declined to a no-productive state as the result of mismanagement or over-farming.

The European Commission, through the RED, has proposed that a bonus of 29 gCO<sub>2</sub>eq /MJ should be attributed to biofuels if ‘evidence is provided that the land: was not in use for agriculture or any other activity in January 2008; and falls in to the categories for severely degraded, including land that was formerly in agricultural use or heavily contaminated land.’

The practicality and therefore efficacy of such a measure will be entirely dependent on achieving workable and robust international definitions that can adequately classify ‘degraded land’ and on the verification procedures adopted.

Research Gap 1: There is a need for internationally agreed definitions for degraded land.

### 2) Does research look at where degraded land is likely to be found, and how much there is?

The Öko Institute is currently researching options for sustainable use of degraded lands, and the geospatial-referenced identification of such lands. Outputs include a Joint International Workshop on High Nature Value Criteria and Potential for Sustainable Use of Degraded lands July 2008. The workshop is a joint initiative of the Öko Institute, RSB, and UNEP in collaboration with CI, FAO, IUCN and WWF. Further, interim, results are due at the next workshop in July 2009.

There are existing databases on degraded land. These include the Global Assessment of Human Induced soil degradation (GLASOD) and the Global Land Degradation Assessment in Drylands Project (GLADA) (this is a GEF/UNEP/FAO project).

Lal (2006) has identified that the global potential for biomass production is 1,000,000,000 ha which would be sufficient to supply 25% of global primary energy use. However, the exact definition of this degradation is not explicit.

There are case studies being undertaken in specific countries - for example Brazil, China, South Africa and Tanzania are considering where the degraded land is located and the amount of land.



### 3) Does research look at yield and economic issues which might affect attractiveness?

There are question marks over the profitability of producing biofuels on marginal and degraded land. It has been shown that the yields are lower than production on non-degraded soils, which means that even crops such as Jatropha, which are considered candidates for degraded land, are being grown on fertile land because of the higher yields (and therefore returns). Initial research shows less favourable economics for Jatropha than for other biofuel crops (Gallagher Review), alternative crops such as Moringa, Pongamia and Sweet Sorghum are being researched (e.g. by ICRISAT)

<http://www.icrisat.org/Biopower/WaniBiodieselCropsfordegradedlandsDec2006.pdf>

Second generation woody feedstocks are another possibility, but the technology and economics of their use for biofuels is still pre-commercial.

### 4) Does research include an assessment of the impact of using degraded land upon biodiversity, natural resources, social issues (etc.)?

Research by the Öko Institute with Conservation International and RSB is considering the use of High Nature Value Criteria across all biofuels, including those grown on degraded land.

The RSB are taking this research forward. Conservation International is also undertaking work on Biodiversity Prioritisation.

The RSB are also considering the impact of the use of degraded land on social issues.

Research Gap 2: Methodologies for monitoring and verification are needed to ensure that degraded land is being used appropriately for biofuels production.

Research Gap 3: Taking into account the above there is a need for an overarching research/policy gap considering how the EU could influence production on appropriate lands.

### 5) Are there (direct or indirect) benefits from producing from degraded land?

It is thought that production of biofuels on degraded land may have benefits in terms of reclaiming the land, for example, by increasing soil organic carbon, improvement in water retention and water cycling and general improvements in soil invertebrate populations (AEA 2008). However, beyond the theory of this use, little has been practically proven. More work is needed to demonstrate the value of reclamation of degraded land by biofuels crops.

Research Gap 4: The value of the reclamation of degraded land.

## 2.4.6 Summary and Conclusions

The concept of degraded lands is not a new one, and there is ongoing research in the area. The links between degraded lands and idle and marginal land are important and should be taking into account when considering research needs.

As with idle and marginal lands a key issue is the requirement for internationally agreed definitions on degraded land and the research to underpin this. This is a gap of high significance and, reflecting the timescales for the RED, is of high urgency. It is a medium to large sized research gap reflecting that, although the skills sets are in place and data is available, there needs to be international cooperation to take this forward.

As with idle and marginal lands methodologies for monitoring and verification are required. This is a research gap of high significance and medium to high urgency. It is a medium to large sized gap reflecting that while the skills sets are in place it needs to take place on a longer timescale and involve international cooperation.

There is a research / policy gap, which involves considering the role of the EU in influencing production. This is a research gap of medium to high significance and urgency. It is a small to medium sized gap reflecting that there are data and skill sets in place.

There is also a requirement to understand the value of reclamation of lands. This is a gap of medium urgency and significance.

Table 2-7 Key research gaps

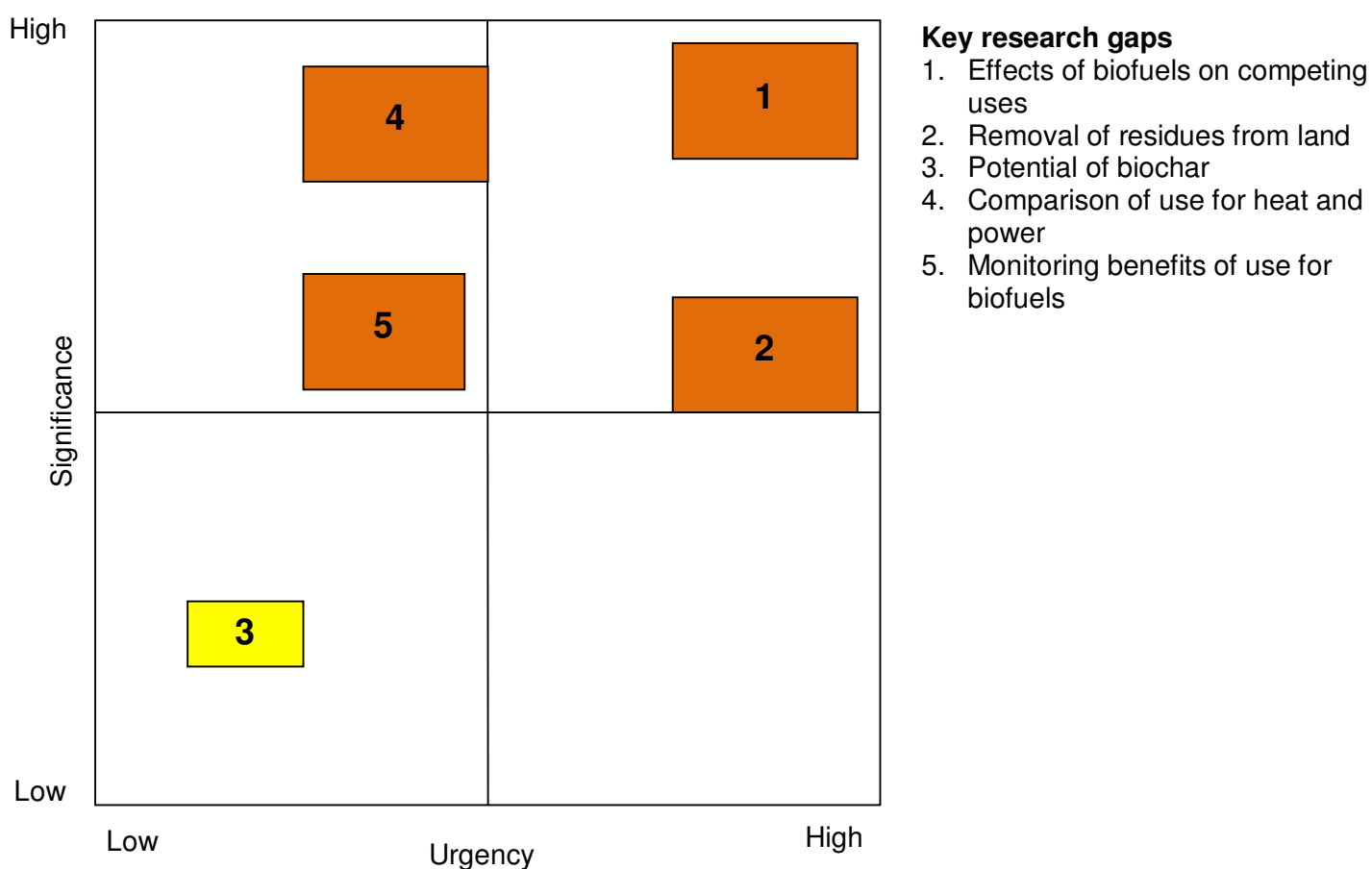
<b>Research Gap</b>	<b>1) Internationally agreed definitions</b>	<b>2) Methodologies for monitoring and verification</b>	<b>3) EU influence in production</b>	<b>4) Value of reclamation</b>
Key related work	Öko Institute	Öko Institute with Conservation International and RSB	RTFO RED	
Complexity	***	**	**	**
Time scale	**	**	**	**
Potential costs	***	**	**	**
National or international?	International	International	International	International
Availability of data	**	*	*	**
Availability of skill sets	**	**	**	**

**Key**

<b>Significance</b> – please see matrix	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k * <£100k	<b>National or international</b> i.e. can the work be done in the UK or would it be better done internationally?
<b>Availability of data</b> This will refer to the IPR/availability of R&D already ongoing in the area (e.g. Commercial – restricted; or published/available)			<b>Availability of skill sets</b> *** a number of organisations working in area ** availability restricted to a few groups or only on international scale * skills gap, significant training required	

## 2.5 Wastes, by-products and residues

Figure 2-4 Matrix prioritising research gaps for wastes, by-products and residues



Size of Research Gap	
<span style="background-color: yellow; border: 1px solid black; width: 20px; height: 20px; display: inline-block;"></span>	Small
<span style="background-color: orange; border: 1px solid black; width: 20px; height: 20px; display: inline-block;"></span>	Small / Medium
<span style="background-color: green; border: 1px solid black; width: 20px; height: 20px; display: inline-block;"></span>	Medium / Large
<span style="background-color: blue; border: 1px solid black; width: 20px; height: 20px; display: inline-block;"></span>	Large

### 2.5.1 Executive Summary

*What evidence is there to suggest that requiring biofuels to be produced from wastes / by-products and residues can be a) incorporated into the indirect sustainability criteria? and b) a sustainable and viable way of achieving the 10% target without causing indirect impacts?*

This section examines research on the potential use of wastes, by-products and residues as feedstock for biofuel production.

Relevant wastes include kitchen and food factory wastes; by-products include by products of agriculture, forestry and food processes, such as glycerol produced as a result of biodiesel production or wood residues from wood processing; and residues include the biomass remaining from agricultural production such as stubble and corn stover.

It has been suggested that these materials are potentially sustainable feedstocks for biofuels production; and that their use should be encouraged. The Gallagher review suggested that these feedstocks should be considered as a way to avoid indirect land use change. The RED states that biofuels produced from wastes and residues should be incentivised by a factor of two compared to other biofuels.

However, there is little work comparing the alternative uses of these feedstocks for other purposes with that of biofuels and the relative sustainability of these uses<sup>10</sup>.

This chapter considers current and future research in this area in order to identify the research gaps, which must start to be filled before wastes, by products and residues can be incorporated into the indirect sustainability criteria and before we can be sure they can be a sustainable and viable way of achieving the 10% target without causing indirect impacts.

Research Gap 1: Evidence is needed to understand whether these wastes, by-products and residues have any alternative uses and the impact of support for biofuels on these competing markets. For example, there are alternative uses for many waste/by-products and residues which compete (potentially) with their use as feedstocks for biofuels. These uses include heat and power; the use of waste wood for panel board manufacture; the use of tallow in oleochemicals; the use of residues as animal feed or animal bedding. Consequently, there are likely to be economic consequences to encouraging the use of these feedstocks for biofuels, as prices could increase as a result of the competition.

Research Gap 2: It is important to understand the environmental impacts of increased agricultural and forestry residue removal for biofuel production internationally. Returning crop residues to the soil has been shown to increase yields, which is a major driver for increased uptake of conservation agriculture ('zero-tillage') around the world. Further work is needed in this area to provide specific information on how much residue can be removed for biofuels without harming the inherent benefits of leaving agricultural residues on the ground.

<sup>10</sup> For example wood residues are currently used in the panel board industry; agricultural residues are frequently used for animal feed; and many biomass wastes are being considered for heat and power generation. In addition the value of returning agricultural and forestry residues to soil is important for recycling of minerals and maintaining soil organic content and fertility. Residue removal needs to take this into account.

Research Gap 3: More needs to be understood about the extent to which strategies and technologies to maximise the availability and use of biomass, including the potential of biochar and other similar techniques, can substitute the returning of crop residues to the soil each year, enabling a portion of them available for other uses such as biofuel production.

Research Gap 4: There is a need for comparison of the use of waste, by-products and residues for biofuels and heat and power, including GHG and other environmental emissions, and to provide guidance on the efficient and effective use of these feedstocks, particularly the potential for multi-use as in biorefineries or the use of by-products from biofuels production for heat and power.

Research Gap 5: Monitoring of the non-land use indirect effects of wastes, by-products and residues for biofuels, to provide evidence for the benefits of the use of specific feedstocks for biofuels and increase understanding of the non-land use indirect effects.

If the contribution of biofuels from wastes, by-products and residues is to be a viable and sustainable way of achieving the 10% target without causing indirect land use change it needs to be a satisfactory solution economically, environmentally and socially. Currently little R&D has been undertaken to demonstrate that this is true. Therefore, in all cases the existing uses must be considered in order to take account of the knock-on effects and their sustainability implications.

## **2.5.2 Context**

Growing crops specifically for biofuel production gives rise to potential issues of land use change. At first glance, it may appear that crop residues, wastes and by-products could be a sustainable source of bioenergy without needing to set land aside for additional crop production, or expend additional energy and resources for its production. However, markets for biofuels and bioenergy are potentially almost limitless, unlike the supply of 'waste' biomass and by-products or residues. Consideration must be made of the current use of these feedstocks, where they exist, other potential future uses and the impacts of large-scale drivers on markets and sustainability.

Where there is a current use, what would be the sustainability benefits or drawbacks of diverting the feedstock to biofuel? For example, woodchip is a potential source of bioenergy but may currently be used for chipboard manufacturing. Woody biomass may be used in the future for heat and power production, which may provide greater GHG benefits than biofuels. Another example is the impact of the use of crop residues for biofuels. These may be currently returned to the soil and maintain its carbon levels, without which productivity would diminish (LUC 2007). Taking this a stage further, conservation agriculture is becoming increasingly popular internationally as a means of achieving high productivity with minimal damage to soil and ecosystems. It advocates crop production without ploughing and with all crop residues returned to the soil in order to increase soil carbon levels. However, removing those residues for biofuel production would reduce or eliminate these environmental benefits.

Therefore, there is a need to understand these underlying issues in order to create a framework that facilitates the most sustainable outcomes.

### 2.5.3 Key research questions

The key research questions include what evidence is there to suggest that requiring biofuels to be produced from wastes / by-products and residues can be a) incorporated into the indirect sustainability criteria? and b) a sustainable and viable way of achieving the 10% target without causing indirect impacts?

This is underpinned by the following questions:

- 1) What research is there on the indirect land use change impacts of using wastes, residues and by-products, competition with other uses of these products, etc?
- 2) What about the wider sustainability issues of using these products – GHGs, water/soil/air, social etc?
- 3) Are there attempts to capture the likely interaction between the renewable heating/electricity demand and biofuel demand of these products?
- 4) Are there (direct or indirect) benefits from producing biofuels from wastes/by-products/residues?

### 2.5.4 Research in the area

**Table 2-8 Research in the area of wastes, by-products and residues**

Funding or research organisation and budget where available	Current status
<b>UK</b>	
The Gallagher Review	The Gallagher Review (June 2008) included a section: 'Estimating Indirect Land-Use Impacts from By-Products Utilisation' which is one of the few attempts to quantify land savings from crop by-products. This report indicated there were a number of gaps in data.
Department for Transport	In April 2008, a report was published for the Department for Transport, entitled: 'Advice on the Economic and Environmental Impacts of Government Support for Biodiesel Production from Tallow.' This report showed that there could be considerable indirect impacts from tallow use for biofuels, including impacts on GHG emissions and socio-economic impacts. It also demonstrated the need for more data and it is likely that the Renewable Fuels Agency (RFA) will examine the issue in more depth.
Defra	Defra has supported work at Rothamsted and Cranfield to examine the impact of the removal of straw from land on soil organic matter, drought resistance and other criteria. This work estimated the amount of straw that could be removed from agricultural land without harming the soil.
CSL	CSL is researching the potential environmental impacts of increased bioenergy use as a result of increasing demand for heat, power and transport fuels.

Funding or research organisation and budget where available	Current status
NNFCC	The NNFCC is also investigating the potential impacts of meeting increased biomass demand on UK agriculture and the wider environment. It is also proposing to research how 'closed-loop' agricultural systems could optimise the use of biomass for food and fuel production.
Newcastle University	Newcastle University is researching the use of biochar as a soil amendment, with a view to storing carbon in the soil and increasing yields over long time frames.
RFA	The RFA is interested in undertaking work on the indirect effects of the use of residues and by-products for biofuels, although this work has not yet been formally agreed.
Porter Alliance / Cambridge University  Funded through BBSRC	Effective technologies using waste materials e.g. straw and bagasse and potential reduction on indirect land use effects. Project aims are better understanding of the process of conversion of plant biomass to sugars for fermentation. Better enzymes for the process. Knowledge for breeding of plants better suited to the process. First outputs for industry in 18 months from now. Better enzymes in 3-5 years. Better crop plants 10 years onwards.
<b>Europe</b>	
European Commission	There is FP7-funded research being carried out around use of wastes and by-products for biofuel production and biorefineries (KBBE 2007 2A). In part, this aims to maximise the value of the wastes and by-products through energy-saving bioprocesses. However, there is no mention of the strategic issues and impacts being investigated by this study as it is primarily aimed at seeking to make such technologies more cost-effective at the demonstration phase.
European Environment Agency	In the 2006 EEA study on how much biomass the EU could produce without harming the environment, the figures produced for agricultural and forestry residue took into account the environmental functions of forest residues, deadwood and straw. This reduced the full potential by 60% to allow sufficient residue to remain on the land to combat issues such as soil erosion, water flow, biodiversity and removal of nutrients. As a result, the report recommended that roots and foliage should always be left on or in the ground. This report also examined the impact of various environmental scenarios on how much biomass would be available for bioenergy.
<b>US</b>	
Sandia National Laboratory	The '90-Billion Gallon Biofuel Deployment Study' has just been released by the Sandia National Laboratory (February 2009). It advises on the potential for large-scale ethanol production from biomass in the USA. The target of 90 billion gallons per year by 2030 would be met by sustainable biomass from four sources: agricultural residue, forest residue, perennial energy crops (e.g. switchgrass) and short rotation coppice. See further details at <a href="http://hitectransportation.org/news/">http://hitectransportation.org/news/</a>



Funding or research organisation and budget where available	Current status
Brookings	'Improved uses and values for the by-products of the developing biofuels industry' (2007 to April 30th 2009). Evaluated biomass streams from current and potential future biofuel production processes and their applicability for use in beef, dairy and pig rations, along with other value-added products. This turns the second generation biofuel concept on its head: instead of using food crop residues as biofuel feedstock, this targeted biofuel crop remains for food production (via livestock).
Renewable Energy Assessment Project	REAP (Renewable Energy Assessment Project), is investigating the 'Impact of Residue Removal for Biofuel Production on Soil.' The work is based on maize. The study aims to identify optimal levels of residue that must be left in the field after a crop has been harvested in order to preserve soil carbon levels. It also examines management techniques that could be deployed to support sustainable harvesting of residues, such as the use of cover crops, no tillage and organic amendment. June 2007-May 2011. See: <a href="http://www.ars.usda.gov/research/projects/projects.htm?accn_no=410653">http://www.ars.usda.gov/research/projects/projects.htm?accn_no=410653</a> .

### 2.5.5 Research gaps

We have considered research gaps in relation to the key research questions set out in 2.5.3.

#### 1) What research is there on the indirect land use change impacts of using wastes, residues and by-products, competition with other uses of these products, etc?

Prior to considering this issue it is necessary to clarify the definitions of wastes, by-products and residues in this context and the differences between them. In addition it is important to have an appreciation of whether or not these feedstocks have any alternative markets and the impact of biofuels use on these markets. For example, if end-users compete for the limited biomass already in availability, then prices will increase and the markets will change in nature. This has already been examined, for example, in the DfT study of tallow for biodiesel (AEA 2008). This report considered the conflicting demands of the oleochemical and biofuels industries for this feedstock and the impact on economics and GHG emissions of alternative uses. The example of tallow illustrates the complex nature of the topic and the issues that must be taken into account when identifying potential feedstocks for biofuels. In the case of cellulosic ethanol feedstocks, the technology is still not commercial, which makes the task even more complex as it is necessary to predict future alternative uses for the same raw materials and their respective environmental benefits.

Research Gap 1: There is a need to increase understanding of competition of biofuels with other uses of the waste, residue and by-product feedstocks. This will include examining the impact of the use of wastes/by-products and residues for biofuels on alternative markets for these feedstocks in terms of GHG emissions and socio-economic impacts.

#### 2) What about the wider sustainability issues of using these products – GHGs, water/soil/air, social etc?

If crop residues are to be used for biofuels production, the requirements of soil fertility, and structure must first be considered. Returning crop residues to the soil has been shown to increase yields, because it increases soil carbon and nitrogen levels, water holding capacity and the development of a healthy soil fauna. It also improves the physical properties of the soil and helps protect it from water and wind erosion. These characteristics are well documented and are a major driver for the increased uptake of conservation agriculture ('zero-tillage') around the world. Further work is needed in this area to provide specific information on how much residue can be removed for biofuels without harming the inherent benefit of leaving agricultural residues in the ground. There is good quality work being carried out around the world, such as the REAP project's investigations into sustainable crop residue management and Rothamsted's work on the quantity of straw that should be left on the soil. Understanding this will be of value not only to the emerging biofuel industry, but also for agriculture and the environment as a whole. Increased understanding of this field will be essential to meeting growing world food demand, whilst minimising further conversion to cropland.

Research Gap 2: There is therefore a clear need to understand the environmental impacts of increased residue removal for biofuel production on soil, water and the potential effect on GHG emissions.

The research may ultimately benefit from being extended across different crops, soil types and climatic zones. This would be a long-term project with international collaboration, again costing £millions; however, it is considered a high priority as demands on biomass resources increase.

There are techniques and processes that can potentially help to offer solutions to these issues. For example, terra preta techniques are being used to increase soil fertility. These techniques take advantage of the properties of pyrolysed biomass to aid retention of organic matter in the soil. The idea is to pyrolyse crop residues to create a char that is recalcitrant and remains in the soil potentially for centuries or millennia. The International Biochar Initiative (IBI) is a network of stakeholders and researchers around the world who are seeking to develop knowledge in this area. Individual institutions such as Newcastle University, Edinburgh University, Imperial College and Cornell University are active in this area of research. Among the questions being looked at is: to what extent can biochar – on a one-off basis - substitute for the returning of crop residues to the soil each year, thus making a portion of them available for other uses such as biofuel production? This research would require £millions in funding but is a potential way of maximising the use of crop residues. Indeed, it could become a method of carbon capture and storage that could help to reverse GHG emissions on a global scale whilst simultaneously increasing agricultural productivity.

Research Gap 3: Investigation of the extent to which biochar may substitute for the returning of crop residues to the soil on an annual basis.

**3) Are there attempts being made to capture the likely interaction between the renewable heating/electricity demand and biofuel demand of these products?**

Most of the wastes, by-products and residues considered for biofuels production are also being considered for generation of heat and power. The Environment Agency in England and Wales has commissioned some work to compare the GHG emissions from these end uses, but otherwise little work has been done to consider the likely interaction between the renewable heat/power demand and biofuel demand of these feedstocks. Such work needs to consider the overall potential to displace transport fuels and the emissions benefits attained from this, not just the GHG benefits of these alternative uses on a per tonne basis. Other benefits, including reductions in other emissions need to be considered; and also the potential for multiple energy products from these feedstocks (e.g. through gasification, pyrolysis, or through the use of by-products from biofuels production as sources of heat and power). There also needs to be a better appreciation of the size of the resource and whether or not it can meet heat, power and biofuels demand and what the best use/most cost effective use of the resource is.

Research Gap 4: There is a need to compare the use of waste, by-products and residues for biofuels and heat and power, including GHG and other environmental emissions, and to provide guidance on the efficient and cost-effective use of these feedstocks, particularly the potential for multi-use as in biorefineries or the use of by-products from biofuels production for heat and power.

#### **4) Are there (direct or indirect) benefits from producing biofuels from wastes/by-products/residues?**

The benefits of using biofuels from wastes, by-products and residues relate to the potential to provide GHG emissions savings without affecting land use for crops and other commodities. However, as we have discussed above many of these feedstock have alternative uses and there may be non-land use indirect impacts of their use for biofuels. These could have socio-economic and environmental implications. To understand the benefits of using these feedstocks for biofuels we have suggested in (1) above that a comprehensive comparison of the use of these feedstocks should be undertaken, encompassing GHG emissions, socio-economic impacts and other environmental factors. In addition we need to understand the full benefits of the use of these feedstocks for biofuels. This work has to be done through evidence based R&D over a period of time to demonstrate the preliminary and continuing benefits.

Research Gap 5: Monitoring of the non-land use indirect effects of wastes, by-products and residues for biofuels, to provide evidence for the benefits of the use of specific feedstocks for biofuels and increase understanding of the non-land use indirect effects.

### **2.5.6 Summary and conclusions**

The use of wastes, residues and by-products initially appears to resolve core issues for biofuels, those of ILUC and the competition with food crops. However, on consideration they raise a number of other issues that have to be considered, such as the impact on alternative uses for these materials, e.g. their potential use for heat and power or as a feedstock for chemical processing or board manufacture. There has been little work done in this area and there are a number of research gaps. The first research gap identified in this work is to understand the potential socio-economic and GHG consequences of policies to encourage the use of these feedstocks for biofuels. This is a research gap of high significance and high urgency, which needs to be examined prior to inclusion in any indirect sustainability criteria for biofuels in the RED. However, in terms of size, it is a medium to small gap, reflecting that while much new work will need to be undertaken, existing skills sets are in place and the cost and number of issues which need to be considered are, in comparison with other research gaps, relatively low.

The second key research gap identified was the impact of the removal of residues from land is also important. In this analysis, it has been ranked as high urgency but slightly lower significance, reflecting the need for improved understanding in the short to medium term. However, it is mainly relevant to second generation processing, on a longer time-scale. The gap has been ranked as small to medium sized reflecting the amount of information already available for a number of key crops (e.g. wheat straw and corn stover) and the comparatively low cost and number of skills involved. Nevertheless, the types of residues involved and the international nature of biofuels means that some of this work will need to be done on an international basis, particularly for residues imported from developing nations.

Related to the above, the potential of biochar as a soil carbon source is an extremely interesting research area because it may allow more residue removal from land over time. However, this work is assessed to be of relatively low significance and urgency compared with the other gaps. This is because it will be more relevant in the longer term as second generation biofuels are developed; it is therefore not as important to the immediate development of indirect sustainability criteria. Nevertheless, the development of biochar and an understanding of its properties and the potential for improving soil organic carbon will need to be considered in the future.

The use of these feedstocks directly competes with their use as feedstocks for biomass heat and power. This needs to be examined in detail, not only to understand the impact of this competition, but to understand the impact across the whole sector for the UK and to examine whether or not there is the potential for combining the production of biofuels, heat and power from wastes, by-products and residues to make more effective energy use of the resource. This work will be of significance in addressing the questions asked in this report, but is not urgent as it will be of greater importance for second generation biofuel. It is also not a large research gap: we have ranked this as small to medium.

We have ranked the need for better understanding of the benefits of using wastes and residues as a highly significant research gap, but of lower urgency than the other gaps. This is work that needs to demonstrate the continued benefits of the use of these feedstocks for biofuels over time. While this research is important it is also more relevant to second generation biofuels and therefore can be done over a longer time-scale. It is a small to medium sized gap, reflecting that new work will need to take place but that the number of issues and costs are low and existing skills sets are in place.

Table 2-9 Key research gaps

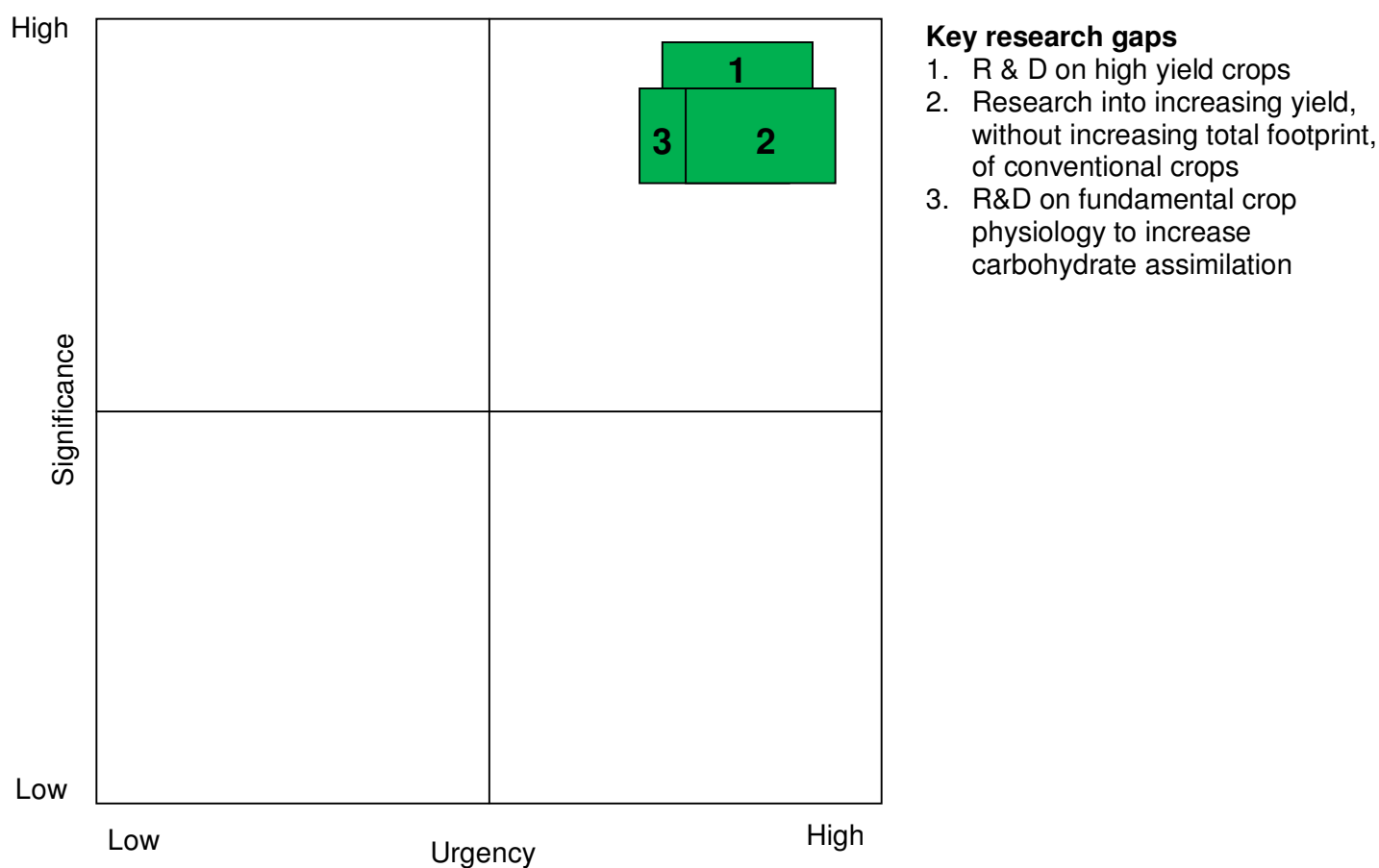
Research Gap	1) Competition with other uses of these feedstocks	2) Removal of residues from land (non-US)	3) Potential of biochar as soil carbon source	4) Understanding of use of wastes, by-products and residues for heat, power and biofuels	5) Monitoring of benefits of use of wastes, by-products and residues for biofuels
Key related work	RFA, DfT, EC	REAP	Newcastle, Imperial		
Complexity	***	***	***	**	**
Time scale	**	**	***	*	*
Potential costs	***	***	***	*	*
National or international?	UK	International	International	UK	UK / EU
Availability of data	Available	Available	Available	Available	Available
Availability of skill sets	***	**	**	***	**

## Key

<b>Significance</b> – please see matrix	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k * <£100k	<b>National or international</b> i.e. can the work be done in the UK or would it be better done internationally?
<b>Availability of data</b> This will refer to the IPR/availability of R&D already ongoing in the area (e.g. Commercial – restricted; or published/available)			<b>Availability of skill sets</b> *** a number of organisations working in area ** availability restricted to a few groups or only on international scale * skills gap, significant training required	

## 2.6 Increases in yield/productivity

**Figure 2-5 Matrix prioritising key research gaps for increases in yield/ productivity**



**Size of Research Gap**

	Small
	Small / Medium
	Medium / Large
	Large

### 2.6.1 Executive Summary

*Can increased yield, productivity improvements, or agricultural intensification be a) incorporated into the indirect sustainability criteria, and b) a sustainable and viable way of achieving the 10% target without causing indirect land use change?*

Increasing yields and the productivity of land is seen as one option for reducing the potential for ILUC from biofuels production. The Gallagher review concluded that there were realistic prospects for substantial improvements in yields, but that such advances were dependent on a combination of three drivers: public investment in research and infrastructure; supportive legislative and trade agreements and private investment supported by profitability of production.

This chapter considers current and future research in this area in order to identify the research gaps which must start to be filled before yield, productivity improvements or agricultural intensification can be incorporated into the indirect sustainability criteria and before we can be sure they can be a sustainable and viable way of achieving the 10% target without causing indirect impacts.

These key research gaps include:

Research Gap 1: Further work is needed to understand and develop high yield crops, both for biomass and food that do not disrupt current production models.

Research Gap 2: It is important to carry out further research into increasing yield without increasing the total footprint of conventional crops. For example, rather than increasing yield at all costs (including increasing emissions from fertiliser input), research should look at using varieties with reduced input requirements, therefore leading to reduced pollution and demands on resources.

Research Gap 3: A better understanding is needed of crop physiology to increase carbohydrate assimilation, and the critical factors for increasing production per hectare.

This may be seen as a hierarchy: firstly increasing yields by conventional means such as breeding or greater inputs; then taking account of the environmental impact; and finally looking at fundamental processes within the plant.

In order to avoid indirect land use change, it is also important to understand the consequences of measures to improve the environmental performance of crops for biofuels. For example, a reduction in the use of fertilisers can have direct GHG benefits when using crops for biofuels, but if this results in reduced yield, the negative ILUC consequences elsewhere could dwarf the GHG savings made.

The academic material we have reviewed suggests that there is the potential that current RED targets for biofuel production could be met by feasible increases in yield. However, even the most productive biomass crops will require some land and, if land use change is to be avoided, this will need to be met from land currently under arable crops. Hence, new varieties of greater yielding food crops also need to be developed to maintain food production.

## 2.6.2 Context

Over the last 40 years, the earth's population has increased from 3.5 billion to 6 billion (an increase of 70%) with forecasts of further increases to between 9 and 11 billion by 2060. Global food production has also increased by around 70% over the last 40 years, and so is broadly in line with the increased demand for food. Most of this increase has arisen from greater production per ha, since over the past 40 years the total area under crops has increased by only around 15%, from 1.3 to 1.5 billion ha. This reflects, to a certain extent, the availability of uncultivated land.

This increase in productivity has been beneficial because there are limits to land that can be used for agriculture without unwanted impacts. About 35% of the earth's surface has already been converted to agriculture and much of the remainder is desert or mountainous regions unsuitable for cultivation. Much of the uncultivated land that may have potential for increased agricultural production has the greatest biodiversity or, due to the nature of the soil in many locations, may not be able to sustain agriculture in the longer term. There is concern that in the future, improved productivity, at recent rates of increase, might not meet the combined increase in demand from biofuels and food. Hence, directly or indirectly, the demand for biofuel feedstocks might lead to land use change and its associated negative impacts.

This section evaluates research that is currently being done on increasing yield, both for biofuels crops and for food crops, in order to identify key research gaps.

## 2.6.3 Key research questions

The key research question to assess the issues of yield and productivity was: "Can increased yield, productivity improvements, or agricultural intensification be a) incorporated into the indirect sustainability criteria, and b) a sustainable and viable way of achieving the 10% target without causing indirect land use change?"

Underpinning questions include:

- 1) Are there assessments of predicted future yield improvements for biofuel crops, for example over the next 5-50 years? Is this broken down by scenarios, countries, regions, climatic conditions?
- 2) Can this yield improvement contribute to a reduction in use of land, or the world's ability to meet future increased demand for food/feed/fuel without causing Land Use Change (LUC)?
- 3) Is there any analysis of what these yield improvements mean for: biodiversity; water / soil resources; NOX / fertiliser; GHGs more generally; co-products; or anything else?
- 4) Does this include the interaction with Genetic Modification (GM)?
- 5) Can broader agricultural intensification free up land to source biofuels sustainably?
- 6) Is there any research on the drivers for yield, intensification, or productivity increases, and what is required for these improvements in different parts of the world?
- 7) Does this research compare with drivers on land use change?
- 8) Can we incorporate the drivers into indirect sustainability criteria?



9) What practical or conceptual difficulties are there involved with:

- Measuring yield improvements?
- Isolating to what extent yield has improved as a result of the different drivers/sustainability criteria, as opposed to weather, and which these different drivers are?
- Assessments of future yield improvements?

#### **2.6.4 Research in the area**

The research evaluated in this study falls into two categories, that directly related to improving the yield of specific perennial biomass crops, and that related to improving yields of crops for other purposes, which may also provide benefits for biofuel production.

An example of the latter is the Defra-Link 'Green Grain' project. One of the main aims of this work is to breed wheat varieties with better quality grain protein with respect to essential amino acids (EAA) and a more appropriate ratio of protein to carbohydrate for stock feed that may be grown with less fertiliser-N. The main driver is to reduce N pollution from livestock production. However, such grain could also be of use as a feedstock for biofuel. The work programme proposed by the Biotechnology and Biological Sciences Research Council (BBSRC) for crop improvement (i.e. greater yields) addresses fundamental aspects of crop physiology that could be utilised in biofuel production. This involves optimising sustainable biomass/yield by genetically improving plants to increase the amount of sunlight they capture, the amount of carbon they can assimilate over a growing season and the partitioning of the carbon in harvested biomass.

Traditionally, most work on crop improvements has been supported by Government, EU and UN agricultural organisations and by the seed and fertiliser manufacturers. For example in the UK this work is supported by Defra, and sometimes through organisations like HCGA. In addition work has been supported on energy crops through the UK Department responsible for renewable energy (variably BIS, DECC and Defra), EU DG\_AGRI and the USDA. The table below provides a list of current projects being supported in the UK, EU and internationally, but it must be remembered that a lot of work has been supported in the UK by BIS and Defra on energy crops at, for example, Rothamsted, ADAS and IGER in the past and that BBSRC, NERC and Defra are continuing this work (Karp and Shield 2008).

**Table 2-10 Research in the area of yields and productivity**

<b>Funding or research organisation and budget where available</b>	<b>Current research</b>
<b>UK</b>	
Defra	Perennial biofuel crops. NF0424 – Improving SRC through breeding & genomics.
Defra	Perennial biofuel crops. NF0426 - The genetic improvement of miscanthus for biomass.
Defra	Perennial biofuel crops. NF0439 - Identifying the causes for limitations in the establishment of perennial biomass energy crops, with a focus on Miscanthus.
Defra	Agricultural crops. LK0959 - Green grain project. Examining producing higher starch grain more suited to uses such as biofuels.
Defra	Agricultural crops. IF0144 OREGIN. Pre-breeding research to support climate change adaptation and reduction of the environmental footprint of Oilseed rape.
HGCA	Agricultural crops. HGCA project 2890 'Evaluation of factors affecting yield improvement in oilseed rape'.
BBSRC, ESRC and NERC	Are also supporting various relevant projects to examine land use for bioenergy crops – see, for example, the work of Lovett et al on Miscanthus yields in England.
Rothamsted	Breeding and improvement of SRC willow; yield trials and improvement of dedicated energy grasses; long-term trials of energy crops. Rothamsted are co-ordinating the BEGIN project to improve SRC yield and pest resistance ( <a href="http://www.biomass4energy.org/index.php?area=home">http://www.biomass4energy.org/index.php?area=home</a> ) and have done work on the genetics of SRC. They are also co-ordinating work on improving yields of oils seed rape (OREGIN) ( <a href="http://www.oregin.info/">http://www.oregin.info/</a> ), which runs from 2008-2013 (1.32M Defra funding).
IGER	Doing work on breeding and improvement of energy grasses for yield and quality. Co-ordinates Miscanthus genetic improvement programme in UK.
Southampton University	Southampton University have reviewed work on yields of SRC in the UK in work supported by UKERC and NERC, identifying precipitation as a major yield limiting factor at present (Aylott et al 2008).
<b>Europe</b>	
EC FP7	Annual biofuel crops. EU - KBBE-2009-3-2-02: Sustainable use of seas and oceans. Biomass from micro- and macro-algae for industrial applications (greater yield potential than land plants).
EC FP7	EU - KBBE-2009-1-2-05: Water stress tolerance and water use efficiency in food crops. Work to improve tolerance to water stress and water use efficiency has relevance to biofuel crops.

Funding or research organisation and budget where available	Current research
EC FP7	EU - KBBE-2009-1-2-04: Improving performance and quality of crops in the context of organic and low-input systems by breeding and management. While the context of organic cropping will have no relevance to biofuels, improving yield under low input systems will be important since proposals have been made to minimise the impact of biomass crops by growing them on poor quality or degraded land.
<b>US</b>	
USDA	US Federal agencies are conducting R&D into high-yield biomass systems and dedicated energy crops that do not disrupt current production paradigms.
USDA	Regional Biomass Energy Feedstock Partnerships conducting in-field studies to determine best location for dedicated energy crops in – collaboration with USDA, the Sun Grant Initiative universities, and other regional partners.
USDA	Developing a tool to identify the amount of corn stover that should be left on the field to maintain soil carbon and biomass yields.

### 2.6.5 Research gaps

The following gaps in current research in this area were identified by this study in relation to the following questions.

**1) Are there assessments of predicted future yield improvements for biofuel crops over the next (e.g.) 5-50 years? Is this broken down by scenarios, countries, regions, climatic conditions?**

No explicit assessments of predicted future yield improvements for biofuel crops were found. However, for the UK, annual yield increases of around 2% per year until 2025 are considered feasible, thus it would appear that the additional production needed to meet biofuel targets could be achieved within the next 5-10 years. Data presented by the Food and Agriculture Organisation (FAO) suggests that the global rate of increase in agricultural production will decrease over the period 1998-2015 to 1.4% per year from 2.2% between 1969 and 1999. For Europe and North America this increase is forecast to be 0.8% per year compared with 1.3% between 1969 and 1999. In transition countries, the increase will be smaller still at 0.5%, but this is compared with a decrease of 0.2% from 1969-99.

The OECD and EEA both suggest that the factors critical for increasing yields need to be identified (e.g. fertilizers, crop rotations, and access to markets). The likely speed and geographic spread of trends in agricultural management and likely future yield increases also need to be identified.

**2) Can this yield improvement contribute to reduction in use of land, or the world's ability to meet future increased demand for food/feed/fuel without causing LUC?**

This is theoretically possible. However, yield increases are unlikely to be driven by anything other than increased prices, and hence will depend on significant private (as well as public) investment. However, improved prices and returns are likely to encourage expansion of cropping onto uncropped land, unless there are constraints on LUC.

A recent FAO report pointed out that the differences among countries in current average yields can be very large, but they do not always denote potential for growth in countries with low yields.

Research Gap 1: R&D into high yield biomass systems and dedicated energy crops that do not disrupt current production paradigms.

**3) Is there analysis of what these yield improvements mean for: biodiversity; water / soil resources; NO<sub>x</sub> / fertiliser; GHGs more generally; co-products; or anything else?**

There has been some analysis of these issues in the UK, e.g. for combinable crops, but not exclusively biofuels. The general view is that improvements in productivity will reduce GHG emissions per tonne of grain production. However, life-cycle analysis indicates that the most favourable outcomes for GHG emissions may not be the most favourable for air and water quality or for biodiversity. The HGCA has conducted work on the environmental effects of biofuels, but has not looked explicitly at environmental impacts of yield improvements.

The British Society of Plant Breeders (BSPB) says in its response to a Royal Society Study that targets for breeding should be for crop varieties which have reduced input requirements but which maintain or increase their yields. Hence there will be less pollution and fewer demands on resources. It should be possible to meet such targets with joined up government strategies and investment.

Research is therefore needed into increasing yields and reducing the environmental footprint of conventional agricultural crops.

Research Gap 2: Research into increasing yield and reducing environmental footprint of conventional agricultural crops.

#### 4) Does this include the interaction with GM?

No research on GM was found in this study. The processes governing carbohydrate assimilation by crops are too many, too complex and not always sufficiently well understood to lend themselves to improvement via GM technology. However, GM should be considered as one tool in the fight against pests and diseases. In its submission, the BSPB expressed the view that public resistance to GM needs to be overcome if the full benefit is to be derived from increasing the UK's scientific knowledge and understanding.

#### 5) Can broader agricultural intensification free up land to sustainably source biofuels?

Clearly greater yields can substitute for increasing land use if demand is increasing at rates no greater than the rate of yield increase:

$$D = Y * LU$$

where D = demand

Y = yield per land area

LU = Land used

However, increased yields may not keep pace with growing demand if this is significantly added to by a demand for biofuel feedstocks. In the UK and EU, feedstock requirements for 10% biofuel have been estimated to be equivalent to around 5-15 % of total production from current tillage. In order to keep pace with this demand, without increasing land use, will require commensurate increases in yields per ha.

The FAO concluded, as a very general assessment, that worldwide around 80% of the increase in production between 1961 and 1999 arose from increased yield per ha and only about 20% from increased land use. However, this varied among regions, with increased land use accounting for about a 40% of the increase in sub-Saharan Africa and around 55% in Latin America. The report suggests that increases in yield per ha arise where there is no other option, in other words, where most of the land is already cultivated. The evidence suggests that where uncultivated land exists, then agriculture will encroach upon it.

Research Gap 3: There is a need for fundamental research into crop physiology and photosynthesis to identify means of increasing photosynthetic efficiency and hence increase the production of dry matter per ha.

#### 6) Is there research on the drivers for yield, intensification, or productivity increases, and what is required for these improvements in different parts of the world?

The study found that there is research being carried out in this area, although the key focus is mostly on issues of sustainable development, food security and climate change rather than yield itself. Moreover, the focus is generally on the developing rather than the developed world. The requirements for yield improvements may vary among regions, but often include factors such as investment in infrastructure R&D, crop breeding, knowledge transfer, access to credit and appropriate fiscal and policy regimes.

The main driver for increasing yields in commercial farming is the goal of increasing profit. Even if yield increases can only be achieved by increasing inputs such as fertilisers (at variable costs), then profit can increase if greater yields are spread over the fixed costs (such as labour, machinery, and land rent).

## **7) Does this research compare with drivers on land use change?**

Many studies compare the contribution of increased crop area versus crop yield to increases in total crop production. However, no studies were found that directly contrast the drivers of yields with the drivers for land use change.

Drivers for LUC are complex and varied, but the need for increased production is important. Essentially, land will be converted to agriculture if the demand for a product cannot be matched by increasing output from the current area. The most dramatic examples of this are the expansion of soybean production in Brazil, in both the Cerrhado and the Amazon rainforest, and the destruction of rainforest in Indonesia to provide land for palm oil production. While neither of these crops is grown primarily as biofuels both may be used as feedstocks for biodiesel. For this reason, the issue of increasing the yield of biofuel crops to prevent LUC cannot be isolated from the broader issue of meeting increased demands for foodstuffs. The question is whether the additional stimulus to demand provided by biofuels may lead to aggregate demand outstripping the capacity of productivity improvements to meet that demand.

## **8) Can we incorporate the drivers into indirect sustainability criteria?**

The answer to this question is - not readily. ADAS considered there could be criteria to achieve economic optimal yields to help avoid LUC, and possible obligations on governments and companies producing biofuels to invest in agricultural R&D to promote yield improvement. But is this likely? This is a topic that needs further evaluation.

More generally, there is a need to balance economic drivers with sustainability criteria. For example, the use of less N fertilizer on crops could significantly reduce the GHG intensity of the grain for biofuel use. However, reducing N fertiliser would reduce grain yield and hence the consequences of indirect land use change could be worse elsewhere. ADAS has carried out work which shows that the GHG impacts on ILUC of reduced yield from reduced fertiliser rates can dwarf the GHG savings from using less fertiliser.

## **9) What practical or conceptual difficulties are there involved with:**

- 1) Measuring yield improvements.
- 2) Isolating to what extent yield has improved as a result of the different drivers/sustainability criteria, as opposed to weather, and which these different drivers are?

There is a lot of data available to measure yield improvements at farm, sub-state, and regional levels. However, it is likely that economic impact, or sustainability criteria can only be assessed retrospectively, for example after 5 years or more. Even then, it is uncertain how the effects of 'sustainability criteria' could be separated from the more general economic and political drivers.

### 2.6.6 Summary and conclusions

The study found that there is a good opportunity to improve the yield of specific energy crops that could be used for first and second generation processing, particularly perennial crops which are still relatively new to large-scale deployment in agriculture. These include crops proposed for developing countries such as *Jatropha* and *Pongamia*<sup>11</sup> (in fact for some of these crops there is a need to provide clear information on their current yields in different climatic conditions and for different soils). However, no matter how much these yields are improved, it is likely in the short to medium term that they will displace the production of conventional agricultural commodities and therefore some additional land use change will take place. Consequently, there is a need to improve the yield of these conventional commodity crops as well. In reviewing the work carried out on yield improvements, this study concluded that a three-stage approach is required, as summarised in Table 2-11 below.

R&D on high yield biomass and dedicated energy crops that do not disrupt current production paradigms is considered to be both urgent and significant in addressing the key research questions in the study. The urgency ranking assigned to this research gap is mainly due to the fact that this is long term work that can sometimes take years. For example, if the UK does not keep up its momentum on research into energy crops, it will not have the results for the development of second generation fuels by the middle of the next decade. This is ranked as a medium to large research gap. Many of the skills required are available in the UK, however, some of the work will need to be done on an international basis (depending on the crop) and for some crops there may be a lack of skills available for the research.

Research into increasing yields without increasing the total footprint of conventional crops is also ranked as significant and urgent for the same reason: this is long term work that will take years to bear fruit; but it is also significant in contributing to the key research questions in this study. The gap is considered medium to large because this is an area that has been neglected until now and one, which could involve international research effort.

R&D on fundamental crop physiology to increase carbohydrate assimilation examines fundamental processes within the plant. This is, perhaps, the bottom of the hierarchy of work that needs to be done and therefore has been ranked as less urgent or significant than the two areas above. However, it can still deliver benefits. It has the same issues with skills and international requirements as above, which means that it too, has been ranked as a medium to large technical research area.

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<sup>11</sup> The International Crops Research Institute for Semi-Arid Tropics (ICRISAT) reported there has not been much genetic improvement and domestication of *Jatropha* and *Pongamia*.

Table 2-11 Key research gaps

Research Gap	1) R&D into high-yield biomass systems and dedicated energy crops that do not disrupt current production paradigms	2) Research into increasing yield and reducing environmental foot print of conventional agricultural crops	3) Fundamental research into crop physiology and photosynthesis to identify means of increasing photosynthetic efficiency and hence increase the production of dry matter per ha
Key related work			
Complexity	***	***	***
Time scale	***	***	***
Potential costs	***	***	***
National or international?	International	International	International
Availability of data			
Availability of skill sets	***	***	***

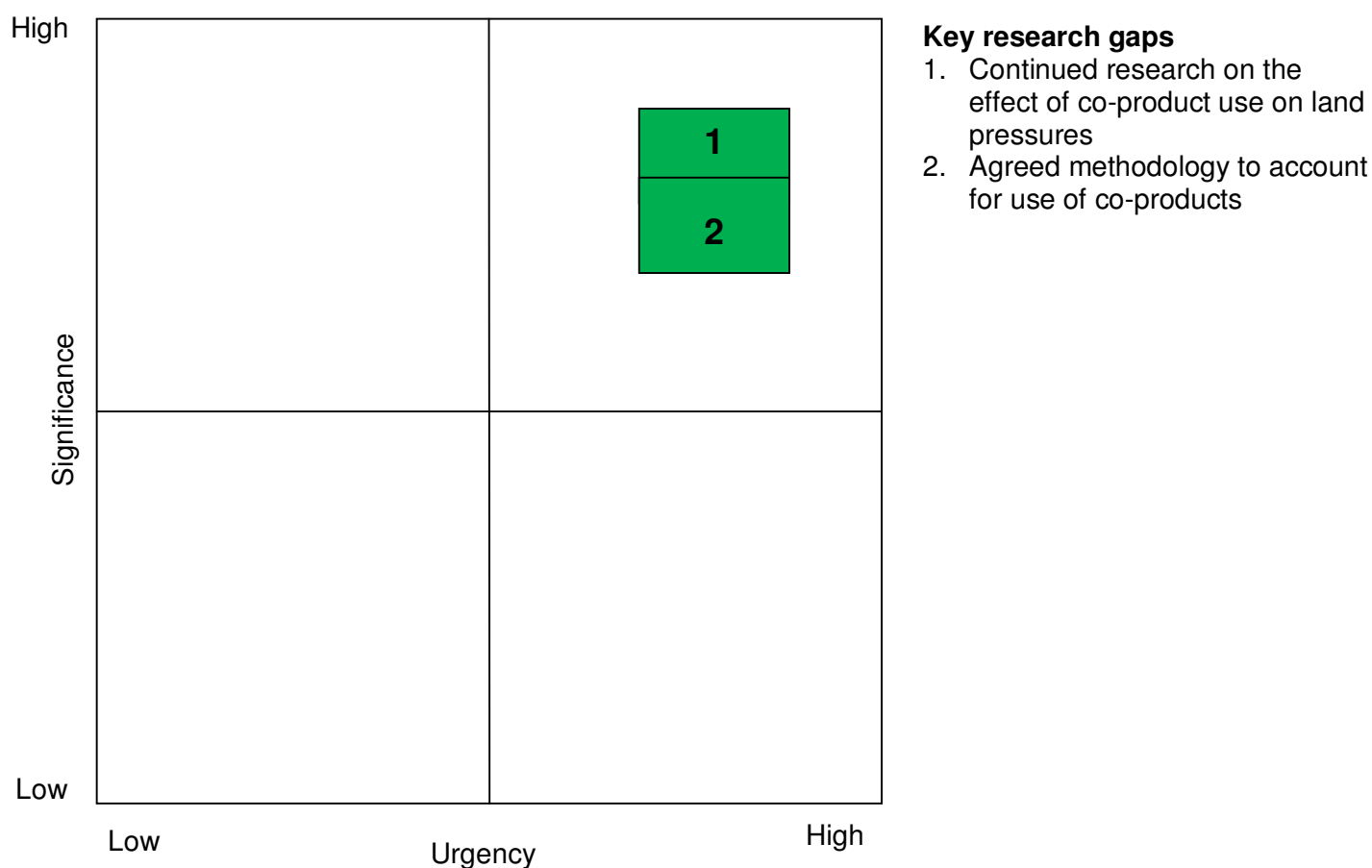
### Key

<b>Significance</b> – please see matrix	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k * <£100k	<b>National or international</b> i.e. can the work be done in the UK or would it be better done internationally?
<b>Availability of data</b> This will refer to the IPR/availability of R&D already ongoing in the area (e.g. Commercial – restricted; or published/available)			<b>Availability of skill sets</b> *** a number of organisations working in area ** availability restricted to a few groups or only on international scale * skills gap, significant training required	



## 2.7 Co-products

**Figure 2-6 Matrix prioritising key research gaps for increases in yield/productivity**



**Size of Research Gap**

	Small
	Small / Medium
	Medium / Large
	Large

### 2.7.1 Executive Summary

*We need to understand whether the effective use of co-products can be a) incorporated into the indirect sustainability criteria, and b) a sustainable and viable way of achieving the 10% target without causing indirect land use change?*

Co-products are additional low market value products produced alongside a main higher value product. In biofuels, a number of co-products are produced, including meals, dried distillers' grains and solids (DDGS), glycerol and low CV fuels that can be used in heat and power. The market for these co-products includes animal feed (DDGS) and meals, oleochemicals and pharmaceuticals as well as heat and power.

In the Gallagher Review, the case for substituting current animal feeds such as soy with DDGS was examined. It suggested that the production of these co-products could help reduce land use. Other uses of co-products could also help to reduce GHG emissions and therefore further research is needed in this area.

This chapter considers current and future research in this area in order to identify the research gaps, which must start to be filled before co-products can be incorporated into the indirect sustainability criteria and before we can be sure they can be a sustainable and viable way of achieving the 10% target without causing indirect impacts.

These gaps include:

Research Gap 1: Continued research on the impact of co-product use on land pressures.

Research Gap 2: The production of a robust methodology that takes account of all evidence to develop a weighting to GHG savings, land-use savings, local environment benefits and other sustainability advantages/impacts such as job creation.

### 2.7.2 Context

Co-products from biofuel production include:

- DDGS from wheat or corn ethanol production.
- Rapeseed meal and presscake from biodiesel production.
- Steam/electricity from second generation biofuel production.
- Glycerol from transesterification for biodiesel production.

Where the co-products are used for livestock feed, there are potential land savings as they may displace other crops, such as soy protein, that are used to meet dietary needs in livestock feed.

In assessing research needs on land use savings from the use of co-products there are a number of factors to be considered. These include the quality and quantity of livestock feed requirements; how to improve the suitability of biofuel co-products for animal feed; how to prove the substitution actually took place; and how to allocate land-savings to that element of the animals' diet. Where the use of co-products results in displacement of a different crop in another area (e.g. DDGS replacing soy protein) then there are issues of demarcation, as each crop has different characteristics (for example, soy protein has different feed values to DDGS even though both are essentially sources of protein).

Other complications arise when comparing GHG savings with avoidance of indirect land use change. For example, soy can be grown in many places and where it potentially displaces rainforest (or displaces a current land use, such as cattle ranching to rainforest, resulting in forest clearance), the GHG implications are higher than in other cases. GHG savings may also be achieved by the combustion of co-products. This must be quantified and compared with those from avoided indirect land use change, factoring in the other environmental issues that accompany each option.

A co-product of biodiesel production, glycerol has also been used to boost the production of biogas from anaerobic digestion, allowing energy gains from this process. These examples demonstrate the potential GHG emission benefits from the use of co-products. Further work is needed to define these. However, it is also necessary to consider the knock-on effects on world markets of the use of such co-products; for example, how they might affect prices and demand and what implications they may have for socio-economic sustainability.

### 2.7.3 Key research questions

The key question in this area is whether the effective use of co-products can be (a) a sustainable and viable way to achieve the 10% target without causing indirect land use change, and (b) can this be driven through indirect sustainability criteria? This can be broken down into a number of sub-questions on the status of R&D in the area:

Questions underpinning this include:

- 1) What research is there on the interaction between co-product use and land use change/land pressures?
- 2) Is there research on sustainability issues relating to co-products, e.g. impacts on or benefits for water/soil/GHG emissions?
- 3) What research is there on the future development of co-products, new techniques which are likely to improve co-product and provide better utilisation of co-products, etc?

- 4) Is there any analysis on the impact of the EU RED GHG calculation methodology on co-product markets?
- 5) Is there analysis of how the different co-product calculation methodologies (including that in the RED) will impact on markets, investment decisions, and GHG emissions of biofuels (including ILUC)?

#### 2.7.4 Research in the area

Although there has not been a great deal of research work on co-products from biofuels, they are nevertheless of value to the producer and their use is important. The research that has been undertaken concentrates on their use and how they can be processed to improve their value. However, their treatment within the RED GHG methodology, potential sustainability issues and the assessment of competing uses (e.g. animal feed versus use as a fuel) have stimulated an interest in this area and the amount of R&D is now increasing.

**Table 2-12 Research in the area of co-products**

Funding or research organisation and budget where available	Current status and R&D
<b>UK</b>	
The Gallagher Review	The Gallagher Review (June 2008) included a report by CE Delft (2008): 'Estimating Indirect Land-Use Impacts from By-Products Utilisation' which attempted to quantify land savings from crop by-products and co-products.
Ensus	Ensus have produced a methodology for GHG balances from different biofuel crops, which takes into consideration the use of co-products and knock-on effects on GHG and land-use. They are involved in a modest programme of feeding trials (Ensus 2008). Further work examining the use of DDGS as an animal feed is being undertaken (Ensus 2009a, b).
Vireol	Vireol are planning research into how bioethanol can be produced from wheat in the UK without leading to indirect land use change, including accrediting co-products with land-savings by crop displacement.
BBSRC	BBSRC – The IBTI Club is seeking to fund proposals for biological routes towards biorefining, with three research themes covering optimisation of feedstock composition, integrative bio-processing and enhancing product value.
BIS	<p>BIS is planning to commission work on Industrial Biotechnology (IB) - the aim of which is to model a series of scenarios that map the interaction of a range of drivers for the development of IB and renewable chemicals. The analysis will focus on defining and examining the strategic drivers and subsequently modelling them into a series of scenarios to establish their interactions and interdependencies. This will allow BIS to identify what economic conditions are required to catalyse the bio-based production of speciality, fine and platform chemicals and where the market opportunities might lie to achieve higher than today uptake of IB within the UK chemicals sector.</p> <p>This work will allow policy makers to identify a range of options to meet</p>

Funding or research organisation and budget where available	Current status and R&D
	the overarching aim of the IB-IGT (to ensure UK companies are better positioned and encouraged to leverage opportunities in IB) and will provide an assessment on the scale of the opportunities, risks and challenges in achieving higher uptake of IB in the medium and longer term.
NNFCC	NNFCC plan to build on work by the Low Carbon Vehicle Partnership to develop a 'closed-loop' agricultural system that seeks to significantly reduce land-use and greenhouse gas emissions from biofuel production whilst producing food co-products in a synergistic concept where the by-products of one process become the feedstock for another. A model is planned that would demonstrate these savings in comparison to 'conventional' first generation biofuels.
ADAS	The ADAS 'Better Grain' Project seeks to improve the DDGS qualities of grain varieties for fuel and feed co-production in dry mill processing.
UKERC	UKERC with CEH have been investigating the implications of biofuel co-products use and accreditation for sustainability criteria.
<b>Europe</b>	
EC FP7	FP7 is funding research and development into better processes and technologies for co-product refining.
Propanergy	Propanergy is developing the integrated bioconversion of glycerine into value-added products (1,3-propanediol and fertilizer) and biogas at pilot plant scale.
Super Methanol	Super Methanol is investigating a glycerine to methanol process
Glyfinery project	The Glyfinery project is researching optimised biological routes for refining of glycerine to advanced biofuels, bioenergy and biochemicals as part of an efficient biorefinery.
<b>US</b>	
Brookings	<p>Undertaking research to: 'Assess utility and value of distillers grains and modified distillers grains.' Five year project (2007-2012). Will evaluate current and future fuel ethanol co-product streams and determine their applicability for use in animal rations, human foods and other value-added products.</p> <p>Brookings are also 'Examining the effects of processing parameters on physical and flow properties of DDGS,' (two year project completing at the end of 2009).</p>
Taconi	Investigating 'Biological conversion of biodiesel-derived crude glycerol to produce value-added industrial products.' (\$100,000 two-year project ending 31st August 2009).
University of	Researching the use of glycerol as an important building block chemical,

Funding or research organisation and budget where available	Current status and R&D
Alabama	evaluating its potential to produce value-added products including butanol using anaerobic fermentation.
The Nature Conservancy	Producing a paper on the land use implications for ethanol from the use of its co-products as livestock feed. The paper is planned to be completed at the end of February 2009.
The Ohio State University	The university is carrying out a number of significant studies on co-product value and uses and the effect on soil quality of the removal of co-products from land (impact of harvest residues from corn on soil quality).
<b>International</b>	
ICRISAT	ICRISAT is developing super hybrid sweet sorghums that are able to produce food (grains), feed (nutritious stems for cattle fodder) and sugary juice for ethanol production in the semi-arid tropics. The value of this work is approximately \$500,000. ICRISAT is also developing oil-bearing <i>Jatropha</i> and <i>Pongamia</i> for biodiesel production with co-product usage for fertiliser to increase productivity of other crops.

### 2.7.5 Research gaps

The study has identified a number of gaps in research in the development and use of biofuel co-products. The gaps are in connection with the following questions.

#### 1) What research is there on the interaction between co-product use and land use change/land pressures?

The concept of biofuel co-products substituting for other crops is in some ways indisputable. The difficulty lies in quantifying how much can be replaced and in allocating GHG costs and savings in a way that is fair. Some co-products may offer GHG savings rather than land-use implications, e.g. valorisation of glycerine from biodiesel production for renewable chemicals. There is on going work by the Nature Conservancy in this area, which aims to gather greater evidence of the impacts of co-product use on land pressures and to quantify land savings. However, it is clear there is still a need for more research in this area.

Research Gap 1: Continued research on the impact of co-product use on land pressures, including gathering data on how the co-product is used and evidence that this use decreases pressures on land use.

#### 2) What research is there on the future development of co-products, new techniques which are likely to improve co-product, better utilisation of co-products, etc?

Current research in this area includes work by Brookings, in South Dakota, USA, to: 'Assess utility and value of distillers grains and modified distillers grains'. This is a five-year project to 2012 that seeks to evaluate current and future fuel ethanol co-product streams and determine their applicability for use in animal rations, human foods and other value-added products. Other research is also planned. For example, Vireol will consider how bioethanol can be produced from wheat in the UK without leading to indirect land use change, including accrediting co-products with land-savings by crop displacement.

**3) Is there analysis of how the different co-product calculation methodologies (including that in the RED) will impact on markets, investment decisions, and GHG emissions of biofuels (including ILUC)?**

Methodologies are needed to develop a weighting to GHG savings, land-use savings, local environment benefits and other sustainability advantages/impacts such as job creation. Land-use is not a homogenous value, as some products may save a small amount of high quality cropland, whereas others may save a larger area of lower grade grazing land for cattle, which has less intensive agricultural potential. ILUC may also be impacted by the use of co-products, as substitution of a co-product for an agricultural commodity may result in lower land use pressures and less displacement of, for example, ranching to high carbon stock areas. Proving which crop is being replaced and where, creates particular challenges, especially when it is a different crop and in a different part of the world. Such methodologies are likely to be crude but they do require a broad consensus, which has yet to be reached. Further international work is needed over a period of years and this is likely to cost hundreds of thousands of pounds.

Research Gap 2: The production of a robust methodology that takes account of all evidence to develop a weighting to GHG savings, land-use savings, local environment benefits and other sustainability advantages/impacts such as job creation. This must be broadly agreed by stakeholders and therefore would be likely to require an international effort over a period of years.

## **2.7.6 Summary and conclusions**

The most important issue in the area of co-products is how exactly to clarify their impact on land pressures. More evidence is needed to demonstrate that substitution of co-products does take place and that it does alleviate ILUC. For this reason, this research gap is assessed to be both urgent and significant. However, the skills are available to carry out this work and only a few research projects are likely to be needed. Although being international in scope, this work is ranked as a medium to large gap.

There is also a need to develop a robust methodology to account for co-product use in LCA of GHG. This includes defining the boundaries of accrediting co-products and examining (and reconciling) the impact of calculation methodologies. Currently, the use of co-products is not included in policy tools for GHG LCA. However, if this omission is to be rectified, then the development of a robust methodology is both urgent and significant. Although the issues are complex and international, only a limited amount of work needs to be done and the skills already exist to carry out the research. The gap has therefore been assessed as medium to large.

Table 2-13 Key research gaps

Research Gap	1) Continued research into the effect of co-product use on land pressures	2) Agreed methodology to account for use of co-products
Key related work	Ensus, Vireol, NNFCC	UKERC / CEH
Complexity	***	***
Time scale	**	***
Potential costs	**	**
National or international?	UK	EU wide
Availability of data	Available	Available
Availability of skill sets	***	**

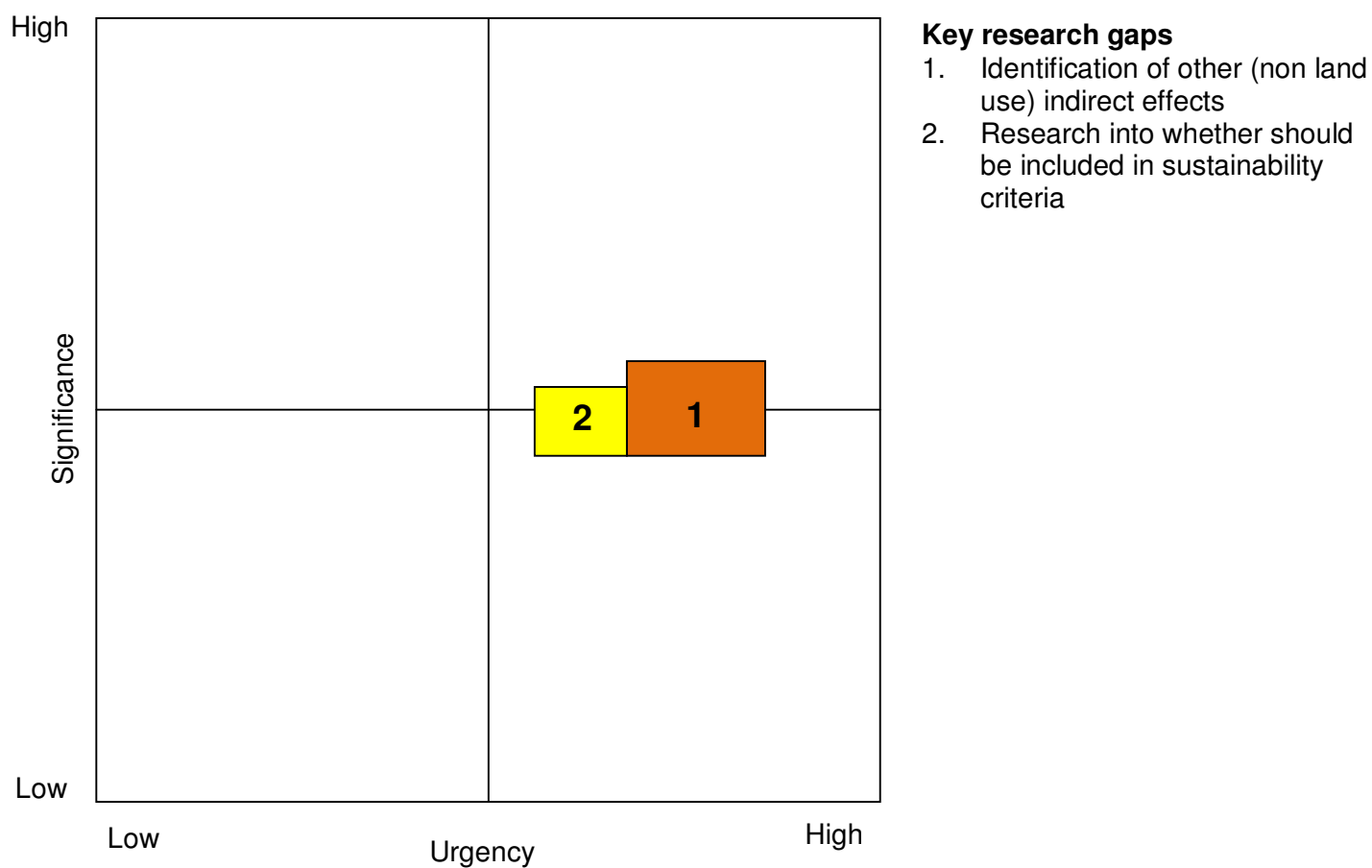
**Key**

<b>Significance</b> – please see matrix	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k * <£100k	<b>National or international</b> i.e. can the work be done in the UK or would it be better done internationally?
<b>Availability of data</b> This will refer to the IPR/availability of R&D already ongoing in the area (e.g. Commercial – restricted; or published/available)			<b>Availability of skill sets</b> *** a number of organisations working in area ** availability restricted to a few groups or only on international scale * skills gap, significant training required	



## 2.8 Other indirect effects

Figure 2-7 Matrix prioritising key research gaps for other indirect effects



Size of Research Gap

	Small
	Small / Medium
	Medium / Large
	Large

### 2.8.1 Executive Summary

*How important are the other (non-ILUC) indirect effects of biofuel production, and should sustainability criteria be designed for them?*

The indirect effects of increased biofuels production include all of the issues discussed in the preceding sections of this chapter. They encompass ILUC; the use of wastes, residues and by-products; and the use of co-products from the biofuels production process. Indirect effects include the impact on GHG (and other) emissions, other environmental impacts/benefits and the socio-economic impacts/benefits. However, there are other issues that could impact on the sustainability of biofuels:

- The indirect impact of the use of oil crops in the EU for biodiesel on international trade in oil crops (including price rises).
- The indirect impact of the use of all lignocellulose feedstocks for biofuels rather than heat and power.
- The impact of the use of non-food crops for biofuels compared to their use for production of other chemicals.

Research gaps include:

Research Gap 1: Identification of other (non land use) indirect effects of biofuels, leading to recommendations for work on key issues that are uncovered.

Research Gap 2: What are the boundaries of the sustainability criteria for biofuels and should these other indirect effects be included? There needs to be consideration of which factors are important to definition of sustainability for biofuels and whether the factors uncovered in (1) should be included in these sustainability criteria.

### 2.8.2 Key research questions

The key question for this issue is how important are the other (non-ILUC) indirect effects of biofuel production, and should sustainability criteria be designed for them?

Questions underpinning this are:

- 1) Is there work, which has tried to define and categorise indirect effects versus direct effects, or clarify where the boundaries should be?
- 2) What are the (non-ILUC) indirect effects of biofuel production, in terms of GHG impacts, other sustainability and economic impacts?
- 3) Is there work to try and catalogue these indirect effects, so they could be incorporated into sustainability criteria?

### 2.8.3 Research in the area

As well as the direct and indirect land use change effects examined elsewhere in this report there is a potential for other indirect effects from biofuels production, which include the impact on other markets for the by-product, the impact on agricultural practice and the impact of developing advanced conversion and second generation processing on the use of lignocellulosic feedstocks on generation of biomass heat and power. We have examined many of these issues as part of other chapters:

- The chapter on wastes/by-products and residues includes examination of the impact of the use of wastes, by-product and residue feedstocks on the alternative markets for these feedstocks, including GHG and other emissions, other environmental impacts/benefits and socio-economic impacts.
- The co-products chapter includes examination of the indirect impact of the use of DDGS, oil seed meals and glycerol on land use for animal feed and the potential for avoiding ILUC.
- The section on yield improvements examines their impact on ILUC.
- The chapter on local environment/natural resources examines positive and negative impact of crops for biofuels on agricultural practice and soil and water resources.

In addition to these indirect impacts there are, potentially, others:

- The impact of the use of oilseed rape in Europe for biodiesel on the import of palm oil and the price of this commodity.
- The use of (all) lignocellulose feedstocks for biofuels rather than heat and power.
- The use of some non-food crops for biofuels rather than alternative non-food uses.

#### 2.8.4 Research in the area

**Table 2-14 Research in the area of other indirect effects**

Funding or research organisation and budget where available	Current status and R&D
<b>UK</b>	
BIS	Planning work on Industrial Biotechnology (IB), the aim of which is to model scenarios that map the interaction of a range of drivers for the development of IB and renewable chemicals. The analysis will focus on defining and examining the strategic drivers and subsequently modelling them into a series of scenarios to establish their interactions and interdependencies. This work is relevant in that it will allow comparison of drivers for biofuels and other renewable chemicals.
DECC	Bioenergy and renewable materials section support non-food crops research, including support of NNFCC.

NNFCC	NNFCC support a whole range non-food crop research in the UK, including: Examination of the potential production of renewable chemicals (e.g. degradable plastics) in the UK; assessment of thermochemical processing of lignocellulose feedstocks for other chemicals as well as biofuels; work on the environmental impact of production of renewable raw materials; opportunities for the development of biorefineries.
<b>Europe</b>	
EC	The European Commission is funding work on bio-based products and produced a vision for this area in 2007 (EU 2007). It has supported work on biological materials for non-food products for some time, particularly under the Framework Programmes. This includes funding a EU Technology Platform on sustainable chemistry (including industrial biochemistry). <sup>12</sup> FP7 funding includes: Bioref-integ (1Meuro). Aim: to develop advanced biorefinery schemes to be integrated into existing industrial fuel producing complexes. Several biomass processing sectors are considered within the BIOREF-INTEG project to include: sugar/starch (bioethanol), biodiesel, pulp and paper, conventional oil refineries, power production, the food industry and the agrosector. Work includes market analysis of the most promising added-value products that could be co-produced with biofuels. Integrated European Network for biomass and waste reutilisation for Bioproducts ('Aqualterre' 0.8M Euro). Aim: integration and unification of efforts and the exchange of knowledge and expertise between partners, to promote the creation of a network for improving biomass and waste reutilisation. Work includes identification of optimum LCA for bioproducts to examine the best sources of biomass feedstock for the sustainable production of biofuels and other added-value products. Crops2industry (1 M Euro). Aim: co-ordination of activities to result in a portfolio of industrial crops suitable for industrial chemicals in EU; map of most promising plant-based products derived from these crops.
European Renewable Raw materials Association	<a href="http://www.errma.com/">www.errma.com/</a> Groups together five national agencies working on renewable raw materials from Belgium, France, Germany, Holland and the UK.
<b>International</b>	
FAO	Commodities and trade division has examined the trends in palm oil trade and biofuels production (Thoenes 2006).
NGOs	NCOs such as Biofuel Watch have examined the increase in the import of palm oil to the EU and compared this with the increase in the use of oilseed rape for biofuels.

### 2.8.5 Research Gaps

The following gaps in current research in this area were identified by this study in relation to the following questions:

<sup>12</sup> [www.suschem.org/](http://www.suschem.org/)

**1) Is there work which has tried to define and categorise indirect effects versus direct effects, or clarify where the boundaries should be?**

There is an increasing amount of work on the indirect effect of biofuels, particularly on ILUC and the use of wastes, residues and co-products, which has been covered in detail in this chapter. Additional indirect effects, e.g. on other raw materials, on the development of other materials from biomass and on the import of other commodities to replace the previous use of the biofuels crop, have only recently been recognised and research is only just beginning in these areas. Some work is being done on the potential conflicts of the use of biomass feedstocks for heat and power versus biofuels (e.g. by the UK Environment Agency; and some work has been done in the EU, as described in the Gallagher review). Work is also being done to examine the potential uses of the biomass raw materials as feedstocks for other non-food chemicals (work by BIS, DECC, NNFFC and the EC as outlined in Table 2-14).

Work has been done on the impact of biofuels on commodity prices and this work is summarised in Chapters 4 and 5. For example, Defra published a summary of biofuels and commodity prices last year (Defra 2008) and the FAO examined biofuels in its State of Food and Agriculture report in 2008. However, within this analysis indirect effects are often missing. For example last year EU palm oil imports rose and there was some indication that because the EU was using so much of its rape seed oil for biodiesel, imports of palm oil increased to fill the traditional markets for rape seed oil. This included the use of palm oil in small CHP plants in Germany, which were designed to use any vegetable oil and switch use according to price. This is a complex market, and price effects require in depth understanding. However to date analysis has concentrated on direct effects (e.g. the use of a commodity for biofuels) not on the indirect effects (i.e. what happened to the market that the commodity was used for). It would be useful if analysis of the impact of biofuels on commodity markets included these potential indirect effects.

**2) What are the (non-ILUC) indirect effects of biofuel production, in terms of GHG impacts, other sustainability and economic impacts?**

This would need to be followed by R&D on the specific issues uncovered by the work. For example, there is probably a need to examine the impact of the drive for biofuels on the development of other renewable raw material (positive and negative); and to examine the indirect impact of the use of raw materials for biofuels on trade in alternative feedstocks for the alternative (established) uses of these raw materials (e.g. the oilseed rape/palm oil example given above).

Research Gap 1: The need to identify other, non land-use, indirect effects of biofuel production and their sustainability impacts.

**3) Is there work to try and catalogue these indirect effects, so they could be incorporated into sustainability criteria?**

The outcomes of this gap analysis suggested that there was limited research in this area.

Research Gap 2: A consideration of the boundaries of the sustainability criteria for biofuels and whether these other indirect effects can be included.

## 2.8.6 Summary and conclusions

This work identified two high level gaps. These may uncover additional work that needs to be done.

The first gap is to identify other indirect effects from biofuels. We have identified three potential indirect effects, but there may be more; and an understanding of the significance of these gaps is important. In addition, as part of the work the need for further research associated with a specific impact should be identified. This is an urgent piece of work because we need to ensure analysis is considering all potential indirect impacts, but we suspect that the significance of such impacts will be low, precisely because they have not been easily identified. This gap is relatively straight forward, but will require a number of scientists from different disciplines. Therefore, it has been ranked as a small to medium gap.

The second gap is to consider whether and how these indirect effects can be included in sustainability criteria. This follows on from the first gap and will need to be undertaken urgently to ensure that it can be considered within policy timescales. However, for the same reason as above we do not think this is a significant gap. It is a relatively straightforward, small piece of work.

**Table 2-15 Key research gaps**

<b>Research Gap</b>	<b>1) Identification of other indirect effects</b>	<b>2) Inclusion in sustainability criteria</b>
Key related work	N/A	N/A
Complexity	**	**
Time scale	**	**
Potential costs	**	**
National or international?	**	**
Availability of data	Available	Available
Availability of skill sets	**	**

**Key**

<b>Significance</b> – please see matrix	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k * <£100k	<b>National or international</b> i.e. can the work be done in the UK or would it be better done internationally?
<b>Availability of data</b> This will refer to the IPR/availability of R&D already ongoing in the area (e.g. Commercial – restricted; or published/available)			<b>Availability of skill sets</b> *** a number of organisations working in area ** availability restricted to a few groups or only on international scale * skills gap, significant training required	



# Biofuels Research Gap Analysis

## Chapter 3 – Other Environmental Issues



**Final report to the Biofuels Research  
Steering Group**

ED45917  
Issue Number 3  
30<sup>th</sup> July 2009



## 3 Other Environmental Issues

### 3.1 Introduction

This chapter considers other environmental issues that were not included in the indirect effects chapter. These are: direct land use change, greenhouse gas (GHG) life-cycle assessment (LCA), local environment/natural resources and biodiversity (which also addresses impacts on ecosystem services).

All agricultural practices affect their environment and biofuels are no exception. The environmental effects of biofuels are, however, complex, essentially being a function of the previous land use, as well as the ways in which the biofuels are produced<sup>13</sup>. Thus, not only does research need to address the effects of the biofuels crop on its environment; consideration of relative impact with previous land use is also required.

The most important factors that cultivation of biofuels crops may affect are:

- Soil – organic matter content, fertility, fauna and flora and structure (including potential for erosion).
- Water resources – both the quality of water (i.e. pollution levels) and the use and availability of water (functions of abstraction and water taken up from the soil and lost in transpiration).
- Air emissions – in producing crops the main air emissions relate to the production and use of nitrate fertiliser.
- Ecosystem impacts – ecosystems have a number of functions or services to the local environment, including provision of food and other commodities, regulation of air quality, climate and carbon sequestration, water cycling, prevention of erosion, recreation and many others.

GHG LCA is a methodology for assessing the impact of biofuels. It is not possible to take into account all of the above impacts using such LCAs, but they can take account of the loss of carbon stock and the impact of farming practices such as use of fertiliser, particularly as a result of direct land use change, providing data is available.

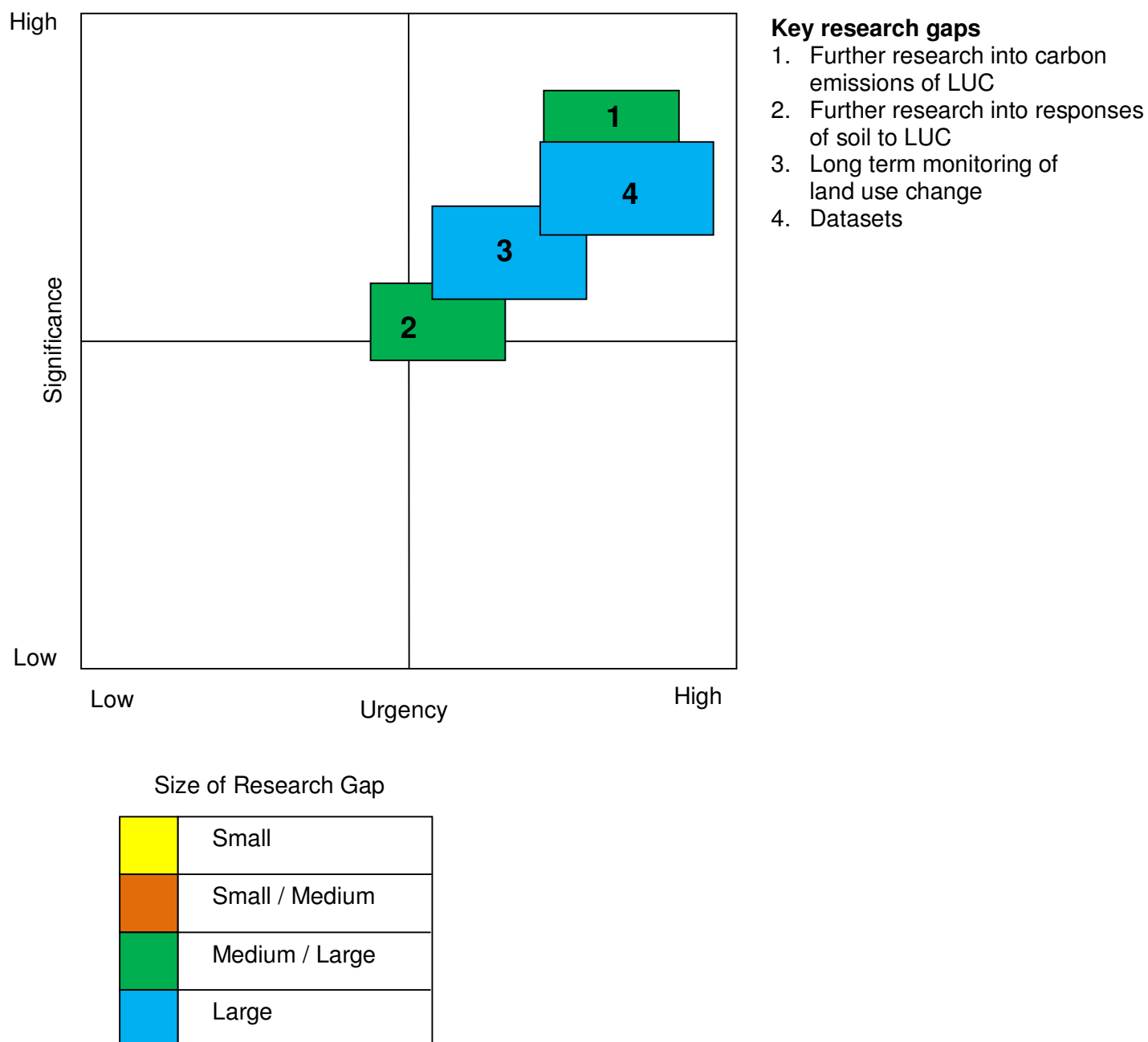
This chapter examines the ongoing research in these areas including work to study the kinds of land use change likely to result from expansion of biofuels; how these changes are represented in GHG LCAs and the data requirements for LCAs; actual research on specific impacts or benefits for local environmental resources; and work on how biodiversity may be affected by expansion of biofuels. In order to ensure that biofuels production does no more environmental harm than the systems they are replacing, it is essential good practice guidelines can be provided and crop systems with better environmental impact can be worked towards;

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<sup>13</sup> For example, replacing intensive cultivation of arable crops with perennial biofuels crops may improve soil organic matter, decrease the need for fertiliser impacts and it may result in improvements in biodiversity or other ecosystem services; on the other hand replacing a highly biodiverse habitat (e.g. grassland or forest that has been established for some time) with biofuels crops will probably decrease biodiversity, release carbon stock from the soil and may (depending on the crop) increase the fertiliser inputs and hence the impact on soil and water resources locally.

## 3.2 Direct land use change

Figure 3-1 Matrix prioritising key research gaps for Direct Land Use Change



### 3.2.1 Executive Summary

*What evidence is available to identify and understand the key issues relating to direct land use change?*

In this chapter, we are mainly concerned with how direct land use change (LUC) may lead to GHG emissions. The issue of the impact of biofuels on land use change is a complex one, mainly because it depends on so many factors, including the nature of the soil, the current use of the land, the period over which the change takes place, and the nature of the change itself (i.e. what type of crop is planted). Other (non-GHG) impacts of LUC (for example on biodiversity) are considered in later chapters.

Increased understanding of the impact of biofuels on LUC, and the GHG emissions associated with this is essential, particularly given the importance of GHG savings from biofuels. With the RED stating that the GHG emission savings from biofuels shall be at least 35%, increasing to 50% in 2017 and 60% from 2018, the contribution of GHG emissions from direct LUC could be a significant factor in compliance with these emissions targets.

This chapter considers current and future research in this area in order to identify the research gaps, which must start to be filled before we are confident in our understanding of direct land use change associated with biofuels. These key research gaps have been identified as:

Research Gap 1: The impact of biofuels crops on soil carbon emissions (including the impacts of management methods on these emissions and their effectiveness).

Research Gap 2: A better understanding of soil processes in response to land use change, particularly the potential to capture carbon.

Research Gap 3: The need for long term experimental facilities (including field work) to assess GHG emissions from conversion to energy crops and how carbon stocks rebuild (for perennial crops).

Research Gap 4: Improved datasets for monitoring land use change.

There is a lot of debate at present on the impact of land use change environmentally and socially, including debate on the impact on food availability. This is discussed further in Chapter 4. Additionally there is concern about impact on soil and water resources and biodiversity. These are discussed in later sections in this chapter.

### 3.2.2 Context

Several studies have shown that the conversion of forest or grass land to grow biofuels feedstocks – direct land use change – can lead to significant GHG emissions that can significantly reduce or negate the GHG savings that biofuels can offer. Understanding how much direct LUC there is likely to be if biofuels feedstock production increases, and the ability to accurately model the GHG emissions which occur is therefore important in assessing the impacts of increased biofuels production. Research needs thus tend to fall into two areas, firstly establishing the amount and type of direct land use change which has occurred or is likely to occur and secondly, estimating the greenhouse gas emissions which occur from this land use change.

For current biofuels production, where the source of biofuels feedstock production is known and the supply chain can be established, a relatively straightforward approach to establishing whether direct land use change has occurred is to establish the prior land use (at a certain date) at the site where biofuels production takes place. However, evaluations of direct land use change from total current biofuels production or future biofuels production require a more generic approach which must rely on modelling, or for current biofuels production, datasets on land use change. In the case of modelling (as with indirect land use change) established models of crop production can be used (for feedstocks which are also used for feed/food) can be used to examine whether land use change might occur.

The GHG emissions from LUC are highly dependent on the carbon stock of the prior land use, but it is increasingly being recognised that factors such as the cultivation techniques employed, the carbon stock in the biofuels feedstock after land use change and changes in emissions of the GHG, methane and nitrous oxide may also be important. A significant amount of work has been done on GHG emissions from LUC in general, to support work on producing national GHG inventories (e.g. IPCC, 1993) and this has sought, in particular to establish the carbon stock associated with different types of land use. Use has been made of this work in current estimates of GHG emissions associated with direct land use change; and continuing research in this area could continue to help inform estimates in the biofuels area. However, this needs to be complemented by work in the other two areas; there may also be an issue in that while the average values for carbon stocks in different types of ecosystems/land use, are suitable for use in national estimates of emissions, more differentiated values are required for use in the biofuels arena.

### 3.2.3 Key research questions

This section explores what research there is available to identify and understand the key issues relating to direct land use change.

This is underpinned by an analysis of the research using the following questions:

- 1) What are the approaches to measuring direct land use change? What are the differences between the approaches?
- 2) What are the relationships between indirect and direct land use change?

### 3.2.4 Research in the area

There is much overlap between this research area and that of GHG emissions (as much of the interest in the impact of direct land use change is on GHG emissions) and also the area of indirect land use. The R&D listed here is therefore restricted to those where the major focus is on direct land use change and its impact on GHG emissions, and this is also the focus of this section. Non-GHG environmental impacts are covered in covered in sections 3.3, 3.4 and 3.5.

**Table 3-1 Research in the area of Direct Land Use Change**

<b>Funding or research organisation and budget where available</b>	<b>Current status of research</b>
<b>UK</b>	
University of Aberdeen	GHG emissions from land use change for energy/biofuel crops and range of work on soil carbon and energy crops.
DECC/Defra funding CSL	Potential impacts of land use change for energy crops and biofuel feedstock cultivation on soil carbon.
NERC (through Imperial)	TSEC-Biosys work
<b>Europe</b>	
IFEU, Germany	Impact of land use change on GHG emissions
EU	Support work for RED will include examination of monitoring land use change and guidance on the impact of biofuels on soil and water resources and air emissions.
The Netherlands Ministry of Environment (VROM)	Netherlands Research Programme on Scientific Assessment and Policy Analysis for Climate Change (WAB) commissioned by the Dutch Ministry of Environment – included work on land use. This work has identified a number of areas for further work including the modelling of land use change.
The Netherlands Ministry of Environment (VROM)	Review of C-flux estimates and other GHG emissions from oil palm cultivation on Tropical Peatlands: Identifying gaps in knowledge (complete). Results indicate: <ul style="list-style-type: none"> <li>- Results of soil CO<sub>2</sub> flux measurements as described in the literature are confusing because of a limited description of the system and the context.</li> <li>- Soil CO<sub>2</sub> fluxes may be highly variable due to heterogeneous peat characteristics, land use type, degree of humidity, microclimatic variations such as soil and air temperature and seasonal variability.</li> </ul>
<b>US</b>	
University of Illinois	Integration of models of land use. Crop productivity and soil C; output will include GHG balance.
<b>International</b>	
ICONE, Brazil	Model of land use change, used to analyse LUC and sugarcane expansion in Brazil.
University of Campinas, Brazil	Assessment of direct and indirect land use change resulting from sugar cane expansion in Brazil.

Funding or research organisation and budget where available	Current status of research
Dutch Ministry of Environment and the Malaysian Government	Malaysia and The Netherlands operate a joint research program to clarify the greenhouse gas balance of oil palm cultivation on former peat land forests. First results expected 2010.
Scientific Committee on Problems of the Environment (SCOPE)	Recent report 'Biofuels: Environmental Consequences and Interactions with Changing Land Use' included a chapter on the GHG implications of land use conversion to biofuels, which used a scenario approach to estimate the LUC emissions associated with meeting 10% of transport fuel needs from biofuels.

### 3.2.5 Research gaps

#### 1) What are the approaches to measuring direct land use change? What are the differences between the approaches?

As discussed above, two elements need to be considered, firstly an assessment of how much land use change has been or is likely to be caused and secondly the greenhouse gas emissions associated with that land use change. Assessing this accurately requires knowledge not only of the area of land that has been converted, but also what the prior land use was, and the location of the land use type, as carbon stocks in vegetation and soils depend on both of these factors.

Estimating direct land use change can be done using modelling techniques, from surveys of land use, or from interpreting satellite data on land cover. Problems with using satellite data include:

- That it is usually interpreted on an area basis, so areas with mixed land use may be misinterpreted,
- How to attribute any observed land use change between increases in production for feedstuffs/food and biofuels production.

Modelling of direct land use change can be based on models used to model agricultural production, and faces many of the same challenges identified in modelling indirect land use change. Alternatively, some research has adopted a scenario approach based on more empirical assumptions about the type of land use change which will occur to meet demand. Some approaches have also modelled direct land use change based on historical land use change patterns.

The IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry (Penman *et al*, 2003), (which is in the process of being updated) and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Vol 4 on Agriculture, Forestry and Other Land Use) provides methods for estimating carbon stock changes and GHG emissions and removals associated with land use change contain default values for different types of biomes and methodologies for producing more accurate estimates using, e.g. carbon soil modelling.

Going forward, improving estimates of the GHG emissions from land use change, e.g. by improving the technology and methods for estimating carbon storage, and improving the understanding of soil processes is important not just for biofuels, but for more general questions about the impact of agriculture and land use change on GHG emissions. It is thus unlikely that this will be a specific research gap (solely) for biofuels where feedstocks are conventional agricultural crops, although it will be important to make sure that this research is transferred to the biofuels research area.

There are, however, some specific areas, which may be of particular importance to biofuels. These are where feedstocks are perennial crops, which may themselves build up a carbon store, and the influence of management techniques used for conversion, e.g. minimising the disturbance of grasslands. In general, a better understanding of grassland systems, including how they are used is also required.

Research Gap 1: The impact of biofuels crops on soil carbon emissions (including the impacts of management methods on these emissions and their effectiveness). Particularly, where feedstocks are not conventional agricultural crops.

Research Gap 2: A better understanding of soil processes in response to land use change, particularly the potential to capture carbon.

Research Gap 3: The need for long term experimental facilities (including field work) to assess GHG emissions from conversion to energy crops and how carbon stocks rebuild (for perennial crops).

Research Gap 4: Improved datasets for monitoring land use change.

## **2) Are there methods of looking at direct land use change, which could lead to reductions in indirect land use change?**

Land use change is caused by many factors – demand for timber, food and feedstocks – not just increased demand for biofuels feedstocks, and some have argued that the current focus on the link between biofuels and land use change, unfairly singles out biofuels production, compared to, for example, other food production. Others point out that one of the main drivers for encouraging the use of biofuels, and in many cases providing public support for them has been the potential GHG savings that they offer, and a full assessment of the emissions related to their production, including those from land use change is therefore justified.

One argument that has been put forward is whether the issue of indirect land use change would be avoided if all agricultural uses of land, for example food production, were subject to sustainability criteria to minimise the impact of direct LUC. This was posed as a potential option for minimising the impact of ILUC at the Stakeholder workshop for this study.

In their paper for Greenenergy, Ecometrica (2009) highlighted the problems with methods of calculating ILUC and the risk of double-counting direct and indirect emissions. The researchers use an allocation approach to estimate the LUC emissions attributable to biofuels, but point to the need for further work to improve understanding of the breakdown of LUC causal factors and to demonstrate how responsibility can be directly attributed.

### 3.2.6 Summary and conclusions

The understanding of the carbon emissions from LUC for biofuels is a research gap of relatively high priority and urgency. This reflects the potential significance these emissions may have on some biofuel crops, which means that there is an urgent need to clarify the level of the impact and that the issue is highly significant in addressing the key research questions in this study. The uncertainty in this area at present is due to the wide range of factors that influence the carbon emissions from LUC (e.g. the type of crop, farming practices previous land use etc); and the current lack of data. The research gap has been ranked as a medium to large gap because, while many of the skills required exist, a lot of work on different crop/land use systems will be required to gather data that is not readily available at present. This work will have a high overall cost and will need to be done internationally.

The responses of soil to LUC need to be studied in order to attain a better understanding of soil processes, particularly the potential to capture carbon. This has been assessed to be of slightly lower urgency and significance to the key research questions in the area because some of this work is being done for the IPCC and because monitoring of the responses of soil to land use change is a longer term data-gathering exercise. It is a medium sized gap reflecting high cost over time (due to the many areas where this work will need to take place) and it will involve interaction at the international level, but the existing skill sets are in place. This work is, however, relatively straightforward requiring a one-off dataset for relevant land types and biofuel crops.

Long term monitoring of LUC is needed to establish field studies of initial carbon/nitrogen levels in soil, and changes due to the planting of energy crops. This is a research gap of high significance and urgency, reflecting its impact on the key research questions and the need to put mechanisms in place to improve our understanding of land use and LUC rapidly. This area represents a large amount of work, which perhaps could inform other areas of policy (e.g. agriculture), and will be high cost and international in scope and delivery. The UK Government should fund not all of this work. Consequently, we have ranked it as a large sized research gap.

The need for datasets (including data on land cover) is a common theme in this report. What is needed is a clearer understanding of land use than we currently have, using on the ground and experimental systems for gathering data for land use modelling. This is long term work that will be underpinned by work in a number of areas and countries and we have therefore ranked it of medium urgency and significance. However, it is a large research gap because of the potential high costs, the number of regions where the work will need to take place to get an accurate picture of what is happening in all biofuels production areas globally, and the need for different skills and a large number of research groups.



Table 3-2 Key research gaps

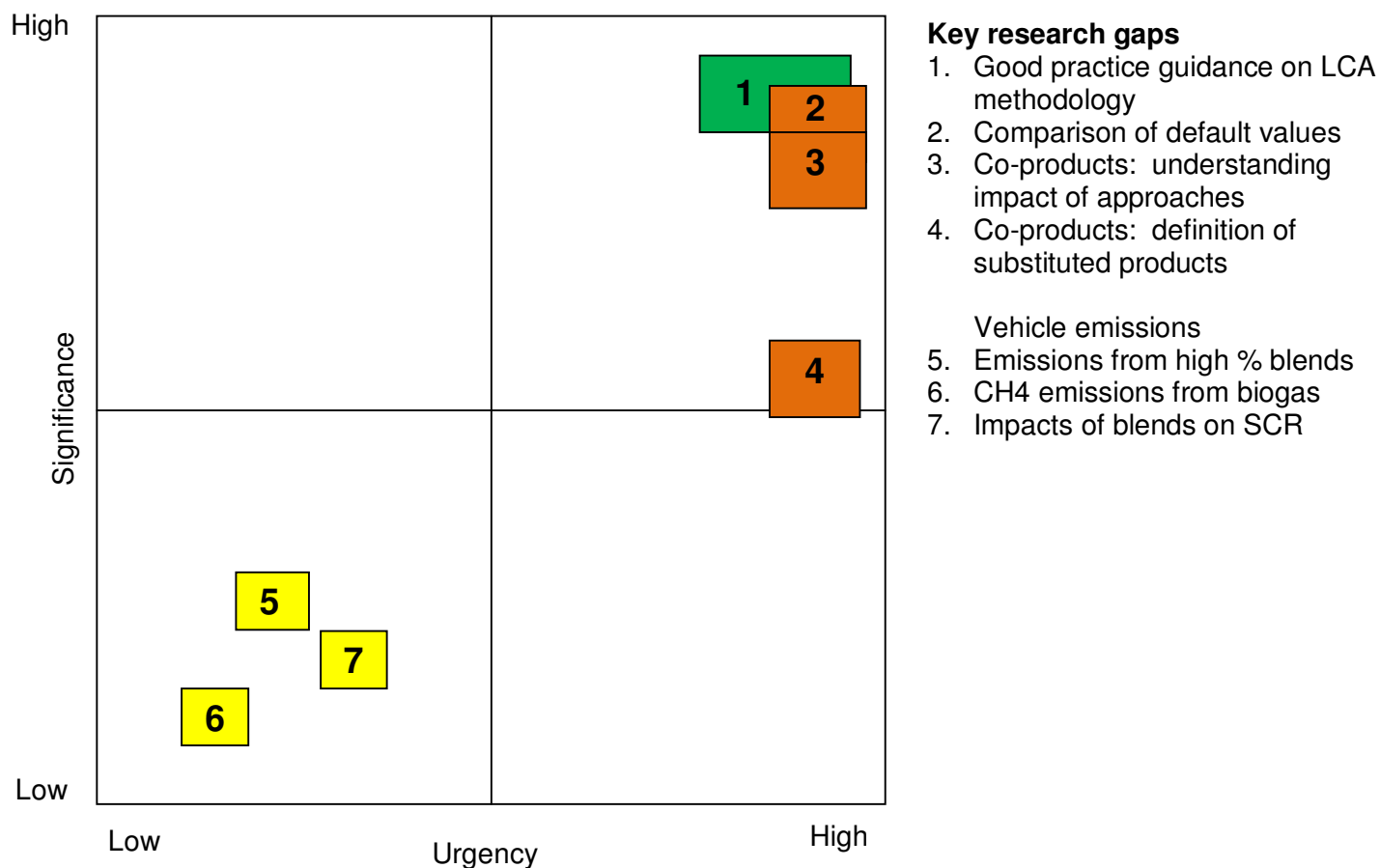
Research Gap	1) Carbon emissions LUC for biofuels	2) Response of soil to LUC	3) Long term monitoring of land use change	4) Datasets
Key related work	IPCC	IPCC	Defra	FAO
Complexity	**	**	**	**
Time scale	***	***	***	***
Potential costs	***	***	***	***
National or international?	National and International	National and International	National and International	International
Availability of data	Some available	Not available	Available	Available
Availability of skill sets	**	**	**	***

**Key**

<b>Significance</b> – please see matrix	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k * <£100k	<b>National or international</b> i.e. can the work be done in the UK or would it be better done internationally?
<b>Availability of data</b> This will refer to the IPR/availability of R&D already ongoing in the area (e.g. Commercial – restricted; or published/available)			<b>Availability of skill sets</b> *** a number of organisations working in area ** availability restricted to a few groups or only on international scale * skills gap, significant training required	

### 3.3 Greenhouse Gas Life-cycle Analysis

Figure 3-2 Matrix prioritising key research gaps for greenhouse gas life-cycle analysis



Size of Research Gap	
	Small
	Small / Medium
	Medium / Large
	Large

### 3.3.1 Executive summary

*Excluding ILUC what is the most accurate and most appropriate method for calculating the life-cycle GHG emissions of biofuels, and (if different) how does this compare with the RED methodology?*

GHG LCA calculations are vital to support and inform policy on biofuels. Consequently there are many initiatives to develop LCAs in Europe and the USA, as well as in the UK. More recently, the Biofuels Directive prompted the development of tools and methodologies at the national level which can be used to report GHG emissions, for example the RTFO methodology in the UK, the methodology developed in Germany (IFEU, 2007) and the CO<sub>2</sub> bioenergy tool developed in the Netherlands.<sup>14</sup>

The RED sets out a methodology for calculating the life-cycle GHG emissions associated with biofuels production, including 'rules' for how to deal with wastes, residues, co-products and excess electricity produced by combined heat and power plant (i.e. electricity which is surplus to the needs of the biofuels plant). It also sets out default values for a number of biofuel chains. This raises a number of questions for UK policymakers. In this chapter we have looked at current and future research in this area and assessed how this addresses these questions.

Our analysis suggests that there are the following research gaps:

Research Gap 1: The need for good practice guidance on LCA methodology. GBEP are supporting a study at the international level to provide a systematic method of comparing the LCA methodologies. This should provide a useful framework to catalogue the differences between methodologies and allow a clearer understanding of them. Future work is needed to develop a template and good practice guidance on what the methodology should be could be useful in helping to define a standard. This work needs to be done at an international level, e.g. through GBEP.

Research Gap 2: Comparison of default values. It is not straightforward to compare the RED default values to 'actual values' because this is a matter of degree. Nevertheless, the RED methodology could be applied, using the default values for operational parameters in the RTFO methodology to give a comparison set of default values.

Research Gap 3: There is a need for increased understanding of the impact of different approaches to the treatment of wastes, residues and co-products. Current LCAs take account of wastes, residues and co-products using differing methodologies. Although some work has been done on the sensitivities to these methodologies, further work is required. The knowledge bases and tools exist to carry out an applied piece of research to explore the implications of different approaches and compare their impact on results. This needs to be done with European co-operation.

Research Gap 4: In dealing with co-products by substitution methods, more work is required to accurately define what will be substituted, taking into account the co-product characteristics.

For tail pipe emissions more data is required on:

<sup>14</sup> The can be found at: [http://www.senternovem.nl/gave\\_english/co2\\_tool/index.asp](http://www.senternovem.nl/gave_english/co2_tool/index.asp)

Research Gap 5: Emissions from high percentage blends.

Research Gap 6: CH<sub>4</sub> emissions from biogas vehicles.

Research Gap 7: Potential interactions between biodiesel tail pipe emissions and Selective Catalytic Reduction (SCR) abatement technology.

### 3.3.2 Context

GHG LCA for a range of biofuels production pathways have been carried out in a large number of countries for several years. These have ranged from research groups carrying out LCAs of specific biofuels production routes of particular interest to them, to research groups which have developed models (e.g. GREET developed at ANL in the US), which can carry out LCAs of a large number of biofuels routes (and often fossil fuel routes as well). Others have developed a standard methodology, which has been applied to a number of biofuels and fossil fuel routes such as, for example, the European JRC/CONCAWE/EUCAR Well to Wheels study (JRC, 2007). In general a larger number of studies are available for 'first generation' biofuels, where the cultivation characteristics of the feedstock are well known and there are working examples of the production process, which can be used to provide data for the LCA. There are GHG LCA studies of second generation biofuels production, but these are, of necessity, based on design data or data for pilot plants.

More recently, the Biofuels Directive has prompted the development of tools and methodologies at the national level which can be used to report GHG emissions, for example the RTFO methodology in the UK, the methodology developed in Germany (IFEU, 2007) and the CO<sub>2</sub> bioenergy tool developed in the Netherlands.<sup>15</sup>

The methodological assumptions, which can significantly influence the results of GHG LCAs of biofuels, are generally well known to those life-cycle practitioners involved in such studies and include issues of allocation and treatment of co-products, including excess electricity. An additional area of uncertainty was raised in a paper by Crutzen et al in 2007, which suggested that N<sub>2</sub>O emissions from the application of nitrogen to crops was being consistently underestimated, and that for some biofuels chains this could significantly increase GHG emissions, to the point where they offered no GHG savings.

### 3.3.3 Key research questions

The RED sets out a methodology for calculating the life-cycle GHG emissions associated with biofuels production, including 'rules' for how to deal with wastes, residues, co-products and excess electricity produced by combined heat and power plant (i.e. electricity which is surplus to the needs of the biofuels plant). It also sets out default values for a number of biofuel chains. The adoption of this methodology at the EU level raises a number of key research questions for UK policy makers. This section explores what research there is on: the different approaches to the LCA calculations of biofuels, and how do these compare to the RED default values

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<sup>15</sup> The can be found at: [http://www.senternovem.nl/gave\\_english/co2\\_tool/index.asp](http://www.senternovem.nl/gave_english/co2_tool/index.asp)

This is underpinned by an analysis of what research is there is on:

- 1) How the default values compare to actual values, and are there serious discrepancies?
- 2) Whether there are particular issues (not including ILUC) with:
  - The method for accounting for wastes and residues?
  - The method for accounting for co-products?
  - Co-generation?
  - The status of agricultural crop residues as co-products?
- 3) Issues which policy makers need to resolve in light of the concerns raised by Crutzen include:
  - What is the most accurate way of calculating N<sub>2</sub>O emissions of biofuel production?
  - What are the best ways to reduce N<sub>2</sub>O emissions of biofuels?
- 4) Air quality impacts. Key questions are:
  - How do the tailpipe emissions of biofuels compare to those of fossil fuels?
  - Do tailpipe emissions vary depending on feedstocks or production pathways?

Reflecting that as the proportion of biofuels in transport, the need to identify any particular impacts on air quality becomes more important.

- 5) The different approaches to defining a fossil fuel comparator, including
  - Whether the comparator should be dynamic or static.
  - Whether the methods for measuring the fossil fuel emissions and the biofuel emissions are inconsistent, e.g. indirect land use change/other indirect effects.
  - Analysis of impact of using different baselines or approaches.

Reflecting that different studies have adopted different models for the fossil fuel comparator against which biofuels are judged.

### 3.3.4 Research in the area

Research in the area of Greenhouse Gas Life-cycle Analysis is shown below in Table 3-2.

**Table 3-2 Research in the area of Greenhouse Gas Life-cycle Analysis**

<b>Funding or research organisation and budget where available</b>	<b>Current status of research</b>
<b>R&amp;D on LCA of biofuels</b>	
<b>UK</b>	
UKERC	Comparison of methodologies in bioenergy LCA studies.
NNFCC	LCA of gasification routes.
RFA	Development of RTFO methodology.
<b>Europe</b>	
Öko Institute (for German Advisory Council on Global Change and UNEP-DTIE respectively), Germany	GHG balances of bioenergy pathways including LUC; review of bioenergy lifecycle including sensitivity analysis of key methodological assumptions and rules.
IFEU, Germany	LCA biofuels studies.
Dutch Ministry for Environment	C flux estimates for palm oil cultivation in Malaysia; development of best practice guidance for oil palm cultivation on peat to reduce GHG emissions.
SenterNovem, Netherlands	Development of greenhouse gas calculator for biofuels.
University of Wageningen, Netherlands	LCAs of biofuels including LUC.
Joint Research Centre	GHG LCA of biofuels and fossil fuels (JRC/CONCAWE/EUCAR 'Well to Wheel' study).
AEA for DG ENV	GHG LCA of biofuels and bioenergy pathways; sensitivity analysis of results to allocation procedures, LUC and N <sub>2</sub> O emissions factors.
<b>US</b>	
US EPA/Office of Transportation and Air Quality	Development of methodology to calculate life-cycle GHG emissions from biofuels pathways (including indirect impacts such as LUC) to support requirements defined in Energy Independence and Security Act (EISA) revision of Renewable Fuels Standard.
California Air Resources Board	Developed GHG methodology based on a version of the GREET model (from Argonne University) adapted to Californian conditions to derive

<b>Funding or research organisation and budget where available</b>	<b>Current status of research</b>
(CARB)	values for biofuels pathways to support implementation of the Low Carbon Fuel Standard. ILUC effects estimated using the GTAP model.
NREL	Work with partners in Brazil on LCA of biofuels on sustainability of biofuels, direct/indirect land use change, the benefits of integrated biorefineries (greenhouse gas reductions).
RAEL at University of Berkeley (funding from The State of California (CARB), Energy Foundation, US National Science Foundation, U. S Dept of Energy)	LCAs of wide range of fuels, including conventional and unconventional fossil fuels, corn-based ethanol, early stage cellulosic fuels, and plug-in and pure electric vehicles, LCAs of water impacts of biofuels, EBAMM model. <sup>16</sup> Helped develop Low Carbon Fuel Standard for California.
University of Ohio	LCA of corn based bioethanol and impact of different farming systems.
Michigan State University	Using LCA to identify environmentally sensitive areas for improvement of first and second generation biofuels.
University of Illinois	Integration of models of land use. Crop productivity and soil carbon; output will include GHG balances.
<b>International</b>	
CENBIO, Brazil	LCA of biodiesel from castor oil.
NEST, Brazil	LCA of second generation biofuels.
RSPO	Summary of literature on GHG emissions and palm oil.
IEA Bioenergy Task 38 Greenhouse Gas Balances of Biomass and Bioenergy Systems	Has looked at developing standard tool (Biomitre) to look at GHG emissions savings from bioenergy. Organising workshop on Land Use Changes due to Bioenergy: Quantifying and Managing Climate Change and Other Environmental Impacts.
GBEP	Formulate a harmonized methodological framework on GHG emission reduction measurement from the use of biofuels for transportation and from the use of solid biomass, by which the results of GHG life-cycle assessments could be compared on an equivalent and consistent basis.
<b>R&amp;D on nitrous oxide emissions</b>	
<b>UK</b>	
Defra funding ADAS	Research on N <sub>2</sub> O emissions from soils, aimed at improving the accuracy of the UK's GHG inventory.
OREGIN	Breeding new varieties of OSR with a lower N requirement, hence reducing N <sub>2</sub> O emissions during cultivation.

<sup>16</sup> <http://rael.berkeley.edu/ebamm>

<b>Funding or research organisation and budget where available</b>	<b>Current status of research</b>
<b>R&amp;D on tailpipe emissions</b>	
<b>UK</b>	
LowCVP	Review of evidence base on tailpipe emissions from different liquid biofuel blends and biomethane (part of larger project).
AEA funded by Defra	Review of tailpipe emission factors for biofuels.
<b>Europe</b>	
NROM (Dutch Environment Ministry)	Impact of biofuels on air pollutant emissions from road vehicles (BOLK-programme) – work completed in 2008. This work indicated that low blends (E5-E10, B5-7) should be used to meet the 2020 target and that a systematic emissions measurement programme is needed for low and high blends. The Dutch call for a 'coordinated and systematic measurement program to fill blanks in the information on emission impacts of biofuels' and a basic measurement programme. They also call for international co-operation in this area.
<b>US</b>	
US EPA/OTAQ	Emissions testing (for regulated and unregulated pollutants of E10 blends and blends up to E20.
<b>R&amp;D on fossil fuel comparator</b>	
<b>International</b>	
CARB (US) & EU	Several of the models and systematic studies also include LCAs of fossil fuel comparators (e.g. JRC/CONCAWE/EUCAR study, GREET model and CARB methodology, GBEP work).



### 3.3.5 Key research gaps

We have considered research gaps in relation to the key research questions set out above.

#### 1) **Are there different approaches to the LCA calculations of biofuels, and how do these compare to the RED default values?**

It is clear that a large number of methodologies already exist or are being developed at both the national and individual research institute level to assess life-cycle GHG emissions from biofuels. There is a widespread appreciation within the research community in this area that there is no standard methodology and that different approaches can lead to significantly different results. There is also a clear understanding of the areas where differences of approach are likely to have a significant impact. The GBEP study is an attempt at the international level to provide a systematic method of comparing the methodologies, and should provide a useful framework to catalogue the differences between methodologies and allow a clearer understanding of them. Future work to develop a template, and good practice guidance on what the methodology should be, could be useful in helping to define a standard.

Default values for biofuels pathways are now available from a number of methodologies, and could be compared to RED default values relatively easily. For this to be meaningful, it would need to be coupled with an understanding of the key assumptions in the methodologies, and methodological differences. DG TREN are planning work to elaborate on how the default values in RED were derived and this would be an essential input to any research to compare values.

Research Gap 1: The need for good practice guidance on LCA methodology. GBEP are supporting a study at the international level to provide a systematic method of comparing the LCA methodologies. This should provide a useful framework to catalogue the differences between methodologies and allow a clearer understanding of them. Future work is needed to develop a template and good practice guidance on what the methodology should be could be useful in helping to define a standard. This work needs to be done at an international level, e.g. through GBEP.

#### 2) **How do the default values in RED compare to actual values, and are there serious discrepancies?**

Resolving this question would require the calculation of GHG emissions for the fuel pathways in RED using the RED methodology and actual values for operational parameters, i.e. as reported for 'real' fuel chains. Evidence for actual values may become available in the UK as data is reported to the RFA under the RTFO so that this kind of comparison could be made. Alternatively, the RED methodology could be applied, using the default values for operational parameters in the RTFO methodology to give a comparison set of default values. This would require a modest piece of research, which could be carried out fairly quickly. Gathering 'actual' values for operational parameters to use in the RED methodology would be more challenging and require a longer time frame.

Research Gap 2: Comparison of default values. It is not straightforward to compare the RED default values to 'actual values' because this is a matter of degree. Nevertheless, the RED methodology could be applied, using the default values for operational parameters in the RTFO methodology to give a comparison set of default values.

**3) Are there particular issues (not including ILUC) with the way that wastes and residues, co-products, cogeneration and agricultural crop residues are accounted for?**

As discussed earlier, it is known that the way these issues are dealt with, for example whether allocation or substitution methods are used to deal with co-products and which allocation method (e.g. price or energy content) is used, can significantly affect results of GHG analysis. The work completed by the Öko Institute for UNEP-DTIE specifically investigates the sensitivity of results to some of these issues, and work by AEA for DG ENV has investigated the sensitivity of results to allocation procedures. The knowledge bases and tools exist to carry out an applied piece of research to explore the implications of different approaches and compare their impact on results. In dealing with co-products by substitution methods, more work is required to accurately define what will be substituted, taking into account the co-product characteristics.

Research Gap 3: There is a need for increased understanding of the impact of different approaches to the treatment of wastes, residues and co-products. Current LCAs take account of wastes, residues and co-products using differing methodologies. Although some work has been done on the sensitivities to these methodologies, further work is required. The knowledge bases and tools exist to carry out an applied piece of research to explore the implications of different approaches and compare their impact on results. This needs to be done with European co-operation.

Research Gap 4: In dealing with co-products by substitution methods, more work is required to accurately define what will be substituted, taking into account the co-product characteristics.

**4) What is the most accurate way of calculating N<sub>2</sub>O emissions of biofuel production, and what are the best ways to reduce N<sub>2</sub>O emissions of biofuels?**

While this study uncovered relatively little ongoing R&D on reducing the uncertainty in calculating N<sub>2</sub>O emissions from biofuels, this is believed to be because of the focus of the study on biofuels-related research. Reducing the uncertainty in N<sub>2</sub>O emissions from soils is a wider issue, which is important for the agricultural sector as a whole in managing its GHG emissions, and many countries are known to be seeking to improve data on emissions, moving to more soil- and climate-specific emissions factors. Within the UK, ADAS are carrying out work for Defra on this topic. While it will be important to ensure that results from this broader research are transferred into GHG LCAs for biofuels, this should not be regarded as a research gap. Similarly, while the table shows little research on ways to reduce N<sub>2</sub>O emissions of biofuels, there is research on options to reduce N<sub>2</sub>O emissions from agriculture, some of which could be applicable to biofuels feedstock cultivation.

**5) How do the tailpipe emissions of biofuels compare to those of fossil fuels and do biofuels tailpipe emissions vary depending on feedstocks or production pathways?**

Available data on tailpipe emissions from biofuels was recently reviewed by AEA for Defra (AEA 2008). It was found that emissions of the GHGs methane and nitrous oxide from low percentage blends were comparable to those of fossil fuels, but more data was required on emissions from high percentage blends. Potential areas where emissions could vary from fossil fuels were emissions of N<sub>2</sub>O from high percentage bioethanol blends, and particulates from high percentage biodiesel blends. Another area requiring further investigation is CH<sub>4</sub> emissions from biogas vehicles and potential interactions between biodiesel tailpipe emissions and Selective Catalytic Reduction (SCR) abatement technology.

Research Gap 5: Emissions from high percentage blends.

Research Gap 6: CH<sub>4</sub> emissions from biogas vehicles.

Research Gap 7: Potential interactions between biodiesel tail pipe emissions and SCR abatement technology.

**6) How should a fossil fuel comparator be defined, e.g. should it be dynamic or static, and are methods for measuring the fossil fuel emissions and the biofuel emissions consistent. What is the impact of using different baselines or approaches?**

Several larger studies and models which deal with a number of biofuel pathways have also applied the same methodology to fossil fuels to derive equivalent fossil fuel comparators. Many have looked at transport fuels derived from future sources of crude oil (e.g. tar sands) as current sources of crude oil. LCA standards would suggest that the question of how a fossil fuel comparator should be defined, should be related to the aim of the study, i.e. this is more of a policy than research question.

### **3.2.6 Summary and conclusions**

GHG LCAs will underpin the EU policy on biofuels, as only technologies that achieve above 35% savings in the short term and higher savings after 2017 will be eligible to be included in support mechanisms. Consequently, it is important to have agreement on the methodology used for calculation, and to agree on what can be included and what cannot.

The first gap identified in this work is the need for good practice guidance on LCA methodology. This should be linked to the findings of the GBEP study on systematic comparison of LCA methodologies, building on the GBEP findings. It is classified as slightly lower urgency for this reason, but it is a piece of work that is highly significant in answering the research questions posed in this study. It has been assessed to be a medium-small gap because it is not a complex piece of work and will probably involve just a few key research groups. The work may need to be international in scope in order to ensure acceptance by researchers across the EU.

A small study to compare default values has been identified to examine the differences between the EU RED defaults and those used elsewhere. This is of low urgency and significance and is likely to be done on a small scale compared with other research gaps.

The work to examine the treatment of co-products is urgent and significant; this work should examine the different approaches to co-products in different LCAs and provide an indication of the sensitivities of these different approaches. This is ranked as a medium small piece of work, as the skills to do the work are available, it will be done by a relatively small number of people, but it may involve some international work.

The study also identified a need to examine what will be substituted by co-products and the impact this will have on the results to GHG LCAs. This was assessed to be an urgent, but less significant piece of work and ranked as a medium small project.

This section also examined what we need to do to provide information on emissions from vehicles for GHG LCAs. Emissions from high percentage blends were considered significant, but not as urgent because the work can be done over a slightly longer time-scale. This work would involve a small trial to monitor emissions under appropriate combustion conditions. Impacts of different blends on SCR were similarly ranked.

Fugitive emissions from biogas vehicles are regarded as a relevant project only if policy decides to support biogas vehicles in the UK. This would also be a relatively small piece of work.

**Table 3-3 Greenhouse gas life-cycle analysis calculations – key findings**

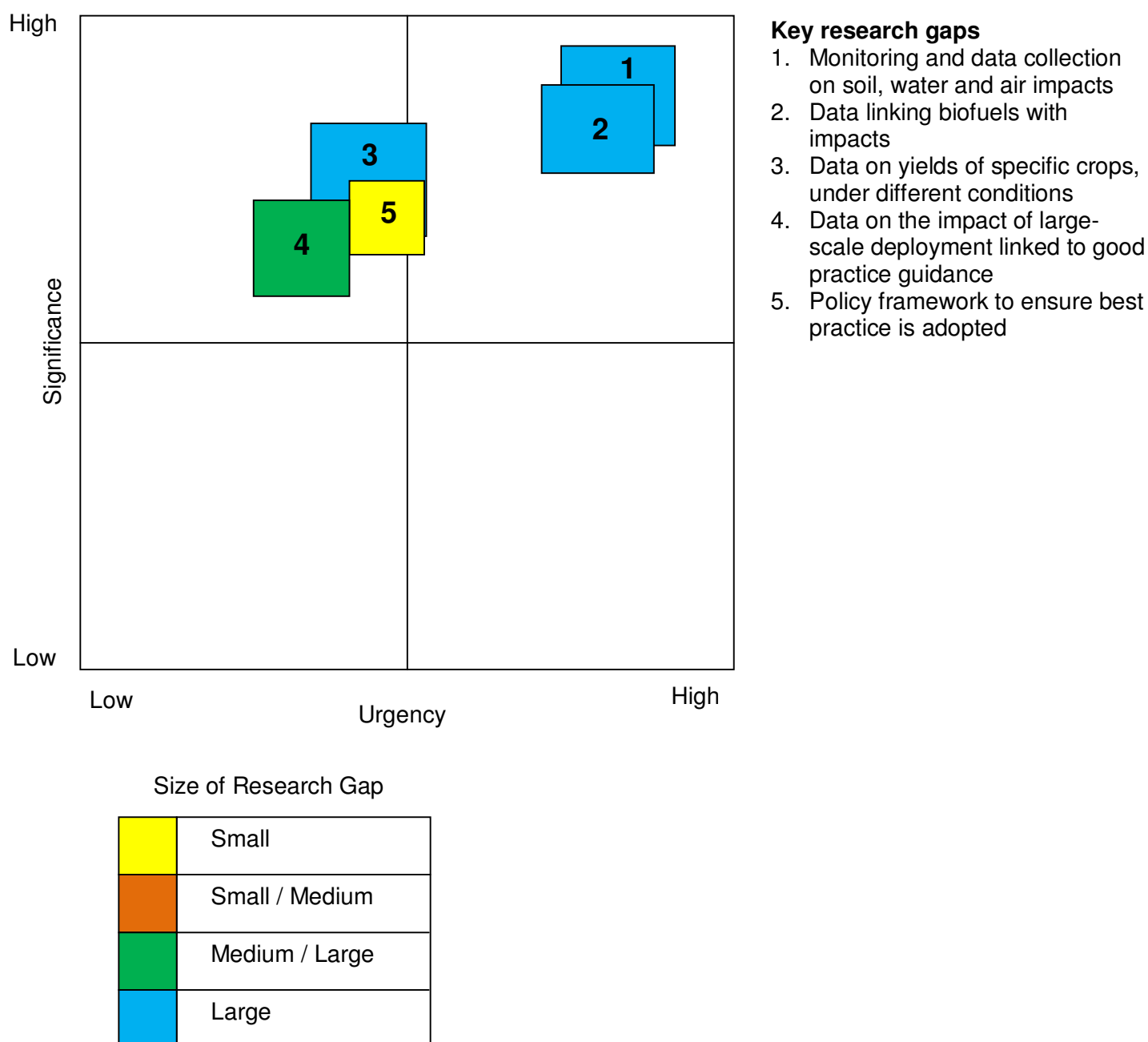
Research Gap	GHG LCA methodology				Vehicle emissions		
	1) Good practice guidance on LCA methodology	2) Comparison of default values	3) Co-products: understanding impact of approach	4) Co-products: substitution	5) Emissions from high % blends	6) CH <sub>4</sub> emissions from biogas vehicles	7) Impact of biofuels on SCR
Key related work	GBEP	RED	Öko Institute			May be some Swedish work	
Complexity	**	*		**	*	*	*
Time scale	***	*		**	**	**	**
Potential costs	**	*		**	**	**	**
National or international?	International	National	International	International	National	National	National
Availability of data	Available	Available	Available	Restricted	Available	Available	Available
Availability of skill sets	***	***	**	**	**	**	**

**Key**

<b>Significance –</b> <i>please see matrix</i>	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k * <£100k	<b>National or international i.e.</b> <i>can the work be done in the UK or would it be better done internationally?</i>
<b>Availability of data</b> <i>This will refer to the IPR/availability of R&amp;D already ongoing in the area (e.g. Commercial – restricted; or published/available)</i>			<b>Availability of skill sets</b> *** a number of organisations working in area ** availability restricted to a few groups or only on international scale * skills gap, significant training required	

### 3.4 Local environment /natural resources

Figure 3-3 Matrix prioritising key research gaps for greenhouse gas life-cycle analysis



### 3.4.1 Executive Summary

*What are the impacts of biofuel production on air quality, water resources, soil quality (and other natural resource issues), and how can policy-makers reduce any negative impact?"*

Biofuel crops, like agricultural crops, can have an impact on soil, air and water quality, water supply and other natural resources. However, the extent varies depending on the crop, the previous land use and other circumstances, and in some cases can be positive. Policy makers can also reduce negative impact through encouraging the use of innovative production methods, addressing some of the externalities that result in the use of unsustainable methods and ensuring good practice is linked to rewards for biofuels.

The RED requires the Commission to report by the end of 2012 on whether it is feasible and appropriate to introduce mandatory requirements in relation to air, soil or water protection, taking into account the latest scientific evidence and the Community's international obligations. This chapter examines current and future research in this area in order to help identify the research gaps which must start to be filled before the 2012 deadline.

Our analysis suggests that there is a lot of information on the impact of agriculture on natural resources and the key areas of concern are known. For biofuels, work has been done on conventional European crops and on energy crops such as short rotation coppice and Miscanthus. However, there are key gaps:

Research Gap 1: There is a significant need for monitoring and data collection, particularly on irrigation, fertiliser impacts and impacts of biofuels on carbon in soils. There is a need for data on specific crops, particularly the novel energy crops.

Research Gap 2: There is a need for clear data linking environmental impacts or benefits with biofuels.

Research Gap 3: Further breeding programmes to develop cultivars with high water efficiency are required. The UN, FAO, Indian Government and private companies have supported work on *Jatropha* in arid areas. This work gives contradictory results, particularly on yield. Therefore, further data and research is required.

Research Gap 4: Good practice guidance is needed for many crops<sup>17</sup> (involves data on the impact of large scale deployment), which should include information on ways to minimise the environmental impact.

Research / Policy Gap 5: There is a need for a policy framework to ensure best practice is adopted.

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<sup>17</sup> Defra has produced good practice guidance for SRC and Miscanthus, which are available from the Biomass Energy Centre website.



### 3.4.2 Context

This section examines the effects of biofuels production on Local Environment and Natural Resources. Biofuel crops, like all agricultural crops, can have an impact on soil, air and water quality, and water and other natural resources. An understanding of these impacts is essential from a number of perspectives including, as with biodiversity, its impact on ecosystem services.

The impact of agricultural crops on soil include: loss of carbon (leading to loss of soil fauna, loss of soil structure and loss of water holding capacity), erosion and depletion of fertility. These are all serious issues, and a lot of work has been done on these impacts worldwide. Fargione et al (2008) discuss soil carbon: 'soils, along with plant biomass are the two largest biologically active stores of terrestrial carbon, containing ~2.7 times more carbon than the atmosphere'. The paper then continues to discuss the mechanism by which soil carbon may be released from soils and the carbon impacts of biofuels as a result of land use change. Conversely, perennial biofuel crops may improve soil carbon in degraded or cultivated soils (EEA, 2006), which shows the importance and complexity of the issue of soil organic carbon. It is important that sufficient good quality data are available on the impact of biofuel crops on soil carbon to enable the assessment of GHG emissions from biofuels production, taking carbon release from land conversion into account.

The impact of agricultural crops on water includes depletion of resources and pollution from run-off as a result of excessive use of fertiliser. Again, these are serious issues, where much work has been done worldwide.

Impacts on soil and water are difficult to allocate specifically to biofuels, in part because it is difficult to separate them from the impact of agriculture in general; and in part because there are a variety of biofuel crops (including potential energy crops for second generation), which are planted in widely varying agricultural environments. Nevertheless, some work has been done on individual crops (e.g. energy crops such as *Miscanthus* and short rotation coppice in the UK and elsewhere in Europe, and perennial crops such as *Jatropha* and *Pongamia* in India, China and Southern Africa). In addition, a lot is known about the growing conditions of conventional crops used for biofuels such as maize, oilseed rape and wheat (AEA, 2008). From this it is possible to understand some of the immediate impacts that may arise from biofuels expansion – and also to develop guidelines and strategies to minimise impacts and maximise benefits, where possible.

### 3.4.3 Key research questions

This section explores what research there is on the:

- 1) Impact of biofuel production (notably feedstock production) on:
  - Air quality.
  - Water resources.
  - Soil quality.
  - Other natural resources issues.

This is underpinned by an analysis of what research there is on:

- 2) Innovative production methods to avoid these problems.
- 3) Potential benefits of biofuel production on these natural resources.
- 4) The policy levers which can be used to reduce the negative impacts.

### 3.4.4 Research in the area

There has been a lot of work worldwide on the major impacts of agriculture on soil and water resources, much of which is relevant to biofuels, although there is a danger of generalisation and a need to do work on specific crops, particularly some of the more novel energy crops. Much work has been done on vulnerable habitats (e.g. arid areas and areas prone to erosion) and a lot is known about the way that different types of crops impact (negatively and beneficially) on such environments. This is important to biofuels as it has been suggested that biofuels could be planted on marginal or degraded land rather than land used for food crop production. It has been suggested that perennial crops such as those proposed for biofuels (EEA, 2006), could be advantageous in that they help build up organic matter in the soil through development of roots and leaf drop. There is quite a lot of work ongoing in this area in Southern Africa, India, China and the USA where erosion and arid environments are key issues.

Not surprisingly, given the variety of crops potentially used for biofuels (first and second generation), current evidence suggests that impacts vary with the type of crops, current land use, local farm management techniques, soil conditions, water use and climate. Many of the crops used for biofuels are also grown for food and/or fibre and it is difficult to separate the impacts from biofuels production. Key reviews of research in this area include EEA (2006), AEA (2008), and the Dutch Government study by Dornberg et al (2008).

Examples of research are summarised in Table 3-4 for UK, EU and Internationally. Further information on research by topic area and organisation is provided in Table 3-5.

More information on work on air emissions from vehicles is given in Chapter 6. This information is expanded in Annex 3, which provides more detail on work being done by individual research programmes and research groups. Much of the work is being supported by funding agencies normally involved in agricultural research and done by agricultural research organisations and universities involved in agricultural research.<sup>18</sup>

**Table 3-4 Examples of research on impacts of biofuels on soil, water and air in UK, EU and internationally**

Funding or research organisation and budget where available	Current status of research
<b>UK</b>	
Rowe R.I., Steel, N.R. and Taylor G.	Identifying potential environmental impacts of large-scale deployment of dedicated bioenergy crops in the UK Renewable and sustainable Energy (2009)

<sup>18</sup> For example in the UK researchers include Rothamsted, ADAS, IGER, MLURI, SAC, Aberdeen University, Cranfield University, Southampton University and the University of Reading; and key funding agencies include: Defra, BBSRC, NERC, UKERC and SEERAD.

Funding or research organisation and budget where available	Current status of research
Turley D., Boatman N., Huxtable H., and Liddle N.	Environmental impacts of cereal and oilseed rape cropping in the UK and assessment of the potential impacts arising from cultivation for liquid biofuel production (2008)
<b>Europe</b>	
EEA	How much bioenergy can Europe produce without harming the environment? 2007
<b>USA</b>	
Simpson T., Pease J., McGee B., Smith M and Korcak R	Biofuels and water quality – meeting the challenge and protecting the environment, submitted to Mid-Atlantic Water Program USDA-CSREES
Sandia	<p>90 Billion Gallon Deployment Study – 2009. Considers land use and water availability  <a href="http://www.sandia.gov/news/resources/releases/2009/biofuels_study.html">http://www.sandia.gov/news/resources/releases/2009/biofuels_study.html</a></p> <p>Report to Congress on the Interdependency of Energy and Water  <a href="http://www.sandia.gov/energy-water/docs/121-RptToCongress-EWwEIAcomments-FINAL.pdf">http://www.sandia.gov/energy-water/docs/121-RptToCongress-EWwEIAcomments-FINAL.pdf</a></p>
USDA	Field Study to develop Sustainable Production Practices for Energy Cane to reduce soil erosion and agro-chemical loss in drainage runoff. Completes September 2009.
<b>International</b>	
De Fraiture C., Giordano M and Yongsong L	Biofuels and implications for agricultural water use: blue impacts of green energy. International Water Management Institute, Sri Lanka 2007
Fargione J., Hill J., Tilman, D., Polasky S., Hawthorne P (2008)	Land Clearing and the Biofuel Carbon Debt Science 310 1235-1238
AEA	<p>Review of work on the environmental sustainability of international biofuels production and use. Report for DEFRA (CEOSA), available from Defra Web site (completed 2008)  <a href="http://randd.defra.gov.uk/Document.aspx?Document=GA01105_7190_ABS.pdf">http://randd.defra.gov.uk/Document.aspx?Document=GA01105_7190_ABS.pdf</a></p>

**Table 3-5 Research by Topic area and different research groups**

Topic	UK	EU	International
Soil carbon	NERC (TSEC-biosys), DEFRA	FP7 (SOILSERVICE)	FAO, UNFCC USA: USDA, Ohio State University, UC Davies, The Nature Conservancy
Soil impacts and benefits from biofuels	CSL, HGCA, Land Use Policy Group,	EEA, FP7, Öko Institute, University of Utrecht	FAO, UNEP, UN – Energy, USA: CSREES, USDA, The Nature Conservancy
Water quality	SEERAD		Brazil (Sao Paulo, UNICA, University of Campinas) Committee on water implications of biofuels in USA, ESMAP (USA).
Water resources	NERC (TSEC-biosys), DEFRA UKERC, BBSRC, Rothamsted, ADAS, CSL	EEA, FP7, University of Utrecht, Delft Hydraulics	FAO, ICRISAT, India Government, WWF, International Water Management, Wetlands International, Institute Sri Lanka, US DoE, USDA, Ohio Institute, University of Colorado, UC Berkeley,
Air emissions (other than GHG) – from farming practices	ODI, UK Air Quality Expert Group. SEERAD	JRC, GAVE	FAO, WWF, ODI, Wetlands International, Sao Paulo, World Bank, ASEAN (Far East), RSPO, UNDP, US ESMAP
Air emissions (other than GHG) from biofuels production and use. <sup>19</sup>	Defra, Environment Agency		Brazil US EPA

### 3.4.5 Research gaps

This section shows that there is a lot of information on the impact of agriculture on natural resources and that the key areas of concern are known. For biofuels, work has been done on conventional European crops and on energy crops such as short rotation coppice and Miscanthus.

These are examined for each of the key questions listed above.

#### 1) Impact of biofuel production (notably feedstock production) on:

- Air quality.
- Water resources.
- Soil quality.
- Other natural resource issues.

<sup>19</sup> See also chapter on vehicles.

Research has been undertaken on all of the above topics. For example:

Research on air quality has tended to focus on the use of fire in land clearance and reclamation of wetlands and as part of cropping practices, and the relationship of this to crops used for biofuels production (e.g. palm oil or sugar cane plantations). Thus most of this is international work rather than specific to the UK. Concern about the related health and environmental effects have led to legislated bans on this practice in South America and the Far East, although the bans have proved difficult to enforce.

Berndes (2002) highlights agriculture as one of our greatest uses of water. It suggests that the effect on water demand depends on local environmental conditions, the type of crop and the extent of planting. Water use should be taken into consideration when planning large-scale biofuels crop plantations, as should potential benefits from such crops including erosion control and increased sequestration of carbon. Research suggests that it is unlikely that fast growing economies such as China and India will be able to meet future food, feed and biofuel demand without substantially aggravating existing water scarcity problems, or importing grain (De Fraiture et al 2007). Fingerman et al (2008) examines the impact of water on California's in-State feedstock and fuel production of biofuels production. It suggests that biofuel production in California could either increase or decrease the sustainability of the state's water resource use, and suggests that water resources are considered under the Low Carbon Fuel Standard. Winrock International is currently undertaking research on the Role of Water in the Sustainable Supply of Biofuels (Winrock International 2009).

This is also considered an issue in other parts of the US (Kreider and Curtiss 2007), particularly in the drier areas where irrigation is a key issue. The use of crops such as *Jatropha* that can tolerate draught has been proposed for Sub Saharan Africa, India and China, to address water shortages in these countries. Fieldwork is underway to examine the use of *Jatropha* and *Pongamia* in India and sub Saharan Africa and on sweet sorghum, which requires less water than sugar cane.

Biofuel crops may have mixed impacts on water resources on a wider scale. These are a result of indirect impacts of large-scale biofuels production on deforestation, water abstraction and the impact of run-off from fertiliser.

**Deforestation:** In tropical areas, deforestation of the rainforest may have important impacts on the rainforest's role in climatic recycling water. This effect will not be entirely (or even directly) due to biofuels, but rather to general agricultural pressures in these areas, of which biofuels could be increasingly important. Better understanding of the pressures on deforestation is needed. Indirect effects of Biofuels (including land use change) are considered in Chapter 2.

**Water abstraction:** This is also an issue for agricultural expansion in general and one where it will be difficult to separate out the specific impacts from biofuel crops. But there is one important issue. A number of crops have been proposed for biofuels because of their ability to use water efficiently and tolerate drought. However, some of these crops also respond well to irrigation, producing much higher yields when irrigated. Work is being undertaken on this issue to provide guidance.

**Run-off:** There are many concerns in areas where agriculture is already intense about the effect of increased use of fertilisers on local ground and surface water, particularly on the downstream effects on wetlands. The AEA (2008) report includes case studies on this issue in Brazil and the USA, but the effect is also important in the EU. If biofuels add to intensification pressures this could be an important indirect effect. Defra have undertaken work on the impact of loss of set aside, which mainly looks at impacts on biodiversity, but using these areas for conventional crops (including first generation biofuels) could result in water pollution from run-off. Nutrient input is generally large for wheat, grain maize, potatoes, sugar beet and OSR but varies between countries and farming practices.

Research has also been undertaken on soil quality. European work on biofuels (for example on sugar beet) has examined the potential to increase soil erosion and their potential to improve soil structure and organic matter content due to leaf drop and root structure. The use of perennial grass and wood crops for their lignocellulose will have a number of benefits for degraded or arable land. They could provide stability for the soil, replenish organic matter (to a limited degree) and provide cover against the elements (and erosion).

For the use of residues for biofuels key findings are that the removal of straw or stover from the ground may expose it to the elements and erosion. In addition, removal also leads to loss of organic matter from the soil.

Ongoing work by the EUFP7 'Soilservice' project will look at how soil nutrients can be maintained.

The impacts and benefits of second generation crops have also been considered. It is thought that perennials will increase shade and the organic matter of soil, both of which act to increase water retention in soils. On the other hand, some perennials have deep roots, which tap into ground water supplies and others increase the amount of evapotranspiration (AEA, 2008). Both of these strategies could lower water availability to other crops. Rowe et al (2009) have examined the impact of large-scale plantations of perennial energy crops in the UK, but further work is needed internationally.

Good practice guidelines are available for Miscanthus and SRC in the UK, which recommend practices to minimise impact, including on soil and water. HGCA have examined fertiliser input for wheat grown for biofuels and published their findings.

There is a need to provide overviews and recommendations on all biofuel crops to optimise benefits and decrease potential negative impacts.

In conclusion there is a lot of work on these issues and the research area is recognised to be important. However, there are important gaps:

Research Gap 1: There is a significant need for monitoring and data collection, particularly on irrigation, fertiliser impacts and impacts of biofuels on carbon in soils. There is a need for data on specific crops, particularly the novel energy crops.

## **2) Innovative production methods to avoid these problems.**

Research has been undertaken on innovative methods to avoid environmental problems. These include:

1) **Use of ecological approaches** such as zero/minimal tillage, permaculture and conservation agriculture (CSL), considering the location of biofuel crops, planting crops to allow the staggering of water use, and use of new varieties with lower water use when they become available.

2) **Terra Preta (biochar) techniques** which involve the use of charcoal and organic material (such as manure) to improve soil fertility and organic matter without the use of synthetic, potentially more damaging, fertilisers.

3) **Closed-loop systems.** Steps can also be taken to reduce energy and fertiliser inputs. For example, HGCA have supported work to examine the potential to reduce nitrate fertiliser for wheat used for biofuels.

Further work in this area is needed and is considered under Question 4.

### 3) Are there potential benefits of biofuel production on these natural resources?

Biofuel production may bring benefits to natural resources, depending on the biofuel, the natural resource issue, the local environment, and the growing conditions.

For example, positive impacts may be achieved for soil condition with perennial biofuels if they are used to 'reforest' degraded land, from the resultant increase in soil carbon.

Additionally, perennial biofuels could be used to create a more sustainable approach to farming in areas where there have been severe impacts from over-grazing or over-cropping. Miscanthus and SRC may help to prevent soil erosion by providing year-round soil coverage; in the USA, switchgrass is also considered in part because of its benefit in preventing erosion. These potential benefits are discussed by EEA (2006) and for the UK (Rowe et al 2009, in work funded by UKERC). Information on growing conditions for these energy crops is provided on the Biomass Energy Centre website.

Biofuel crops, in certain conditions, may also decrease pressure on irrigation. As mentioned above, crops that survive well in drought conditions, such as *Jatropha*, are being trialled in countries where water is scarce (for example in India and China, where agriculture is water limited).

With regard to water quality, biofuel/bioenergy crops may help to reduce the overall inputs to a cropping system, if they replace crops needing greater inputs and/or their introduction leads to a wider crop rotation.

As above, the main gaps relate to the need for more data on specific crops (particularly novel crops being proposed for arid conditions in developing countries), but there is much data already available on crops suitable for northern Europe. This data could usefully be gathered in one easily accessible biofuels information web site. It is also important to ensure that Defra's, best practice guidelines for energy crops (Defra, 2007), is routinely updated with the results of new research as they become available (such as the recent work by Southampton and trials conducted by Rothamsted) and in addition, there is a need for more information on novel energy grasses such as reed canary grass, grown in UK conditions.

Research Gap 2: There is a need for clear data linking environmental impacts or benefits with biofuels.

### 4) What are the policy levers which can be used to reduce the negative impacts?

Policy levers that can be used to reduce negative impacts include:

- Elimination of hidden subsidies on natural resources, e.g. oil-based fuels and fertilisers, water and land.
- Internalise negative externalities to reflect true environmental costs and encourage more resource-efficient crops and production methods.

- Development of third generation feedstocks with decreased fertiliser and water-use and increased solar conversion efficiencies, drought and stress tolerance.

Policy measures can be used to support a move towards the positive benefits of biofuels and away from the negative impacts. Thus, moves towards low fertiliser input crops, perennial crops grown on degraded land and the use of residues and wastes (providing sufficient residue remains on the ground) will all support a more sustainable biofuels production. The adoption of good practice in farming as included in the RED and the move towards second generation biofuels will encourage this. However, such policy measures cannot be developed without the data on which to base them.

Research Gap 3: The UN, FAO, Indian Government and private companies have supported work on *Jatropha* in arid areas. This work gives contradictory results, particularly on yield. Good quality data is required. Further breeding programmes to develop cultivars with high water efficiency.

Research Gap 4: Good practice guidance is needed for many crops<sup>20</sup>, which should include information on ways to minimise environmental impact and research to take this forward. There is also the need for dissemination of information on best practice, for example on the use of set aside, on the use of fertilisers for specific crops (HGCA has examined this issue for wheat in the UK, but work could be done on other crops). This is linked to the requirement for data on large-scale deployment.

Research / Policy Gap 5: There is a need for a policy framework to ensure best practice is adopted.

### 3.4.6 Summary and conclusions

Quite a lot of relevant activities are taking place in this research area, since the impacts of agriculture on air, soil and water are well researched. However, further research linking biofuel feedstock production to environmental impacts and to provide clear data on the benefits requires greater research effort. This is particularly the case outside of Europe.

The monitoring and data collection for crop requirements is a research gap of high urgency and significance, because we need to understand biofuel crop requirements to develop good practice for biofuel crops, particularly on fertiliser requirements, the impact of irrigation and the impact of the crop on soil carbon. This work was ranked as a large research gap because of the multi-disciplinary needs for the work, the many different crops and impacts that need to be examined and because the work is international in context.

Data on the impacts and benefits of biofuel crops is also considered to be an urgent and significant piece of work. To develop good practice guidance and for developers to use best practice there is an urgent need to catalogue where biofuel crops have a negative impact on environmental resources and where the impact is beneficial. This is a large piece of work due to the large number of crops and different agricultural/environmental conditions that need to be monitored. The work is likely to have implications for the UK and globally.

Further understanding of agronomy of perennial crops for arid areas is a research gap of high significance, but medium urgency, reflecting that these crops are more relevant to second generation processing. It is a medium to large research gap because the work is likely to concentrate on trials of a few key perennial crops. Nevertheless, such work needs to begin in the near future in order to provide information for long-term policy.

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<sup>20</sup> Defra has produced good practice guidance for SRC and *Miscanthus*, which are available from the Biomass Energy Centre web site.



The impacts of large-scale deployment may be different to the impacts of a few small-scale plants. This work is significant in addressing the key research area but is less urgent because large plantations will be developed over a slightly longer time-scale. The work is not complex (although there may be challenges in obtaining data in some countries) and is ranked as a small to medium piece of work. This is linked to the need to provide good practice guidance.

The results of the above will need to be fed into policy frameworks to ensure best practice is adopted not only in the UK but also elsewhere. The challenges here are in development of best practice and ensuring producers follow it. This work has been ranked as significant, but less urgent and in general a small piece of work, involving one research group in each of the relevant countries.

**Table 3-7 Local environment/natural resources – key findings**

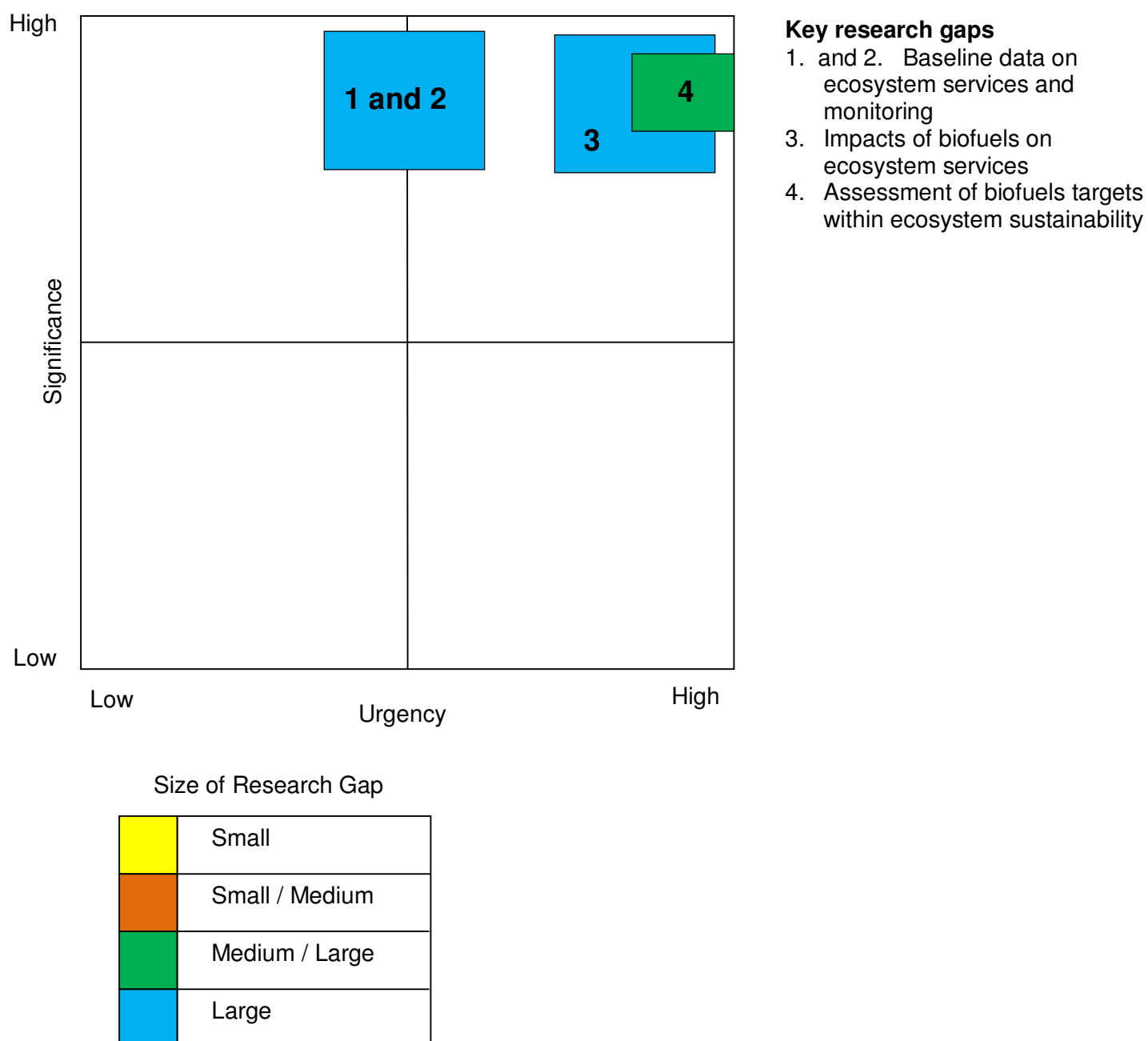
Research Gap	1) Monitoring and data collection, particularly on irrigation, fertiliser impacts and impacts of biofuels on carbon	2) .Linking environmental impacts with biofuels	3) Development of cultivars with high water efficiency	4) Understanding the impacts of large-scale deployment (to inform good practice guidance)	5) Policy frameworks
Key related work	Defra, FAO, UN, USDA			BBSRC, NERC, UKERC	EU RED
Complexity	**	***	*	**	***
Time scale	***	**	***	**	**
Potential costs	***	**	***	**	**
National or international	International	National and International	National and International	National and International	National and International
Availability of data	*	*	**	**	*
Availability of skill sets	**	**	**	**	**

**Key**

<b>Significance –</b> please see matrix	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k * <£100k	<b>National or international i.e.</b> can the work be done in the UK or would it be better done internationally?
<b>Availability of data</b> This will refer to the IPR/availability of R&D already ongoing in the area (e.g. Commercial – restricted; or published/available)			<b>Availability of skill sets</b> *** a number of organisations working in area ** availability restricted to a few groups or only on international scale * skills gap, significant training required	

### 3.5 Biodiversity

Figure 3-4 Matrix prioritising key research gaps for biodiversity



### 3.5.1 Executive Summary

*What is the impact of biofuel production on biodiversity, and how can policy makers reduce any impacts?*

This section refers to the impacts of biofuel feedstock and associated changes in land use on biodiversity and ecosystem services.

The potential impact of biofuels production on biodiversity has been an on-going area of concern. The RED recognises this and states “biofuels and other bioliquids shall not be made from raw material obtained from land with recognised high biodiversity value”. The importance of viewing biodiversity within a wider ecosystem services approach<sup>21</sup> was highlighted at the stakeholder workshop associated with this project.

This chapter considers current and future research in this area in order to identify key research gaps. These include:

Research Gap 1 and 2: The need for continued development of baseline ecosystem services/biodiversity datasets and monitoring of ecosystem services. There are significant gaps in these baseline data at global and regional geographic scales, among taxonomic groups and across the range of other ecosystem services. Future research efforts to fill this gap will improve the understanding of direct and indirect impacts of biofuels on biodiversity and ecosystem services and improve the available data to map biodiversity and ecosystem services. Basic maps of species richness tend to be focused on a few data-rich taxa (e.g. birds, and plants), while other ecologically important taxa (e.g. insects) have not advanced dramatically. Mapping of other ecosystem services is reasonably well developed (carbon sequestration and carbon stocks) but some (climate regulation, nutrient cycling flood protection) have not received significant attention.

Research Gap 3: Assessments of biofuel impacts on ecosystem services and biodiversity. At present, limited research in this area has been undertaken.

Research Gap 4: High-level assessment of the compatibility of biofuel targets and sustainability criteria for biodiversity and ecosystem services.

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<sup>21</sup> The Fifth Conference of the Parties to the Convention on Biological Diversity defined the Ecosystem Approach as ‘a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way’ (Decision V/6, Annex A, section 1). As such, it provides a broader framework to examine the consequences of managing ecosystems for one specific ecosystem service (i.e. biofuels) at the expense of others (e.g. biodiversity, climate regulation, food provision, etc.).

### 3.5.2 Context

Growing crops specifically for biofuel production gives rise to a range of issues for biodiversity and ecosystem services that are largely centred on land use change. Frequently, regions affected by this land use change have seen dramatic reductions in native vegetation due to agricultural conversion and it is difficult to separate the impact of biofuels from that of agriculture generally.

Depending on the methods employed to produce biofuel crops, the application of irrigation, pesticides and fertilisers can be extremely high. Soil erosion, agricultural pollution of wetlands and other aquatic habitats, and other forms of land degradation are all commonly associated with modern farming methods. It is therefore essential to understand the full range of impacts on ecosystem services this land use change causes. The discussion paper by Knauf et al (2007) considered the balance between climate protection, biodiversity and development policy in relation to bioenergy, and the EC funded Bioscore project has examined the potential impact of large-scale biofuel crops on biodiversity<sup>22</sup>.

### 3.5.3 Key research questions

This section explores what research there is on:

The impact of biofuel production on biodiversity, and how can policy makers reduce any impacts?

This is underpinned by an analysis of what research there is on:

- 1) The impacts of biofuel production (notably feedstock production) on biodiversity and biodiverse ecosystems and ecosystem services.
- 2) Can biodiverse areas be mapped and effectively turned into 'no go' areas?
- 3) The impacts of biofuel expansion on migratory species.

### 3.5.4 Research in the area

Generally speaking, research on the direct impacts of biofuel feedstock production on biodiversity and ecosystem services is sparse. In response to this lack of awareness, a number of UK, EU and international organisations will engage in scoping research similar to this project including UNEP-WCMC, RSPB and Wetlands International. Additionally, the Secretariat for the Convention on Biological Diversity will host regional workshops during 2009 and 2010 to consider the implications of biofuels on biodiversity and ecosystem services.

The major activities reported in the survey are described below for UK, EU and international biofuel/ecosystem services/biodiversity initiatives. These activities can be further subdivided into direct research on impacts of biofuels on ecosystem services, mapping biodiversity/ecosystem services and policy research.

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<sup>22</sup> See <http://www.ecnc.org/programmes?action=detail&id=69>

Table 3-8 Research in the area of biodiversity

Funding or research organisation and budget where available	Current status of research
<b>UK</b>	
RSPB	While significant amounts of research have been conducted on the impacts of oilseed rape (OSR) on biodiversity in the UK over the past decade, a significant number of research activities of UK organisations examined impacts of biofuels outside the boundaries of the UK. For example, RSPB is attempting to map the distribution of biofuel crops worldwide and in the context on avian diversity and carbon stocks to assess the implications of biofuels on both ecosystem services and biodiversity.
JNCC	Another significant project is the Global Impacts project of JNCC to determine the nature, scale and location of the UK's economic trade impacts (including biofuels) on overseas biodiversity. The biodiversity context consists of a 'biodiversity profile' that includes a range of biodiversity-relevant information including determination of priorities. As part of its Global Advice programme, JNCC is currently working with Defra, FCO and DFID to help to establish global biodiversity priority issues. This project can be located at: <a href="http://www.ukglobalinfluence.org/">http://www.ukglobalinfluence.org/</a> .
NERC, Imperial College London	Quatermass is the third theme of QUEST, a 6-year project funded by NERC, and is led by researchers from Imperial College London with support from Forest Research, the University of Aberdeen and IIASA. This project will carry out a quantitative assessment of the global potential for terrestrial biosphere management activities, including biomass energy production, to offset fossil fuel emissions taking into account all long-term climatic effects, and their sustainability. The project's goal is to characterise, quantify, map and evaluate the key mitigation options at national, regional and global level based on the demand and potential supply as well as implications from international trade (biomass fuels and emissions). Further project details are available at: <a href="http://badc.nerc.ac.uk/data/quest/QUATERMASS.html">http://badc.nerc.ac.uk/data/quest/QUATERMASS.html</a>
University of Southampton (UKERC and NERC funded)	Work on the potential environmental impacts of large-scale deployment of dedicated bioenergy crops in the UK has been undertaken by the University of Southampton and funded by UKERC and NERC. <sup>23</sup> This research examined the impacts of short rotation coppice (SRC) and <i>Miscanthus</i> on biodiversity and covered a range of literature. The impacts depend on the previous land use. Positive effects tended to be found when growth is compared to arable crops. However, benefits are less apparent when compared to the replacement of set-aside and permanent unimproved grassland.

<sup>23</sup> The NERC Towards and sustainable energy economy (TSEC) programme through the TSEC-BIOSYS project and a PhD award. Rowe et al 2007 Identifying potential environmental impacts of large-scale deployment of dedicated bioenergy crops in the UK.

Funding or research organisation and budget where available	Current status of research
Defra 2006 - 2008 BBSRC	Field-scale impacts on biodiversity from new crops. This project aims to expand the evidence base on biodiversity studied in RELU-Biomass by: (1) Evaluating, modelling and testing predictions for weed and invertebrate biodiversity changes with the scale of planting; (2) Measuring the dynamics of biodiversity through the succession from previous crops to well established plantations; (3) Manipulating the time of harvest to identify biodiversity impacts of cutting date, and; (4) Evaluating bird use of miscanthus in relation to scale and changes in vegetation structure.
Defra 2007-2009 £158,748	Impacts of increasing biomass production on biodiversity and landscape.
<b>Europe</b>	
Within the European Union, considerable amounts of mapping activities are occurring within the EU to locate significant areas of biodiversity and ecosystem services.	
University of Bonn	Among them is the BIOMAPS project led by the University of Bonn. The aim of this project is to associate broad trends in plant diversity with diversity of other taxa. Project information can be found at: <a href="http://www.nees.uni-bonn.de/biomaps/biomaps.html">http://www.nees.uni-bonn.de/biomaps/biomaps.html</a> .
Öko-Institute	The Öko-Institute is working on various aspects of biodiversity mapping in association with international partners including UNEP, CI, FAO, IUCN and WWF. The Öko-Institut is involved in "A Process for Identifying and Mapping Biodiversity-Compatible Bioenergy Land with available Data Sources and Tools." The aim of the process is to identify and map land biodiversity-compatible for bioenergy feedstock production and thus to mitigate risks associated with biofuel feedstock production. Land was categorized into areas of no bioenergy production characterized as being high biodiversity-relevant, and areas of potential biodiversity-friendly production where associated negative impacts can be minimized or avoided, or even positive impacts seem possible (e.g. reduced erosion, increased agrobiodiversity).
JRC	JRC is actively examining impacts of European biofuel policies on biodiversity. For example, Biofuels Action builds on the experiences gained with the joint JRC-CONCAWE-EUCAR Well-To-Wheels study, which is recognised as one of the main existing references for life-cycle assessment of biofuels. This study addresses the costs of alternative fuels including biofuels, incorporating environmental impacts such as water consumption, soil degradation and loss of biodiversity. This project will address the environmental impact assessment of biofuels/bioenergy policy options.
Dutch Ministry of the Environment	Assessment of global biomass potentials and their links to food, water, biodiversity, energy demand and economy.
<b>US</b>	
MIT Joint Program on the	A component of the MIT Joint Program on the Science and Policy of Global Change deals with impacts of a global biofuels programme on ecosystem

Funding or research organisation and budget where available	Current status of research
Science and Policy of Global Change	services and biodiversity. Simulation modelling was used to explore two scenarios for cellulosic biofuels production and found that both could contribute substantially to future global-scale energy needs, but with significant unintended environmental consequences. The project was completed in 2009 and concluded that as the land supply is squeezed to make way for vast areas of biofuel crops, the global landscape is defined by either the clearing of large swathes of natural forest, or the intensification of agricultural operations worldwide. The greenhouse gas implications of land-use conversion differ substantially between the two scenarios but, in both, numerous biodiversity hotspots suffer from serious habitat loss.
Conservation International (Funded by the US DOE)	Conservation International is currently engaged in a three-year project funded by the United States Department of Energy whose primary goals are threefold: (1) an analysis at a global scale of the overlap between areas of likely biofuel crop expansion and areas of high importance for biodiversity conservation and maintenance of ecosystem services; (2) field studies in Indonesia and Brazil to develop techniques for locating and managing biofuel crops responsibly; and (3) development of environmental policies and standards for biofuel crop production at national and international levels.
<b>International</b> Among the initiatives found in the international community are projects related to direct impacts of biofuel feedstock production on biodiversity and ecosystem services, simulation modelling to explore the impacts of the growing demand for biofuels on environmental resources and programmes to assess the implications of EU biofuel policies on biodiversity.	
Wetlands International	Wetlands International has examined the life cycles of palm oil and the relative emissions of carbon. The provisional report of the Central Kalimantan Peatland Project was completed in late 2008 and addressed a number of impacts of palm oil production on ecosystem services and biodiversity.
UNEP-WCMC	Another example is UNEP-WCMC's recent publication of their Biodiversity and Carbon Atlas. This project, supported with funds from UNEP-WCMC, the German government and Humane Society International, provides mapped data to indicate where high densities of carbon coincide with high levels of biodiversity. These data can be found at: <a href="http://www.unep-wcmc.org/l/news/atlas/Carbon%20&amp;Biodiversity%20print%20version.pdf">http://www.unep-wcmc.org/l/news/atlas/Carbon &amp; Biodiversity%20print%20version.pdf</a> .
Scientific and Technical Advisory Panel	The Scientific and Technical Advisory Panel Work – Global Environment Facility Program for FY09, includes two projects to develop guidance for investment in biofuels to mitigate impacts on biodiversity: CC - SP4 “Promoting sustainable energy production from biomass” and BD- SO2 “To mainstream biodiversity into production landscapes/ seascapes and sectors.” GEFSEC has expressed interest in having STAP provide guidance to the GEF on biofuels, both investments and the implication of biofuel development on biodiversity. STAP interpretation of the requests was that there was confusion as to what the most current scientific literature had to say about the relationship between biofuels, climate change mitigation, biodiversity and land



Funding or research organisation and budget where available	Current status of research
	degradation, and the GEF family would benefit from a cogent summary of the state of knowledge on this relationship.

### 3.5.5 Research gaps

#### 1) What are the direct and indirect impacts of biofuels on biodiversity and ecosystem services?

Robust answers to this question are constrained by insufficient baseline data on the variety and magnitude of services provided by ecosystems. There are significant gaps in this baseline data at global and regional geographic scales, among taxonomic groups and across the range of other ecosystem services. Future research efforts to fill this gap will improve the understanding of direct and indirect impacts of biofuels on biodiversity and ecosystem services and improve the available data to map biodiversity and ecosystem services (question 2 below).

While global baseline data for certain ecosystem services are available (e.g. biodiversity, carbon stocks and sequestration), these data are often patchy in their coverage, not consistently updated or are inadequate for regional or local level assessments. Continued development of global and regional level datasets is urgently needed if the impacts of lost or degraded ecosystem services are to be fully understood. This research gap will require significant international cooperation and funding levels to achieve meaningful results beyond coarse global scales.

Because baseline data is relatively limited, only modest amounts of research have been undertaken in the field of direct impacts of biofuels on biodiversity and ecosystem services. However, it is possible to learn about the potential impacts of biofuels on biodiversity based on past experience of agriculture in general and in particular crops such as oil palm, soy and oilseed rape.

For example, the increasing profitability of soybeans production in Brazil has led to the conversion of land used for livestock grazing to soy farming. Livestock producers are then forced to clear tropical forests to create new grazing lands. Palm oil production in Indonesia results in biodiversity losses via large-scale deforestation and habitat fragmentation (WWF, 2002).

The extent of agricultural impacts commonly depends on previous land use. For example, research on short rotation coppice and *Miscanthus* on biodiversity found that the impacts were associated with previous land use. Positive growth effects were observed when compared to arable crops. However, benefits were less apparent when compared to the replacement of set-aside and permanent unimproved grassland.

Many of the impacts of biofuel production on biodiversity occur indirectly. The two most common indirect effects of biofuels on biodiversity are land use change and agricultural intensification. An example of the former is the displacement of livestock grazing by soy production from rich lowland areas towards more marginal lands adjacent to the fringes of the Amazon rainforest. Therefore, if these displaced farmers wish to increase their production, it often comes via clearing of tropical forest. An example of the latter is the increased application and runoff of agro-chemicals that can result in eutrophication, reductions in oxygen levels and algae blooms in adjacent water bodies. These sorts of impacts are best observed in the Gulf of Mexico and they are beginning to show in the Pantanal wetlands of Brazil and Argentina.

Research Gap 1: The need for continued development of baseline ecosystem services/biodiversity datasets and monitoring of ecosystem services. There are significant gaps in this baseline data at global and regional geographic scales, among taxonomic groups and across the range of other ecosystem services. Future research efforts to fill this gap will improve the understanding of direct and indirect impacts of biofuels on biodiversity and ecosystem services and improve the available data to map biodiversity and ecosystem services.

## **2) What progress has been made in mapping biodiversity and ecosystem services?**

The next research gap is data and protocols to support mapping and monitoring of ecosystem services. Many advances have been made in land cover, land use and carbon mapping as well as the mapping of biodiversity. However, basic maps of species richness tend to be focused on a few data-rich taxa (e.g. birds, and plants) while other ecologically important taxa (e.g. insects) have not advanced dramatically. Mapping of other ecosystem services is reasonably well developed (carbon sequestration and carbon stocks) but some (climate regulation, nutrient cycling flood protection) have not received significant attention. These mapping efforts require integration at higher levels and the potential costs of such research are very large and will require many years of dedicated research. Most of these datasets are not sufficient for monitoring purposes.

This overlaps with Research Gap 1 and therefore these two gaps are considered together.

The next identified gap is the assessment of direct impacts of biofuel feedstocks on ecosystem services. Simply put, much of this sort of research has not been done. While the direct assessment of biofuel crops might be lacking, the general impacts of land use change from natural ecosystems to agricultural systems – has been an area of greater activity. Therefore, general observations of agricultural land use change might be broadly applied to increasingly understand the impacts of biofuels on the provision of ecosystem services. This work could be achieved through exhaustive regional surveys and might not require intense international cooperation to complete them.

Research Gap 3: Assessments of biofuel impacts on ecosystem services and biodiversity. At present, limited research in this area has been undertaken.

## **3) What methods are available to mitigate the adverse impacts of biofuels on biodiversity?**

Methods to minimise adverse impacts of biofuels on biodiversity include: the avoidance of converting natural and semi-natural habitats to agriculture and methods to mitigate agricultural impacts.

Habitat destruction is the single greatest cause of biodiversity losses and conversion to agriculture is one of the leading drivers of land use change. Therefore, continued efforts to improve crop yields on existing agricultural lands without a dramatic rise in the application of agro-chemicals would reduce losses of biodiversity and other ecosystem services. Agricultural intensification is an active area of research covered in other chapters of this report and will therefore not be repeated here.

Agricultural impact mitigation techniques are a significant gap that will require further concerted research at international scales and on a wide variety of crop types. Considerable research has been conducted within the UK (for example Rowe et al 2009) and the European Union, however, this project did not produce any significant research from the developing world.

Examples of this research include work from the UK on oilseed rape, *Miscanthus* and short-rotation coppice. In these instances, biodiversity losses were reduced by avoiding the use of sites with high biodiversity value, the preservation of natural habitat elements in a broad mosaic of agriculture and natural habitats, considerations of the timing and magnitude of agro-chemical application, timing of harvesting activities to minimise disturbance of breeding and nesting and vegetation buffers to minimise the runoff of agro-chemicals.

Mixed plantations are gaining in popularity in developing economies and have demonstrated a limited potential to preserve some aspects of biodiversity when compared to monoculture agriculture. These projects produce biofuel crops in a mosaic of other crop types to maintain as much floristic diversity as possible. Unfortunately, these plantations might not produce the economies of scale desired by producers of biofuel feedstocks.

Additional gaps are related to policy research and address the most fundamental questions about the use of biofuels: how do they affect the provision of other ecosystem services and is the large-scale use of biofuels sustainable? The compatibility of biofuel targets with the continued provision of other essential ecosystem services and policies to support them is needed. This would include such questions as (1) how much biofuel is needed to achieve targets set in the EU and US, (2) how much agricultural land will be required to support the feedstock production, (3) where that land is likely to occur globally, and (4) can sustainable production of biofuel feedstocks coincide with the continued provision of the numerous other global ecosystem services. This could link to research going on in this area including work by the MIT on the impacts of a global biofuels programme on ecosystem services and biodiversity.

A related research gap area is an assessment of the economic viability of biofuels if good practice guidance were followed to minimise and mitigate their negative impacts. These really are the ultimate questions that must be addressed by those working in this field.

**Research Gap 4:** High-level assessment of the compatibility of biofuel targets and sustainability criteria for biodiversity and ecosystem services.

Economic/social implications of agricultural impact mitigation techniques for ecosystem services are an important issue and considered in more detail in Chapters 4 and 5.3.

### **3.5.6 Summary and conclusions**

This chapter illustrates the necessity of understanding the impact of biofuel expansion on both biodiversity and ecosystem services in general. There are many large gaps in this area because little research has been undertaken and because our understanding of some of the ecosystems that could be affected is limited. It is also difficult to separate the impact of biofuels from agriculture in general and important to understand where biofuels may deliver benefits.

To achieve a better understanding of this area, baseline data on relevant ecosystem services are important, although it is not only relevant to biofuels. This work was ranked as low urgency but was thought to be highly significant in answering the key questions in the area. This is a large piece of much needed work, but is relatively complex to complete and needs to be on an international basis. The study also identified a need for improvements to global and regional level datasets to monitor changes to ecosystems services. This work would bring together the information on biodiversity that has been done for specific environments and link it with the work that has been done on GIS datasets, and on various ecosystem services, to provide an assessment of a specific region's capacity to produce biofuels. The work was assessed to be of lower urgency but high significance; and it was thought to be a medium-large research gap, reflecting that there are a number of issues, which need to be covered, and its relatively high cost. Linked to this is the requirement for protocols and programmes to monitor ecosystem services is a research gap of medium significance and medium urgency, reflecting the need to obtain data first, particularly for specific regions. It is a small to medium gap reflecting that it is high cost, but that existing skill sets are currently in place and that it should be a relatively straightforward piece of work, providing the data is available. It is likely that this work will be done on a regional and national basis first, but there is scope for identifying internationally agreed protocols as part of the sustainability certification process

Alongside the above work there needs to be work on impacts of biofuels on ecosystem services, probably undertaken as exhaustive regional rather than international studies. This was identified as being both urgent and significant, particularly for areas where large-scale expansion of biofuels is proposed. The work is likely to be large-scale, reflecting the number of disciplines, the number of issues and the need to work in developing countries for some crop systems.

Also on a regional and international basis there is a need to provide a high level assessment of the impact of biofuels targets on ecosystem services. This is considered to be urgent and significant, and will be a medium-large piece of work, reflecting the need to examine the issues on an international basis.

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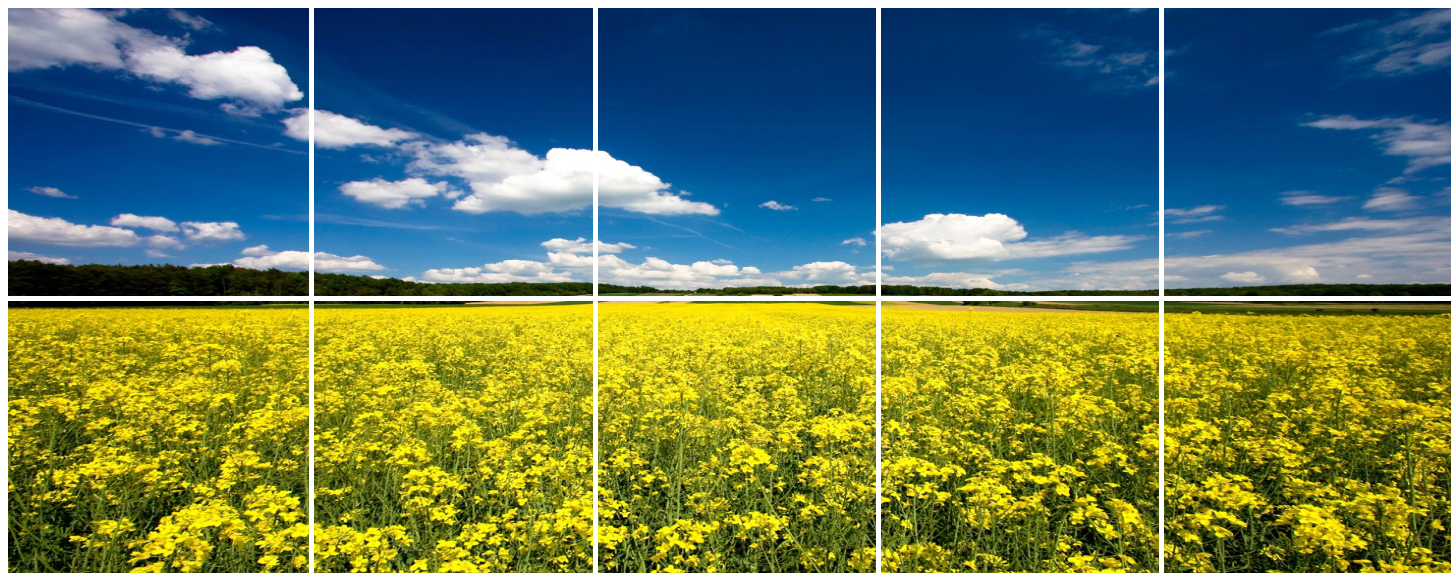
**Table 3-9 Biodiversity – key findings**

Key to ratings provided on the next page

Research Gap	1) and 2) Baseline data on ecosystem services (including biodiversity) and improvements for datasets for monitoring	3) Quantitative assessment of impacts of biofuels on ecosystem services	4) High level assessments of compatibility of biofuel targets and sustainability criteria for ecosystem services
Key related work	University of Bonn, UNEP-WCMC, Öko-Institute RSPB	Wetlands International, RSPB	Conservation International, JRC, MIT,
Complexity	***	***	***
Time scale	***	***	**
Potential costs	***	***	**
National or international	International Monitoring EU wide	International	EU-wide
Availability of data	Consistently repeated global and regional land cover and land use mapping is needed	Carbon sequestration datasets are perhaps the best available, global soils also ok, global water availability; aquatic impacts	Consistently repeated global and regional land cover and land use mapping is needed
Availability of skill sets	***	Skills are available but must be focussed on biofuels	**

Key

<b>Significance</b> – please see matrix	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k *<£100k	<b>National or international</b> i.e. can the work be done in the UK or would it be better done internationally?
<b>Availability of data</b> This will refer to the IPR/availability of R&D already ongoing in the area (e.g. Commercial – restricted; or published/available)			<b>Availability of skill sets</b> *** a number of organisations working in area ** availability restricted to a few groups or only on international scale * skills gap, significant training required	



# Biofuels Research Gap Analysis

## Chapter 4 – Economic and Social Effects of Biofuels Production



**Final report to the Biofuels Research  
Steering Group**

ED45917  
Issue Number 3  
30<sup>th</sup> July 2009

## 4 Economic and Social Effects of Biofuels Production

### 4.1 Introduction

Will biofuels harm the poor?

Concern has been expressed – see, for example, Oxfam 2008 – that producing more biofuels could result in economic and social harm, including:

- Increased demand for biofuel feedstock – maize, sugar cane, palm oil, etc. – raises the overall demand for agricultural production, and is therefore likely to raise prices of all agricultural output. Some of the land, labour, fertiliser and other inputs used in farming will be diverted to producing feedstock, while additional factors will be drawn into production, but in all likelihood at higher cost. Consequently food prices will rise and increase hunger and malnutrition amongst poor and vulnerable people who cannot afford to buy more expensive food.
- Attractive returns to growing feedstock will lead to landlords and corporations taking over land that is used by poor and powerless people without formal land rights and leave them destitute.
- Labour employed either on large farms growing feedstock or in biofuel refineries will be paid low wages, expected to work long hours, endure hazardous working conditions, prevented from forming or joining unions, and otherwise be exploited. Children may be employed as labourers as well.

These concerns arise very largely in respect of poor and vulnerable people in the developing world whose livelihoods, health and nutrition may thus be threatened by biofuels.

In addition to such acute effects, questions arise about how biofuels may affect trade and the balance of payments, energy security and dependence on imported fossil fuels, and opportunities for new industries and jobs in producing countries. While these effects apply across the world, they have particular relevance for developing countries in as much as they either contribute to development or undermine it.

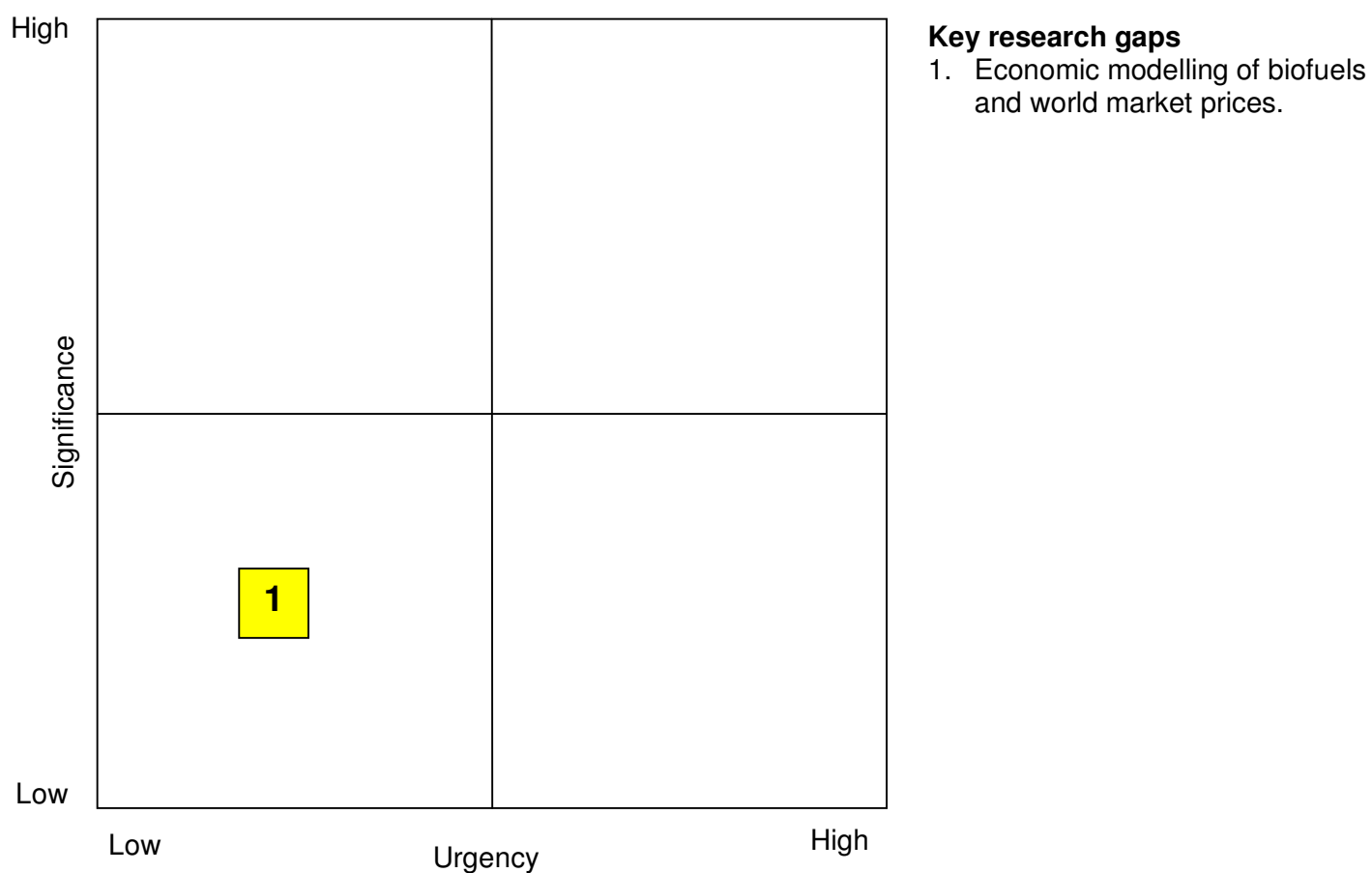
In assessing economic and social impacts, these have been ordered at three levels: on international markets for feedstock and other agricultural commodities in terms of prices and trade; on national economies; and on households, enterprises and their members. For the last two levels, the focus in this review is very largely on developing countries where acute concerns arise.

This chapter is relevant to a number of chapters, in particular, Chapter 5 on Market Forces and Trade.



## 4.2 International markets

Figure 4-1 Matrix prioritising key research gaps for international markets



Size of Research Gap

	Small
	Small / Medium
	Medium / Large
	Large

### 4.2.1 Executive summary

The key issue is how expanded biofuel production will affect the prices of feedstock and other agricultural commodities on international markets.

This came rapidly to prominence in 2008 as researchers sought to explain the 2007/08 spike in food prices and the role of expanded biofuel production in that event. In the medium term, the question of how biofuels produced on sufficient scale to meet the targets and mandates, mainly those of the EU and the USA, would affect world markets arises.

Both partial and general equilibrium economic models have been deployed to address these questions. Most models suggest that biofuels did contribute to the price spike, but were not necessarily the main or dominant factor; and that in the medium term, expanded biofuels production will push up the prices of some agricultural commodities, but it is largely the prices of feedstock for biofuels that will see significant increases.

Plenty of research is planned, generally to refine the models to reflect the particularities of biofuels. There are few clear and substantial gaps. Most of this work, however, will not take place in either the UK or EU. Given the speed with which models can be deployed to address policy questions – in a matter of weeks, as was seen for the Gallagher Review – there are reasons to support research by UK or EU-based researchers so as to have the necessary expertise close to hand. A particular objective would be refining the GTAP-E model to take into account the value of co-products in biofuels production.

This section explores what research there is on:

- The impact of biofuels production on international markets for biofuel feedstock and other agricultural commodities.
- How will achieving policy targets and mandates set by the EU and other OECD countries affect the prices of agricultural commodities on world markets?
- How will achieving the policy targets and mandates affect trade in biofuels and feedstock?

The study found the following research gap in relation to these questions.

Research Gap 1: UK or EU-based economic modelling. Refine models to reflect the value of co-products, and review elasticities of supply and demand used in the main models. Consider modelling of impacts on biofuels on the volatility of world market prices. Start to incorporate climate change into economic models.

#### 4.2.2 Context

In 2007 and 2008 prices of staple foods on international markets spiked dramatically causing consternation across the world. High prices would hurt the poor and vulnerable in the developing world, it was feared. Others wondered whether they might indicate that the world may not be able to feed a growing population in the future.

Given that this price rise coincided with large increases in the production of ethanol in the US and of biodiesel in the EU, the question of whether biofuels were a major cause of higher food prices was raised. Some campaigners decided they were and as a consequence there were demands that the policies of the EU and the US to encourage biofuels be moderated or set aside.

But how justified are these concerns?

#### 4.2.3 Key research questions

This section explores what research there is on:

- 1) The impact of biofuels production on international markets for biofuel feedstock and other agricultural commodities.
- 2) How will achieving policy targets and mandates set by the EU and other OECD countries affect the prices of agricultural commodities on world markets?
- 3) How will achieving the policy targets and mandates affect trade in biofuels and feedstock?

#### 4.2.4 Research in the area

**Table 4–1 Research in the area of international markets**

<b>Funding or research organisation and budget where available</b>	<b>Current status of research</b>
<b>Partial equilibrium models of agricultural markets</b>	
<b>International</b>	
IFPRI	IMPACT model
OECD and FAO	Agilink-COSIMO model
FAPRI	
USDA	
<b>Computable general equilibrium (CGE) models</b>	
CGE models that consider entire economies agriculture and production of biofuels being just part of the overall structure.	
Purdue	GTAP model.
Other	Most of the global economic models used so far draw on the GTAP model from Purdue University, with appropriate modifications with appropriate modifications and extensions to improve the detail of energy sectors and biofuels. CGE models are capable of tracking the ramifications of biofuels production across all sectors of economies, including changes in trade, gross domestic product, employment and incomes.

Funding or research organisation and budget where available	Current status of research
IIASA	Also use an applied general equilibrium model of the world food system.
World Bank US \$400 k in 2008/2009	Developing a CGE model to analyse the short and long term impacts of biofuels on land-use, food prices, energy markets, climate change mitigation and poverty at the national, regional and global levels.
Impacts on Trade	
Hertel et al 2008	GTAP model looking at the impact of US and EU mandates.
General	
<p>'Biofuels and the Poor'<sup>24</sup> brings together as principal partners the Food Security and the Environment (FSE) program of the Freeman-Spogli Institute for International Studies (FSI) at Stanford University, the International Food Policy Research Institute (IFPRI), &amp; the Centre for Chinese Agricultural Policy, Chinese Academy of Sciences; in collaboration with a number of organisations<sup>25</sup></p> <p>The collaboration is funded by the Bill and Melinda Gates Foundation</p>	<p>Aims of the research include:</p> <p>To describe the paths of impact between locations of biofuels production and their ultimate effects on small producers and vulnerable consumers, by quantifying impacts of shifts in world supply and demand for food, feed, feedstocks and biofuels.</p> <p>To assess the feasibility of investing in biofuels systems in poor countries, as well as assess which technologies have the largest positive effects on producers and the least negative effect on consumers.</p> <p>The remit of Biofuels and the Poor is more than just the international markets, extending as it does to considerations of impacts on national economies and on households.</p>

<sup>24</sup> See: <http://www.biofuelsandthepoor.com>

<sup>25</sup> University of Copenhagen, Consortium pour la Recherche Economique et Sociale (CRES) and the Institute Senegalais de Recherches Agricoles (ISRA), Senegal, Ministry of Planning (Mozambique), the Brazilian Agricultural Research Corporation (EMBRAPA), Center for Agricultural and Rural Development (CARD) at Iowa State University, the Copernicus Institute at Utrecht, FAO, Food and Agricultural Policy Research Institute (FAPRI), LEI-Wageningen University, Netherland Environmental Assessment Agency (MNP), OECD and the World Bank.

Funding or research organisation and budget where available	Current status of research
IFPRI funded through the German government	The German government is funding IFPRI to develop its models to consider biofuels in the context of climate change in Africa, to generate 'Set of alternative global scenarios with disaggregation for sub-Saharan Africa with implicit climate change projections focusing on energy demand, resulting changes of crop prices, land use, biomass feedstock usage and traditional food production for biomass production; special focus on typologies of production schemes with competitive trade-offs between agricultural food and biofuel systems'.

#### 4.2.5 Research gaps

##### 1) What research is there on the impact of biofuels production on international markets for biofuel feedstock and other agricultural commodities?

Much of the research to date has focussed on two questions, thus:

- How much did expansion of biofuels production, largely in the USA and the EU, contribute to the food price spike of 2007/08?
- What will be the impact on the prices of food and other agricultural commodities if countries achieve their targets and fulfil their mandates to expand biofuel production over the medium term?

To answer both questions, existing models of markets and economies have been deployed, albeit with some additional refinements to incorporate biofuels.<sup>26</sup> The models fall into two sets:

- Partial equilibrium models of agricultural markets.
- (Computable) general equilibrium (CGE) models.

Results from the models have been prominent largely since the existing models were capable of being used to generate at least preliminary results within a few months, if not weeks, of the policy questions being raised. That said, most of the models used were not designed to capture changes in markets that arise in the short run when some expected reactions have not had time to occur: instead, they look to see the changes likely over the medium term of two years or more, when most of those reactions have taken place. They are thus not so useful for answering questions about the price spike<sup>27</sup> and more reliable when indicating the trends over the medium run.

<sup>26</sup> Although not necessarily their by-products such as the dried distillers' grains that are produced when maize is distilled to ethanol.

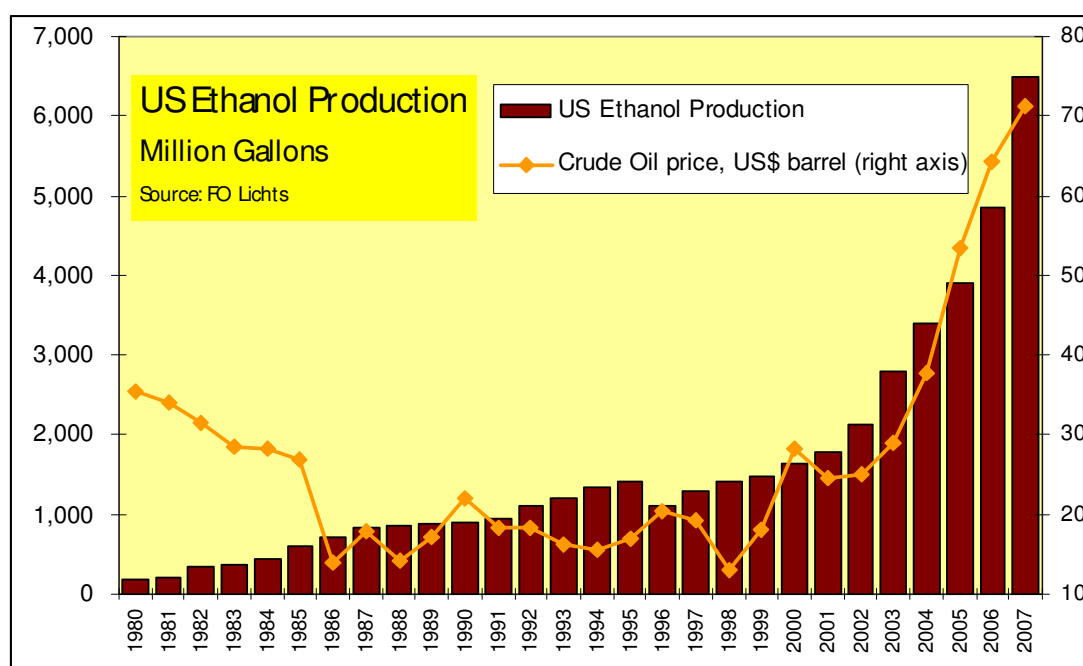
<sup>27</sup> A good example is IFPRI's use of the IMPACT model to look at the effect of increased biofuels production in the US on maize markets. The analysis looks only at the medium term trend of increasing demand over five or more years and does not consider some of the short term issues, such as harvest failures and export bans, that affected cereals markets in 2007/08.

## 2) How will achieving policy targets and mandates set by the EU and other OECD countries affect the prices of agricultural commodities on world markets?

There has been a range of research in this area, reflecting that the extent to which increased production of biofuels, above all from the diversion of the US maize crop to ethanol distillation, caused the 2008 price spike has attracted great controversy. Research includes<sup>28</sup> Lazear's testimony to Congress (2008, IFPRI – Rosegrant, 2008 and the World Bank – Mitchell (2008).

Accepting that biofuels did contribute to the price spike, it has frequently been alleged that food prices rose owing to unhelpful policy to stimulate biofuels production in the US, through the mandates for increased production and the subsidies paid to ethanol distillers. It is, however, far from clear that this was the case. Abbott et al. (2008) argue that the sharp increase in US ethanol production seen since 2001 – see Figure 4-2 – was largely due to the rise in the oil price making ethanol competitive with gasoline, rather than to subsidies – that after all had been in place in the late 1970s – or mandates, since the expansion in US production was growing at rates well in excess of those necessary to fulfil targets. Further support for this comes from Hertel et al. (2008) who use the GTAP model to show that indeed the main drivers of increased US production of ethanol in the 2000s were the oil price and the replacement of MTBE in 2006 as an additive to US gasoline by ethanol.

**Figure 4–2 US Ethanol Production and Oil Prices, 1980 to 2007**



28 Estimates of the contribution range from a barely significant 3% claimed by the Secretary of the USDA on the basis of Lazear's testimony to Congress (2008); to the 30% or so that IFPRI (Rosegrant 2008) estimated from running the IMPACT model to simulate what might have happened to world prices of cereals had biofuel production continued to grow at the rate seen in the 1990s and not accelerated as it did from 2001 onwards; to the 70% or more that some have (mis-)read into a World Bank paper (Mitchell 2008), an exercise that involved assessing the contributions of dollar decline and rising costs of transport and fertiliser to rising cereals prices and attributing the rest to biofuels and – the part that is rarely mentioned – also to low grain stocks, land use change, speculation and export bans.

Of these estimates, IFPRI's is the most precise and rigorous, although not the most reported. The mis-quotation of Mitchell has been so frequent that it barely matters what he actually wrote: the 70% plus datum has become the received wisdom in some circles. IFPRI's estimate suggests that while expanded biofuels production did contribute to the price spike, it was not the main cause.

Sources: Ethanol production from F O Lichts. Crude oil prices are equal weighted averages of Brent, Dubai, and Texas oil prices, from UNCTAD

A particularly controversial aspect of the food price has been the contribution of increased trading – ‘speculation’ – on grains futures markets, apparently since funds that might otherwise have been invested in stocks and shares have been placed on agricultural commodities markets where rising prices seemed to indicate prospects of good returns. Some observers have noted the large new contracts being placed at more or less the same time as price rises and concluded that the one causes the other. In the longer run, this is unlikely: futures prices would only affect spot market prices if higher futures prices caused suppliers to hold grain off the markets. There is little evidence that physical supplies have been hoarded – at least, not for the two grains, maize and wheat, where there are large futures markets. In the short run, however, it is possible that sharp increases in futures prices could cause spot prices to rise through expectations, and by contributing to alarm amongst traders that rising futures prices do reflect fundamental changes in the market as demand outstripping supply.

Perhaps the most revealing aspect of the 2007/08 food price spike, with frequent allegations that a combination of biofuels policies and speculation has driven up prices is that the grain price that spiked far more than any other is that of rice. No one uses rice to make biofuels. Futures markets for rice are weakly developed. That does not mean that biofuels, and speculation did not contribute to the (lesser) rises seen in the prices of maize and wheat, but it does suggest that these may not have been the strongest drivers of the price spike.

Considerations of the recent price spike invite consideration of the likely future impact of biofuels on price volatility. This question has seemingly not been addressed directly by studies to date. That said, it is now well understood that with the current technology of biofuel production together with the mandates, agricultural and transport fuels markets have become linked (Schmidhuber 2006).

When oil prices rise, an increasing range of biofuel production methods become economic – for example, when maize was costing roughly US\$100 a tonne on world markets a few years ago, there was a threshold price for ethanol from maize around a crude oil price of US\$60 a barrel. On the other hand, as biofuel production increases it raises the price of feedstock such as maize and at some point biofuel production will cease to compete with oil. The linkage to the oil market, then, introduces additional uncertainties that can affect agricultural prices.

There are, however, possible effects that would dampen price volatility. Demand for biofuels and their production should increase the size of the world's agriculture. This could then mean fewer variations in harvests. But, if increased production is achieved by farming more marginal lands with more variable weather patterns, then the variability of harvests may increase. In general, world agriculture in the future is likely to be increasingly one where grains and other staples are produced not only for direct consumption as food, but also for animal feed, and for industrial uses including biofuels. This potentially implies that supply-side variations might be borne by varying use for industrial purposes and animal feed, and not by varying the quantities for direct consumption; so that an expanded world agriculture could produce food with more certainty and less price volatility.

But unfortunately this is not the way that agricultural production is likely to be distributed in the near future. Distribution across food, animal feed and industrial uses is determined by purchasing power, not need; and the animal feed and industrial uses respond to demand from urban middle classes who are less sensitive to prices than poorer people who spend large fractions of their budgets on staple foods. Hence it could well be that demand for animal feed and industrial use of staples is less elastic than that for food, and with price levels above those of food, so that when supplies are scarce the adjustment on food markets is one of considerably reduced supply and large increases in prices.

There is also the question of the impact of the various mandates, targets and subsidies for biofuel production. These may introduce strong forces into the market for feedstock for biofuels, and may reduce the flexibility of response to changing world conditions. Potentially they may tend to stabilise production of biofuels, but in the process make the markets for animal feed and food less stable.

All the above is largely conjecture. Assessing the overall impacts of biofuels production on future price volatility would require modelling that included all three sets of uses for staples: including the interactions with world oil market, subject to random variations in the price of oil would presumably represent a major challenge to modellers.

### **The medium term impact of biofuels on food prices**

Much of the impact of biofuels on prices seen in 2007/08 arose since there was an unusual conflation of factors, some of them shocks of short duration such as harvest failures, all driving up food prices. In the medium term, some of those factors may not apply. Moreover, given more time, farmers can respond to higher prices by producing more, and consumers react by reducing consumption and switching their diets towards less expensive foods where good substitutes exist: two effects that should mitigate the tendency for biofuels production to push up the prices of food and other agricultural commodities.

To simulate future prices that may apply if the biofuels production targets are met, several groups of researchers have applied the economic models mentioned – see Box 4-1 for two examples.

Three things are clear from these results:

- Increased production of biofuels will push up the prices of some staple foods: freezing biofuels production or cutting it back will tend to reduce prices.
- The impact of biofuels production is largely restricted to the prices of feedstock such as maize and oilseeds, and to a lesser extent to sugar prices. Effects on the prices of other key staples, such as rice and wheat are minor. Indeed, for some regions, the CGE model used for the Gallagher Review expects prices of these to fall in real terms.
- Impacts on prices of feedstock are not that large – usually around 20% or less, other than for oilseeds and especially oilseeds in the markets of the EU and North America.



**Box 4-1: The medium term effects of expanded biofuels production**

The IFPRI IMPACT partial equilibrium model has been used to model two scenarios for holding constant or eliminating biofuels production, to show by how much prices would fall in real terms by 2015, compared to the prices that would result from expanding biofuels to meet the targets set.

Changes in prices in 2015, in real terms against 2005 baseline	What if biofuel production were frozen at 2007 levels?	What if biofuel production were eliminated after 2007?
Maize	– 14%	– 21%
Wheat	– 4%	– 11%
Sugar	– 4%	– 11%
Oils	– 6%	– 1%
Cassava	– 5%	– 19%

Source: IFPRI, Rosegrant 2008

For the Gallagher Review, a general equilibrium model of world economy was deployed to examine the change in prices that might result from the EU and North America replacing 10% of fossil fuels by biofuels, producing the following results:

Change in prices in real terms against 2001 prices	EU 27	North America (NAFTA)	Latin America	South and SE Asia	Sub-Saharan Africa
Maize	14.9	21.3	11	4	10.8
Oil seeds	53.2	71.8	34.5	31.6	24.9
Wheat	– 2.6	– 0.7	– 0.1	0	0.1
Sugar Cane & Beet	9.2	13.3	4.9	5.9	7.8
Rice	– 2	– 0.6	0.6	– 0.1	0.2

Source: UK Gallagher Report, Wiggins et al. 2008 reporting the work of Levy & McDonald

These are not the only models used. Other significant estimates come from the partial equilibrium analyses carried out by OECD-FAO (2006, 2008) and FAPRI (2005, 2006, Elobeid & Tokgoz 2006, Elobeid & Hart 2007). General equilibrium analyses include those from LEI, Netherlands (Banse *et al.* 2007) as well as the GLOBIOM model (Havlik *et al.* 2008) and the global food system model (OFID 2009) of IIASA.

Comparison of the results of the various models is bedevilled by studies using different scenarios and making significantly different assumptions. That said, few if any of these other modelling exercises come to radically different conclusions to those presented above when such differences are considered.<sup>29</sup>

Although the modellers would probably disagree, this area of work appears to be well covered by existing studies and those planned. Some of these research efforts are based in international institutions with long-term programmes of research, such as IFPRI, FAO, OECD and the World Bank with relatively assured funding. Many of those outside of these tents look likely to benefit from Gates Foundation support to the Biofuels and the Poor coalition. It is unlikely that policy makers will lack guidance from modellers on international impacts in future years.

<sup>29</sup> Obviously if the scenario modelled is not the 10% replacement used in the Gallagher Review, but 20%, price increases are far greater – and not necessarily linearly so in what are, after all, complex systems.

Practically none of this work takes place in the UK, although within the EU there is considerable expertise at FAO in Rome, OECD in Paris and in centres such as DIAL, Paris and LEI, Den Haag. The UK community of economic modellers is small, if talented<sup>30</sup>. They are, however, part of the GTAP community and thus participate to some extent in the work described. Given how little it would cost to fund the UK or EU-based modellers and thus have local expertise that could be drawn on at short notice, there is a case for making some small grants available for further modelling by those based in the UK or EU. £250k would go a long way for this kind of study where the overwhelming cost is the time of the researchers – there are few costs in data collection or experimentation.

Research Gap 1: A potential need here would be refining models, and above all GTAP (the GTAP-E model includes more detail on energy), to improve the modelling of biofuels. That would involve a review of the technical specification of biofuel production, including the value of co-products such as distillers' grains from biofuel production. UK and EU biofuel companies claim considerable benefits from the co-products, so it is important to account for them in the models. At the same time that specifications are checked and improved, it would be useful to have a comparison of the elasticities in supply and demand that are used by the main models. Modelling to assess price volatility is another issue, although it is difficult to state here how straightforward this may be. Last, but not least, would be incorporating climate change scenarios into the models.

### **3) How will achieving the policy targets and mandates affect trade in biofuels and feedstock?**

Studies focusing on trade in feedstocks or biofuels are less common. Those that exist usually draw on CGE models that generate trade impacts. Hertel et al. (2008), for example, use the GTAP model to show that by 2015 achieving the EU and US mandates for biofuels could see major reductions in US exports of maize and other coarse grains, and massive increases in imports to EU of biofuel feedstock, mainly oilseeds but also coarse grains. Correspondingly, these imports signal opportunities for greater exports of these crops from Latin America, Africa, Eastern Europe and the former Soviet Union, and – for oilseeds – from China and North America.

#### **4.2.6 Summary and conclusions**

Research gap is of relatively low urgency and significance, reflecting the number of planned modelling projects. The research gap is relatively small and the area well covered reflecting that there are existing data and skills sets available.

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<sup>30</sup> Their presence was invaluable for the short study done for the Gallagher Review, where Levy & McDonald were able to generate impressive results rapidly with trivial resources.

Table 4-2 International markets –key findings

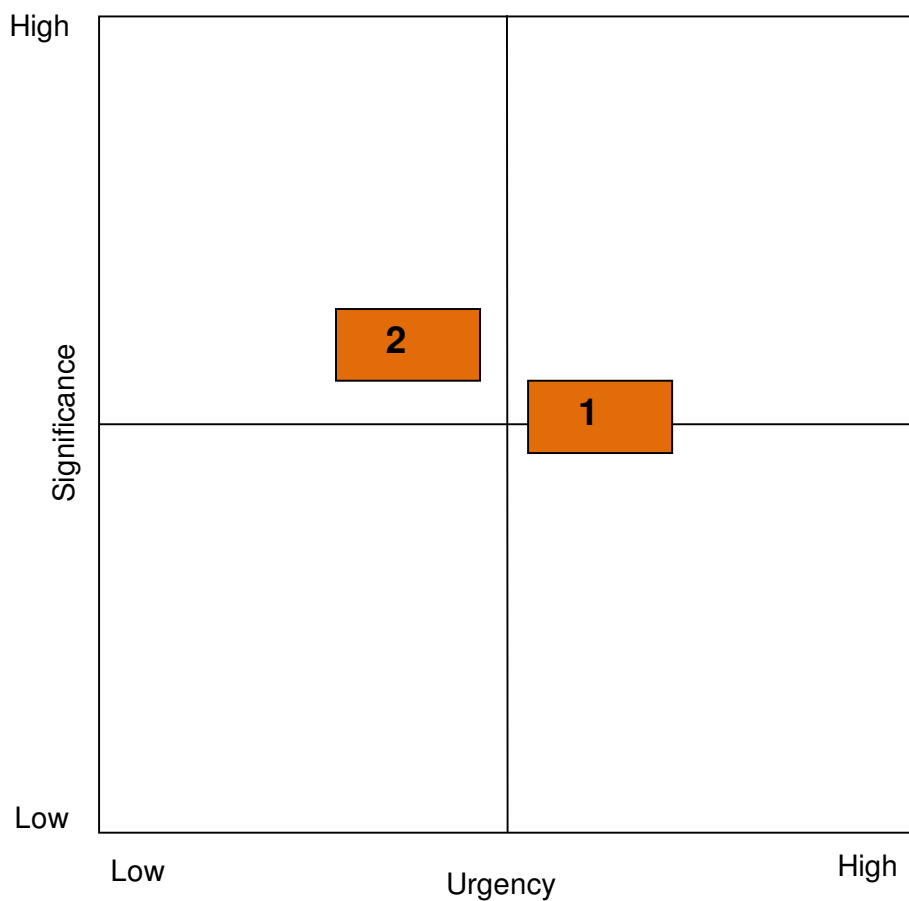
<b>Research Gap</b>	<b>1) UK or EU-based economic modelling. Refine models to reflect the value of co-products. Review the elasticities of supply and demand used in the main models of biofuel production. Consider impacts on price volatility on world markets.</b>
Key related work	
Complexity	**
Time scale	2 years
Potential costs	£250k
National or international?	National
Availability of data	Good, published
Availability of skill sets	*** [Excellent researchers]

**Key**

<b>Significance</b> – please see matrix	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k * <£100k	<b>National or international</b> i.e. can the work be done in the UK or would it be better done internationally?
<b>Availability of data</b> This will refer to the IPR/availability of R&D already ongoing in the area (e.g. Commercial – restricted; or published/available)			<b>Availability of skill sets</b> *** a number of organisations working in area ** availability restricted to a few groups or only on international scale * skills gap, significant training required	

### 4.3 National economies

Figure 4-3 Matrix prioritising key research gaps for national economies



#### Key research gaps

1. Studies of national potential in low income developing countries
2. Comparative analysis of national potential across countries

#### Size of Research Gap

	Small
	Small / Medium
	Medium / Large
	Large

### 4.3.1 Executive summary

Some research on how far world agricultural prices, pushed higher by biofuels as is expected – see previous section, might then affect national economies has been carried out, but only looking at potential increased cost of imports and consequent deflation of economies – and even then such studies assume no reaction to higher prices of imports by consumers, making the studies somewhat rough and ready.

Less has been done to examine the potential for biofuels production to stimulate economies, although some studies exist – including a model that examines how much developing biofuels could boost the growth rate of Mozambique, create jobs and reduce poverty. Some of the larger developing countries, such as Brazil and China have the domestic research capacity to have carried out assessments of their potential for biofuels.

When it comes to smaller and poorer developing countries, some individual governments have commissioned consultancy studies of their potential as biofuel producers. Typically these studies have wide terms of reference, looking at technical, economic, social and administrative feasibility of biofuels and produce lengthy and detailed reports. This review came across a couple of such cases, for Kenya and Mozambique, in both cases financed by donors. It is likely that there will be similar studies for other developing countries, and especially those that well regarded by donor agencies.

The gap here concerns those developing countries that have the land that makes them potential producers of biofuels but which are small, poor, lacking in domestic research capacity and that have not had a donor or external research agency to look at the potential economic and social opportunities. It is not known, however, just how many countries with potential are under-researched.

There may also be value in comparative analysis of those national studies that have been carried out: at present there is apparently no device or forum that would allow for general lessons to be drawn or communicated. One entity that might be used for such comparisons is the Global Bioenergy Partnership (GBEP).

In this section, key research questions include:

- What impacts may higher world prices for agricultural commodities have on developing countries, and especially those that are net food importers?
- What may be the benefits of higher world prices for feedstock and biofuels on countries that may produce biofuel feedstock?

The study found the following research gap in relation to these questions.

Research Gap 1: Studies of national potential in low income developing countries.

Research Gap 2: Comparative analysis of national potential.

### 4.3.2 Context

Biofuels production could harm developing country economies by pushing up the cost of imported food, leading to balance of trade deficits and potentially importing inflation, both of which could put a brake on economic development. On the other hand, countries that have the potential to produce feedstock and biofuel have the opportunity to create new industries, jobs and incomes, to save on imports of fossil fuels, and to earn export revenue. Foreign investment may also be attracted by such opportunities.

### 4.3.3 Key research questions

Key research questions include:

- 1) What impacts may higher world prices for agricultural commodities have on developing countries, and especially those that are net food importers?
- 2) What may be the benefits of higher world prices for feedstock and biofuels on countries that may produce biofuel feedstock?
- 3) What impact may biofuels production in developing countries have on trade balances, balances, of energy imports and dependence on oil imports?

### 4.3.4 Research in the area

Modelling national economies is harder than modelling global markets, owing to the wide diversity of national conditions. Most work in this area tends to be country-specific, carried out by either by researchers and consultants of the countries themselves, or by researchers based in OECD countries who are often country or region specialists. Since the domestic capacity of developing countries for economic and social research varies across countries, as does the interest of foreign investigators equally if not more so,<sup>31</sup> then coverage of national issues is highly uneven. These reports have the virtues of containing much detail and have a pragmatic focus on issues of technical and financial feasibility. They should be valuable for policy makers in the countries concerned. It is not clear, however, that the insights from the detailed analyses in these reports are brought into comparative analyses that could explore important issues that have wider application – an issue that will taken up in the later section on enterprise economics.

It is believed that many developing country governments, often with donor support, have commissioned studies of the potential of biofuels to contribute to economic growth, create jobs and incomes.

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<sup>31</sup> Expatriate interest in regions tends to cluster to a remarkable degree. Take the case of West Africa. In the last 20 years the vast majority of studies on their rural economies has been carried out in no more than half a dozen countries – Senegal, Mali, Burkina Faso and Ghana being some of the most popular. In contrast countries such as Guinea, Chad, Togo, Liberia and Sierra Leone have received very little attention.

**Table 4-3 Research in the area of national economies**

<b>Funding or research organisation and budget where available</b>	<b>Current status of research</b>
<b>Net importers and their balance of trade</b>	
<b>International</b>	
FAO	During the food price spike, FAO compiled lists of countries that were likely to suffer significantly from higher prices for food on world markets, caused in part by more biofuels.
IMF (2008)	The IMF (2008) also has taken keen interest in the effects of higher food prices.
Gallagher Review	For the Gallagher Review, Wiggins et al. (2008) examined the impact of a 10% rise in food prices.
<b>National Analysis</b>	
Brazil - University of Campinas	The University has carried out an assessment of sustainability of the country's ethanol industry (UNICAMP 2008).
Getulio Vargas Foundation	Getulio Vargas Foundation has analysed the food price spike (FGV 2008).
UNICA	UNICA has become an accomplished advocate of the industry and carries out its own studies to support its advocacy.
China	Domestic researchers have conducted studies in and around biofuels issues, see for example, Yang et al. (2008).
Mozambique.  Study by Ecoenegy consulting (2008)	The study addressed in considerable detail the possibilities of growing different feedstock, their costs, market potential and policies necessary to develop the sector. The report shows that Mozambique could produce biofuels both for domestic and foreign markets at costs that would be competitive with fossil fuels, using at least half a dozen feedstocks that can be readily grown in the country.
Mozambique Arndt et al	Mozambique - local and expatriate researchers (Arndt et al. 2008) combined to deploy a national CGE model to explore the consequences of planting 280k ha to sugarcane or 55k ha of jatropha, or both, for economic growth, jobs, incomes and poverty.
Government of Kenya Endeleu & ESD	Suggested scope for replacing at least a part of imported fossil fuels.
Biofuels and the rural poor: the consortium described in the previous section	Intends to carry out detailed modelling for India, Mozambique – this in collaboration with the Arndt et al. team mentioned above – and Senegal. China will also be studied in more detail.
FAO and the Copernicus Institute, Utrecht University are engaged in modelling bioenergy and food security (BEFS) relations (Copernicus & FAO 2008).	In this, the world partial equilibrium model developed by FAO, COSIMO, will be linked to national studies for Peru, Tanzania and Thailand involving assessment of their technical potential, supply functions, and economic potential – results that will then be fed into national CGE and household models to look at the potential of biofuels to reduce poverty and improve food security. This three-year programme is expected to report at the end of 2009.

Funding or research organisation and budget where available	Current status of research
UNDP US\$200k	UNDP is helping carry out an assessment of biofuels potential for West African countries grouped in ECOWAS. Initial findings are expected by mid-2009.
Swiss-led consortium Funded through the EC	Biofuel production possibilities and trade in Eastern and Southern Africa. February 2009.

#### 4.3.5 Research gaps

##### 1) What impacts may higher world prices for agricultural commodities have on developing countries and especially those that are net food importers?

Relevant research has been undertaken in this area. During the food price spike, FAO compiled lists of countries that were likely to suffer significantly from higher prices for food on world markets, caused in part by more biofuels: these were countries that spent substantially on imported staple foods and that were often poor and with low currency reserves. More than 80 developing countries were listed, half of them from Sub-Saharan Africa and another quarter from Asia.

The IMF (2008) also has taken keen interest in the effects of higher food prices; in its Spring 2008 World Economic Outlook it estimated that the net food import bill for 33 net food importers rose by US\$3.9G (billion) from 2007 to 2008, or 0.8% of their GDP<sup>32</sup> – on the basis of increases in food prices of less than 20%, that is for a level below the increases that were observed. For some countries, this was likely to deplete substantially their foreign exchange reserves leaving countries such as Eritrea, Liberia and Tajikistan with less than one month's cover of imports.

For the Gallagher Review, Wiggins et al. (2008) examined the impact of a 10% rise in food prices – close to what might be expected if the EU and the US fulfil their mandates – on 40 low-income food-deficit countries. The increased food import bill was likely to consume 10% or more of reserves for a dozen countries. This study also used a simple estimate of the multiplier to examine the contraction likely in the economy from the leakage to the imports bill: for 13 countries the cost was more than 1% of GDP.

But these calculations assume no response to the higher costs of imported foods. Consumers are assumed not to adjust their food budgets in favour of locally produced items. More importantly, the studies take no account of the stimulus to domestic agriculture that may result from higher food prices, including the promotion of biofuel industries in countries that have the potential to develop them. To these issues, the account now turns.

##### 2) What may be the benefits of higher world prices for feedstock and biofuels on countries that may produce biofuel feedstock? And what impact may biofuels production in developing countries have on trade balances, balances, of energy imports and dependence on oil imports?

<sup>32</sup> This was, however, substantially less than the cost of oil imports, given the rising oil price at the same time.



Surprisingly few studies take account of positive stimuli from biofuels and initially higher agricultural commodity prices. It is easy to see the difficulties in doing so. Supply response can be difficult to estimate with any certainty. Since it almost certainly varies considerably from place to place, it really requires purpose built models for every country. The global CGE models have supply response embedded within them, but these must necessarily be broad estimates. These studies need to be driven by national analyses and those, as mentioned in the introduction to this section, depends heavily on domestic research capacity augmented by the interest of expatriate scholars.

Brazil is an example of a country where there is both the research capacity as well as the world's most highly developed biofuels industry. For example, the University of Campinas has carried out an assessment of sustainability of the country's ethanol industry (UNICAMP 2008). The Getulio Vargas Foundation has analysed the food price spike (FGV 2008). Brazil's ethanol industry is large enough that the cane producers' union, UNICA, has become an accomplished advocate of the industry and carries out its own studies to support its advocacy.

China is another large developing country where domestic researchers have conducted studies in and around biofuels issues, see for example, Yang et al. (2008).

It seems there are many developing countries, above all in Africa, Latin America and South-east Asia that have underused land that could be planted to biofuel feedstock. A preliminary calculation shows that no less than 36 countries could produce enough biofuel to replace all their fossil fuel imports by devoting no more than 10% of underused land,<sup>33</sup> see Figure 4-4 (ODI & ProForest 2008). Unfortunately the data available on land use are subject to wide confidence limits and for some countries the estimates are often ten years or more out of date. Moreover, the FAO database on land use does not allow land under tropical forest, and other critical ecosystems, to be separated out of the 'potentially arable' categories. FAO is currently making efforts to improve data on land use. Better land use data would be useful not only for assessing the potential for biofuels production, but also for assessing the impacts of climate change.

**Figure 4-4 Developing countries with high potential to replace fossil fuels by biofuels**



Notes: Shows countries that can apparently replace all fossil fuels by devoting no more than 10% of land classed as potentially arable and not currently under production to biofuels.

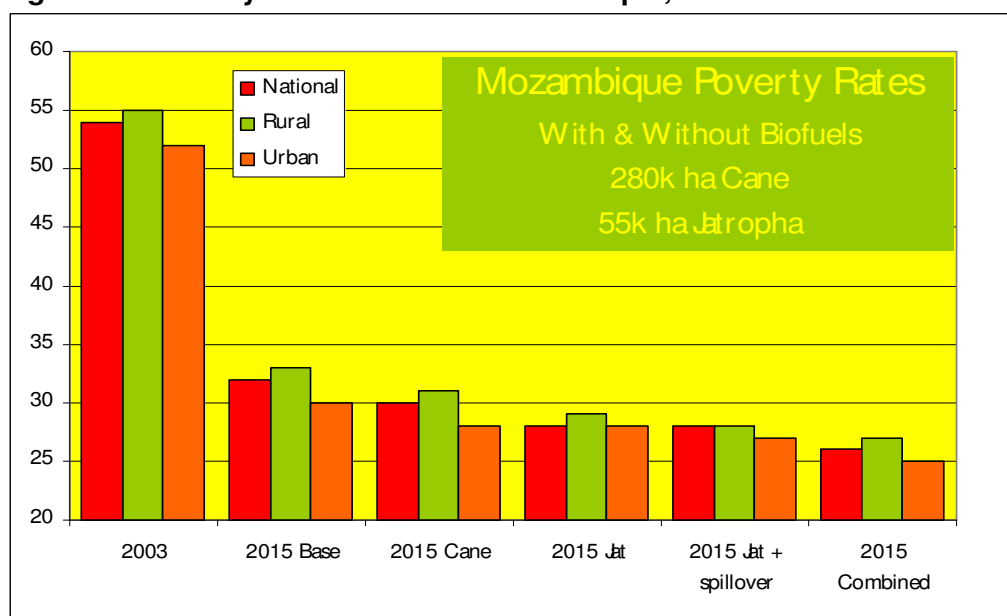
<sup>33</sup> Data on land use are rough and ready and often quite out of date. Moreover, the FAO database on land use does not allow land under tropical forest to be separated out of the 'potentially arable' categories.

It is believed that many developing country governments, often with donor support, have commissioned studies of the potential of biofuels to contribute to economic growth, create jobs and incomes. In 2008 Mozambique, for example, received a 400-page plus study by Ecoenergy (2008) consulting that addressed in considerable detail the possibilities of growing different feedstock, their costs, market potential and policies necessary to develop the sector. The report shows that Mozambique could produce biofuels both for domestic and foreign markets at costs that would be competitive with fossil fuels, using at least half a dozen feedstocks that can be readily grown in the country. A similar study was produced for the Government of Kenya (Endelevu & ESD 2008) suggesting scope for replacing at least a part of imported fossil fuels.

These reports have the virtues of containing much detail and have a pragmatic focus on issues of technical and financial feasibility. They should be valuable for policy makers in the countries concerned. It is not clear, however, that the insights from the detailed analyses in these reports are brought into comparative analyses that could explore important issues that have wider application – an issue that will taken up in the later section on enterprise economics.

A particular issue with these analyses is that the some of the most important results depend on the assumptions and projections made for the cost of oil and petroleum products. The economics of producing biofuels and their feedstock is usually sensitive to this price: at prices above US\$60 a barrel the economics of most feedstocks grown in the tropics are attractive, but they become increasingly marginal as prices fall below around US\$40 a barrel. Ideally the developing countries involved would have the analytical capacity to track changing oil prices and their projections and update the economics. This may be the case in some of the larger and middle income countries: it is less clear that this would be true for smaller and poorer countries, such as Sierra Leone.

More scholarly treatments of national economic potential for biofuels are less common, but Mozambique again provides an example where local and expatriate researchers (Arndt et al. 2008) combined to deploy a national CGE model to explore the consequences of planting 280k ha to sugarcane or 55k ha of Jatropha, or both, for economic growth, jobs, incomes and poverty. The model also allowed the study team to compare growing feedstock on large-scale plantations to use using a smallholder out-grower model – including the intriguing assumption in one scenario of technical spillovers from the feedstock to increased productivity of other crops. With both sets of investments, Mozambique could increase its rate of economic growth from an annual average of 6.1% to 6.7% between 2006 and 2015, create an additional 365k jobs in the biofuel supply chain and considerably reduce poverty. As shown in Figure 4-5, no less than 1.3M persons would be lifted out of poverty by 2015 compared to a baseline without the development of biofuels. Biofuels development using smallholders as outgrowers created more jobs and did more to reduce poverty than development through large-scale estates.

**Figure 4-5 Poverty rates in 2015 in Mozambique, with and without biofuels**

Source: Arndt et al. 2008

Research Gap 1: Studies of national potential in low income developing countries. The main gaps arise with those countries that lack domestic research capacity and that are not popular with scholars based in OECD countries. These tend to be small, low income countries, precisely those that need to develop whatever opportunities might arise.

Sierra Leone may be an example: a country that has ample experience of growing oil palm and sugar cane with many hectares of land that underused since the conflicts of the 1990s; a country short of capital and know-how; and one where jobs for youth are desperately needed if the conditions that led to war are to be overcome. The barriers to developing biofuels industries in such cases are not just matters of information and know-how; usually issues of governance and the investment climate bulk larger. But at some point having the technical and economic analysis will be useful to government and investors.

Research Gap 2: Comparative analysis of national potential. There may also be value in comparative analysis of those national studies that have been carried out: at present there is apparently no device or forum that would allow for general lessons to be drawn or communicated. One entity that might be used for such comparisons is the Global Bioenergy Partnership (GBEP).

#### 4.3.6 Summary and conclusions

Research Gaps 2 and 3 are of medium urgency and significance. They refer to important research to be done in the biofuels context.

The studies for particular countries are of course of prime concern to the national governments of those countries, but will also be important to their donor partners in development. Comparing and synthesising the results of national assessments would be of wider international benefit, useful to global agencies such as FAO and the World Bank that advise developing country and international policy-makers.

Although there is more research to be undertaken, work and capacities have been or are being developed in these areas. These gaps, are therefore still important, but are already partially addressed by planned or ongoing works.

**Table 4-4 National economies – key findings**

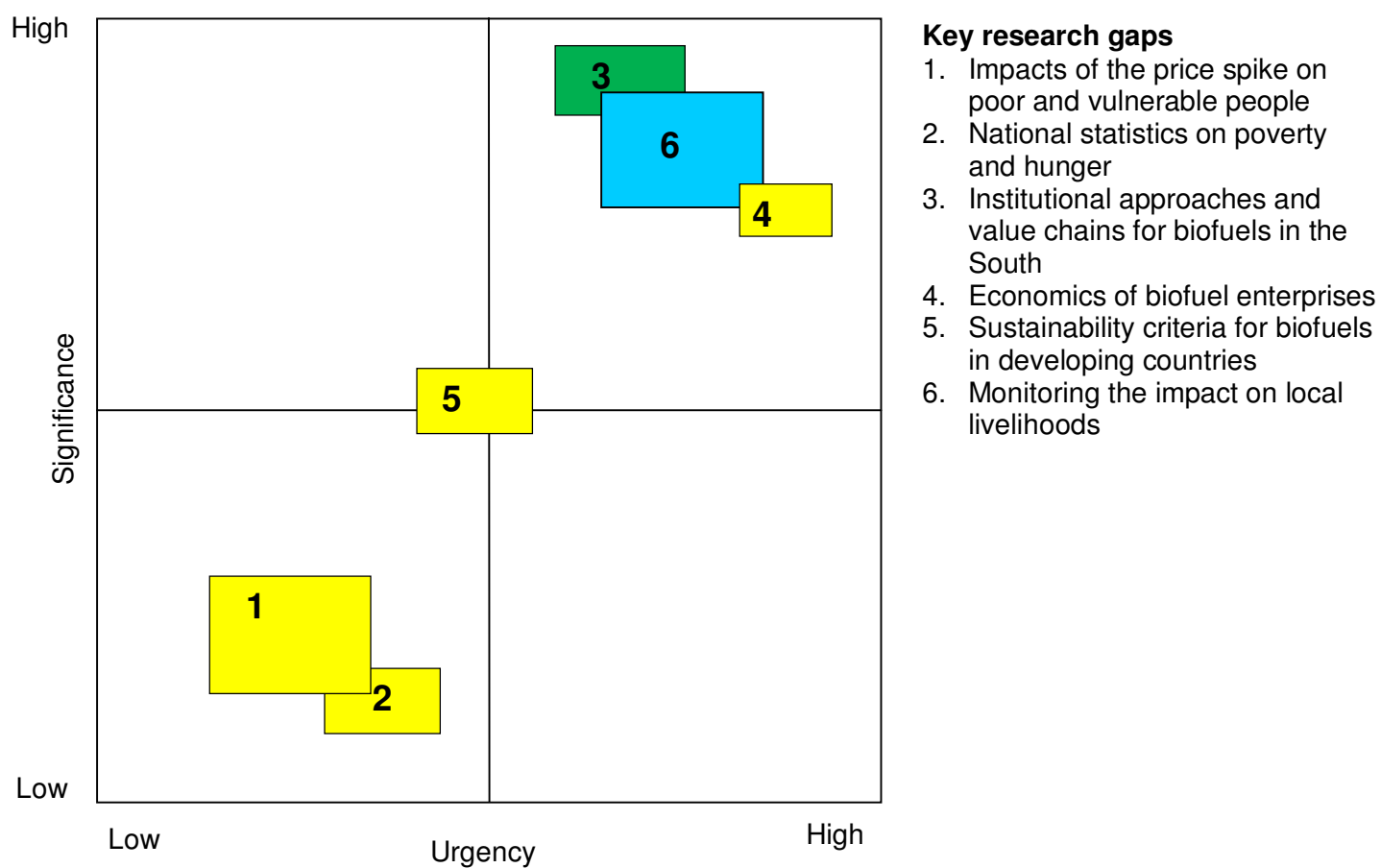
Research Gap	1) Studies of national potential in low income developing countries	2) Comparative analysis of national potential
Key related work		
Complexity	**	*
Time scale	**	*/**
Potential costs	**	*
National or international?	Work needs to be done in country	International: ideally should be under a body with an international mandate to collate experiences, such as GBEP
Availability of data	Will require collection of field data on agronomic potential and the economics of feedstock crops	Would use existing studies
Availability of skill sets	* Local capacity thin: in the short run, external staff needed	*** Fairly straightforward work

### Key

<b>Significance</b> – please see matrix	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k * <£100k	<b>National or international</b> i.e. can the work be done in the UK or would it be better done internationally?
<b>Availability of data</b> This will refer to the IPR/availability of R&D already ongoing in the area (e.g. Commercial – restricted; or published/available)			<b>Availability of skill sets</b> *** a number of organisations working in area ** availability restricted to a few groups or only on international scale * skills gap, significant training required	

## 4.4 Households and Enterprise

Figure 4-6 Matrix prioritising key research gaps for households and enterprise



	Small
	Small / Medium
	Medium / Large
	Large

#### 4.4.1 Executive summary

The concerns over the potential impact of biofuels on the lives of poor and vulnerable people become concrete at the level of households and enterprises. Questions arise of potential harm from food prices pushed higher by biofuels production; and of possible loss of land and poor treatment of the labour. On the more positive side are the questions about the potential for biofuels to create new enterprises, jobs and incomes.

The linkages from world market prices to households and enterprises are diverse and varied: while the potential links are known in outline, how they apply in given circumstances is less well known. It seems that context is critical, and general conclusions are difficult to draw.

Studies on enterprise economics are relatively few, although those that have been carried out often suggest that producing biofuel feedstock in the tropics is economically attractive.

While civil society groups have done much to log particular cases of land alienation and mistreatment of labour, it is not clear how general are these abuses. Moreover, it is unlikely that they are specific to biofuels. Other economically attractive uses of land and natural resources in particular contexts lead as well to similar problems.

Compared to understanding of the functioning of international markets and the impacts on national economies, there are many gaps in understanding impacts on households and enterprises. Many studies could be designed to collect data at field level. However, there are enough studies in progress to suggest a more pressing need and effective research strategy: synthesising the emerging insights.

This section explores what research there is on:

- 1) How do higher international food prices induced by biofuels production affect poor and vulnerable people in developing countries, their incomes, poverty and food security?
- 2) How competitive are enterprises producing biofuel feedstock and biofuels in developing countries?
- 3) What kind of biofuel industries are possible and with what development impacts?
- 4) What are the potential effects of biofuels production in developing countries on the access of poor and vulnerable to land and the condition of labour on biofuel estates and transformation plants?

The research gaps identified in this study include:

Research Gap 1: Synthesis of the studies on the 2007/08 food price spike, drawing out the insights they offer.

Research Gap 2: National statistics on poverty and hunger. Including more frequent surveys of poverty and nutrition, representative at national and sub-national levels.

Research Gap 3: Research to capture experiences of institutional approaches for biofuels development in the South.

Research Gap 4: Economics of biofuel enterprises. The evidence on returns to growing feedstock and producing biofuels in developing countries is currently patchy.

Research Gap 5: Sustainability criteria for biofuels in developing countries. Research on the scope of the demand and approaches that could be developed or are being developed by Southern Countries to ensure sustainability of the biofuel production for local use.

Research Gap 6: Monitoring the impact on local livelihoods: how biofuels are changing the rural poor's daily life's, for the good and for the worse?

#### **4.4.2 Context**

Some of the most pertinent issues raised by the possibilities of biofuels arise at the small scale, when looking at impacts on enterprises and households, and at the interaction between the two. It is here that concern that biofuels could be harmful and impede development becomes manifest in the effects on poor and vulnerable households and individuals.

#### **4.4.3 Key research questions**

Two sets of questions need answering: one, about the impacts of biofuels on households and their members, and especially on those who are poor and vulnerable; the other concerning the economic returns to enterprises – from family farms to large corporations – producing feedstock or biofuel and the ways that land and labour are treated. These last issues lead to questions about the potential role of standards in preventing harm and encouraging better practice for development and social sustainability: questions that are mentioned here, but dealt with in Section 5-2.

This section explores what research there is on:

- 1) How do higher international food prices induced by biofuels production affect poor and vulnerable people in developing countries, their incomes, poverty and food security?
- 2) How competitive are enterprises producing biofuel feedstock and biofuels in developing countries?
- 3) What kind of biofuel industries are possible and with what development impacts?
- 4) What are the potential effects of biofuels production in developing countries on the access of poor and vulnerable to land and the condition of labour on biofuel estates and transformation plants?

#### 4.4.4 Research in the area

**Table 4–5 Research in the area of households and enterprise**

<b>Funding or research organisation and budget where available</b>	<b>Current status of research</b>
<b>Identification of biofuel development opportunities</b>	
World Bank	Research work on opportunities and challenges for foreign investment in agriculture, covering land issues, due end of 2009 (IIED, and FAO partnering).
Stockholm Energy Institute	US\$0.3M for 2 years (Swedish funds) until end of 2009. Focus on socio-economic impacts and opportunities associated to biofuel development in Southern Africa.
<b>Making biofuels projects work in the south</b>	
German cooperation implemented by GTZ	€1.1M / 3years – Funding IFPRI, WI, ICRAF, ZALF, IUW – Strategies to use Biofuel Value Chain Potential in Sub-Saharan Africa to respond to Global Change – Enhancing low-productivity Farming in Tanzania and linking to SMEs.
ICRISAT	US\$0.5M/year (funded by ICAR, IFAD, EC, GTZ, GoIndia, GoAP, and private sector members in the consortia) on improved crop selection for Jatropha, Pangomia and Sweet Sorghum.  Follow up strategies along the lines of: Sweet sorghum ethanol value chain development (centralized and de-centralized), Biodiesel plantations and decentralized use of straight vegetable oils to meet rural energy requirement. ICRISAT is working with other CGIAR centres as well as with other south based research institutions.
CIRAD	Net expansion of bio energy research team planned, with focus on developing bioenergy systems for local use.
Wageningen University	Working specifically together with UNICA in Brazil but also coordination a large Jatropha consortium.
World Bank	Strengthening policies, procedures & regulations for biofuels in Africa: will examine economics of biofuel production and the institutional issues arising. Case studies of 3 biofuel projects. US\$246.5k, including DFID trust funds and RSB. Reports end 2009.
NGOs, Private sector	Direct involvement in technical development by running projects.
<b>Policies and standards development and dissemination</b>	
FAO	Land tenure aspects. FAO, IFAD and IIED working on a gap analysis on land purchases for food or fuel production. Relatively Macro scale, with likely follow up work.  Impacts of large-scale liquid biofuels on rural people / governance issues. Field based follow up work of the gender and biofuel literature review is on its way.  FAO and UNEP are currently developing guidelines on "Sustainable Bioenergy: Planning Strategically and Managing Risks in Investment Choices". These guidelines should be ready as a working document by mid-2009.



Funding or research organisation and budget where available	Current status of research
UNDP	US\$0.2M in West Africa pilot on how to establish national biofuels strategy, then scaling up.
UNEP	The FAO, UNPD, and GTZ above mentioned initiative is actually coordinated under a UNEP Umbrella, UNEP and UNDP sharing different regional areas, the total funding is US\$2.5M and is therefore largely covered by the German funding. Some Research institutes involved such as Öko Institute (Germany).
Monitoring socio-economic impacts in the South	
Bio-fuels for the Poor	Some household-level focus in year 2 and 3 (Impact of biofuel development).
Copernicus Institute	Small research stream on household level socio-economic impacts.
IBE	Little enterprise and household level questions in relation to developing countries in major strategic programs of the IBE. Some researchers are fund raising for studies of socio economic impacts of Biofuels development in the south (e.g. Gender related impact study).
NGOs	A large number of NGOs involved in local bio-energy projects, supporting technical developments. NGOs will keep looking at socio-economic aspects. Additional studies of the impacts of the food price spike will reveal more about the pathways of impact from world prices to household poverty and hunger. Studies are also planned on policy effectiveness.

Most policy level actors (UN, RSB, Donors) are working towards using lessons learnt for from other cash crops value chains for biofuels. They are also investing in technical assistance (advising southern governments on policy development, providing technical support to biofuel project development), as well as the disseminating norms and guidelines.

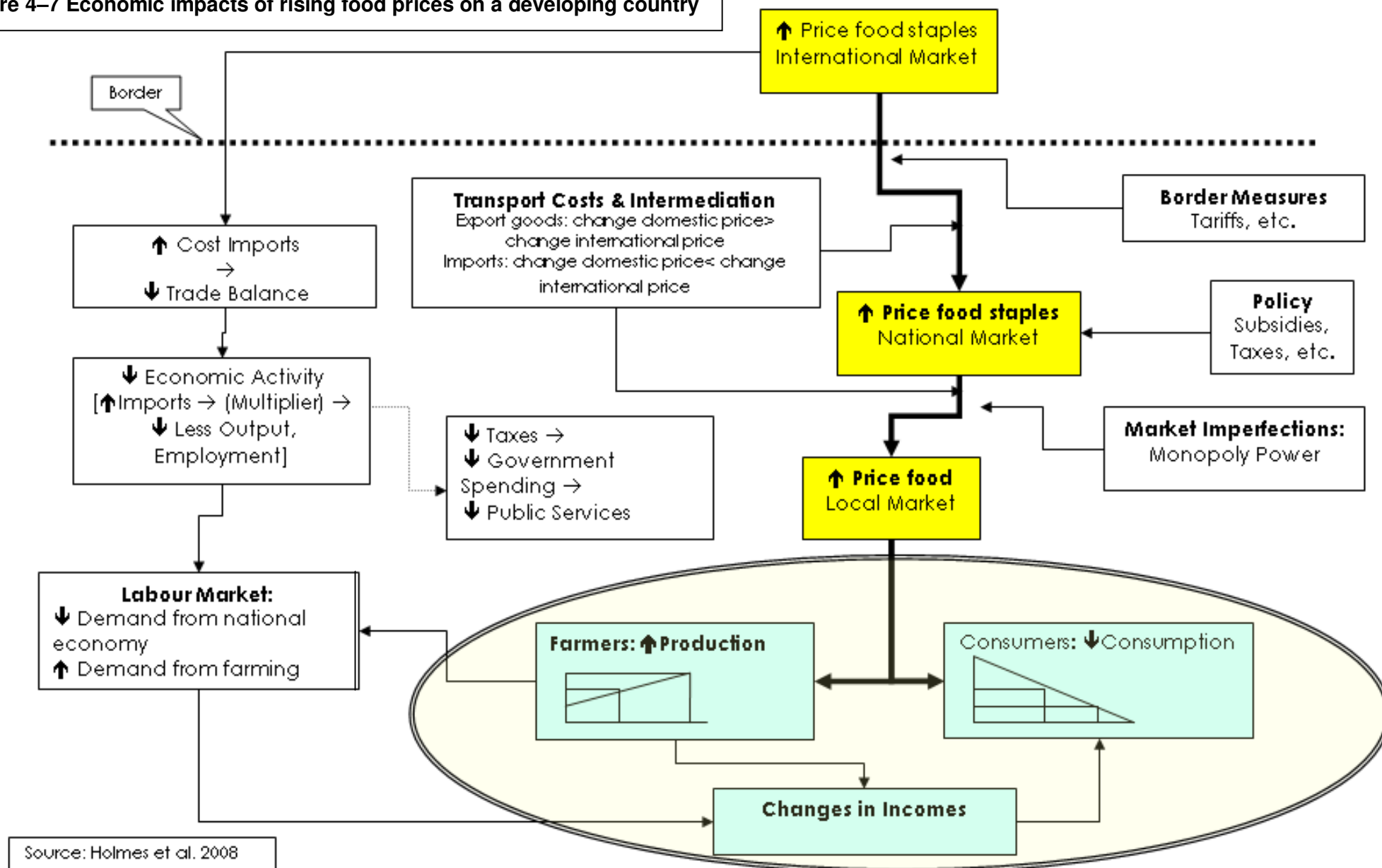
#### 4.4.5 Research gaps

##### 1) How do higher international food prices induced by biofuels production affect poor and vulnerable people in developing countries, their incomes, poverty and food security?

Since biofuels production on a significant scale is so recent, the outcomes for poor and vulnerable people in the developing world are not necessarily evident. Besides, concerns are less about current production and much more about what may happen when production rises to meet the mandates. Hence most of this research consists in assessing how poor households may be affected in the future. This is fraught with difficulty since the influence of rising demand for feedstock and its impacts on world prices pass through several filters before they arrive at the household level. Figure 4-6 illustrates these stages.

This scheme looks only at how biofuels production outside a developing country would affect the domestic economy and livelihoods through impacts on world prices. It does not look at what may be the effects of substantial domestic production of biofuels on food prices and incomes. To date, there is perhaps only one country in the developing world where a large domestic biofuel industry exists, Brazil. Fears have been expressed that the use of land to grow sugar cane for ethanol would dampen production of food leading to higher prices and hardship for the poor. A look at the growth of food production and price trends during the time that the ethanol industry has expanded markedly is reassuring: there are few signs of food production suffering or prices rising (ODI 2008).

Figure 4–7 Economic impacts of rising food prices on a developing country



**Transmission of world to local prices**

This is anything but straightforward. It depends on whether the commodity is exportable or an import substitute, on border measures that may be applied to traded goods, and on market imperfections. The 2007/08 price spike has brought this into focus: studies of the relation of international to national prices are ongoing at FAO – see, for example, Dawes (2008) – and other centres, such as ODI. Preliminary results suggest that in a surprisingly large number of capitals and major cities, the movements of prices of staples over the last ten years or so and into the price spike have not been well correlated with international prices.

**Impacts of higher local food prices on consumers**

In most developing countries, the poor spend a very high proportion of their income on food: as much as 70% in many countries. Even if the majority of the poor live in rural areas and most of them farm, many fail to cover their household needs for staples and are net buyers of staples.<sup>34</sup> Thus it is feared that many of the poor will be hurt by higher food prices. Models suggest as much.

An area of uncertainty is the degree to which poor consumers are able and willing to switch their diets between foods in response to rising food prices. In West Africa, for example, rising prices for rice that is mainly imported are likely to stimulate demand for domestically produced cassava, yams, maize, millet and sorghum. Additional demand for these little-traded foods, of course, is likely to push up their prices, but not by as much as the rise in international price levels.

The food price spike provoked several studies to assess the likely impacts on consumers, usually drawing on simple models of households. The most widely quoted of these is the study of Ivanic & Martin (2008) from the World Bank. Using household datasets from the Living Standards Measurement Surveys in 9 countries, they look at the consequences for real incomes of urban and rural households distributed in different income groups. Their models include some production effects for rural households as sellers of produce whose price has risen, and as labourers on farms with higher earnings from increased food prices.

Their results show considerable differences for countries, but overall poverty rises and rises more for urban than rural households. Only in a few cases do price rises confer sufficient additional income to the poor to offset their rising costs as consumers. The authors also present poverty impacts with and without wage effects: as may be expected increases in poverty rates are greater when wage effects are ignored.

By simple extrapolation, the authors estimated that 105M people could be pushed into poverty as a result of the recent increases in food prices nullifying seven years of poverty reduction efforts – figures that have frequently been quoted.

Their study, as well as similar ones using household models, involves some heroic assumptions about price transmission, about consumers not substituting more expensive foods by cheaper ones, and about how farmers may respond to production incentives. These in reality are all areas of uncertainty. The case of price transmission has been mentioned above. In addition, there is the question of how much poor consumers are able and willing to switch their diets between foods in response to rising food prices. In West Africa, for example, rising prices for rice that is mainly imported are likely to stimulate demand for domestically-produced cassava, yams, maize, millet and sorghum. Additional demand for these little-traded foods, of course, is likely to push up their prices, but not by as much as the rise in international price levels.

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<sup>34</sup> Data from the World Bank's World Development Report for 2008 (World Bank 2007) for seven developing countries (Table 4.2) illustrate the fact that the majority of the poor are not net sellers of (tradable) food staples.

Further uncertainty applies on how much poor consumers may benefit from higher prices either as farmers (see the next section), farm labourers, workers in the agricultural and food chain or others who may gain from consumption links as farmers spend higher incomes.

Even at this point, the effect on food security in terms of hunger and malnutrition is somewhat uncertain. Changes in real incomes and the ability to buy food are important, but they are not the only determinants of nutrition: roughly half of what affects nutrition comes through the use of food and through the ability of individuals to make use of ingested nutrients, largely matters of hygiene and health.

The IFPRI IMPACT model generates likely changes in nutrition. It is estimated that every percentage point increase in real international prices for staple foods would make 16M more people food insecure. Hence, if biofuels production led to a 10% rise in food prices, then 160M more could be made hungry.

### **Impacts of higher local food prices on farmers**

Recent studies of the ability of local farmers to take advantage of higher prices for food are few. Most studies assume farmers' ability to raise production on the basis of some general studies, rather than detailed estimates specific to the country or group of farmers in question. It is likely that farmer responses will differ depending on their access to market and to resources for increased production.

Further assumptions then have to be made about increased use of labour and how this may bid up rural wages if wider effects on rural poverty are to be assessed.

Most such considerations in studies of the impact of the food price spike have been largely conjecture – with those conjectures in some cases being incorporated in household and national models.

A weakness in the studies that have been made is the potential positive impacts on poverty that may result from developing biofuels in the developing world have received less attention than the potential for harm through higher world prices. In some countries where land is relatively abundant, that are landlocked and distant from world markets, the benefits to the poor and vulnerable from biofuels development may well outweigh any drawbacks. The imbalance in studies to date reflects in part the concerns that have motivated those commissioning research, and in part the lack of detailed and accurate information on how widespread and significant the benefits might be. The study by Arndt et al. (2008) on how biofuels could reduce poverty – and by implication hunger – in Mozambique is an honourable exception.

### **Trade liberalisation impacts compared to those of biofuels**

Studies of the potential impact of liberalisation of agricultural trade, together with a reduction in the protection of agriculture in OECD countries, have concluded that the prices of many products on world markets would rise (for example, the review by Valdés & Zietz 1995).<sup>35</sup> Yet trade liberalisation is usually seen as helping to reduce poverty. Bouët (2005), for example, surveys 16 assessments using CGE models of the global consequences of full trade liberalisation from 1999 to 2005, that report gains to world welfare in the range from 0.3% to 3.1%, with from 72M to 440M persons lifted out of poverty.

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<sup>35</sup> Although these authors wonder what would happen if liberalisation also meant reduced negative protection in the developing world where the effect would be to stimulate production and exports.

Does this mean, then, that if biofuels production expands and prices of agricultural commodities rise on world markets, that overall poverty will fall? The logic of this argument is that the poor would benefit from higher prices on world markets since this would provide incentives to agriculture in the developing world and the increased production from farms would both directly and indirectly help reduce poverty. Few of the studies to date of the impact of biofuels find that the potential harm to the poor as net consumers of food would be outweighed by gains in production. This seems to be an anomaly, with the probable explanation being that global models that could take into account the full set of linkages have not been fully geared up to consider the impact of biofuels. If so, the need to encourage more precise modelling in research gap 4.1 becomes stronger.

In summary, given the several pathways that an expansion of biofuels may affect poor and vulnerable people, given their dependence on local circumstances, and the degree of uncertainty about them, it is difficult to generalise. Effects will be highly diverse.

Empirical reports of household reactions to the food price spike are only now beginning to appear, most of them being produced by non-governmental organisations closely engaged in helping people cope with poverty and hunger. The early indications from these studies are of great diversity of experience. A general synthesis of these insights has yet to be produced.

The problem here is that the processes involved, as sketched above, are both complex and diverse. Understanding the relation between the development of any new element in the economy, be it a new activity such as biofuels or a policy, and poverty and hunger is challenging. Broad outlines may be clear, but the all-important detail is not.

Research Gap 1: Impacts of the price spike on poor and vulnerable people. The recent price spike has, however, provided a laboratory that provides the chance to observe – rather than just model – the links from changes on world markets to households and their members. This has prompted several studies to record local level changes in prices, in the responses of poor and vulnerable people, public responses, and impacts on poverty and hunger. The need here is to synthesise these studies and draw out the insights they offer. This is being done at more than one centre, including at the Overseas Development Institute, IFPRI and FAO.

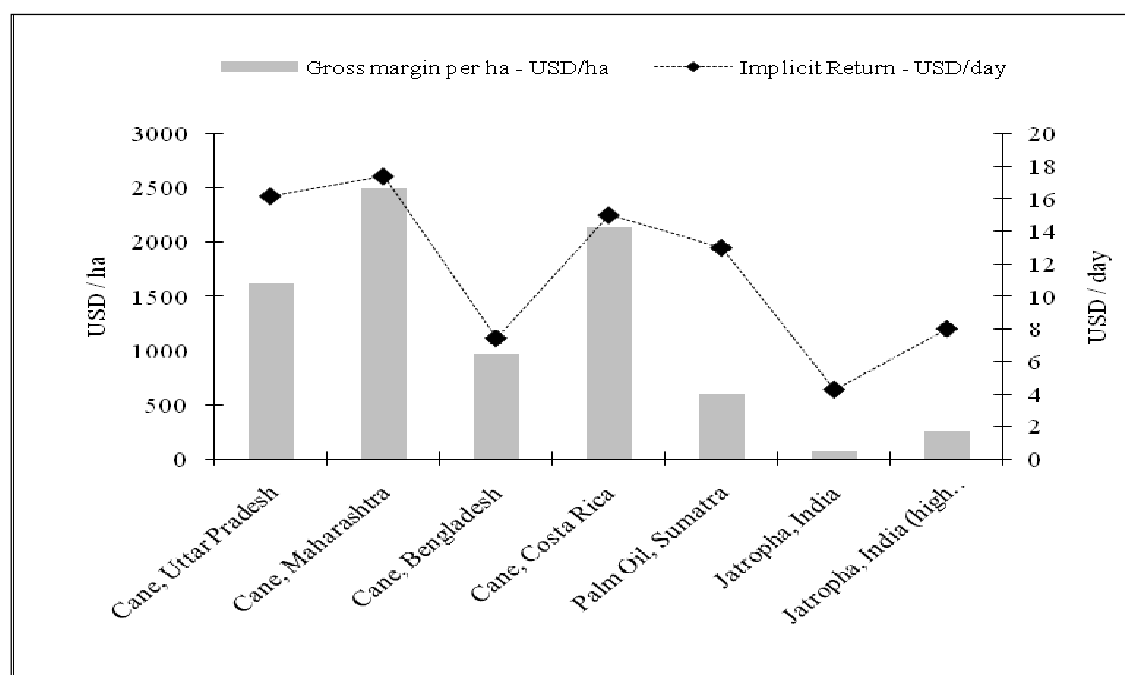
Research Gap 2: A wider consideration in this work: representative datasets for countries or regions within them on food security are few and far between. Most developing countries are fortunate if there are national surveys of poverty and nutrition at intervals of five years or better. These surveys are valuable in presenting an up-to-date view of the situation, in showing trends, and above all – in stimulating debate and interest in the issues they highlight. Without the data and the statistics that can be derived from them, disastrous situations – such as the state of nutrition of infants and their mothers – can go virtually unnoticed.

Proposed research – surveys like these, of course, should be carried out as part of the general statistical and research effort of countries: they are not specifically about biofuels. For that reason although the gap is wide and significant, it is not necessarily something for a biofuels research agenda.

## 2) How competitive are enterprises producing biofuel feedstock and biofuels in developing countries?

Brazil is by far the most efficient biofuel (ethanol) producers (e.g. FAO 2008), but this competitiveness took a long time and commitment to be developed. Now that global demand for biofuel is rising, especially through the Northern targets, what kind of economic opportunity does that represent for southern producers? Potential associated impacts, and assumption will be detailed further and are research questions. However, the answer to this first underlying question of the existence of a potential economic opportunity for southern producers is relatively clear now: yes, there are economic opportunities for southern producers, and there are many of different kinds. Of course, these opportunities largely depend on one critical assumption: the crude oil price. The Figure 4-7 below (from Wiggins et al 2008) illustrates potential implicit returns for feedstock production for different crops and countries. The assumption is a \$65 / barrel oil price. At this price level, feedstock for biofuel production offers very competitive returns compared to typical income level for southern farmers (rarely more than 5\$ / day).

**Figure 4-8 Estimations of implicit returns for feedstock production under a US\$65 / barrel oil price assumption**



Research Gap 3: There is a significant number of projects developing biofuels for local use in the South. Experience from those projects need to be captured, to share best practices and allow for scaling up. Technical issues are comparatively straightforward, but the institutional questions of how to organise and co-ordinate activities up and down the supply chains are more challenging. Effective solutions depend considerably on contexts, yet there will be lessons to learn that have wider application. Currently, it is difficult for those grappling with the issues – be they farmer groups, private firms, NGOs or public agencies – in any given case to find out about other comparable experiences.

Proposed research – comparative research on institutional approaches and value chain development for biofuel development in the South, adapted to local bio-energy needs. Comparisons should relate to different feedstock, contexts, and biofuel uses and cover institutional aspects all along value chains, from crop production and marketing, to transformation, utilization, and biofuels marketing. It should include an assessment of the regulatory frameworks adopted in each country.

Southern leadership is essential for various reasons, among which: (1) Lack of institutional and technical capacity is a gap in itself, and therefore developing southern research (especially in Africa) is an objective in itself; and (2) Southern policy discussions need to be informed by local issues and knowledge, and southern-led research is likely to be more relevant to these. Such a project could need significant resources (for example, three researchers for three years). It would benefit from being well connected to entities such as the GBEP, and relevant CGIAR centres (estimated budget £0.5 to 1M).

Under the heading “developing biofuel for the south”, there is an issue that was little explored by this present study and which relates to developing crops and farming techniques with better input-output ratios. Biofuels crops such as *Jatropha*, *pangomia* and sweet sorghum may still need significant research investments to be further developed. Although it is not possible here to conclude if there is a research gap since this gap analysis did not cover this, scoping the need for more research investment in this area could be useful, and if such a gap is confirmed, investing in such research could make an important difference.

Research Gap 4: Economics of biofuel enterprises. The evidence on returns to growing feedstock and producing biofuels in developing countries is patchy. The various consultancy studies being carried out for governments include valuable data on costs and benefits of enterprises. But there is no central point at which these insights can be drawn together to establish a more reliable source of information for policy-makers and investors.

Proposed research – a one year study located at a centre such as GBEP could systematically seek out the national studies carried out – and any industry studies that may be accessible – and compile a central database of enterprises analyses. The aim would be to make the findings available on a web page accessible to all.

### **3) What kind of biofuel industries are possible and with what development impacts?**

There are important differences between systems. The above figure also illustrates the important variability of potential returns for one feedstock to another. The case of *Jatropha*, widely regarded and promoted as an option to produce biofuel feedstock on marginal land is particularly interesting. At the moment, despite heavy investments in the expansion of *Jatropha* as feedstock, there is evidence that it does not meet all its promises (Jongschaap et al. 2007, FAO 2008). Farm yields are still far from results on experimental stations. Research institutions such as ICRISAT (see ICRISAT 2008) as well as the private sector (e.g. D1Oil), are working to develop improved varieties.

The organisation of the feedstock value chain also matters in terms of impact of feedstock production expansion on rural poverty. Modelling work by IFPRI in Mozambique (see previous section and Figure 4-4), demonstrates that small-scale *Jatropha* production offers better prospects than large-scale sugar cane plantations to reduce rural poverty. The IFPRI model for Mozambique predicts that the better scenario for poverty reduction combines both production systems.

#### **Interaction with the EU sustainability standards**

Beyond the applicability of sustainability standards (discussed in section 5.2), one question is the impact that these standards would have on southern biofuel production systems. Early learning from processes in place to disseminate such standards is quite encouraging: after a few years, the RSPO reports that producers responsible for around 40% of the world's palm oil production are represented under its umbrella. The potential for large-scale impact is there, although some doubt the effectiveness of such mechanisms (Greenpeace).



Finding sustainability criteria that can be applied effectively in developing countries, and especially those where there is conflict or that are otherwise considered to be fragile states, will be a challenge for the EU. [The EU in late 2008 tendered a study into feasible sustainability criteria for biofuels that was awarded in mid-2009, so work on this is in hand.] One of the main points in contention is whether to look to establish set mandatory criteria to be applied in all places and all times; or whether to support processes in which stakeholders agree on the standards to apply in particular countries and times that can subsequently be upgraded and adjusted to match conditions – see ODI & Proforest 2008 for more discussion of the possibilities. The former approach has the value of clarity and specificity, but could produce unintended consequences, may be inflexible, and simply impossible to apply to produce from some areas. The latter, voluntary approach has the advantages of being consensual, adapted to local conditions, and flexible; but could be too weak, unclear and inadequate to satisfy the concerns of Northern consumers.

The biofuel process is more recent: sustainability standards are just being developed: it is therefore too early to draw conclusions on the socio-economic impacts of the implementation of those criteria. However, two points can be made: (1) since modelling work predicts that small scale production systems lead to better poverty reduction outcomes, it will be essential to make sure that sustainability criteria do not tend to exclude small producers; and, (2) many of the prospects for southern biofuel production are geared towards local markets, and there will be issues around sustainability of these biofuel production value chains, independently of northern-led criteria.

### **Local prospects**

With the growing demand for biofuels in northern markets, the ability of southern countries to export is an issue. However, the most promising prospects for southern biofuels might be local as illustrated in Figure 4-2, or regional (e.g. Johnson & Matzika 2008, or Haywood L. et al. 2008 for Southern Africa). Since high transport costs are often due to fuel prices, local bio-energy generation may be a very promising option for southern fuel importers. Although local bio-energy generation in remote areas is not new, with higher oil prices it becomes more attractive. Many bio-energy initiatives exist at local level; lessons learnt about implementation of local projects are emerging and indicate technical capacity gaps (e.g. Practical Action-FAO, 2009). Southern research strategies are well developed (e.g. FARA 2008), but funding gaps are reported (Practical Action - FAO 2009).

The attractiveness of producing biofuels for local markets rises with distance from world markets, since in remote areas the cost of imported petroleum-based fuels rises while the value of locally-produced feedstock in distant markets is correspondingly reduced.<sup>36</sup>

Research Gap 5: Sustainability criteria for biofuels in developing countries. Section 5.2 refers to issues related to the development and impact of biofuels produced in the North and / or imported for the Northern markets. However, it is expected that a significant share of the biofuels produced in the South will be produced for local use. Therefore, there is a case for supporting development of approaches to ensure sustainability of biofuels production for local use.

Proposed research – scope the demand and approaches that could be developed or are being developed by Southern countries to ensure sustainability of the biofuel production for local use to (1) inform Southern governments willing to develop their regulation by approaches being adopted in the most advanced countries; (2) help refine current approaches being developed in the more advanced countries if needed; and (3) inform Northern-led certification initiatives by Southern-led approaches and help convergence.

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<sup>36</sup> Put more technically, the comparison is of import-parity price for oil products against an export-parity price for locally-grown feedstock.

This priority is relevant to the priority question #2 that emerged from the workshop. It could initially take the form of a relatively limited scoping study, connected to the GBEP and RSB, and resourced to a level around £100K.

**4) What are the potential effects of biofuels production in developing countries on**

- The access of poor and vulnerable to land?
- The condition of labour on biofuel estates and transformation plants?

**Land access and land tenure**

There are several examples of countries or companies that have or are trying to invest in purchasing land for food or biofuel production. Examples in Madagascar or Sudan were highly publicised last year. There is also a Tanzania case study detailed in the 2008 State of Food & Agriculture report (FAO 2008b). Although such large scale land acquisitions haven't always materialized, there is a growing literature raising concern about potential impacts of investment in biofuels, and more generally large scale investments on small holders' access to land (e.g. Grain 2007, Oxfam 2008, Action Aid 2008, IEED 2008). Although large-scale land capture isn't documented, these works have gathered evidence of pressure on land tenure from biofuel projects. Traditional land tenure systems can be particularly vulnerable to these impacts (IEED 2008). Although documented impacts are so far limited, this question is of primary importance, since land tenure, access and use are of key importance for socio-economic development and political stability.

**Gender issues**

Some literature-based studies relay specific concerns about gender issues and biofuel expansion (IUCN 2007, FAO, 2009). They report that women are likely to be more vulnerable to risks such as losing land use, but also that women tend to lose control of cash based resources (cash crops such as biofuel in opposition to food crops). The FAO work concludes that promotion of gender equality and women empowerment needs to be associated with biofuel expansion programmes and integrated into sustainability criteria.

**Other impacts on farmers' livelihoods**

A recent study (FAO 2008b) reports concerns about potential impact of feedstock (sugar cane in the study) expansion on rural livelihoods. This study documents that shifts towards cash crops can reduce the diversity of production systems, and therefore reduce resilience to external shocks (e.g. climate, pests, and prices). Here again, documented evidence is limited, but risk mitigation is so crucial for southern farmers that impacts can potentially be important if biofuel expansion policies do not address these issues.

**Labour conditions**

Exploitative labour conditions in Brazilian sugar cane plantations are pointed out by various organisations such as Amnesty International. Wilkinson and Herrera (2008) argue that real wages in sugar cane plantations have decreased since the 1970s. At the same time, a study (Smeets et al. 2008) considering risks on cane plantations in Brazil ranked labour conditions and wages as a "minor" issue, reporting that wages are higher in plantations than in some other sectors of the Brazilian economy – although this study also concluded that systems to monitor such issues need to be improved. The International Food and Trade Policy Council, in a recent (IPC 2008) assessment of the sustainability criteria promoted by the RSB, was particularly critical about labour issues, arguing that "many issues raised in the context of biofuel production are not unique to the biofuel sector".

This short section may highlight the fact that these issues are highly debated and politicised, but nonetheless very little documentation is available to inform the debates. On the other end, as concluded by the SOFA 2008, equity and gender related risks derive from existing institutional and political realities in the countries and call for attention irrespective of developments related to biofuels.

Research Gap 6: Monitoring the impact on Local Livelihoods: how biofuels are changing the daily lives of the rural poor, for the good and for the worse? Research on these topics has so far been patchy. There are some preliminary indications of negative livelihood impacts of biofuel expansion (land access, gender, risk mitigation strategies...), but the available information is not always collected in a consistent manner across studies, and is largely focused on negative impacts.

The current IIED – FAO – World Bank work on land issues will probably cover part of the gap in this area. However, further need will arise when the biofuel expansion will be more effective. This research needs to be strongly connected with policy makers, both in the North and in the South, and with priority question 2 mentioned above, and the research related to the development and roll out of sustainability criteria (Section 5-2).

Proposed research –comparative analysis of the socio-economic impacts of biofuel expansion on social and livelihood related issues (gender, labour, and land access), and ways to mitigate related risks and maximise opportunities. In this area, the key gap is not only lack of consistent information and knowledge, but also the lack of consensus. Running this research through an inclusive process therefore matters.

The following three-step approach is then proposed:

- Conference gathering key stakeholders (Southern governments, International agencies – UNEP, FAO, UNDP, Donors ... –private sector, NGOs, farmers associations...), with the aim to assess existing evidence, and set priorities for further research.
- Research phase: grants offered to potential research groups in a co-ordinated but decentralised approach, involving some of the key stakeholders mentioned above in its decentralized management.
- Conference gathering key stakeholders with the aim to disseminate the key research findings and the ways forward to mitigate risks and maximise opportunities.

This type of research project would benefit from being hosted by one of the key UN agencies involved in this sector, such as FAO (or possibly UNEP), and given the importance of the inclusive process would certainly be quite an expensive and labour intensive enterprise. A budget over £1M (probably closer to £2-3M) is estimated.

#### **4.4.6 Summary and conclusions**

Policies and mandates to encourage the production and use of biofuels in OECD countries have increasingly attracted concern and indeed vociferous criticism, largely owing to fears of the economic and social impacts on poor and vulnerable people in the developing world. These potential impacts include raising the price of food, expropriation of land used by the poor for large farmers to grow feedstock, and poor treatment of labour on farms and in processing plants.

In addition to such acute effects, questions arise about how biofuels may affect trade and the balance of payments, energy security and dependence on imported fossil fuels, and opportunities for new industries and jobs in producing countries. While these effects apply across the world, they have particular relevance for developing countries in as much as they either contribute to development or undermine it.

The effect of expanded biofuel production on international markets for food and other agricultural commodities came to prominence in 2008 as researchers sought to explain the 2007/08 spike in food prices and the role of expanded biofuel production in that event. Both partial and general equilibrium models have been deployed to address this question. Most models suggest that biofuels did contribute to the price spike, but were not necessarily the main or dominant factor.

Studies have also examined how expanded biofuels production will affect markets in the medium term. Using the same models, they show that producing biofuels to fulfil the mandates of the EU and North America will indeed push up the prices of some agricultural commodities, but generally only those that are feedstock by any significant degree. Prices of maize and sugar cane could rise by 10–30% in real terms, while those for vegetable oils might rise by up to 50% in some models.

Plenty of research is planned, generally to refine the models to reflect the particularities of biofuels. There are few clear and substantial gaps. Most of this work, however, will not take place in either the UK or EU. Given the speed with which models can be deployed to address policy questions – in a matter of weeks, as was seen for the Gallagher Review – there are reasons to support research by UK or EU-based researchers. A clear objective here could be refining the GTAP-E model to take into account the value of co-products in biofuels production. It would also be useful to review the estimates of elasticity used for supply and demand. Consideration of modelling impacts on price volatility would be worthwhile.

Some research on how far world agricultural prices, pushed higher by biofuels as expected might then affect national economies has been carried out, but only looking at potential increased cost of imports and consequent deflation of economies. Such studies assume no reaction to higher prices of imports by consumers.

Less has been done to examine the potential for biofuels production to stimulate economies; although some studies exist – including a model that examines how much developing biofuels could boost the growth rate of Mozambique, create jobs and reduce poverty. Some of the larger developing countries, such as Brazil and China, have the domestic research capacity to assess their potential for biofuels.

When it comes to smaller and poorer developing countries, some governments such as those of Kenya and Mozambique have commissioned consultancy studies of their potential as biofuel producers. Typically these studies have wide terms of reference, looking at technical, economic, social and administrative feasibility of biofuels and produce lengthy and detailed reports.

A gap here concerns developing countries that have land to make them potential producers of biofuels but which are small, poor, lacking in domestic research capacity and that have not had an external research agency examine the potential economic and social opportunities.

There may also be value in comparing national studies that have been carried out: at present there is apparently no device or forum that would allow for general lessons to be drawn or communicated. One entity that might be used for such comparisons is the Global Bioenergy Partnership (GBEP).

Linkages from world market prices to households and enterprises are diverse and varied: while the pathways are known in outline, their application to given circumstances is less well known. It seems that context is critical, and general conclusions are difficult to draw.

Studies on enterprise economics are relatively few, although those that have been carried out suggest that producing biofuel feedstock in the tropics can be economically attractive – although it does depend on oil prices being US\$60 or more a barrel in the medium term.

While civil society groups have logged particular cases of land alienation and mistreatment of labour, it is not clear how general are these abuses. Moreover, it is unlikely that they are specific to biofuels: other economically attractive uses of land and natural resources in particular contexts also lead to similar problems.

Many gaps arise in understanding impacts on households and enterprises. While additional studies could be recommended, there are enough studies in progress to suggest a more pressing need and effective research strategy: synthesising the emerging insights from the studies planned and in progress. These would include syntheses of:

- Impacts of the 2007/08 food price spike on poor and vulnerable people and the effectiveness of public responses.
- Experiences of institutional arrangements in biofuels supply chains in developing countries.
- Returns to biofuel enterprises in different countries and conditions.
- Initiatives for applying criteria for decent and sustainable value chains in developing countries.
- Instances of abuses of land rights and labour conditions, and of effective responses to them.

Finally, there is an overarching research priority beyond the scope of biofuels research: more frequent national surveys of the incidence of poverty and hunger [4.5]. In many countries such surveys are so infrequent that important trends are not clear until late in the day.

In sum, most of the research that has been conducted on the economic and social impacts of biofuels has dealt with international dimensions using models to generate useful, but somewhat broad, insights into effects. The range of research questions expands as the focus moves down from international concerns to those that apply to firms and households in the developing world; while little research has been done on potential impacts to them. Consequently there are some substantial research gaps at this level.

While most studies, reflecting the concerns of their commissioners, look for adverse impacts; less has been done to estimate the potential benefits to the poor from biofuel industries in the developing world. Preliminary studies suggest that for countries with underused arable land, –although the extent of such land needs confirmation –the benefits could be considerable.

The missing research at the micro level is of prime concern to governments and civil society in developing countries, but also concerns those international agencies that partner these countries and help their development – including multilateral and bilateral donors and international NGOs. If the UK Government is to be the responsible and influential citizen on the world stage that it seeks to be, it needs to understand these issues.

**Table 4-6 Households and enterprises – key findings**

Key to ratings provided below

Research Gap	1) Impacts of the price spike on poor and vulnerable people	2) National statistics on poverty and hunger More frequent surveys of poverty and nutrition, representative at national and sub-national levels.	3) Institutional approaches and value chains for biofuels in the South	4) Economics of biofuel enterprises Synthesise information in consultancy studies and the like	5) Sustainability criteria for biofuels in developing countries	6) Monitoring the impact on local livelihoods Abuses of land rights and labour conditions of poor and vulnerable; and of effective responses
Key related work	Work in progress		Comparative research on institutional approaches and value chain development for biofuel development in the South	Draws on existing studies, usually national assessments		NGO reports of specific incidents and events
Complexity	*	*	**	*	**	*** (many variables, need to involve numerous stakeholders)
Time scale	**	2 years **	***	**	*	**

Research Gap	1) Impacts of the price spike on poor and vulnerable people	2) National statistics on poverty and hunger More frequent surveys of poverty and nutrition, representative at national and sub-national levels.	3) Institutional approaches and value chains for biofuels in the South	4) Economics of biofuel enterprises Synthesise information in consultancy studies and the like	5) Sustainability criteria for biofuels in developing countries	6) Monitoring the impact on local livelihoods Abuses of land rights and labour conditions of poor and vulnerable; and of effective responses
Potential costs	*	***	**	*	*	**
National or international?	International	National	International, but regional of national focus important	International	International	International
Availability of data	Draws on studies completed or in progress	All about collecting the data	*** (many local projects)	Draws on studies completed or in progress	** (a few countries are developing these – e.g. India, Tanzania...)	**
Availability of skill sets	***	** (Fairly straightforward)	* Developing local capacity is an aim here	**	***	** (data relatively simple to collect and many actors involved, the issue is more about measuring

Research Gap	1) Impacts of the price spike on poor and vulnerable people	2) National statistics on poverty and hunger More frequent surveys of poverty and nutrition, representative at national and sub-national levels.	3) Institutional approaches and value chains for biofuels in the South	4) Economics of biofuel enterprises Synthesise information in consultancy studies and the like	5) Sustainability criteria for biofuels in developing countries	6) Monitoring the impact on local livelihoods Abuses of land rights and labour conditions of poor and vulnerable; and of effective responses
						thing consistently)



**Key**

<b>Significance</b> – please see matrix	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k *<£100k	<b>National or international</b> i.e. can the work be done in the UK or would it be better done internationally?
<b>Availability of data</b> This will refer to the IPR/availability of R&D already ongoing in the area (e.g. Commercial – restricted; or published/available)			<b>Availability of skill sets</b> *** a number of organisations working in area ** availability restricted to a few groups or only on international scale * skills gap, significant training required	



# Biofuels Research Gap Analysis

## Chapter 5 – Market Forces and Trade



**Final report to the Biofuels Research  
Steering Group**

ED45917  
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## **5 Market Forces/Trade**

### **5.1 Introduction**

This chapter is concerned with research and research gaps in the operation of the biofuels market, in particular with reference to the application and effects of policy interventions. The first section focuses on the impacts on investment, markets and trade of policy decisions in support of biofuels mandates (the RTFO and EU Directives). The second section covers sustainability and supply chain issues in the context of the application of sustainability criteria and reporting requirements for biofuels mandates, as existing in a number of sustainability criteria schemes and as set out in the RED. The third section addresses the application of grandfathering clauses in the context of biofuels policy and the implications of the inclusion of such clauses in the RED.

A key linking theme to the sections of the chapter is that they address research issues relevant to current policy developments in the biofuels sector and how these will impact on UK biofuels production and supply. A wider international perspective on biofuels production and its impacts on other sectors, in particular in developing countries, is given in Chapter 4 on Economic and Social Effects. Discussions on Indirect Effects in Chapter 2 and Other Environmental Issues in Chapter 3 inform the assessment in this chapter of the application of sustainability criteria as a biofuels policy instrument. Moreover, technical discussion of Vehicle Capability in Chapter 6 and Advanced/Second Generation Technology in Chapter 7 provides background to the development of biofuels markets, investment and trade in meeting biofuels targets that are covered in this chapter.

## 5.2 Impacts of policy decisions on investment and market forces

Figure 5-1 Matrix on the impacts of policy decisions on investment and market forces



Size of Research Gap

	Small
	Small / Medium
	Medium / Large
	Large

### 5.2.1 Executive Summary

*What investment and market issues influence the effectiveness of policy measures to increase production of the best, most sustainable biofuels (which include consideration of ILUC)?*

This section focuses on the operation of the UK biofuels market<sup>37</sup>, including investment, supply and trade issues, in the light of interventions to promote their use. The emphasis is on research in UK Biofuel production and trade (so this is all supply in UK including domestic production and imports, as well as what we export) but this is informed by wider EU and international research about how the biofuels market and trade works.

Therefore we are interested here in the impact on the market of policy decisions on biofuels mandates and sustainability criteria (rather than in issues of the rationale and methodology of these criteria). In particular, we are interested in the RED 10% target for energy from renewable sources in transport and the associated requirement that biofuel production should be required to fulfil sustainability criteria.

This chapter considers current and future research in this area in order to identify the research gaps which must start to be filled before we have a full understanding of the investment and market issues which influence the effectiveness of policy measures, in particular RED. These key research gaps include:

#### 1. Impacts of biofuel policy decisions on:

Research Gap 1: Market and investment decisions according to scenarios for **trajectories to targets** (this would include slow down of targets in RTFO, EU review clause in 2014).

Research Gap 2: Market and investment decisions according to scenarios for the design and introduction of **sustainability requirements** including ILUC factors.

Research Gap 3: **Trade** in biofuels and feedstocks (i.e. imports and exports of biofuels and feedstocks, taking into account scenarios for trajectories to targets and sustainability requirements and including issues of WTO interpretations of sustainability criteria and differing biofuel policy regimes to trading partner countries). To what extent might these policies drive imports of biofuels if investment in domestic production does not produce the required capacity, where would this be sourced and what would be the impacts on price?

Research Gap 4: Different scenarios for the impact of **development of technologies** (i.e. changes in production capacity and costs due to development of second generation technologies and other production enhancements).

#### 2. Impacts of other factors on market and investment decisions:

Research Gap 5: **Other market factors** such as economic slowdown, input commodity prices, oil prices and exchange rates.

<sup>37</sup> It should be noted that reference to the biofuels market or sector is something of a simplification of a diverse market of different products (chiefly bioethanol and biodiesel) using different feedstocks and with a range of different company operating models.

Bearing in mind the short timescales in current development of policy at UK and EU level and the current policy uncertainty which affects the investment climate, there is an urgency to address the research gaps identified in order to provide a firm foundation for meeting mandate targets through promotion of the most sustainable biofuels.

Overall, this study found that while there is a great amount of international and UK based research on the economic and market aspects of biofuels, this can be fragmented and uncoordinated and there appear to be gaps in available studies that directly address the key questions and sub questions given in Section 5.1.3. This is partly because some key specific questions are focused on recent and future policy developments and, although existing relevant studies from different countries can inform the analysis, further UK context-specific research answering the questions would be required.

To take forward the research on markets and investment in the UK context, a key question to address, which underlies the subsidiary questions in Section 5.1.3, is how will targets be met? Conditions for investment, capacity/supply and trade, and the impacts of policy measures on these, should be better understood in order to fully understand the impact of different scenarios to meet mandates (for example, lack of investment in UK capacity). We would stress the importance of an integrated assessment of the impacts of specific policy decisions and other market factors in order to address the question of how targets will be met, rather than taking these factors in isolation.

A longer term prospect to fill research gaps is the detailed modelling of the biofuels market based on an extension of existing global market models (as described in Section 5.1.4) but, in order to improve understanding in the short and medium term as dictated by current policy developments, a number of inter-related ad hoc studies could be undertaken on different research gaps identified above related to how the biofuels mandates will be met. These would build on available data and surveys in order to estimate the impacts on the biofuels sector of given scenarios of policy development and market conditions.

## **5.2.2 Context**

We focus here on key issues in understanding the operation of the biofuels market, including investment, supply and trade, in the light of intervention to promote their use. The primary interest is the UK context although research in the EU and international experience informs this understanding. Key issues can be divided as follows although there are, of course, interlinkages between these.

### **Government interventions**

Biofuels production would not exist in the UK in its present form without some form of Government support. The two main instruments used internationally are subsidies through tax incentives, such as reduced levels of fuel excise duty, and mandatory uptake, such as the RTFO. Biofuels can also benefit indirectly from measures such as tax allowances in the capital cost of low carbon vehicles and refuelling infrastructure. There has been a switch to obligation schemes in the EU due to high revenue losses from tax exemption schemes. In the UK the current fuel duty rebate for biodiesel and bioethanol will cease in 2010, following the introduction of the RTFO in 2008.

The current development of the RTFO has been complicated by a number of factors, including the proposed order which effectively reduced the target for the first year of operation. In the future the implementation of RED and FQD could (if the RTFO is used in implementing them) require major RTFO amendments for 2010. Representations from the biofuels industry cite these as key factors, along with the economic slowdown, in the significantly worsened UK investment climate for biofuels over the last year. This particularly affects investment in high Carbon & Sustainability biofuels. Therefore, a key call from the industry side is for a less uncertain policy environment to provide confidence for long-term investment decisions and to avoid undermining policy objectives. On the Government side the challenge is to balance the requirements of promoting sustainable biofuels based on sound evidence and addressing stakeholder concerns, the implementation of EU Directives, and a stable market and investment environment.

A further issue is the impact of biofuel policy on other market sectors. While the impacts on food security and prices, and economic impacts on non-food commodities, are addressed elsewhere in this report it is noted that there can also be serious impacts on sectors such as oleochemicals.

### **Market conditions**

Aside from policy intervention, the biofuels market should be understood in the context of other factors, in general, outside the control of businesses including the economic slowdown, exchange rates, input commodity prices, product demand and non price factors such as standard product specifications. It should also be noted that the oil price is a key determinant of biofuel production.

UK biofuel sector characteristics:

A further issue to take into account is the nature of the biofuels sector globally and in the UK. This includes capacity, growth, and diversity of operating models and products and technological development. Other study teams have covered research into development of advanced/second generation technologies and infrastructure. Investment in these is needed for market development and in meeting future targets and sustainability requirements but as these new technologies have higher investment risks the importance of a stable policy environment is underlined.

### **Trade**

Trade is an increasingly important issue in the biofuels sector given the international nature of the expansion of biofuels production. Biofuels promotion policies including supply mandates, which in the current UK context is the RTFO, raise specific questions on the implications for trade in biofuels. To what extent will targets be met by imports, in particular if capacity is not developed fast enough, and what scenarios would drive exports of domestically produced biofuels? For example, if there are uneven policy regimes related to GHG savings there is a risk of 'shuffling', where biofuels may be moved around the EU or elsewhere to benefit from the highest rewards. Such trade incentives may result in targets being met (in UK or other countries) with a different ratio of imports to domestically produced biofuels than would have been the case with even policy regimes. Another example of how differences in policy regimes create trade incentives is the recent so-called 'splash and dash' issue, where biodiesel trade was routed through the US to gain maximum benefit from subsidies.

A further issue here is clarification of how international trade rules of the WTO apply to the biofuels sector. Key aspects of this subject are (i) lack of uniform classification of biofuels in international trade data systems and (ii) interpretation and compliance with rules on barriers to trade. Domestically produced biofuels can be protected directly by tariffs on imported biofuels (such as in the US and EU) and by technical (including sustainability) requirements, and indirectly by subsidies for agricultural production, other inputs (irrigation, fuels and credit) and in some cases biofuel production-related subsidies. Of particular relevance here is establishing how WTO rules on barriers to trade might apply to mandates for use of biofuels.

A key consideration for implementation of biofuels mandates is compliance of the introduction of sustainability requirements on biofuels imports (through the RTFO and EU Directives) with WTO rules on barriers to trade, specifically the General Agreement on Tariffs and Trade (GATT) and on Technical Barriers to Trade (TBT). GATT provisions on 'like products' produced in different countries do not in principle allow for differentiation according to production processes and associated environmental or social impacts. However, certain GATT articles do allow distinctions to be made for sustainability reasons<sup>38</sup>.

It should be noted that, although the research questions regarding the application of WTO rules to trade in biofuels are largely of a legal and technical rather than economic nature, the answers to these questions have considerable implications for investment and trading decisions and therefore on the nature of the biofuels market.

### 5.2.3 Key research questions

The main focus here is on how producers operate in response to policy measures supporting biofuel production. It includes general questions on how biofuel producers reach decisions on investment and deal with policy risk, and very specific policy questions concerning the market impact of the slow down of mandate targets, introduction of sustainability criteria and the 2014 EU review clause. These latter questions are interlinked and refer not only to analysis of current market impacts but also to forecasting scenarios, for example for increasing production capacity to meet targets and sustainability criteria, where specifics of policy are subject to uncertainty.

This section explores what research there is on:

What investment and market issues influence the effectiveness of policy measures to increase production of most sustainable biofuels?

This is underpinned by an analysis of what research there is on:

- 1) How do biofuel producers develop their investment decisions?
- 2) How do producers factor in policy risk?
- 3) Relative impact of slowing down biofuel mandates compared to the impact of other factors (economic slowdown; oil prices; exchange rates; individual operating models)?
- 4) Relative importance of local versus export markets for investment decisions?
- 5) How much uncertainty is there with:
  - The 2014 review clause?
  - The ILUC factor?

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<sup>38</sup> Article XX of GATT gives the possibility of distinctions between products to be made for sustainability reasons where this is "necessary to protect human, animal or plant life or health" or "relating to the conservation of exhaustible natural resources," but such distinctions should not constitute "arbitrarily discriminatory, unjustifiably discriminatory or a disguised restriction on trade".



- 6) How long will it take for producers to ramp up production to meet a 10% target (with varying breakdowns of first versus second generation)?
- 7) How much impact will either have on investment and market decisions, compared to other factors?
- 8) When will we see installation of production methods which take account of any additional ILUC sustainability criteria agreed in 2010, and the review clause?

#### **5.2.4 Research in the area**

Research on the economic, market and trade issues outlined above is covered by a large number of programmes and organisations worldwide. While there are some key multi-agency research initiatives, research contributions are rather fragmented and uncoordinated. This may be partly due to the nature of the subject drawing specialists from different sub-disciplines, such as agricultural economics, energy economics and market analysts, with their distinctive approaches and research communities. Four different types of research into biofuels markets are identified below which, while overlapping, illustrate this diversity of approaches and research constituencies. Details of main project initiatives under each heading are given in Annex 5.

#### **Modelling of biofuels market**

A number of ambitious multi partner international projects have modelled the global biofuel market in the context of wider agricultural markets. Details of the OECD Aglink model (used to model impacts of biofuels policies by Defra), the GTAP model (based at Purdue University and which has been used by LEI to model biofuel policies) and FAO/IIASA AEZ/BLS (world agricultural economy and trade model) are given Table 5-1. Models have been used to evaluate the future impact of biofuel production on commodity prices (this is covered in Section 4 of the report). However, there are current weaknesses in this analysis in terms of data availability for biofuels, impacts of 'advanced' biofuels and the inclusion of international trade in biofuels and therefore results should be interpreted with caution. There is also limited current UK detail in these models. The OECD Aglink model is presently at EU15 level and in the timescale of current policy development (RTFO revisions, RED and FQD) will not provide EU country-specific analysis to answer the very specific UK policy questions given above. These would still need to be addressed in ad hoc studies.

## **International Research**

Here there is a great range of international research, including by international organisations, other multi-national initiatives for biofuel policies and markets, and single country analyses. Key multi-national programmes including market analysis are Biofuels TP, Elobio and IEA Bioenergy (Task 40 for Trade). There are also single studies on biofuel mandate policies e.g. in U.S, Canada, New Zealand. These studies to some extent inform understanding of UK policy and provide useful methodologies for economic analysis. However, they are not a replacement for UK specific analysis to address priority questions.

Studies on the implications of WTO rules for biofuels trade, in particular relating to the legality of sustainability requirements and certification, have been undertaken by a number of organisations. The implications of WTO rules for the RTFO was covered by the E4Tech (2005) study<sup>39</sup> and the international situation has been analysed by, for example, the Biomass Technology Group, International Food & Agricultural Trade Policy Council and de Vera<sup>40</sup> (see Annex 5 for details). These studies suggest that obligatory criteria based on GHG savings and other global environmental policy objectives should be possible. However, mandatory requirements focused on social and local environmental issues are more problematic in meeting WTO rules and this may be an issue for some ILUC factors.

Research in this area of uncertainty can highlight where there are risks that specific sustainability criteria may be challenged but, of course, clear answers to these questions may only be fully established if dispute settlement procedures come into play.

## **UK based Government and academic research**

Here we include on-going Government studies in support of biofuels policy. These are the RIAs, consultations and other ad hoc documents by DfT for the RTFO and RED, as well as biofuel economic studies by Defra and market analysis through DECC. Of importance for assessment of the RTFO is the on-going reporting by the RFA as part of the post regulatory impact assessment process. There are also ad hoc commissioned studies related to Government support for biofuels.

## **UK Industry and independent agency research**

There is some sector level analysis, principally the LowCVP programme (the proposed Impact of the RTFO on UK businesses study is intended to inform the RFA annual report). However, many market analyses undertaken at company level and used as a basis for investment plans are unavailable due to commercial confidentiality. There is some market analysis aimed at business. However, our conclusion here is that there is limited independent and open access research on the investment and market issues at the level of detail needed to answer some of the key research questions.

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<sup>39</sup> E4Tech (2005) "Feasibility Study on Certification for a Renewable Transport Fuel Obligation" was part of the initial RTFO feasibility study.

<http://www.dft.gov.uk/pgr/roads/environment/rtfo/secrfoprogdocs/annex2feasibilitystudy.pdf>

<sup>40</sup> de Vera (2008) "The WTO and Biofuels: The Possibility of Unilateral Sustainability Requirements", Chicago Journal of International Law, Jan, 2008.

With regard to trade, research gaps exist both at a global trade level (understanding the international market for biofuels and the impact of trade barriers of various types) and at the level of the UK market (specifically how trade in biofuels may be impacted by mandates and sustainability requirements). To what extent might these policies drive imports of biofuels if investment in domestic production does not produce the required capacity, where would this be sourced and what would be the impacts on price? Additionally, what scenarios would drive exports of UK produced biofuels to where overall returns may be better. Basic understanding of biofuel trade has been hampered by the lack of biofuels data in international trade databases due to the lack of a designated customs code. Under RTFO reporting requirements the RFA is now collecting country of origin data for biofuels by feedstock which will go some way to filling this gap for the UK.

**Table 5-1 Research in the area of market forces and trade**

Funding or research organisation and budget where available	Current status of research
<b>Modelling of biofuels market</b>	
<b>International</b>	
OECD FAO Aglink Cosimo Model	Used by Defra to model impacts of biofuels policies, and by DfT to analyse the impact of policy mandates on the biofuels markets and wider agricultural market impacts. However, this model currently provides results only at the EU15 level and is not UK specific. The DfT work with this model does not plan to focus on the industry specifics as in the breakdown of questions outlined above.
GTAP Model	Model to assess the impacts of policies and other changes on production, land use, prices, and trade. Based at Purdue University, this model has been used by LEI to model biofuel policies. Other research has been carried out by institutes such as the Energy Biosciences Institute. The Hague have built a global CGE, using GTAP, that models the effects of policy changes in the EU and their effects on a number of parameters including world prices, trade, land use, farm incomes and subsidies needed to meet mandated targets.
IIASA	A global spatial and integrated agro-ecological and socio-economic assessment of biofuel development study to be released in March "Biofuels - Avoiding the Pitfalls and Mobilizing the Potentials". The study was commissioned by the OPEC Fund for International Development. The study is based on an integration of the FAO/IIASA AEZ (Agro-Ecological Zone methodology) and IIASA BLS( Basic Linked System of the world agricultural economy and trade model). Future work is planned for more detailed national and regional studies.

International Trade Research	
UK	
E4Tech for DfT	2005 feasibility study on Certification for a Renewable Transport Fuel Obligation by E4Tech <sup>41</sup> on the implications of WTO rules for the RTFO.
Europe	
Biofuels Technology Platform (Biofuels TP)	<p><i>Biofuels Technology Platform (aka Biofuels TP)</i>  <a href="http://www.biofuelstp.eu/biofuelsmarkets.html">http://www.biofuelstp.eu/biofuelsmarkets.html</a>  The Biofuels TP was launched in 2006 to increase biofuel use in the EU and worldwide. It has a wide-ranging remit and is covered in other parts of this report, but Working Group 5 looks at the marketing of biofuels, and the obstacles and opportunities therein. The European Biofuels Technology Platform is supported by a Secretariat, which is funded in part by the European Commission (FP6). The Secretariat is coordinated by the Swedish Energy Agency (STEM, Eskilstuna, Sweden) in association with Fachagentur Nachwachsende Rohstoffe e.V (FNR, Gülzow, Germany). The members of WG5 are from private sector and trade associations.</p>
Biomass Technology Group	<p>Consultancy group operating worldwide in fields of sustainable energy production from biomass and waste. BTG (2008) includes an assessment of WTO rules as a barrier to sustainability criteria and certification, which draws on work on the Dutch case undertaken by of Bossche, Schrijver et al (2007) and Bronckers, Verberne et al (2007).</p> <p>BTG (2008) Sustainability Criteria &amp; Certification: Systems for Biomass Production, report for DG TREN of European Commission.</p>
Carensa	Network of researchers, policy-makers, and industry representatives demonstrating the role of sugarcane resources in supporting sustainable energy solutions and improving economic competitiveness within the sugar industry and its affiliates in southern Africa.
ELOBIO	<p>ELOBIO is an EU-wide project with seven partners, funded through Intelligent Energy – Europe. Has a policy-orientated project which looks at how biofuel policies may impact other markets and how to develop ‘low-disturbing’ policy options.</p> <p>Work Package 2 is led by VITO and covers an inventory of existing biofuel policies. The results are published in “Inventory of biofuel policy measures and their impact on the market” by Pelkmans, Govaerts and Kessels of VITO, available at <a href="http://www.elobio.eu/fileadmin/elobio/user/docs/Elobio_D2_1_PolicyInventory.pdf">http://www.elobio.eu/fileadmin/elobio/user/docs/Elobio_D2_1_PolicyInventory.pdf</a></p> <p>This looks in particular at Government Intervention, with Table 1 outlining the key measures and where they are in place (e.g. EU15, EU27, individual countries). It also covers certain countries in more depth and provides an overview of biofuel development outside the EU.</p> <p>Work Package 4 is led by COWI and is policy development and evaluation. Work Package 7 is led by ECN and assesses potentials, impacts and costs at the identified best policies.</p>

<sup>41</sup> E4Tech (2005) “Feasibility Study on Certification for a Renewable Transport Fuel Obligation” was part of the initial RTFO feasibility study.  
<http://www.dft.gov.uk/pgr/roads/environment/rtfo/secrfoprodocs/annex2feasibilitystudy.pdf>

	There is a strong emphasis on stakeholder input throughout the project. ( <a href="http://www.elobio.eu/">http://www.elobio.eu/</a> )
<b>US</b>	
SRI Consulting	US company undertaking research in biofuels including market issues.
German Marshall Fund	The Economic Policy Program at the German Marshall Fund of the United States has established a Biofuels Project to: 1. explore the various risks and opportunities involved in the production of biofuels; 2. commission research and disseminate cutting-edge data on biofuels; 3. convene in neutral yet dynamic settings to discuss biofuels policies, and, most importantly, to 4. create a set of policy recommendations that offer a viable policy path forward for the United States, the European Union, and other countries.
University of California Berkeley	<p>UC Berkeley is linked to the Energy Biosciences Institute and University of Illinois. Experts including Prof Zilberman focus on the economics of biofuels. Papers include:</p> <p>Turner, B. T., Plevin R.J., O'Hare, M. &amp; Farrell, A.E. (2007) Creating Markets for Green Biofuels: Measuring and improving environmental performance, Institute of Transportation Studies, UC Berkeley Transportation Sustainability Research Center.</p> <p>Zilberman, David, and Deepak Rajagopal. Review of Environmental, Economic and Policy Aspects of Biofuels. The World Bank, Policy Research Working Paper Series: 4341 (2007).</p> <p>Utrecht, the Netherlands: Department of Science, Technology and Society, Copernicus Institute. See publication list: <a href="http://www.metis.modules.uu.nl/umetiprd/pk_apn.onderzoek?p_url_id=5716">http://www.metis.modules.uu.nl/umetiprd/pk_apn.onderzoek?p_url_id=5716</a></p>
Purdue University	<p>Purdue University specialists have written a number of papers on the economics of biofuels including:</p> <p>Hertel et al (2008) Biofuels and their By-Products: Global Economic and Environmental Implications, Department of Agricultural Economics, Purdue University. <a href="https://www.gtap.agecon.purdue.edu/resources/download/3974.pdf">https://www.gtap.agecon.purdue.edu/resources/download/3974.pdf</a></p> <p>Ethanol Pricing Issues for 2008 by Wallace E. Tyner, Frank Dooley, Chris Hurt, and Justin Quear Purdue University</p> <p>The Economics of Biomass Collection, Transportation, and Supply to Indiana Cellulosic and Electric Utility Facilities by Sarah C. Brechbill and Wallace E. Tyner, Purdue University</p> <p>Biofuels for all? Understanding the global Impacts of Multinational Mandates by Thomas W. Hertel, Wallace E. Tyner and Dileep K. Birur, Center for Global Trade Analysis Department of Agricultural Economics, Purdue University</p> <p>Biofuels, Policy Options, and Their Implications: Analyses Using Partial and General Equilibrium Approaches, by Tyner, Wallace and Taheripour, Farzad. 2007 Papers</p>

SRI Consulting	US company undertaking research in biofuels market issues including a process economics program. <a href="http://www.sriconsulting.com/">http://www.sriconsulting.com/</a>
<b>International</b>	
IEA Bioenergy (Task 40 for Trade)	<p>Task 40 addresses Sustainable Bioenergy Trade: Securing Supply and Demand. It contributes to the development of sustainable biomass markets in the short and long term and on different scale levels (from regional to global). For reports see: <a href="http://www.bioenergytrade.org/t40reportspapers/index.html">http://www.bioenergytrade.org/t40reportspapers/index.html</a></p> <p>See also: Literature review of lessons learned from European Bioenergy Policies (Martin Junginger, 2007). Including key lesson on continuity of policy support. <a href="http://igitur-archive.library.uu.nl/chem/2008-0423-200511/NWS-E-2007-122.pdf">http://igitur-archive.library.uu.nl/chem/2008-0423-200511/NWS-E-2007-122.pdf</a></p> <p>Workham and Rosillo Calle (2008) On Biofuels: Investor Confidence and Corporate Responsibility. A Case Study of Exxon Mobil, Royal Dutch Shell and British Petroleum (Unpublished report).</p>
International Food and Agricultural Trade Policy Council	Convenes policy makers, agribusiness executives, farm leaders, and academics from developed and developing countries to clarify complex issues, build consensus, and advocate policies to decision-makers.
de Vera	2008 report named 'The WTO and Biofuels: The Possibility of Unilateral Sustainability Requirements', published in the Chicago Journal of International Law, Jan, 2008.
OECD	<p>Trade and Agriculture Directorate has produced a number of studies on bioenergy including policy and economic issues of biofuels. Key publications are: OECD (2008) Biofuel Support Policies: An Economic Assessment, OECD, July 2008. For list of reports see: <a href="http://www.oecd.org/document/25/0,3343,en_2649_33785_39633881_1_1_1_1,00.html">http://www.oecd.org/document/25/0,3343,en_2649_33785_39633881_1_1_1_1,00.html</a></p> <p>OECD (2006) Agricultural Market Impacts of Future Growth in the Production of Biofuels, Working Party on Agricultural Policies and Markets, OECD. <a href="http://www.oecd.org/dataoecd/58/62/36074135.pdf">http://www.oecd.org/dataoecd/58/62/36074135.pdf</a></p>
Parliament of Australia	Webb, R. (2008) The Economic Effects of an Ethanol Mandate, Department of Parliamentary Services. <a href="http://www.aph.gov.au/library/pubs/rp/2007-08/08rp18.pdf">http://www.aph.gov.au/library/pubs/rp/2007-08/08rp18.pdf</a>
UNCTAD BioTrade Initiative	The Initiative seeks to add value by providing interested countries with access to sound economic and trade policy analysis, capacity building activities and consensus building tools. UNCTAD has implemented biofuels assessment studies for several developing countries that have requested it. There are plans for 2009 to review investments in biofuels to understand investment trends and defaults. <a href="http://www.unctad.org/Templates/Page.asp?intItemID=4344&amp;lang=1">http://www.unctad.org/Templates/Page.asp?intItemID=4344&amp;lang=1</a>
ICONE (Institute for international trade)	Brazilian project for the promotion of ethanol as an internationally traded commodity.

negotiations - Private sector sponsored)	
IPC	<p>International organisation promoting trade and development policies in food and agriculture. Its discussion paper (IPC, 2006) outlines key issues that require clarity in the biofuels and trade area.</p> <p>IPC (2006) WTO Disciplines and Biofuels: Opportunities and Constraints in the Creation of a Global Marketplace, IPC and Renewable Energy and International Law (REIL)  <a href="http://www.agritrade.org/Publications/wto_biofuels.html">http://www.agritrade.org/Publications/wto_biofuels.html</a></p>
McKinsey	Caesar W, Riese, J. & Seitz, T. (2007) Betting on Biofuels, Report for McKinsey Quarterly
<b>On-going Government Studies in Support of Biofuels Policy</b>	
<b>UK</b>	
DECC	Market analysis and technology analysis being done through NNFFC (see notes on NNFFC). Ongoing research interests include incentivising second generation biofuels (follow on from the NNFFC barriers of biofuels work) and economic study of how to meet biofuels targets after 2020.
Defra	<p>Key studies include:</p> <p>Deconti, M. (2008) Estimating the Value for Money of Government Support for Biofuels, Defra Economics Group, April 2008.</p> <p>Pfuderer, S. &amp; del Castillo, M.(2008) The Impact of Biofuels on Commodity Prices, Defra Agricultural Economics Unit, April 2008.</p>
Renewable Fuels Agency	Ongoing reporting as part of post-regulatory impact assessment process. Under RTFO reporting requirements the RFA is now collecting country of origin data for biofuels by feedstock.
University of Essex	<p>European level research headed by Mark Harvey</p> <ol style="list-style-type: none"> <li>1. Collaborative partnership between social scientists in Essex and Manchester and the Bioscience for Business Knowledge Transfer Network. (October 2008 to March 2010). ESRC Research Award</li> <li>2. Foresight for European Biofuel Futures – A 2020 Vision (December 2008-09)</li> </ol>
<b>UK Industry and Independent Agency Research</b>	
<b>UK</b>	
LowCVP Programme/ RFA	'Impact of the RTFO on UK businesses' in collaboration with the RFA. It will aim to assess how UK companies, and the agricultural sector, have been affected by the introduction of the RTFO. LowCVP proposes to undertake a review of business effects to inform the RFA's preparation of its annual report. It will involve a survey of LowCVP members and other businesses.
NNFFC	Various projects investigating biofuels market, giving economic evaluations of a number of new technologies and informing investment decisions.
RNCOS	An industry research firm that has published market analysis aimed at industry, e.g. UK Biofuel Market (2006) and Biofuels Outlook (2007).
Vireol plc	Undertaking work on "the role that EU cereal crops can play in providing sustainable bioethanol to assist in meeting the 10% RED target and what policy instruments are needed to ensure this happens". A report 'Sustainable Biofuels For Us' is to be peer reviewed. It will also include an analysis of the potential for biodiesel crops. There are intentions to develop the research in partnership with an academic organisation to address how to deliver sustainable bioethanol for Europe and the role it should play in

	meeting 2020 and future climate change targets.
Company-level research	Limited independent, open-access research on investment and market issues at the level of detail needed to inform some of the key questions, as many analyses are unavailable due to commercial confidentiality.

### 5.2.5 Research gaps

While there is a great amount of research on the economic and market aspects of biofuels, there appear to be gaps in available studies that directly address some of the priority questions and sub questions in this area. As outlined above, the existing work on global modelling of markets does not yet focus on the detailed questions of impacts of biofuels policies on markets and investment at national level. Moreover, they could not realistically be adapted to address UK context questions in the timescale required given the imminent need to adapt to RED and FQD requirements. International studies provide useful general policy analysis and some ad hoc detailed analysis of the workings of mandate policies in other developed countries but these would only inform more UK relevant analysis. The most relevant forthcoming studies at UK level are likely to be the RFA progress reports and supporting LowCVP reviews and surveys of businesses, alongside other industry level research (e.g. by IEA Bioenergy Task 40 on Biofuels investor confidence). While the key source of information regarding questions of investment decisions and market responses to biofuel policy is the industry itself, there is, according to our consultations, a lack of published independent studies in this area. The issue of commercial confidentiality to some extent limits the amount of information available on individual investment intentions on which to build up a picture for the industry as a whole.

Research gaps for the subsidiary questions on impacts of policy decisions on investment and market forces are briefly addressed below:

#### 1) How do biofuel producers develop their investment decisions?

Investments in the biofuels industry in general need to take into account three risk factors: the cost and availability of feedstock, the impact of government regulation and production costs using conversion technologies. These issues are addressed by a number of industry forums<sup>42</sup> and reports aiming to guide potential investors, for example, the report for McKinsey by Caesar et al (2007) and biofuels market reports by RNCOS market research analysts. Other academic research address particular aspects of the developing market, for example, the IEA Task 40 report (Workham and Rosillo Calle, 2008) assesses the reasons for oil companies investing in the biofuels sector. While clearly the detail of specific investment decisions by businesses would vary case by case and would be confidential, we do not consider the general principles of how investment decisions are developed to be a significant research gap. This is distinct from concluding in this chapter that research is needed to estimate how mandates will be met in a number of scenarios (such as ILUC, technical constraints, trade and trajectories to targets) based on future investment decisions.

#### 2) How do producers factor in policy risk?

<sup>42</sup> See for example the bioenergy business newsletter which covers issues influencing investments in the sector: <http://www.bioenergy-business.com/index.cfm?section=home>



Regulatory risk is an important contributory factor to the general question of how investment decisions are developed. This is discussed above and is addressed in the literature cited. Therefore we do not consider how producers factor in policy risk to be a key research gap. However, the question of its relative importance in the current biofuels investment climate in the UK is not yet clear from available research and would be worthy of further investigation (as covered below).

### **3) Relative impact of slowing down biofuel mandates compared to the impact of other factors (economic slowdown; oil prices; exchange rates; individual operating models)?**

The issue of the uncertainty within the current UK biofuels policy environment is explained in Section 5.1.2 and is cited by industry stakeholders as a major factor in recent investment trends. The relative importance of uncertainty over mandate schedules compared to other explanatory factors in explaining the current investment climate is not yet established by available research, although indications are that it is a main determinant. This issue is included in the research gaps conclusions given below (Table 5-2) within the assessment of the impact on markets and investment decisions of trajectories to targets.

Research Gap 1: Market and investment decisions according to scenarios for **trajectories to targets** (this would include slow down of targets in RTFO, EU review clause in 2014).

### **4) How much uncertainty is there with: (a) The 2014 EU review clause? (b) The ILUC factor?**

Both these issues have not been researched in any depth in the UK context in terms of their impacts on market and investment decisions relative to other factors. In the case of the EU review clause, although there has been strong opposition by industry representatives, this is a relatively recent development for research, and studies which analyse the likely impact of this aspect of policy have yet to be published. One industry consultee gave the opinion that the clause is unlikely to affect investment and that, while groups may try to influence long term direction, decisions are still likely to be based on short-term options. The methodology of an ILUC factor and production specific application in future sustainability criteria is unknown. Therefore, this is part of the picture of policy uncertainty relevant to investment decisions for products and processes.

Research Gap 2: Market and investment decisions according to scenarios for the design and introduction of **sustainability requirements** including ILUC factors

### **5) Relative importance of local vs. export markets for investment decisions?**

A number of factors determine investment for local or export markets. These include differences in biofuels support policies between countries, barriers to trade, exchange rates and other trading variables that will vary over time. Research gaps on trade issues exist both at a global level (understanding the international market for biofuels and the impact of trade barriers of various types) and at the level of the UK market (specifically how trade in biofuels may be impacted by mandates and sustainability requirements). To what extent might these policies drive imports of biofuels or domestic production. Where would any imports be sourced and what would be the impacts on price? Additionally, what scenarios would drive exports of UK produced biofuels to where overall returns may be better? Basic understanding of biofuel trade has been hampered by the lack of biofuels data in international trade databases due to the lack of a designated customs code. Under RTFO reporting requirements the RFA is now collecting country of origin data for biofuels by feedstock, which will go some way to filling this gap for the UK.

There remain uncertainties about the application of sustainability requirements under WTO rules. A number of studies address the legal and technical questions in interpreting WTO rules but a research gap here is the market and trade ramifications of the answers to these questions. That is, how will interpretations and rulings on sustainability requirements for biofuels mandates impact on investment and international trading decisions?

Research Gap 3: **Trade** in biofuels and feedstocks (i.e. imports and exports of biofuels and feedstocks, taking into account scenarios for trajectories to targets and sustainability requirements and including issues of WTO interpretations of sustainability criteria and differing biofuel policy regimes to trading partner countries). To what extent might these policies drive imports of biofuels or domestic production? Where would imports be sourced and what would be the impacts on price?

**6) How long will it take for producers to ramp up production to meet a 10% target (with varying breakdowns of first versus second generation)?**

This is a complex question which depends upon a variety of market factors and resolution of policy uncertainties. Indeed, as mentioned above, there is no guarantee that UK producers will increase production to meet targets if it is not economic for them to do so and it may be that imports fill the gap. Key research gaps here are therefore to understand how biofuels mandates will be met under a number of possible policy, market and trade scenarios and this is addressed further below.

**7) When will we see installation of production methods which take account of any additional ILUC sustainability criteria agreed in 2010, and the review clause?**

From our review of sources, these issues of timescales to meet sustainability criteria and any changes brought about by the review clause are not analysed in any depth. This is understandable given the current uncertainties about ILUC methodologies and what changes may result from the review clause.

Research Gap 4: Different scenarios for the impact of **development of technologies** (i.e. changes in production capacity and costs due to development of second generation technologies and other production enhancements)

**8) How much impact will either have on investment and market decisions, compared to other factors?**

See previous answer.

Research Gap 5: **Other market factors** such as economic slowdown, input commodity prices, oil prices and exchange rates

## **5.2.6 Summary and conclusions**

To take forward the research on markets and investment in the UK context, a key question to address, which underlies the subsidiary questions given above, is how will targets be met?

Conditions for investment, capacity/supply and trade, and the impacts of policy measures on these, should be better understood in order to map out scenarios whereby mandates are fulfilled without unintended market consequences (for example, lack of UK investment in capacity may necessitate sourcing of imports). We would stress the importance of an integrated assessment of the impacts of specific policy decisions and other market factors in order to address the question of how targets will be met, rather than taking these factors in isolation.

Detailed modelling of the biofuels market based on an extension of existing global market models (as described in Section 5.1.4) is a longer term prospect but, in order to improve understanding in the short and medium term as dictated by current policy developments, a number of inter-related ad hoc studies could be undertaken on different aspects of how the biofuels mandates will be met. These would build on available data and surveys in order to estimate the impacts in the biofuels sector of given scenarios of policy development and market conditions.

The key research gaps that we suggest need to be addressed are given in Table 5-2. Taken together these address the question of how UK mandate targets will be met and include:

1. Impacts of biofuel policy decisions on:

Research Gap 1: Market and investment decisions according to scenarios for **trajectories to targets** (this would include slow down of targets in RTFO, EU review clause in 2014),

Research Gap 2: Market and investment decisions according to scenarios for the design and introduction of **sustainability requirements** including ILUC factors.

Research Gap 3: **Trade** in biofuels and feedstocks (i.e. imports and exports of biofuels and feedstocks, taking into account scenarios for trajectories to targets and sustainability requirements and including issues of WTO interpretations of sustainability criteria and differing biofuel policy regimes to trading partner countries). To what extent might these policies drive imports of biofuels if investment in domestic production does not produce the required capacity, where would this be sourced and what would be the impacts on price?

Research Gap 4: Different scenarios for the impact of **development of technologies** (i.e. changes in production capacity and costs due to development of second generation technologies and other production enhancements).

2. Impacts of other factors on market and investment decisions:

Research Gap 5: **Other market factors** such as economic slowdown, input commodity prices, oil prices and exchange rates.

Bearing in mind the short timescales in current development of policy at UK and EU level and the current policy uncertainty which affects the investment climate, there is a high urgency to address all the research gaps identified in order to provide a firm foundation for meeting mandate targets through promotion of the most sustainable biofuels.

Similarly the significance of each of the identified research gaps is rated as high in the matrix at the start of this section. This is because each of these gaps represents a key factor in the analysis of future development of the market which should not be missed from the overall assessment. Differences in the size of the gap between the identified research issues reflect differences in the estimated amount of work involved in addressing the issues. The complexity of assessing the impact of 'sustainability criteria', 'development of technologies', 'trade' and 'other market factors' on market and investment decisions are estimated at medium to large due mainly to the number of issues involved. Assessment of impacts of 'Trajectories to targets' may be relatively less complex (small to medium) due to the limited number of likely trajectories to take into account.

**Table 5-2 Policy decisions on investment and market forces – key findings<sup>43</sup>**

Research Gap	<i>Impacts on market and investment decisions of biofuel mandates</i>				<i>5) Impact of other factors on market and investment decisions (Economic slowdown, commodity prices, exchange rates.</i>
	1) Trajectories to targets	2) Sustainability criteria	3) Trade	4) Development of technologies	
Key related work	Some ad hoc studies	Some ad hoc studies	IEA Task 40	Some ad hoc studies	Some ad hoc studies
Complexity	**	**	**	**	**
Time scale	*	*	*	*	*
Potential costs	*	*	*	*	*
National or international?	UK/EU	UK/EU	UK/EU	UK/EU	UK/EU
Availability of data		Being developed	Some available	Some commercial	Some commercial/ some available
Availability of skill sets	**	**	***	**	**

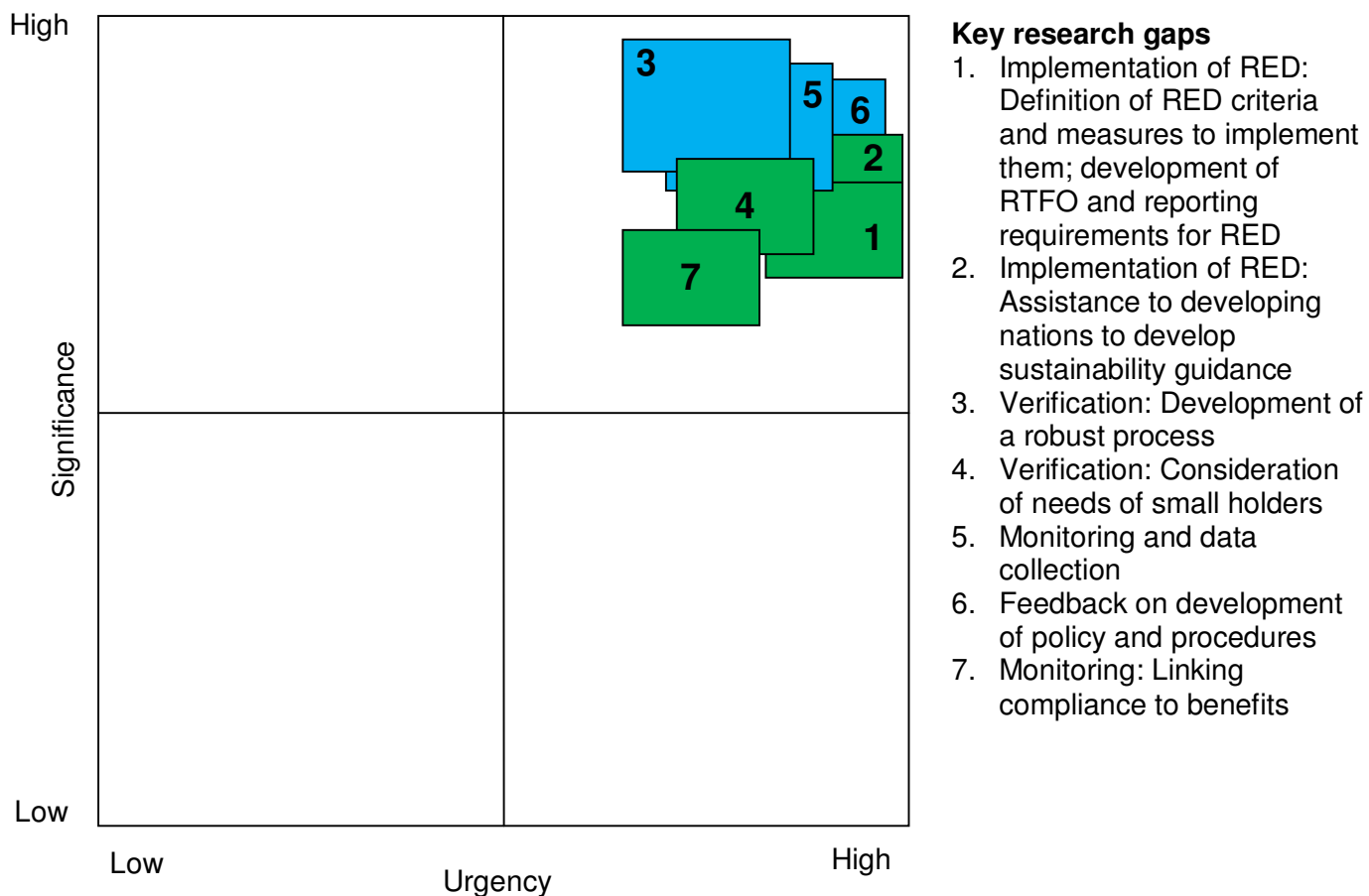
**Key**

<b>Significance</b> – please see matrix	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k * <£100k	<b>National or international</b> i.e. Can the work be done in the UK or would it be better done internationally?
<b>Availability of data</b> This will refer to the IPR/availability of R&D already ongoing in the area (e.g. Commercial – restricted; or published/available)			<b>Availability of skill sets</b> *** A number of organisations working in area ** Availability restricted to a few groups or only on international scale * Skills gap, significant training required.	

<sup>43</sup> Guidance on the ratings is provided in the Executive Summary

## 5.3 Sustainability and supply chain

Figure 5-2 Matrix prioritising key research gaps for sustainability and supply chain



Size of Research Gap

	Small
	Small / Medium
	Medium / Large
	Large

### 5.3.1 Executive Summary

*1) What are the most effective, efficient and economic ways to trace the sustainability characteristics of biofuels along supply chains and what are the benefits, costs and risks of different approaches? How do we ensure that we can trace the sustainability of biofuels used in the UK?*

*2) Do sustainability standards work in terms of achieving the outcomes they are developed for? Are there better or worse approaches?*

*3) If the aim is to increase development, should the EU have mandatory social sustainability criteria, or reporting standards, or anything? If reporting standards, are the current EU formulations the best kind?*

This chapter examines the work that has been done on one of the key tools available to assist the implementation of sustainability policies for biofuels – that is certification of sustainable practices, coupled with independent auditing to verify that the biofuels supplied are sustainable. This is not the only tool open to policy makers: we have already discussed the use of GHG life-cycle assessment; and there are options to use selective eligibility for support through elimination of biofuels produced from certain types of land or of specific biofuels crops. However, if good practice is to be rewarded there is a need for a framework through which it can be developed, monitored, certified and audited.

In the case of biofuels the RED has already defined the fundamental sustainability criteria and reporting requirements. The UK has to define a framework to achieve these, but it is fortunate in that the work that went into defining the RTFO is very relevant to the implementation of the biofuels sustainability criteria in RED. In addition, the Dutch and German governments have supported work in the area; the EC itself is developing guidelines over the next year; and internationally there has been considerable work by the UN and FAO, as well as producer groups such as the roundtables on sustainable palm oil and soy and the Better Sugar Initiative. The UK is also already participating in initiatives such as the Roundtable on Sustainable Biofuels (RSB) and the Global Bioenergy Partnership (GBEP), both of which are examining the potential for international harmonisation and integration.

This chapter considers current and future research in this area in order to identify the research gaps, which must start to be filled before we continue to take forward sustainability criteria. These gaps cover three areas: the implementation of RED in the UK; verification; monitoring and feedback.

#### **Implementation of RED in the UK**

Research Gap 1: There is a need to define exactly what the RED sustainability criteria mean and what key indicators will measure them. This work could co-ordinate with the work of the EC and other EU nations to achieve these sustainability requirements and build on the work that the LowCVP is proposing in the area to examine how the impact of RED on the RTFO. There is also a need to ensure that RED covers all of the sustainability criteria of importance to the UK and to examine ways to achieve these in areas where RED is lacking. This work will need to consider mechanisms for demonstrating compliance and that the impact on biodiversity, water resources, water quality and soil quality is reported.

Research Gap 2: There is a need to provide assistance to developing nations to help them develop sustainability guidance to enable their producers to provide sustainable biofuels.

**Verification**

Research Gap 3: Development of a robust verification process, based on the experience of sustainability schemes for other commodities.

Research Gap 4: Consideration of needs of smallholders. Including rules that do not exclude or disadvantage small producers or suppliers.

**Monitoring and feedback**

Research Gap 5: Monitoring and data collection on both the positive and negative impacts of biofuels production are vital to inform policy development in this area. Operational monitoring would mean compliance with the standards and strategic monitoring would allow the EU to understand whether the criteria are actually working, i.e. delivering the desired impacts. This monitoring should also provide information on costs and consumer decisions related to the certification.

Research Gap 6: Developing a mechanism to feed back the results of the above work into improvement of sustainability schemes and into the development of policy and procedures.

Research Gap 7: Research into systems that link compliance with benefits.

**5.3.2 Context**

In Europe, biofuels policies have been driven by three drivers: a need to cut GHG emissions from transport fuels, security of supply and agricultural development. In achieving the former it has been important to ensure that environmental impacts are minimised. In order to do this, sustainability criteria have been applied to biofuels in a number of EU member states (e.g. UK, the Netherlands, Germany and Sweden). Biofuels are not the only commodity that sustainability criteria are being applied to, merely the latest. Over the past decade or so, sustainability has been applied to a variety of agricultural and forestry commodities. There is a wealth of experience from these schemes. What is generally unique to biofuels is the consideration of GHG life-cycle assessment (LCA) as a key requirement to demonstrate sustainability and to try to capture complex issues such as land use change and indirect effects.

In terms of development of policy, the UK is probably the furthest ahead with its development of sustainable biofuels policy, with the development of the Renewable Transport Fuel Obligation (RTFO), but other countries (noticeably Germany and the Netherlands) have been developing similar schemes and some companies have also been involved in roundtable discussions on sustainability schemes (e.g. for soy, palm oil and sugar).

All of this means that there is a wealth of knowledge on the establishment and verification of sustainability schemes. Over the past few years a number of very good reviews of the topic have been produced to examine what can be learnt from other certification schemes, the requirements of verification and the way in which sustainability can be tracked through the supply chain. Examples of these reviews are listed in Box 5-1; they can be found on the Global Bioenergy Partnership (GBEP) web site.<sup>44</sup> In addition the LowCVP has recently summarised work in the area (LowCVP 2008).

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<sup>44</sup> [www.globalbioenergy.org](http://www.globalbioenergy.org)



**Box 5-1 Recent reviews of sustainability schemes for agricultural commodities**

- BTG (2008) Sustainability criteria and certification systems for biomass production, prepared for DG TREN – European Commission
- Dam, J. v., Junginger, M., Faaij A., Jürgens, I., Best, G. and Fritsche, U. 2006. Overview of recent developments in sustainable biomass certification
- Dehue B., Meyer S. and Hamelinck C 2007. Towards a harmonised sustainable biomass certification scheme. Report commissioned by WWF International
- E4Tech, ECCM and Imperial College, London, June 2005. Feasibility Study on Certification for a Renewable Transport Fuel Obligation. Final Report
- Ecofys 2007. Sustainability reporting within the RTFO: Framework report, prepared for UK DfT  
<http://www.dft.gov.uk/consultations/closed/rtforeporting/sustainabilityreportingv2>
- Cramer et al. 2007 Testing framework for sustainable biomass
- Nussbaum R and Simula M 2004. Forest Certification; A review of impacts and assessment Frameworks. The Forests Dialogue
- UNEP 2007. Working Group on developing sustainability criteria and standards for the cultivation of biomass used for biofuels

These reports have expressed concerns about the potential environmental impacts of biofuels production, many of which have been covered in other chapters of this report (see Chapters 2 and 3). It is important that these impacts are addressed so that biofuels deliver maximum benefit with minimal negative effects. For example, there are potential benefits from biofuels, particularly at a small-scale in rural areas in developing countries and in their role in decreasing emissions from and providing security of supply for transport fuels. The role of sustainability schemes is to preserve (or enable) the benefits, while minimising the impacts. This includes methods to monitor the sustainability of biofuels (benefits and impacts) and their effectiveness and costs, including:

- How to source and track sustainable feedstock and the role of certification schemes in enabling this.
- Supply chain issues (including certification).
- How efficient, effective and economic are certification schemes? What are their core risks?
- Assessment of enforcement and operability of sustainability criteria.
- Effectiveness of sustainability in markets (consumer and supplier choices).

In the EU there are a number of significant developments on monitoring the sustainability of biofuels in addition to the UK's RTFO:

- Germany has developed the BioNachV (Biofuels Sustainability Regulation, 2007), which is designed to achieve sustainability criteria in the German Biofuel Quota Act (sustainable management of agricultural areas, protection of natural biospheres and a specific GHG reduction potential). (See: Fehrenbach et al (2008).
- The Dutch will also develop their own standard (NTA8080) based on Cramer criteria (Cramer et al 2006).
- The Swedish biofuels supplier SEKAB has developed a sustainability scheme bilaterally with Brazilian biofuels suppliers.<sup>45</sup>

<sup>45</sup> See: <http://www.sustainableethanolinitiative.com/default.asp?id=1062>

- The EU RED also includes sustainability criteria related to the land on which biofuels feedstocks are grown and the greenhouse gas savings achieved.

Elsewhere, the Renewable Fuel Standard (RFS) of the Energy Independence and Security Act (EISA) in the USA has targets for life-cycle GHG emission savings from biofuels production and specifies that this must cover direct and indirect emissions.<sup>46</sup> In other countries including Brazil, Australia and New Zealand, sustainability issues are also being examined. Brazil is developing a sustainability scheme through INMETRO.

As a result of this interest, it has been recognised that harmonisation of sustainability standards is important to prevent a proliferation of schemes and confusion/additional costs for suppliers. A number of Governments are working internationally to ensure harmonisation and have welcomed the initiatives of the Roundtable on Sustainable Biofuels (RSB),<sup>47</sup> which is seeking to enable harmonisation and to provide a vehicle for international discussion.

Thus sustainability schemes for biofuels are under development, but there are still a number of issues to be examined. These include understanding how effective certification schemes are (including whether they result in exclusion of small scale production<sup>48</sup>); understanding how predominantly Northern/Western initiatives can be applied effectively in the 'south'; and understanding how verification will work: who will play the watchdog?

### 5.3.3 Key research questions

The above section indicates that there are policy issues for sustainability monitoring, which relate to ensuring that the methods of monitoring sustainability are efficient and effective and that the sustainability standards achieve what they set out to do. This section explores what research exists in relation to three key questions, and a number of sub-questions for each:

#### 1) **What research is there on the most effective, efficient and economic ways to trace the sustainability characteristics of biofuels along supply chains and what are the benefits, costs and risks of different approaches? How do we ensure that we can trace sustainability of biofuels used in the UK?**

This is underpinned by an analysis of what research there is on:

- What are the most effective, efficient and economic techniques to source sustainable feedstock (e.g. book and claim, mass balance, track and trace), including assessment of administrative burdens?
- What role can and do certification schemes play? Can they make the process more effective, efficient and economic?
- What are the risks in tracing sustainability (e.g. double counting (book and claim), exploitation of the system)?
- What are the approaches to verification?
- Is there evidence on whether requirements for sustainability result in biofuels trading in alternative markets?
- How operable and enforceable are the various types of sustainability criteria and how can they be made easier?

<sup>46</sup> See: <http://epa.gov/otaq/renewablefuels/index.htm#regulations>

<sup>47</sup> See, for example, RSB workshop on biofuels and land use change Brazil 20-21 November 2008. <http://cgse.epfl.ch/page76199.html>

<sup>48</sup> UNCTAD work is specifically warning about these issues. There is good evidence from socio-economic studies that small-scale production can have many advantages, but also evidence that sustainability certification can be one of the factors that encourages the concentration of production onto plantations. In addition previous certification schemes have resulted in non tariff barriers. The cost of these are often higher for smallholders, and these certification schemes could therefore block their access to northern markets (UNCTAD 2008).

- Can sustainability criteria be circumnavigated or avoided - are there loopholes?

**2) What research is there on whether sustainability standards work in terms of achieving the outcomes they are developed for? Are there better or worse approaches?**

This is underpinned by an analysis of what research there is on:

- Do sustainability standards work in terms of achieving the outcomes they are developed for? Does this differ depending on whether they are mandatory or if reporting is voluntary?
- Reporting standards: to what extent do consumers base choices on fuel supplier sustainability records and are fuel suppliers changing their production methods to ensure they can provide positive sustainability reports?
- What is the price premium for biofuel producers (EU or elsewhere) to produce sustainably and does it compensate for the extra cost?
- Do individual biofuel producers produce biofuels with differing sustainability characteristics for different markets?

**3) What research is there on whether, if the aim is to increase development, should the EU have mandatory social sustainability criteria, or reporting standards, or anything? If reporting standards, are the current EU formulations the best kind?**

This is underpinned by an analysis of what research there is on:

- What are the impacts of biofuel sustainability criteria on social sustainability in developing countries? How does this differ depending whether the standards are mandatory or reporting obligations? Are exporters of biofuels likely to change behaviours to meet the EU sustainability criteria?
- Are there other approaches by which biofuel production can drive up developing country social sustainability?
- Would sustainability standards price developing country biofuel out of UK/EU markets?
- Are there unintended consequences of social sustainability standards?
- Is there research on the trade impacts of social sustainability criteria?

The section below looks at R&D already being undertaken in these areas and then examines where the key gaps are.

### 5.3.4 Research in the area

**Table 5-3 Current research work on sustainability and supply chains**

Funding or research organisation and budget where available	Current status of research
<b>UK</b>	
RFA	Monitoring and analysis of RTFO - this is the first biofuels national sustainability scheme and, as such, its results are invaluable.
LowCVP	Has done a lot of work to support the development of the RTFO and produced reports on sustainability reporting and development of a biofuel label. Over the next year plans to support implementation of the RED and FQD.

<b>Funding or research organisation and budget where available</b>	<b>Current status of research</b>
Rothamsted (jointly managed by ESSRC and BBSRC)	Under RELU, Rothamsted developed a framework (encompassing social, environmental and economic consequences) for sustainability appraisal of the conversion of land to energy crops (SRC and Miscanthus) in 2008. This represents a useful analysis of the UK situation regarding these crops and uses fundamental principles for assessing sustainability and provides useful data for development of sustainability monitoring for the UK, particularly for biodiversity.
BBSRC	BBSRC is participating in an ERA ARD Net Call on a project entitled 'Is bioenergy an opportunity or threat to the rural poor?' This work will provide information for sustainability certification, but not directly contribute to the development of sustainability schemes.
University of Nottingham, funded by BBSRC and industry.	BBSRC will be working on environmental sustainability of biofuels. The work will involve several quantitative appraisal methods, such as environmental LCA, including ILUC and net energy analysis. The environmental (specifically carbon) implications of selected biofuel routes will be mapped. Whole work programme complete by 2014.
<b>Europe</b>	
DG TREN	Support for the development of sustainability criteria within the RED.
DGR TD FP7, current call KBBE 2009-3-4-01	Sustainability certification and socio-economic implications, to include Latin America and/or African ACP and/or Asia.
CEN	Development of sustainability standards for biomass (CEN TS 383). NEN is leading this work. Timeframe for delivery of standards is May 2011.
COMPETE	Supports work on bioenergy across Africa, including support for workshops on sustainability and data gathering for criteria important to sustainability.
Germany	German standard includes requirements for protection of natural habitats and GHG reduction potentials (more stringent than the EU RED requirement). Soy and palm oil biodiesel excluded.
GTZ/PROBEX	Monitoring system on the impacts of biofuels development. Will be developing a pilot methodology for implementation of sustainability for specific African countries.
The German Agency for Renewable Resources (FNR). Project co-ordinator: Méo consulting.	German International Sustainability and Carbon Certification (ISCC project): a pilot project on the certification of sustainable biofuel production. Creation of a certification system for Europe, Brazil, Argentina, Malaysia and Indonesia to enable the verification of sustainability and reduction of GHG emissions, using mass balance monitoring along the supply chain and independent verification.
GTZ and German ministry for Economic Cooperation and Development (BMZ)	ZALF proposed work on socio-economics relevant to biofuels. This work will include a sustainability impact assessment for an African case study region to include assessment of implications of biofuels for livelihood, environment, regional economy, and implications for food security, as well as the development of a decision support model for farmers and local authorities on the planting and cultivation of biofuels crops.
Dutch government	Implementation of trial projects to produce biomass more sustainably, in cooperation with producing countries. There is support for a pilot project on the import of sustainable biomass from developing countries and large producing countries.

<b>Funding or research organisation and budget where available</b>	<b>Current status of research</b>
NEN (Dutch standards institute)	CEN TC383 – Dutch government is supporting this EU-wide development of sustainability standards for biofuels. This work is divided into six working groups including WG5 on verification and auditing.
Stockholm Environment Institute, CARENDA project	Aimed at synthesis, policy analysis and North-South-South knowledge transfer. Ran from 2002-2006. Did not develop sustainability criteria or certification, but examined the experience of sugar cane producers in Africa and the experience of improving best practice (e.g. use of water resources, air emissions, social issues and the use of co-products).
SEKAB (renewable fuel supplier)	Sweden-Brazil sustainable ethanol initiative (including environmental and social criteria). A list of principles has been agreed (including GHG calculation methodology guided by RTFO methods). The scheme will have independent third party verification and will include a chain of custody (track and trace) audit.
<b>US</b>	
Council for Sustainable Biomass Production	A North American initiative to develop voluntary sustainability principles for biomass (USDA and USDOE both on steering committee). These will apply to biofuels from lignocellulosic processes. Will develop principles, guidelines and/or measures to address core issues. Working with RSB.
California Air Resources Board (CARB)	The California LCFS establishes GHG emission reduction requirements and is examining sustainability issues associated with LUC. Target is to develop a plan for incorporating sustainability metrics into the LCFS by December 2009. CARB will work together with other State agencies, national and international organisations, NGOs, and other interested parties to develop an appropriate sustainability strategy.
National Biodiesel Board (NBB)	Biofuel sustainability task force – supports industry to develop sustainable biofuel (as seen through improved life-cycle GHG emissions), but it is also looking at the issues of ILUC and working with RSB. The NBB has also developed a list of principles for sustainable biodiesel and will develop guidance statements for each principle to be used by industry to develop best management practice.
Packard Foundation (\$250,000 - 1 year)	Winrock international will be doing work to support effective sustainability standards. The work will seek to collate and disseminate existing information and data related to biofuel sustainability; deliver a report on Building Capacity to Monitor Standards for Biofuels; and develop Country Profiles, which will summarise the impact evaluations for 3 countries (Brazil, Indonesia and US) and illustrate how the criteria used in various sustainability standards, if applied, could impact quantities of biofuels produced, GHG emissions and other parameters.
<b>International</b>	
UNCTAD	Has examined 'fair certification schemes' (2008), to balance positive benefits with risks of discrimination for some producers, as part of its BioTrade initiative.
UNEP	Active in the area of biofuels and biofuels certification through the RSB and FAO. Is supporting a joint international workshop on bioenergy, biodiversity mapping and degraded lands (July 2009). Has also supported workshops with the RSB, IUCN, and FAO on high conservation value areas. With GEF funding is undertaking work on assessment and guidelines for sustainable liquid biofuels production in developing countries. (see:

Funding or research organisation and budget where available	Current status of research
	<a href="http://gefonline.org/projectDetailsSQL.cfm?projID=3224">http://gefonline.org/projectDetailsSQL.cfm?projID=3224</a> ). This work will include examination of standards and criteria for indicators including methods for their determination.
US	USDA, USDoE and EPA involved in interagency working group that will examine the sustainability of biofuels (mainly for US grown biofuels). USDA is also supporting work on improved uses and values for the by-products of the developing biofuels industry as well as the social implications of alternative farming systems.
Sustainable Biodiesel Alliance	Has issued sustainability criteria.
Leonardo Academy leading with multi-stakeholder approach	ANSI - national sustainable agriculture standard that includes the development of a biofuel section.
EMBRAPA (Brazilian Research Centre for Agriculture)	Sustainability certification is one of Brazil's key priorities: <ul style="list-style-type: none"> <li>• Program of Biofuels Certification developed by INMETRO which is working with US National Institute of standards and EU CEN initiatives to develop standards for sustainable biofuels.</li> <li>• EMBRAPA is co-ordinating AEZ for sugar cane at national level (zoning refers to guidance for licensing and credits concessions).</li> <li>• Also examining sustainability of small production systems, the potential to recuperate degraded areas sustainability of production systems and environmental quality policies.</li> </ul>
UNICAMP	Undertook a review of sustainability of ethanol production in Brazil, supported by Defra (Walter et al 2008).
Roundtable on Sustainable Palm Oil, Better Sugar Initiative and Roundtable on Responsible Soy	These agreements are central to sector efforts to develop sustainability certification for crops relevant to biofuels. These are some of the most significant developments in the area. See: <a href="http://www.repo.org">www.repo.org</a> ; <a href="http://www.bettersugarcane.org">www.bettersugarcane.org</a> ; <a href="http://www.responsiblesoy.org/">www.responsiblesoy.org/</a> .
GBEP	The Global Bioenergy Partnership's programme of work includes a thematic focus on sustainability and trade. It has established a Task Force on Sustainability, which facilitates the sustainable development of bioenergy and collaboration on bioenergy field projects. This Task Force is working to develop a set of global science-based criteria and indicators as well as examples of experiences and best practice. (see <a href="http://www.globalbioenergy.org/programmeofwork/en/">http://www.globalbioenergy.org/programmeofwork/en/</a> )
Jatropha Sustainable Biofuels Alliance	Aim is to support development of Jatropha as a sustainable biofuel. Also works with the RSB as the 'Jatropha Working Group'. This alliance also keeps a record of Jatropha projects worldwide. Will examine the viability of Jatropha on marginal land and the GHG balance of applications.
International Energy Agency	Bioenergy Agreement Task 40 (Sustainable International Bioenergy Trade) – information exchange including workshops and publications on trade and sustainability certification. Workplan for 2010–2012 currently under discussion.
Dutch and Malian organisations and World Bank.	Mali Folkecenter – Malian NGO committed to sustainable development of rural populations. Working on sustainable production of Jatropha. Work completed in 2010.
CURES	Undertaking impact evaluations of a sample (8) of small to medium scale biofuels projects run by NGOs or SMEs. Mostly look at socio-economic impacts of the rural households and looking at a few

Funding or research organisation and budget where available	Current status of research
	environmental effects. Has worked with RSB on sustainability certification.
ERIA	The Sustainable Biomass Utilization Vision in East Asia: research within individual academic member institutions now underway and will explore sustainability metrics in a regional context.
InterAmerican Development Bank	Has created a scorecard based on version zero of the RSB. The World Bank is also developing a draft with WWF.
Industry	
Greenergy	Supporting work on the development of practical measures to manage ILUC. Very little direct information provided by industry on its work, due to confidentiality issues; however, we know that industry is involved in sustainability certification through membership of initiatives such as the RSB, BSI and RSPO; and that some companies are establishing internal procedures to source sustainable biofuel and others are undertaking or commissioning their own work on GHG emissions methodologies.
Shell, BP and Petrobras	Shell has a detailed policy for sustainable sourcing of feedstock. Shell, BP and Petrobras are working together to address sustainability and are participating in the RSB. Many of the oil suppliers are investing in second generation biofuels or in more sustainable feedstock for first generation fuels (e.g. Jatropha or algae).
Neste oil	Studying the whole production chain in terms of sustainability. The goal is to understand all the effects of biofuel production (direct and indirect) and then create a system that mitigates unwanted effects.

### 5.3.5 Research Gaps

The global biofuels market is still developing and expanding. Development of sustainability schemes to ensure that biofuels meet certain standards has to take this into account; and it has to result in schemes that are flexible enough to work within an immature and evolving market, that do not add additional (bureaucratic and cost) burden to the supply chain, and that are clear and transparent enough to allow enforcement and verification. This is a big demand of a developing market and we are at the beginning rather than the end of the process. Sustainability schemes still have to be developed and agreed on an international level; often data are still required to enable quantitative criteria to be developed; some issues are outside certification (e.g. GHG life-cycle assessment still has to be adopted in many certification schemes) and some factors (e.g. indirect land use change) are always likely to be controversial and therefore difficult to gain agreement on or to measure in a transparent way.

The questions posed above are broken down into three areas. We have examined gaps in each of these areas separately.

**1) What research is there on the most effective, efficient and economic techniques to source sustainable feedstock (e.g. book and claim, mass balance, track and trace), including assessment of administrative burdens?**

**Certification schemes**

Certification schemes are in place for a number of biomass commodities, notably timber (e.g. the FSC). Experience with these schemes indicates that industry finds them a good practical mechanism for identifying origin and sustainability of the certified commodity (Proforest and ODI 2008). Because of this experience the international community is working on a number of initiatives to develop sustainable biofuels, including the development of meta-standards for biofuel certification. This indicates that there is a consensus that certification is an important tool for sustainability, although there is also agreement that there are gaps in certification and issues with its deployment and that other tools need to be developed as well. For example, GHG life-cycle assessment is often not included in current certification schemes and many schemes do not include social sustainability. In addition, there is a role for other tools, such as the definition of designated areas where development of biofuels should not be allowed. All of these tools require further development, particularly for compliance with WTO, development of methodologies to take ILUC into account and incorporation of GHG LCA into current certification schemes. In the EU there is an urgent need to develop a sustainability scheme to meet the sustainability criteria in the RED and the EC is supporting work at JRC and recruiting other work to meet this need.

Table 5-3 above and Annex 5 show that there is a lot of ongoing work, particularly in the EU, the USA and Brazil. The UK could usefully examine where it would be more effective to work with these initiatives rather than working alone. Mechanisms such as UK participation in EU initiatives and its involvement with GBEP and relevant UN initiatives will enable the UK to work internationally.

There have been many calls for harmonisation of schemes to decrease costs and bureaucracy (from industry and developing nations) and to prevent the development of different markets with subtly different requirements. The RSB is active in attempting to rationalise this development and to provide a focus for discussion and information exchange. However, legal requirements for sustainability in the US are dictated by the GHG emissions requirements of the EISA and are different to the sustainability requirements in the RED in the EU; these are also different to the RTFO in the UK and to schemes proposed for Germany and the NL. The World Trade Organisation also has an important influence on trade of any commodity. Thus the **harmonisation of sustainability criteria** seems a long way off, but without it there is a serious problem of proliferation of schemes, of confusion of the market and of addition burdens of cost and bureaucracy, such that the more stringent schemes may fail. If the UK is serious about ensuring its biofuels are sustainable it must be active in international negotiation and it must be clear about what is and what is not acceptable. It should be possible to harmonise minimum requirements, particularly as there are sustainability principles and criteria that are common to many schemes. GBEP, the EU RED sustainability scheme and the RSB are all mechanisms by which the UK can influence the development of harmonised schemes.<sup>49</sup> Working with the other like-minded countries, which have developed principles and criteria similar to the RTFO, would add strength to the UK's position.

<sup>49</sup> Proforest states that 'where roundtable approaches are adopted there is the potential to change the perceptions of an entire sector about the way a feedstock should be produced. For example, in Malaysia the national government has just made a commitment to support implementation of the RSPO Principles and Criteria for the whole oil palm sector in the country. This includes a very substantial budget (MR\$50 million) to support small producers.' (Proforest and ODI 2008)



The European Environment Agency has said that: “more work is required on the ultimate scale of biofuels that are possible within sustainability/biodiversity guidelines”. It also says that this work needs to be done on an international rather than just a EU basis and that land use change should be included in considerations. In 2007, the EEA Scientific Committee made public its opinion on the environmental impacts of biofuels use in EU and called for a new comprehensive study on the environmental risks and benefits of biofuels. Table 5-3 shows that there is ongoing work on the environmental risks and benefits of biofuels, for example, the work being supported by BBSRC and the work being done by NGOs and UN organisations in developing countries. Nevertheless, more data is required; UNCTAD (2008) list the following areas for work:

- The credibility of certification schemes may be closely linked to the inclusion of criteria that are quantifiable and verifiable – efforts should be deployed to develop this kind of criteria.
- Convening regional meetings to discuss the criteria and approaches that best suit a specific region.
- Spreading the costs of the certification scheme along the whole supply chain.
- Capacity building for compliance, testing and conformity assessment, particularly fostering the involvement of producers in developing countries.
- Linking compliance to benefits to encourage producers to engage in sustainable production.
- At policy level coherent strategies are needed for biofuels (e.g. a comprehensive approach could include objectives for access to energy, rural development and climate change stabilisation).

The results of such work have to be fed back into sustainability criteria and certification, but the mechanism for doing so is not currently clear.

There are many opportunities for biofuels feedstock production in Africa, but GTZ (2008) says that there is “still little knowledge and understanding on how Africa should be able to implement sustainability criteria imposed by the importing nations.” There are some pilot schemes designed to develop guidelines for sustainability in specific areas (for example the GTZ work reported in Table 5-3 and work supported by the UN). The success of these schemes needs to be evaluated and, if they are successful, the schemes will need to be rolled out regionally.

Certification schemes often do not encompass indirect land use change (ILUC). This issue is examined in detail Chapter 2. Currently, most initiatives are focused on inclusion of some form of accounting for ILUC in GHG LCAs. This is a highly complex area in which the UK would benefit from international effort - and some of our key researchers are already working internationally on this topic.

This work has led us to define the following gaps:

Research Gap 1: The RED provides a number of sustainability criteria, including a requirement to achieve a minimum GHG saving, as measured through life-cycle assessment and including an appreciation of land use change, which has been discussed in Chapter 3. Here we are interested in how the RED will ensure that biofuels produced from conversion of land of high carbon stocks, including wetland and continuously forested areas, will be excluded; that biofuels do not originate from bio-diverse land (which are defined as forest undisturbed by significant human activity or highly biodiverse grassland); and that biofuels produced within the EU should comply with agricultural good practice. There is a need to define exactly what the RED sustainability criteria mean and what key indicators will measure them: there is a need to define the lands that are excluded and the precise meaning of the terms used; to define how an inventory of such lands will be developed; and to define the precise mechanism by which exclusion of such lands will be verified. This work could co-ordinate with the work of the EC and other EU nations to achieve these sustainability requirements and build on the work that the LowCVP is proposing in the area to examine how the impact of RED on the RTFO. There is also a need to ensure that RED covers all of the sustainability criteria of importance to the UK and to examine ways to achieve these in areas where RED is lacking.

Research Gap 2: There is a need to provide assistance to developing nations to help them develop sustainability guidelines to enable their producers to provide sustainable biofuels.

**Verification of supply chain.** Proforest and ODI (2008) state that the “key to the effectiveness of the scheme is that there is a robust mechanism in place to verify whether or not the standard is being implemented”. There is a lot of experience of verification in established certification schemes, from which much can be learnt. There are two issues with verification that biofuels sustainability schemes need to address: the need to develop verification procedures to ensure that sustainability can be tracked through the whole supply chain; and the treatment of small scale schemes.

BTG (2008) outlines two main ways to verify supply chains, either by transport of sustainable biofuels entirely separately to uncertified supply; or by labelling of certified supplies mixed with non-certified supplies (often referred to as the mass balance method). The RSPO specifies four ways:<sup>50</sup> ‘identity preserved, segregation, mass balance and book and claim’. As part of the work for support of the sustainability criteria in the RED the EU is proposing to do work on the verification system proposed. This work will define the verification process and compliance procedures required in the EU sustainability scheme and it should be possible for the UK to influence this process using its experience of the RTFO. The EU indicate that they will examine the use of mass balance but will review other verification systems as well.

Within this process it should be possible to establish monitoring and feedback from verification of schemes, to see how improvements have been made and to understand where the key issues with biofuels sustainability are for specific crops and regions.

Experience with other certification schemes leads us to suspect that there will be opportunities for circumnavigating biofuels sustainability, particularly in developing nations and throughout the supply chain. Consequently it is important to ensure that there is a good tracking system throughout the biofuels chain. One suggestion is for the development of a central overseeing organisation to manage this system and to ensure that international systems are compatible. More importantly there is the possibility that there will be markets where sustainability is not required, which means that there may also be opportunities to sell produce that is not certified and the overall objective will not be achieved.

Research Gap 3: Development of a robust verification process, based on the experience of sustainability schemes for other commodities and on the experience of the RTFO.

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<sup>50</sup> See [http://www.rspo.org/resource\\_centre/RSPO%20Supply%20Chain%20Certification%20Systems.pdf](http://www.rspo.org/resource_centre/RSPO%20Supply%20Chain%20Certification%20Systems.pdf)

Two approaches have been taken for certification of small-scale schemes. The first is to allow certification of a consortium of schemes, to decrease the costs to individual producers; and the second is to develop less stringent criteria for small-scale producers. Whatever the solution, verification will remain an issue because of the cost of verification of a large number of small-scale producers. The RSPO smallholder certification scheme has been developed to address this issue and useful lessons could be learnt from their experience. The UNCTAD suggests that the pilot schemes developing methodologies for sustainability in developing countries might also be useful in examining verification (UNCTAD 2008). It is likely that there will need to be investment in verification/auditing expertise in developing nations.

There is not a lot of information on the cost of achieving sustainability certification for large or small-scale producers and the impact this has on suppliers' markets. However, a review of costs of pesticide standards for food indicated that small-scale farmers find it difficult to comply without help (Webb). UNCTAD (2008) also expressed concerns for small holders; and GTZ (2008) reporting on the PROBEC work expressed the same concern. There is information in the RTFO framework report (Dehue et al 2007) on costs of achieving different certification – but ranges can differ greatly depending on sizes of farms, organisation of paperwork for verification etc. Evidence on costs seems to indicate that the cost of compliance per ha is higher for smaller schemes. There is also some evidence that in regions where it is difficult to meet sustainability criteria, producers simply seek alternative markets (this evidence comes from timber certification). This adds further weight to research gap 4 to devise schemes that do not disadvantage small scale producers.

Research Gap 4: Establishment of rules that do not exclude or disadvantage small producers or suppliers.

## **2) What research is there on whether sustainability standards work in terms of achieving the outcomes they are developed for? Are there better or worse approaches?**

Evaluation of current certification schemes shows a mixed picture regarding achievement. It is therefore important to learn from these schemes. Many current standards were set to meet other policies such as biodiversity goals. We have information on compliance for these standards, but it is not yet certain whether the standards are having their desired impact. We are still at too early a stage to have collected enough data from monitoring and particularly so for biofuels. There is a need to establish base data and monitoring of biofuels to examine whether or not sustainability schemes are achieving their objectives. The EC will be undertaking some of this work to provide baseline information on the impact of the RED, but a concerted international monitoring effort is required. This will be expensive work and there may be opportunities to streamline it within other initiatives designed to monitor the agriculture and forestry, such as REDD ("reducing emissions from deforestation and degradation").

In addition the effectiveness of voluntary versus mandatory schemes requires further consideration, particularly in view of the fact that voluntary schemes may be one of the few ways to achieve social sustainability.

There is some evidence on consumer choice from a survey done by HGCA and LowCVP in the UK. When asked, consumers care about sustainability of fuels (and care more about social issues than environmental issues in the LowCVP study), but it was not clear whether they would take action to choose labelled fuel. Evidence from other certification schemes shows that some retailers use the sustainability certification label as a selling feature; and that consumers will select a well known label for certain goods. Perhaps these examples demonstrate that once a label is understood then the consumers will begin to accept it.

We also need to consider how producers benefit from compliance with standards (and obtain evidence that they do) and how we can link compliance with benefits. If compliance cannot readily be linked to benefits (such as access to secure markets, a better price for produce, improved access to agricultural technology or improvements in soil or water resources) then producers may not be interested in continuing production of sustainable crops. This link is thus important in stimulating improvements in practice globally.

Key gaps identified in this area are:

Research Gap 5: Monitoring and data collection on both the positive and negative impacts of biofuels production are vital to inform policy development in this area, particularly GHG life-cycle analysis. Operational monitoring would mean compliance with the standards and strategic monitoring would allow the EU to understand whether the criteria are actually working, i.e. delivering the desired impacts. This monitoring should also provide information on costs and consumer decisions related to the certification. This work should also include an evaluation of the mechanisms being developed for other goals such as REDD to see if a data supply infrastructure could be introduced between international organisations that could benefit biofuel monitoring.

Research Gap 6: Developing a mechanism to feed back the results of the above work into improvement of sustainability schemes.

Research Gap 7: Developing systems to link compliance with benefits.

**3) What research is there on whether, if the aim is to increase development, should the EU have mandatory social sustainability criteria, or reporting standards, or anything? If reporting standards, are the current EU formulations the best kind?**

Social sustainability is difficult because of the need to comply with the World Trade Organisation rules. BTG (2008) examined this for the EC and concluded that it would be difficult to include social sustainability as a legal requirement in the RED.

Furthermore, the feedback between sustainability schemes and the improvement of social sustainability in developing countries is not clear. Post implementation of sustainability criteria needs to be done. This means that we need to understand current practice prior to sustainability standards being put in place. It is not clear that we have this level of understanding or knowledge.

Industry can provide significant benefits – not just developing plantations, but also providing for their workers' social needs by building schools and providing medical facilities. Results from this study suggest that this practice is commonplace and in some regions it is impossible to develop new plantations without including such facilities.

Biofuel sustainability criteria are not the only way to ensure social sustainability - there are political and economic tools as well. In fact, it is essential that the law is enforced within countries to ensure fair working practices and this should not be left to sustainability standards alone. This whole area needs further investigation and is dealt with additionally in Chapter 4 on social issues.

In addition to this we have no idea whether or not there are unintended consequences of social sustainability standards. It is known from experience with forestry certification that sustainability certification can drive developing nations towards other markets. This may also be the case for biofuels, but initiatives are too immature for assessment at present.

The research gaps in this area are defined in the chapter on social-economic impacts (Chapter 4).

**Time scales and costs**

None of the above work will be cheap; development of sustainability schemes for biofuels is likely to cost millions of pounds, but not all of these costs will fall on the UK.

If we are to achieve biofuels targets in a sustainable manner, there is urgent need to develop clear, transparent sustainability schemes, which are based on quantifiable criteria, in the near future. It is probable that these will be developed but will evolve with time. The experience of schemes such as the FSC indicates that the schemes will need time to develop and will then need to be modified from practical experience.

The UK has good experience through its development of the RTFO. This scheme has taken considerable time and effort (and stakeholder consultation) over the last few years. With the introduction of the EU RED sustainability scheme, the RTFO will either require further modification or it will need to be replaced. The RED scheme includes reporting requirements not in the RTFO and the RTFO includes social sustainability criteria not in RED. These issues will need to be considered on a fairly urgent basis. However, not all of the costs of this development will fall to the UK. The development of the RED sustainability scheme will be funded at EU level, although the UK may wish to actively participate in this process.

There is also a need for data for the evaluation of GHG emissions. This needs to be addressed on an urgent basis, but the UK has an opportunity here to work with other EU member states and to cut costs by doing so. Nevertheless, the cost of data gathering is likely to be of the order of hundreds of thousands to millions of pounds.

This work must also ensure that double counting of GHG emission reductions does not happen – for example, if reductions in emissions are made in fertiliser plants, the emissions reductions should not be credited to both the fertiliser manufacturer and the biofuels supplier.

The development of sustainability schemes that are applicable to developing nations will involve inclusion of these countries. We have mentioned UN initiatives to develop pilot schemes to produce guidelines for sustainability practices for these countries. There is a probability that further funding will be required to ensure the results of this work are rolled out and the UK may wish to provide aid or funding for some of this work. This is likely to cost in the region of £100,000+ based on the costs quoted by aid agencies and the UN for their current work.

### 5.3.6 Summary and conclusions

Achieving the sustainability criteria in the RED will be difficult because there are a number of gaps in the tools we have to measure sustainability. The first gap is to define what is meant by these sustainability criteria and how we should develop the tools (including certification) to monitor and measure them. This is not as difficult as it at first seems as the UK has good experience from the development of the RTFO, while the EC and other EU Governments (e.g. in the Netherlands and Germany) are supporting work in the area. Nevertheless it is an important first stage in ensuring sustainability and is urgent and significant work. The research gap is defined as medium to large, because of the need to act internationally and to ensure that the EU has a harmonised approach. There is also a need to examine all of the tools at the disposal of policy and decide which will enable the UK to achieve its target and reporting requirements and where further development is required. This work encompasses the development of the mechanisms for compliance building on the RTFO and EU work. It should be possible for the UK to use international mechanisms such as GBEP and the RSB to assist its thinking and to enable international harmonisation. In addition RED also requires reporting requirements for soil, water and air impacts. Research is needed to ensure that the UK can comply with these requirements. This work is subsidiary to the task of compliance with RED, but it is an important part of it.

One area where a number of researchers have identified a gap is in assisting developing countries to develop sustainability guidance for local growers. A number of projects have already been initiated through aid agencies and the UN but it is likely that more help will be needed. Depending on the amount of biofuels the UK imports this could be an urgent task in the medium term, and highly significant. We have assessed it as a medium to large gap, requiring international effort and cooperation and a multi-disciplinary team. It is also likely that UK funding could be leveraged alongside international funds.

Verification of sustainability is a key area that has already been considered for the RTFO. Nevertheless further work is required on an international basis. The EU will provide guidelines on its chosen methods for tracking sustainability but the UK will need to put procedures in place and ensure that there are sufficient trained auditors to make the scheme work. This is an urgent and significant piece of work, which will require a large, international effort.

It has been demonstrated in current sustainability schemes that small producers are frequently disadvantaged with greater costs per ha than large schemes. Procedures need to be developed to ensure that small producers can meet sustainability criteria. The UK will need to examine and develop its options. This is an urgent and significant piece of work, which we have ranked as a medium to large gap because of the diversity of small producers potentially involved in the UK and internationally. Separate advice and guidance may also need to be developed for these producers.

There is also a significant need to monitor and obtain feedback on the mechanisms put in place, so that improvements can be made in policy and to enable us to measure whether or not compliance with the schemes actually leads to the benefits that the schemes were designed to achieve. The need for monitoring and feedback is urgent and significant and should be considered in developing sustainability schemes. This is regarded as a large research gap because of the significant amount of work that needs to be done globally. Linking compliance to benefits will need to be undertaken over a longer timescale and is ranked as less urgent but highly significant. The size of the gap is ranked medium to large because of the amount of work involved over a long time period around the world. The monitoring of UK or EU produced biofuel may be easier to demonstrate as there are already organisations established to monitor the necessary factors. Monitoring in developing countries may prove more difficult.

**Table 5-4 Policy decisions on sustainability and supply chains – key findings**

Key to ratings provided below

Research Gap	Implementation of RED in the UK		Verification		Monitoring and feedback	
	1) Definition of RED criteria and measure to implement them, demonstration of compliance and development of reporting requirements	2) Assistance to developing nations to develop sustainability guidance	3) Development of a robust process	4) Consideration of needs of smallholders	5&6) Monitoring: feedback into development of policy and procedures.	7) Linking compliance to benefits
Key related work	RTFO, EU RED sustainability scheme.	GTZ, COMPETE	Other certification schemes International aid organisations (e.g. GTZ)		NGOs, Research councils, other national Governments, EC	
Complexity	**	**	**	**	***	**
Time scale	**\*	**	**	**	***	***
Potential costs	**	**	**	**	**	**
National or international?	International		International		International	International
Availability of data	Mainly available; some restricted data	More information needed.	Available	Further information needed	Information required	Information required
Availability of skill sets	***	*	**	**	**	**

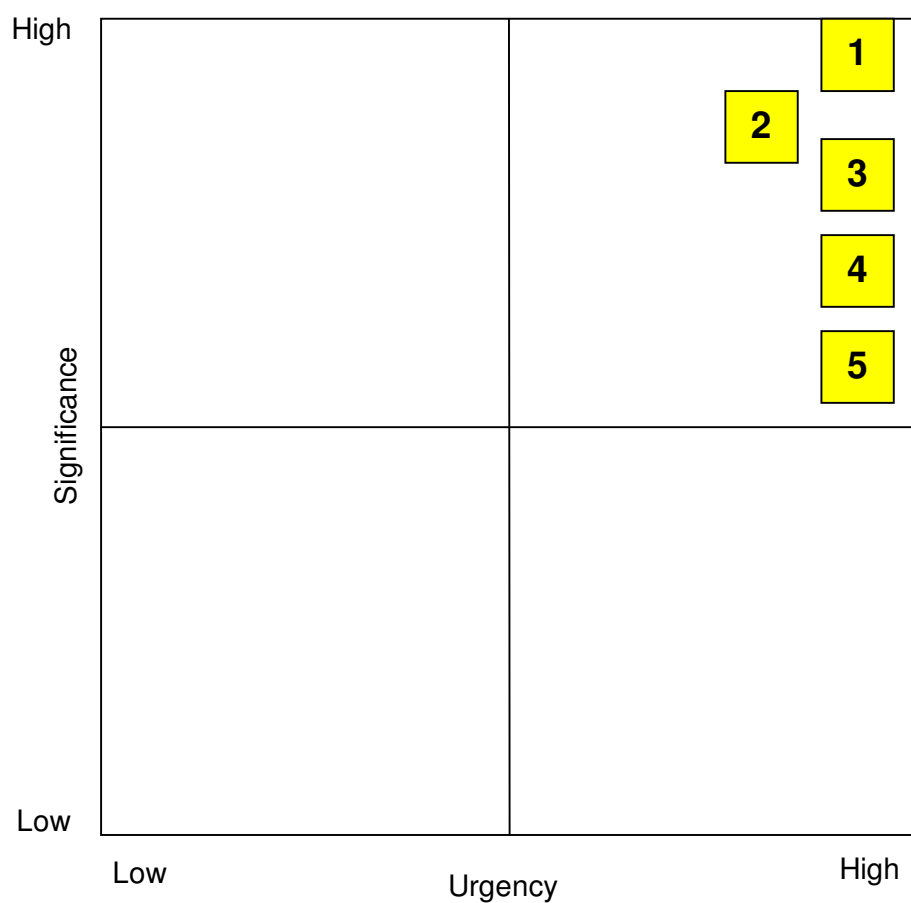
**Key**

<b>Significance</b> – please see matrix	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k *<£100k	<b>National or international</b> i.e. can the work be done in the UK or would it be better done internationally?
<b>Availability of data</b> This will refer to the IPR/availability of R&D already ongoing in the area (e.g. Commercial – restricted; or published/available)			<b>Availability of skill sets</b> *** a number of organisations working in area ** availability restricted to a few groups or only on international scale * skills gap, significant training required.	



## 5.4 Grandfathering

Figure 5-3 Matrix prioritising key research gaps for grandfathering



### Key research gaps

1. Investment/financial impacts
2. Technological and sustainability impacts
3. Potential for misuse of grandfathering
4. Comparison of different grandfathering regimes
5. Modelling of optimum level of grandfathering

### Size of Research Gap

	Small
	Small / Medium
	Medium / Large
	Large

### 5.4.1 Executive Summary

*What is the impact of grandfathering provisions for long run investment, sustainability and technology?*

Grandfathering provisions allow for existing companies/organisations/plants/machinery to be temporarily or permanently outside incoming legislation. These provisions may be written in to allow companies to spread the financial and business costs of meeting such legislation, or to encourage investment in an uncertain legislative environment. They may apply to some or all actors in the relevant field.

Under the RED application of ILUC requirements, grandfathering provisions are in place for facilities built before 2013 to receive 'grandfathering rights' until 2017, as long as they provide a minimum of 45% greenhouse gas saving compared to petrol/diesel. This means that facilities built under the earlier legislative criteria can continue to operate under these criteria for a limited time.

Grandfathering in this context is therefore aimed at encouraging early investment and giving confidence to investors that changes in legislation will not cause undue instability. However, assuming the legislative changes are aimed at increasing sustainable behaviour, grandfathering can, in some circumstances, be a disincentive to sustainability, and may encourage people to move their plans forward to qualify for the more lax legislation. Similarly, the technological impact could be to make it easier for companies to keep using existing or sub-optimal technology.

This chapter considers current and future research in this area in order to identify the research gaps which must start to be filled before we have a full understanding of the impact of grandfathering provisions including impacts on sustainability. These key research gaps include:

Research Gap 1: Investment/financial impacts. There is very little relevant research on how grandfathering provisions may impact on investment, technology or any other aspect of biofuel production/use. Whilst superficial or intuitive answers may be easily produced, in-depth academic or consultancy research has not been carried out.

Research Gap 2: Technology/sustainability impacts. There is very little relevant research on how grandfathering provisions may impact on technology and sustainability. Further research in this area is therefore required.

Research Gap 3: Increased understanding of the potential for the misuse of grandfathering. It would be of particular use to understand the extent to which firms can manipulate or abuse the grandfathering provisions. If the legislation is written too loosely, or is anticipated, firms may be able to act sooner than they would have in order to benefit from the longer time under the old legislation.

Research Gap 4: There is the requirement for a comparison of different grandfathering regimes or proposals.

Research Gap 5: Research into the modelling of the optimum level of grandfathering is required.

Grandfathering clauses have been considered to biofuels mandate legislation in the UK and US so as not to punish companies who acted under the previous legislation or to encourage investment to take place sooner rather than later (i.e. when investors feel there is stability in the legislation).

#### 5.4.2 Context

As climate change has risen up the legislative agenda over the previous decade, biofuels have been seen as an important option for reducing transport's dependency on fossil fuels. However, after directives have been installed setting a target for biofuel use, opinion has shifted to allow for the fact that not all biofuels have equal climate change benefits. Changes to the directives and national mandates have been proposed or implemented, but in order not to slow down investment, or to avoid 'punishing' early adopters, grandfathering provisions are used to ameliorate the impact of the newer legislation for companies that have already acted to comply with the old legislation.

In the EU, the RED contains grandfathering related to mandatory sustainability criteria for biofuels and bioliquids and indirect land use calculations<sup>51</sup>. In the US, the Renewable Fuels Standard may be updated to include climate change impacts, with grandfathering provisions.

An issue arising from this inclusion of grandfathering into sustainability criteria is its compatibility with WTO rules since there are precedents for grandfathering clauses to be challenged. In 2006, the WTO ruled that the US's Foreign Sales Corporation tax regimes were in violation of WTO rules. In particular, the grandfathering clause allowed US companies which entered a contract before 17 September 2003 to benefit from tax breaks beyond 2006. The EU was allowed to apply punitive tariffs on US products in retaliation until the original regimes were repealed in May 2006. In this case, the grandfathering arrangement was to give tax incentives to companies, whereas under biofuel grandfathering, the issue is about firms complying with sustainability standards where the focus is on GHG savings. This is less likely to be an issue for the WTO (see discussion in Section 5.1.4).

#### 5.4.3 Key research questions

This section explores what research is there on:

- 1) The impact of grandfathering provisions for investment, sustainability and technology?  
Are there different short run vs. long run impacts?
- 2) Can grandfathering provisions be misused?
- 3) Are there different forms of, or substitutes for, grandfathering provisions?

#### 5.4.4 Research in the area

There is very little relevant research on how grandfathering provisions may impact on sustainability, investment, technology or any other aspect of biofuel production/use. Whilst superficial or intuitive answers may be easily produced, in-depth academic or consultancy research has not been carried out.

<sup>51</sup> According to Summary draft of RED (17 December 2008), the mandatory sustainability criteria for biofuels and bioliquids (article 17) the minimum GHG saving rises to 50% from 2017 but new installations from 2017 must meet 60% minimum.

Under application of indirect land use change and GHG calculations (article 19/annex V) no biofuel produced from an installation that was operational in 2013 shall be excluded until the end of 2017, if it: (i) would otherwise have met the Directive's sustainability criteria, and (ii) achieves GHG savings of at least 45%.

There has been some research in the UK in a similar situation, which looks at the impact of allowing certain filling stations a derogation from the requirement to fit relatively expensive vapour capture technology (SEEG 2004). This is not grandfathering per se, but shares features in that it allows some agents to be exempt from incoming legislation in order to meet a higher aim. In the case of the filling stations, the study looked at the role small, rural stations hold in the local society/economy and compared the estimated closure rate of such stations with the new technology costs and without. Similar work would need to be done with biofuel grandfathering, comparing the total costs (including climate change emissions and business costs) of a universal application of new legislation, against the total costs of the proposed grandfathering provisions. Indeed, in-depth research should also consider alternatives to grandfathering and the potential for agents to manipulate or misuse grandfathering. Other existing research on grandfathering has looked at power plant legislation in the USA. These are not about biofuel use, but rather about emissions standards being tighter for newly built power stations than older ones. For example, Ackerman et al (1999) summarise the economic theory for such grandfathering, and find it to be weak. They also estimate the impact of removing these grandfathering provisions by analysing scenarios based on aggregating all coal plants together and all gas plants, rather than on a plant by plant basis.

#### 5.4.5 Research Gaps

There are clearly large gaps in the research around grandfathering and its impacts. This is probably due to two reasons, firstly the relatively new relevance of grandfathering in the biofuel arena, and secondly because it is not necessarily the most important aspect. However, Friends of the Earth USA expects “almost all of the 15 billion gallons of corn ethanol will be grandfathered in” (<http://www.foe.org/energy/biofuels/biofuels-mandate-campaign>) which suggests that in both relative and absolute terms grandfathering can have large repercussions.

Research gaps for the subsidiary questions on grandfathering are briefly addressed below:

##### **1) What is the impact of grandfathering provisions for investment, sustainability and technology? Are there different short run vs. long run impacts**

There is very little relevant research on how grandfathering provisions may impact on sustainability, investment, technology or any other aspect of biofuel production/use. Whilst superficial or intuitive answers may be easily produced, in-depth academic or consultancy research has not been carried out in this context.

Research Gap 1: Investment/financial impacts. There is very limited research on how grandfathering provisions may impact on investment in the biofuels sector. While some research is available on economic impacts of grandfathering or grandfathering-like provisions in other contexts, the specific impacts on investment of grandfathering provisions in sustainability criteria in the RED would need more detailed analysis for the UK and EU context.

Research Gap 2: Technology/sustainability impacts. There is very little relevant research on how grandfathering provisions may impact on technology and sustainability. As in the case of Research Gap 1, the specific impacts of grandfathering provisions under the RED would need further research at UK and EU levels.

## 2) Can grandfathering provisions be misused?

Of particular interest would be research into the extent to which firms can manipulate or abuse the grandfathering provisions if the legislation is written too loosely or is anticipated. Moreover, what is the potential (and what appropriate safeguards should be set) for producers to increase production, diversify production or expand into new markets in order to benefit from grandfathering provisions?

Research Gap 3: Increased understanding of the potential for the misuse of grandfathering in the context of biofuels sustainability criteria. Ideally such research would be able to suggest how likely firms are to abuse grandfathering, rather than just model or estimate without direct input from any firms.

## 3) Are there different forms of, or substitutes for, grandfathering provisions?

While there are different forms and aims for grandfathering in different policy contexts, for biofuels policy the main rationale and form of grandfathering provisions for production facilities do not differ in principle. The main issue is therefore the detail of the clause in order to achieve best the policy objectives.

Overall, there may be two main approaches to studying grandfathering. One is to take a proposed grandfathering scheme and research its implications, the second is to model a generalised scenario and calculate an optimum level of grandfathering. The second type is more of an economic modelling approach which would be calibrated for specific economies, and would have to be developed from a simple basis to a more complex model. However, it would provide a theoretical basis for more applied research. The first type of research would be highly context-specific, and so would provide insights for a specific grandfathering provision, or be able to compare a number of suggested provisions.

Since grandfathering cannot exist as a subject in its own right, as it is intrinsically tied in with other legislation, it seems best that grandfathering research be carried out as part of a wider policy research programme. Otherwise, the impacts of the policy as a whole would have to be researched first, before the grandfathering impacts can be compared.

A potentially important area of research is how grandfathering interacts with and can be used within the WTO framework. As noted above grandfathering is less likely to be an issue for the WTO where it relates to sustainability criteria for GHG savings, although in the studies (outlined in Section 5.1.4) on the implications of WTO rules for biofuels sustainability criteria grandfathering is not explicitly covered. This highlights the need for a more detailed appraisal of how the proposed grandfathering under the RED may fit in with WTO legislation.

Research Gap 4: There is the requirement for a comparison of different grandfathering regimes or proposals. This would assess the impacts of different possible grandfathering provisions in terms of, for example, periods of exclusion from sustainability criteria and terms of the exclusion, to draw conclusions on the relative benefits of different provisions.

Research Gap 5: Research into the modelling of the optimum level of grandfathering is required. This is linked to Research Gap 4 above and would take an economic modelling approach to provide a theoretical basis for more applied research into the most efficient level of grandfathering to achieve policy objectives in a given economy.

#### 5.4.6 Summary and conclusions

There is a clear lack of research about the impacts of grandfathering in every area, in terms of impacts on trade, trade agreements, finance and investment, and technology. However, it seems likely that such research can be relatively easily incorporated into other research projects and does not need stand-alone research. This would require a well-defined picture of what grandfathering clauses would be invoked, since there can be a variety of such legislation.

If there were sufficient research resources, a multi-layered research approach could be taken. In such a case, the foundation to the project would be to strengthen the theoretical modelling and development of grandfathering, perhaps incorporating grandfathering into existing economic models. From this foundation, more specific research can be carried out to examine the effects of specific policies or to estimate the optimum grandfathering level.

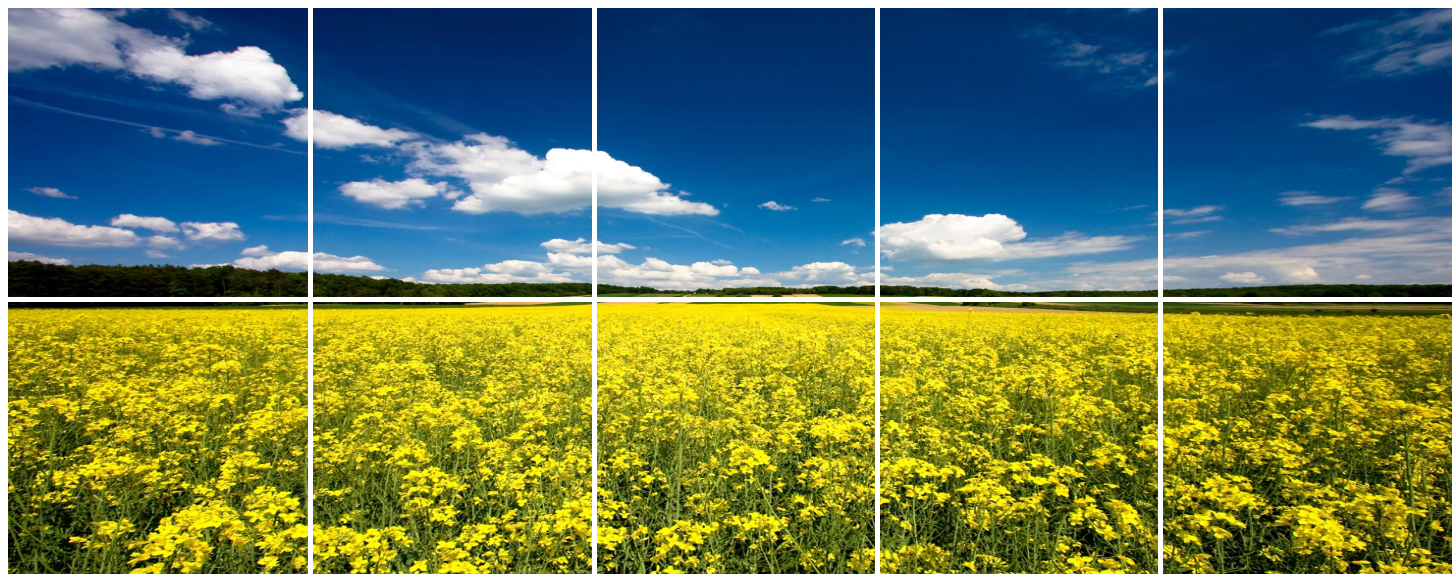
In itself, grandfathering may not seem an urgent or important research matter. However, it can be a serious issue for the WTO and other international trade agreements, and may also significantly distort the aims of environmental legislation. The matrix given at the start of this section rates the research gaps relating to grandfathering in the biofuels context as urgent, bearing in mind the inclusion of such provisions in the RED. Similarly the significance of each of the identified research gaps is rated as high because they represent important factors in the effective operation and impact of grandfathering provisions related to biofuels. The size of the gap for the identified research issues is rated as small to reflect the relative lack of complexity or data-intensity.

Table 5-5 Key research gaps

Research Gap	1) Investment /financial impacts	2) Technological and Sustainability impacts	3) Potential for misuse of grandfathering	4) Comparison of different grandfathering regimes or proposals	5) Modelling of optimum level of grandfathering
Key related work	Scottish Parliament Study of Derogation for Rural Filling Stations	Research on sustainability of RED/similar without grandfathering			
Complexity	**	**	**	**	**
Time scale	*	*	*	*	*
Potential costs	*	*	*	*	*
National or international?	UK	UK	UK	UK	UK
Availability of data			Should need input from firms		Could be done with no/little data
Availability of skill sets					

**Key**

<b>Significance –</b> please see matrix	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k * <£100k	<b>National or international</b> i.e. can the work be done in the UK or would it be better done internationally?
<b>Availability of data</b> This will refer to the IPR/availability of R&D already ongoing in the area (e.g. Commercial – restricted; or published/available)			<b>Availability of skill sets</b> *** a number of organisations working in area ** availability restricted to a few groups or only on international scale * skills gap, significant training required.	



# Biofuels Research Gap Analysis

## Chapter 6 – Vehicle Capability



**Final report to the Biofuels Research  
Steering Group**

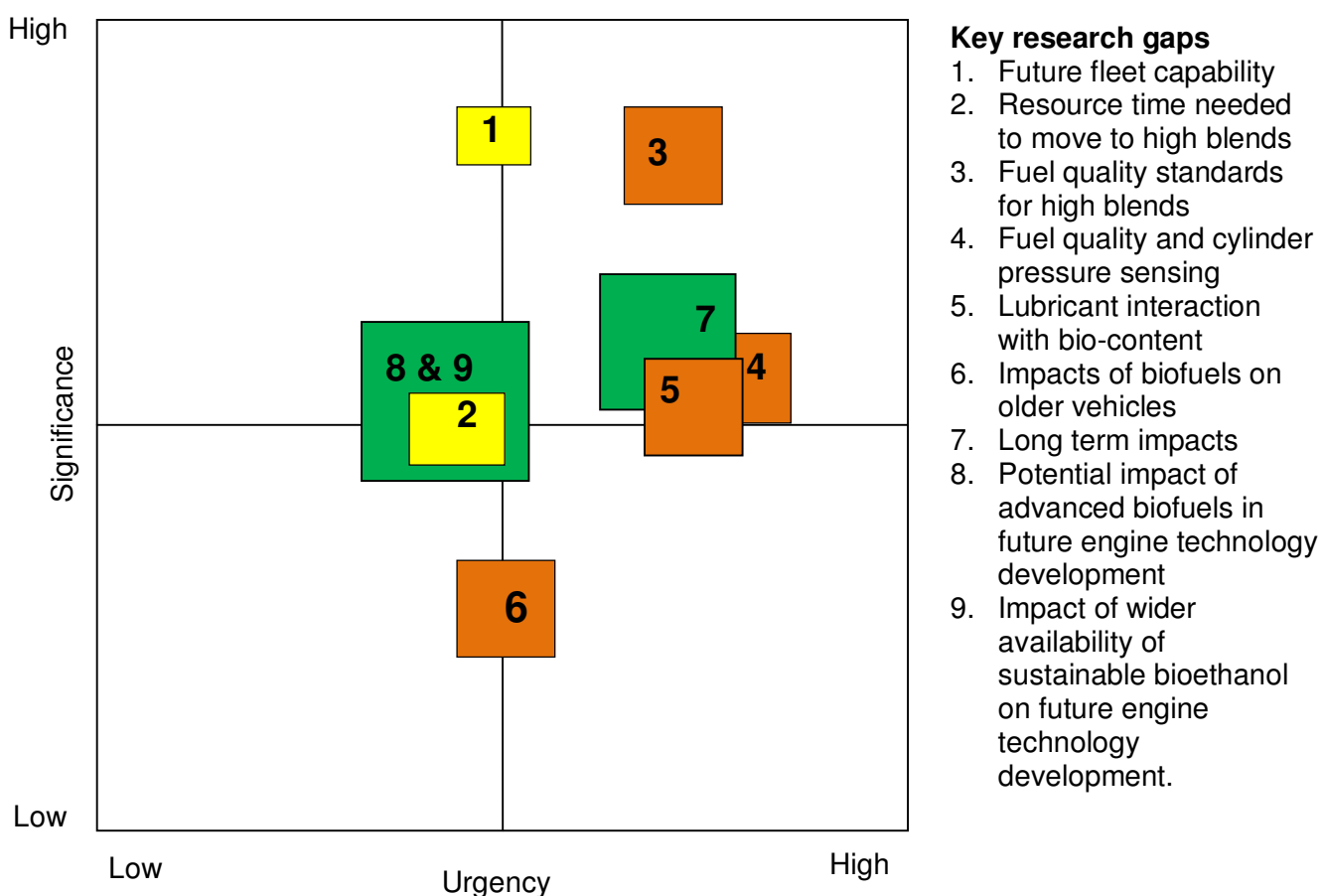
ED45917  
Issue Number 3  
30<sup>th</sup> July 2009



## 6 Vehicle Capability

### 6.1 Vehicle engines and flex fuel vehicles

**Figure 6-1 Matrix prioritising key research gaps for vehicle engines and flex fuel vehicles**



**Size of Research Gap**

	Small
	Small / Medium
	Medium / Large
	Large

### 6.1.1 Executive summary

*“What are the technical vehicle issues around potential pathways for increasing biofuel mandates?”*

It is essential that the UK vehicle fleet market has the ability to cope with an increase in biofuels if the UK is to meet the 10% transport RED target. To achieve this will involve examining the use of biofuels in ‘conventional’ vehicle engines and in ‘flex-fuel’ vehicles, which can take both biofuels and petrol or diesel. With the latter the time required for the replacement of the vehicle stock is an important issue.

This chapter considers current and future research in this area in order to identify the research gaps which must start to be filled before the UK can put itself on a pathway to achieving the 10% RED Target.

The study found the following research gaps:

Research Gap 1: In relation to future fleet capability, an overall evaluation of the vehicle capability of the European road transport fleet is missing, although the LowCVP has done some work from a UK perspective.

Research Gap 2: No work could be identified that examines the resource time needed to move to high-blend fuels. However, current work commissioned by the LowCVP is looking at the market for high-blend biofuels, which may address this to an extent.

Research Gap 3: There is a need for fuel quality standards for high blends, with the manufacturers’ main concern being for first generation biodiesel fuel quality. This is highlighted as having particular importance given that there is significant variability in the quality of first generation biodiesel fuels sourced from different feedstocks and suppliers.

Research Gap 4: Research into fuel quality sensors, cylinder pressure sensing to optimise combustion independent of fuel.

Research Gap 5: Research into lubricant interaction with the bio-content of fuel for engine wear protection.

Research Gap 6: An assessment of the compatibility of second-hand vehicles, and thus the impact of biofuels on older vehicles, is currently lacking, although the Environment Agency’s trials on predominantly ‘out of warranty’ vehicles in its fleet might produce some useful information.

Research Gap 7: Similarly, this study did not identify any research currently being carried out on long-term impacts to vehicles.

Research Gap 8: Potential impacts of advanced biofuels on future engine technology development. Although it appears to be generally accepted that Biomass to Liquid (BtL) biodiesel will be of equivalent or higher quality than conventional diesel, research on the performance and potential of Hydrotreated Vegetable Oil (HVO) biodiesel fuels has not been identified through this work. As it seems likely that such fuels will become widely commercially available in a shorter timeframe than BtL biodiesel, this is an area that may require further investigation.

Research Gap 9: Impact of wider availability of sustainable bioethanol on future engine technology development.

Overall, not much detail has been found on current activities being carried out in this area. This appears to be partly due to the fact that much of the research is being carried out by industry and is therefore commercially sensitive. Vehicle capability does not appear to be a significant research priority outside industry as the technical issues with current biofuels are relatively well understood and so work is more focused on addressing the existing limitations and on fuel quality issues. With regard to ethanol, the issues are the same as for current and advanced biofuels, so engine and flex-fuel vehicle development is focused on optimisation to take advantage of ethanol's higher octane rating. For biodiesel, the principal barriers to higher blend biodiesel fuels are limited to current generation biodiesel. Future advanced HVO and BtL biodiesel fuels are anticipated to have far fewer or no limitations at all compared to conventional diesel.

The study concluded that engine technology development would not be able to take advantage of future fuels without joined-up research between fuel suppliers and the automotive industry. However, there are signs this is starting to take place. Already, there are a number of enabling technologies that would help in future proofing and optimising engine performance across a wider range of biofuel blends.

### **6.1.2 Context**

The RED states that there is a mandatory 10% minimum target to be achieved by all Member States for the share of renewable energy in transport by 2020, which is expected to be met mainly through the use of biofuels. First generation biofuels are currently limited to 7% blends for biodiesel and 5% blends for bioethanol in petrol (although for bioethanol a recent amendment to the FQD allows separate blends up to 10% in the future). Second generation biofuels offer the greater potential but would need to be on-stream to achieve the 10% target by 2020.

Research in this area is therefore essential.

### **6.1.3 Research in the area**

There is already considerable experience and understanding of the impacts of biofuel use in road vehicles resulting from their use over many years. Compatibility issues with existing engine technologies are already well documented with research being primarily carried out on fuel quality. On the vehicle technologies side, current research is mainly being carried out within industry. The status of compatibility and research concerning the use of the main biofuels is as follows:

#### **1) Diesel engines**

Biodiesel: Higher blend (>5%) vehicle compatibility issues are essentially restricted to first generation biodiesel (via esterification of oils), as second generation BtL type fuels are fully compatible with existing specifications. Recent developments in HVO (hydrotreated vegetable oil) fuels are also promising and such hydrotreating processes could deliver high quality biodiesel without the drawbacks of biodiesel from conventional esterification processes.

**Bio-DME:** Bio-DME (dimethylether) is an alternative diesel engine fuel still with a number of significant issues to overcome. DME cannot be blended with fossil diesel and its volumetric energy content is much lower, approximately half that of diesel. Retrofitting diesel engines for the use of DME is therefore necessary, but relatively simple. Though not being corrosive to metals it may affect certain kinds of plastics, elastomers and rubbers after some time. DME is gaseous at ambient temperature and therefore likely to be used as a liquid at 5-10 bar, with transport, storage and distribution similar to that of LPG.

## **2) Petrol engines**

**Bioethanol:** Ethanol use is a more mature area, so research is primarily on optimisation rather than solving problems. Bioethanol is commonly used in blends with petrol in existing road vehicles worldwide, in a similar way to Biodiesel – for example, as a 5% blend (E5) in Germany and France, and a 20% blend (E20) in Brazil. Blends with petrol to use in conventional petrol vehicles in Europe are currently limited to 5% (although recent proposals are to allow separate blends up to 10% in the future). It can also be used at higher levels up to 85% bioethanol (E85) in specific flexi-fuel vehicles – with relatively little modification (and extra cost) needed compared to regular models.

**Biobutanol:** Butanol is a higher energy density alternative to ethanol with improved compatibility with existing petrol engines. Current research is focused on production side, rather than vehicle side.

**Bio-DMF:** DMF (2,5-Dimethylfuran) has a number of attractions as a biofuel. It has an energy density 40% greater than ethanol, making it comparable to petrol. Its use in vehicle engines is still at the laboratory research stage, with little known about its combustion and emission characteristics, especially about the speciation of non-regulated emissions from its combustion in engines.

## **3) Liquefied Petroleum Gas (LPG) engines**

**Bio-DME:** Bio-DME, discussed above for use in converted diesel engines, may also be used in a 30% blend with LPG in suitable engines.

## **4) Natural gas engines**

**Biomethane:** Natural Gas Vehicles (NGVs) are mostly still conversions, but there are essentially no compatibility issues of biomethane (of suitable quality/purity) with engines that can run on natural gas. In this area there are currently pilots on HGVs and interest in upgrading Euro IV/V engines to Euro VI using natural gas/biomethane.

### **6.1.4 Key research questions**

This section explores what research there is on the technical vehicle issues around potential pathways for increasing biofuel mandates.

This is underpinned by an analysis of what research there is on:

- 1) What levels of biofuels can be taken (without modification) by which proportions in car, van and HGV fleets, and how much of the overall UK vehicle fleet is flex-fuel or can take high proportions of biofuel?
  - What are vehicle manufacturers planning?
  - How is this likely to change over the next 10 years and how might this vary with, or without, Government interventions?

- How much does it cost to move to flex-fuel and are there other complications to be considered?
- 2) What will it take to get current and future engines up to higher blend levels?
- How much resource and time is needed to do this?
  - What are the logistical problems?
- 3) What impacts do biofuels have on car, van and HGV engines and are there uncertainties around this, including warranty issues? Are there differences between:
- Short term versus long term impacts?
  - First generation/current biofuels versus Second generation/advanced biofuels?
  - Different types of biofuels?
  - New versus second-hand cars?
- 4) To what extent will vehicle technology issues change as more advanced biofuels come on stream?

### 6.1.5 Research in the area

Current research is predominantly on biofuels that can be used in the conventional diesel and petrol engine vehicles that comprise the majority of the fleet. The primary focus of concern for such vehicles is different for petrol and diesel vehicles:

**Diesel engines:** The primary issues that concern first generation biodiesel include:

- Poor low temperature starting and operation.
- Oil dilution and integrity of the lubricant.
- Oxidation stability, cold filter plugging and particulate formation.
- Impurities and contaminants and their impact on the engine, after-treatment systems (e.g. alkali metals present in fuel via esterification process).
- Emissions control and fuel economy.
- Degradation and bacterial growth during longer-term storage.

**Petrol engines:** Ethanol related research is mainly ongoing in material compatibility (due to its corrosive and hygroscopic nature) and optimisation of future gasoline technologies for use with high-blend (E85) ethanol fuels to take advantage of its high octane rating.

For biobutanol the primary issue on the vehicle side concerns the different smell (mainly public perception), particularly when combusted.

Levels of compatibility with existing/new vehicles appear to vary by manufacturer and by vehicle type. More heavy-duty OEMs warrant engines for use with B100, this is in an engine by engine basis with additional guidelines on use (e.g. changes in service intervals). The engines warranted for use with high blends of biodiesel are generally lower technology engines (e.g. no/low EGR and no after treatment).

### Current status and research work on vehicle engines and flex-fuel vehicles

A number of organisations involved directly and indirectly in R&D on this area were contacted as part of this work. Table 6-1 below summarises the current technical status and R&D work that is being done on this issue at UK, European and international level.

**Table 6-1 Research in the area of vehicle engines and flex fuel vehicles**

<b>Funding or research organisation and budget where available</b>	<b>Current status of research</b>
<b>UK</b>	
LowCVP undertaken by TTR and Fleetsolve	Market opportunities for high blend biofuels and biomethane.
Birmingham University EPSRC funded £500k	The impact of DMF on Engine Performance and Emissions as a New Generation of Sustainable Biofuel.
AEA - Environment Agency funded project, budget: £105,000	Design and Evaluation of Biodiesel trial July 2009.
<b>Europe</b>	
European Commission Total budget: 28.4 M€ (FP7) (8.2 M€) and the Swedish Energy Agency (9.6 M€)	BioDME, which started in September 2008. BioDME is a unique cooperative project involving the automotive industry as well as fuel producers and distributors regarding the fuel DME.
European Committee for Standardization	<p>In the European Standards Organisation (CEN) the oil industry is working with the manufacturers /biofuel suppliers to allow greater percentages of biofuels to be incorporated in conventional petrol and diesel and to set quality standards that can be used in vehicle design.</p> <p>Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 provides information on new limits and information on what is being done to develop new standards.</p>
<b>US</b>	
US Department of Defence	US Defence Advanced Research Projects Agency: \$14.9M to Science Applications International Corp and \$19.9M for General Atomics: research into algae based jet fuels. Runs to mid-2010.
US Department of Energy	<p>USDOE are carrying out a wide range of biofuels R&amp;D. Research in the vehicles area includes:</p> <ul style="list-style-type: none"> <li>• Developing safety standards for E85 fuel dispensing systems.</li> <li>• Testing of intermediate blends to assess impacts on small engines and vehicle performance, emissions, durability, and other factors.</li> <li>• Assessing FFV (flex-fuel vehicle) technology development for mileage and emissions impacts and providing data to vehicle manufacturers.</li> <li>• Evaluating options for improving performance of/optimising FFVs for ethanol use.</li> </ul> <p>Validating market data on fuel use as a function of vehicle performance, fuel cost, and availability.</p>

Funding or research organisation and budget where available	Current status of research
EPA/Office of Transportation and Air Quality	<p>EPA/ OTAQ</p> <ul style="list-style-type: none"> <li>has completed screening for ethanol blends up to 10% (E10). Blends up to E10 passed durability testing and emissions testing (including tests for currently regulated and unregulated pollutants) and were certified by EPA.</li> <li>In co-ordination with DOE and industry, EPA is currently conducting extensive studies on the durability and emissions impacts of blends higher than E10 up to E20.</li> </ul> <p>EPA has also tested and permitted E85 as an alternative fuel (different testing regime)</p>
California Air Resources Board (CARB) \$25 million	CARB has \$25m over next 2 years on development and implementation of activities related to E85, e.g. project including infrastructure financing. \$2m on performance testing of vehicles on biodiesel and \$1m for in-house testing (over 4 to 5 years).
<b>Industry</b>	
BP	Have in-house fuel technologists conducting development work on the impact of higher percentage biofuels on the infrastructure and on vehicles.
Corning	Corning are currently carrying out joint work with the biodiesel board on alkali ash specification for safe operation of DPFs.
DAF	DAF's testing and validation of biodiesel (-blends) are related to reliability of engine operation and potential function impacts.
Daimler	All trucks from Mercedes-Benz produced since 1988 are approved for operation with EN14214 biodiesel at any concentration up to and including 100%. Van range limited to a maximum of 5%. Daimler also conducted a trial operating in Germany using Pure Plant Oil but will not be extending it or recommending its use as a vehicle fuel.
Ford	<p>Ford has been developing vehicles to run on renewable biofuels, such as bioethanol and flexi-fuel vehicle (FFV) models.</p> <p>Research supported by Ford includes:</p> <p>(A) A project with Bath University which is investigating the effect of biodiesel on fuel and oil properties including:</p> <p>(1) Oxidation rates, (2) Soot to oil transfer rates, and (3) Recovery rates (2012).</p> <p>(B) Internal research into the compatibility of our vehicle fleet with bio-diesels from varying feed stocks (RME,</p>

Funding or research organisation and budget where available	Current status of research
	<p>SME, etc) and increasing ratios of biodiesel, up to B30. (2010).</p> <p>(C) An E85 ethanol project with Somerset council &amp; BP as part of the BEST project to assess the potential to extend oil service intervals for ethanol vehicles. The objective of the work is to better understand the compatibility of vehicles to increasing levels of biodiesel content in diesel fuel (2011).</p>
GM	<p>GM also has various experts in the US, Sweden, etc. carrying out research in conjunction with academic institutions into various aspects of bio-fuels. However, GMUK is not currently closely involved in this work.</p> <p>GM has conducted fleet trials of B30 on Vivaro van. GM's passenger car engineering vehicle fleet in Germany is currently carrying out a long-term trial of E10 and B10.</p>
PSA	<p>Promote the use of ethanol in petrol up to 10%, and this blending process can be achieved without adjusting the current engine technology. Anticipated to come into industrial production by 2020.</p> <p>In China, the Group is conducting biodiesel research with the China Automotive Technology &amp; Research Center (CATARC). In Latin America, PSA Peugeot Citroën has initiated a series of trials with Ladetel, a Brazilian clean technologies laboratory specialized in biofuels, to assess the performance of Brazil's B30 biodiesel.</p>
Ricardo	<p>R&amp;D carried out by Ricardo includes:</p> <p>Ethanol boosted gasoline technologies.</p> <p>Diesel engine operation on high biodiesel content (up to B30) and impact on emissions (regulated &amp; unregulated).</p> <p>Existing engine technology using virgin vegetable oil (VVO).</p> <p>Future R&amp;D is likely to focus on future engine technologies and how they will operate on high bio-content fuels.</p>
Saab	<p>Saab works in flexible-fuel and turbocharging technology, Including the BioPower 100 Concept a production-based turbocharged engine to be optimised for pure E100 ethanol.</p>



Funding or research organisation and budget where available	Current status of research
Scania	<p>Issues Scania is researching include:</p> <p>(1) Problems with bacterial growth in biodiesel and the issue of sourcing good quality fuel.</p> <p>(2) The need to replace fuel filters very regularly at first when converting across to biodiesel (due to re-suspension of deposits in the fuel lines by biodiesel, which is a more effective solvent).</p> <p>(3) Use of E95 in converted diesel engine buses and trucks.</p>
Volvo	The Volvo Group is the co-ordinator for the European project BioDME, see above.
VW	<p>Volkswagen has been working on concepts for the industrial production of next-generation biofuels since the year 2000, and has co-operated with other carmakers, biotech companies and oil corporations in the process. In collaboration with Choren, as well as other partners, Volkswagen has already developed its SunFuel, a fully synthetic diesel fuel produced using a biomass-to-liquids (BtL) process. The goal now is to forge stronger ties between industry and the scientific community so as to come up with environmentally less damaging alternatives to petroleum as a source of energy.</p>

### 6.1.6 Research gaps

In general, there appears to be relatively little publicly funded research in the vehicle technologies area. Most appears to be conducted mainly in-house by the auto industry, with some additional work being carried out by the oil industry. As such, it is difficult to get detail on the specifics of research topics, timing and budgets, as this information is commercially sensitive. However, more general information on the current state of compatibility with different biofuels and the general focus of different organisations is available – from which certain conclusions can be drawn.

Discussions at the stakeholder workshop organised by this study and held at the end of February 2009, focused more on the production and quality of the biofuels themselves, rather than on issues specifically concerning vehicle technologies. This seems to confirm the general impression that research into particular technical issues is already in hand and therefore not at the top of the list of concerns of most organisations.

The key research questions and potential research gaps under consideration are as follows:

#### 1) **What is the level of compatibility of the UK fleet with low, medium and high biofuel blends and how might this evolve?**

Different levels of compatibility (at least under warranty) exist for different manufacturers.

There was little evidence to suggest that an evaluation of the overall compatibility of the UK fleet (at blends above 5%) has been previously covered in research. However, work commissioned by the LowCVP is currently looking at the market for high-blend (>10% by volume) liquid and gaseous biofuels and will recommend the most appropriate mechanisms to stimulate take-up. The study aims to develop evidence based answers to a number of questions including:

- What are the areas of consensus and areas of uncertainty about use of high blend liquid and gaseous biofuels (potentially by vehicle sector)?
- What technologies do vehicle manufacturers currently have which may point towards certain high blend products?

Similarly, an overall evaluation of the vehicle capability of the European road transport fleet is missing. The work by the LowCVP may provide a useful starting point to assess the future evolution of fleet compatibility with higher biofuel blends. To an extent this will also depend (at least for diesel vehicles) on the timing and rate of penetration of second generation biodiesel fuels, which do not have the same compatibility issues with existing technologies.

Previous estimates on the cost to produce a flex-fuel version of a current petrol vehicle (taking up to E85) have suggested it could be as low as £200 per car. However, there is relatively little specific information on how transferable this is across the range of market segments and its practical consequences.

Research Gap 1: In relation to future fleet capability, an overall evaluation of the vehicle capability of the European road transport fleet is missing, although some work has been done by LowCVP from a UK perspective.

## 2) What is needed to get current and future engines up to higher blend levels?

There is some work being carried out by industry in the UK (and abroad) and the LowCVP project. The USA is also very active in the bioethanol area, with a wide range of R&D currently being carried out. For example, the USDOE is testing intermediate blends to assess impacts on small engines and vehicle performance, emissions, durability and other factors.

For bioethanol, research is generally further forward, influenced particularly by the Brazilian market and by developments in Sweden. EPA/OTAQ has completed screening for ethanol blends up to 10% (E10). Blends up to E10 passed durability testing and emissions testing (including tests for currently regulated and unregulated pollutants) and were certified by EPA. In co-ordination with DOE and industry, EPA is currently conducting extensive studies on the durability and emissions impacts of blends higher than E10 up to E20. EPA has also tested and permitted E85 as an alternative fuel.

Further research is also required to understand the effects of different biodiesel feedstocks on the stability of the biodiesel fuel produced from them. Work is also needed on the long-term effect on engine robustness of lubricant dilution by biodiesel fuel and contamination with oxidation by-products.

Here, joined up research between fuel suppliers and the automotive industry is essential as future engine technology cannot be developed and validated without knowing the characteristics of future fuels. At the moment, activity in this area is being coordinated by the European Committee for Standardisation (CEN) – at least in Europe, – which is developing quality standards that can be used in vehicle design. Specific items also identified as valuable in this area, include:

- Cylinder pressure sensing to optimise combustion independent of fuel.
- Fuel quality sensors (especially for first generation biodiesel).
- Lubricant interaction with the bio-content of fuel to protect engines from wear (limiting negative impacts caused by oil dilution by the fuel).

Research Gap 2: No work could be identified that examines the resource time needed to move to high-blend fuels. However, current work commissioned by the LowCVP is looking at the market for high-blend biofuels, which may address this to an extent.

Research Gap 3: There is a need for fuel quality standards for high blends, with the manufacturers' main concern being for first generation biodiesel fuel quality. This is highlighted as having particular importance given that there is significant variability in the quality of first generation biodiesel fuels sourced from different feedstocks and suppliers.

Research Gap 4: Research into fuel quality sensors, cylinder pressure sensing to optimise combustion independent of fuel.

Research Gap 5: Research into lubricant interaction with the bio-content of fuel for engine wear protection.

## 3) What are the impacts on vehicle engines (and uncertainties) in different areas?

Industry is carrying out work on the impacts on vehicle engines internally, i.e. for their own models, with a number of manufacturers (e.g. Scania) also providing customer detail on differences in maintenance levels needed when running high-blend fuels.

For the manufacturers, the main concern is the fuel quality of first generation biodiesel, particularly with regard to its shelf life and stability. The significant variance in the quality of first generation biodiesel fuels produced from different feedstocks and sourced from different suppliers is problematic – hence the importance vehicle manufacturers place on fuel quality standards. Such problems are reportedly reduced or eliminated in HVO biodiesel and BtL biodiesel fuels.

The need for significant research in this area will therefore depend on the timing and rate of market rollout of such fuels and if, and how quickly, they replace conventional biodiesel fuels.

In view of the potential massive increase in the types of fuel available to customers (e.g. E5, B5, E7, B7, E10, B10, B30, E75, E85, etc.), there is a related need for more work to be done in:

- Optimisation and legislation on the range of fuels on the market.
- Labelling of pumps.
- Whether there is sufficient space (for new fuel infrastructure) on fuel station forecourts.
- The education of end users.

This will help minimise the possibilities for negative impacts through the use of blends, which are not suitable for certain vehicles.

No research on long-term impacts was identified. A relative assessment of the compatibility of new versus second-hand vehicles is also lacking, although the Environment Agency's trials on predominantly out-of-warranty vehicles in its fleet might result in some useful information.

Research Gap 6: An assessment of the compatibility of second-hand vehicles, and thus the impact of biofuels on older vehicles, is currently lacking, although the Environment Agency's trials on predominantly 'out of warranty' vehicles in its fleet might produce some useful information.

Research Gap 7: Similarly, this study did not identify any research currently being carried out on long-term impacts to vehicles.

## **5) How much will vehicle technology issues change as advanced biofuels come on stream?**

The introduction of advanced bioethanol production is not expected to impact on vehicle technology, because the resulting fuel is chemically exactly the same as existing fuels unlike for biodiesel. In addition, research is being carried out by industry on optimising flex-fuel vehicles to take advantage of high-blend bioethanol fuels (independent of the production method).

The situation is different for biodiesel, where future advanced biodiesel fuels are anticipated to be of equivalent or higher quality and more compatible with conventional diesel technologies, e.g. BtL biodiesel. Some companies, which favour such fuel in their vehicles (e.g. VW and Daimler), have indicated that their research is geared towards taking advantage of these fuels when they become commercially available. Research on the performance and potential of HVO biodiesel fuels has not been identified through this work. This is an area that may require further investigation since it seems likely such fuels will become widely commercially available in a shorter timeframe than BtL biodiesel.

There are already a number of enabling technologies that would help to optimise engine performance across a wider range of biofuel blends, such as cylinder pressure sensing and fuel quality sensors. It is worth reiterating that without joined-up research between fuel suppliers and the automotive industry, the development of engine technology will not be able to take advantage of future biofuels. It would be interesting to understand the potential ethanol-petrol engine performance that might be possible if engines were designed and optimised to run high ethanol-petrol blends (e.g. ethanol boosted direct injection (EBDI) engines such as those being developed by Ricardo plc, and also ethanol–diesel blends). If bioethanol production costs are significantly lower than for biodiesel, and if the performance gap in fuel consumption with diesel engines was reduced, it could be envisaged that the trend in Europe towards diesel and away from petrol might be reversed.

Research Gap 8: Although it appears to be generally accepted that Biomass to Liquid (BtL) biodiesel will be of equivalent or higher quality than conventional diesel, research on the performance and potential of Hydrotreated Vegetable Oil (HVO) biodiesel fuels has not been identified through this work. As it seems likely that such fuels will become widely commercially available in a shorter timeframe than BtL biodiesel, this is an area that may require further investigation

Research Gap 9: Impact of wider availability of sustainable bioethanol on future engine technology development

### **6.1.7 Summary and conclusions**

The research gaps for the use of biofuels in vehicle capability in the UK relate in general to understanding the capability of the UK fleet to use biofuels and understanding what impact biofuels have on engines and fuel supply systems for both current and future biofuels. These are often relatively small pieces of work, although some may involve monitoring trials over longer time periods and most involve co-operation between car and component manufacturers and fuel suppliers.

#### **Key research gaps on the compatibility of the UK fleet with biofuels**

Immediate gaps identified in this study include an evaluation of the current UK road transport fleet to use biofuels blends greater than 5% and an examination of future fleet capability to use (conventional and advanced) biofuels (at blends above 5%). It was suggested that such work could build on the foundation provided by current LowCVP work. This gap is considered to be important in the medium-term and of high significance in determining what needs to be done to adopt potential future biofuels. The projects themselves are not large (the size is ranked as small); and could be done through existing government agencies, such as the LowCVP, although there would need to be input and co-operation from industry and fuel suppliers

#### **Key research gaps on achieving a move to higher blend levels**

There is a need to assess the resource time needed to move to higher blends in the UK, which would also build on current work by LowCVP. This work is relatively significant and urgent in the medium-term, but would be a relatively small project, probably done through one organisation. The co-operation of industry would also be required.

If there is to be a move towards high blend biofuels, there will be a need for fuel quality standards to be established for high blends, particularly given the significant variation in first generation biodiesel. Work on fuel quality standards is currently being co-ordinated by CEN and any similar work in the future would presumably also be part of this process. Consequently, this work has been assessed as urgent in the medium-term (as high blend biofuels will not be introduced over the next 12 months), but significant in terms of acceptability of the fuel. This is assessed to be a medium to small project because of the need to work on an international basis (e.g. with CEN) and to ensure that there is joined up research between fuel suppliers and the vehicle and component manufacturers.

In addition the study identified a need to understand specific impacts on components, including:

- Fuel quality and cylinder pressure sensing to optimise combustion independent of fuel – this is an urgent gap which was assessed to be of moderate significance. The size of the gap is medium to small because it is relatively straightforward, of moderate cost and could be co-funded by industry.
- Lubricant interaction with biofuel content – work on the long-term effect on engine robustness of lubricant dilution by biodiesel fuel and contamination with oxidation by-products. This is an urgent research gap, of medium significance. The gap has been assessed to be small to medium, because it is a relatively straightforward piece of work, but may require time and there does need to be co-operation with industry.

### **Key research gaps on the impacts of biofuel use on vehicle engines**

The study identified gaps in understanding the impacts of biofuels on older vehicles and on long-term use of biofuels generally:

- Some work has been done on the impacts of biofuels on older vehicles (e.g. by the Environment Agency), but there is a need to provide guidance on the compatibility of older vehicles with biofuel blends. This is urgent in the medium term but is not considered too significant unless higher blends are rapidly introduced. The research gap is a medium to small piece of work; it is relatively straightforward, although it may require time and the testing of a large number of different technologies and models of different ages across all vehicle types.
- Assessment of the long-term impacts of biofuels on vehicles is urgently needed and a significant piece of work, because it may produce results that guide future work on component design. Work is also needed to examine the range of potential fuels types to allow guidance on optimisation and legislation on a range of fuels on the market, identification of pumps and the education of end users. Although a fairly straightforward piece of work, it has been assessed to be a medium to large piece of work. This is because of the timescale over which the work will need to be done; the need for interaction between manufacturers and the fuel supply industry; the number of different fuels that need to be tested; and the number of different vehicles on which assessment will need to take place.

### **Key research gaps on changes to vehicle technology resulting from the introduction of advanced biofuels**

Two main research gaps have been identified in this area – the potential impacts of advanced biofuels on the development of future engine technology, and the impact of the wider availability of sustainable bioethanol.

- Although some work has been carried out by vehicle manufacturers on looking at the impacts of advanced biofuels on engine technology, (particularly on optimising flex-fuel vehicles for the use of higher blends of bioethanol), further work is needed on specific fuels. For example, there is a need to understand the impacts of hydrotreated vegetable oil in the short term and to examine the impact of BtL biodiesel, as this is also likely to be one of the next available biofuels. This work is assessed as being of medium-term urgency and significance, because the fuels are not likely to be available on a wide-scale in the immediate future. The amount of work needed is assessed to be medium to large, because of the need to ensure that fuel suppliers work with industry in this area, and the need to ensure comprehensive cover of all relevant fuels.
- The impact of wider availability of sustainable bioethanol on future engine technology development may be important if bioethanol becomes available at a lower cost than biodiesel, thus reversing the impact of the trend towards diesel within the EU. This study indicated that modelling of this situation is required, together with an examination of the implications for engine technologies. This is of medium-term urgency and medium significance; but it is important to understand the potential for it to happen. The work is relatively straightforward, but is thought to be medium to large in size. This is because of the international nature of the work, the restricted availability of information, and the need to work with industry.

Table 6-2 Vehicle engines – key findings

Research Gap	1) Potential evolution of future fleet capability	2) Assessment of resource, time needed to move to high-blends	3) Fuel quality standards for high-blend biofuels	4) Fuel quality and cylinder pressure sensing	5) Lubricant interaction with bio-content	6) Impacts of biofuels on older vehicles	7) Long term impacts of biofuels	8) Potential impacts of advanced biofuels on future engine technology development	9) Impact of wider availability of sustainable bioethanol on future engine technology development
Key related work	LowCVP, industry								
Complexity	**	*	**	**	**	**	**	**	**
Time scale	*	*	**	***	***	***	***	**	**
Potential costs	*	*	**	**	**	**	**	*	*
National or international?	UK	International	International	International	International	Both	Both	National or International	National or International
Availability of data	Some restricted data	Restricted	Mixture	Restricted	Restricted	?	?	Restricted	Restricted
Availability of skill sets	***	**	**	**	**	**	**	*	**

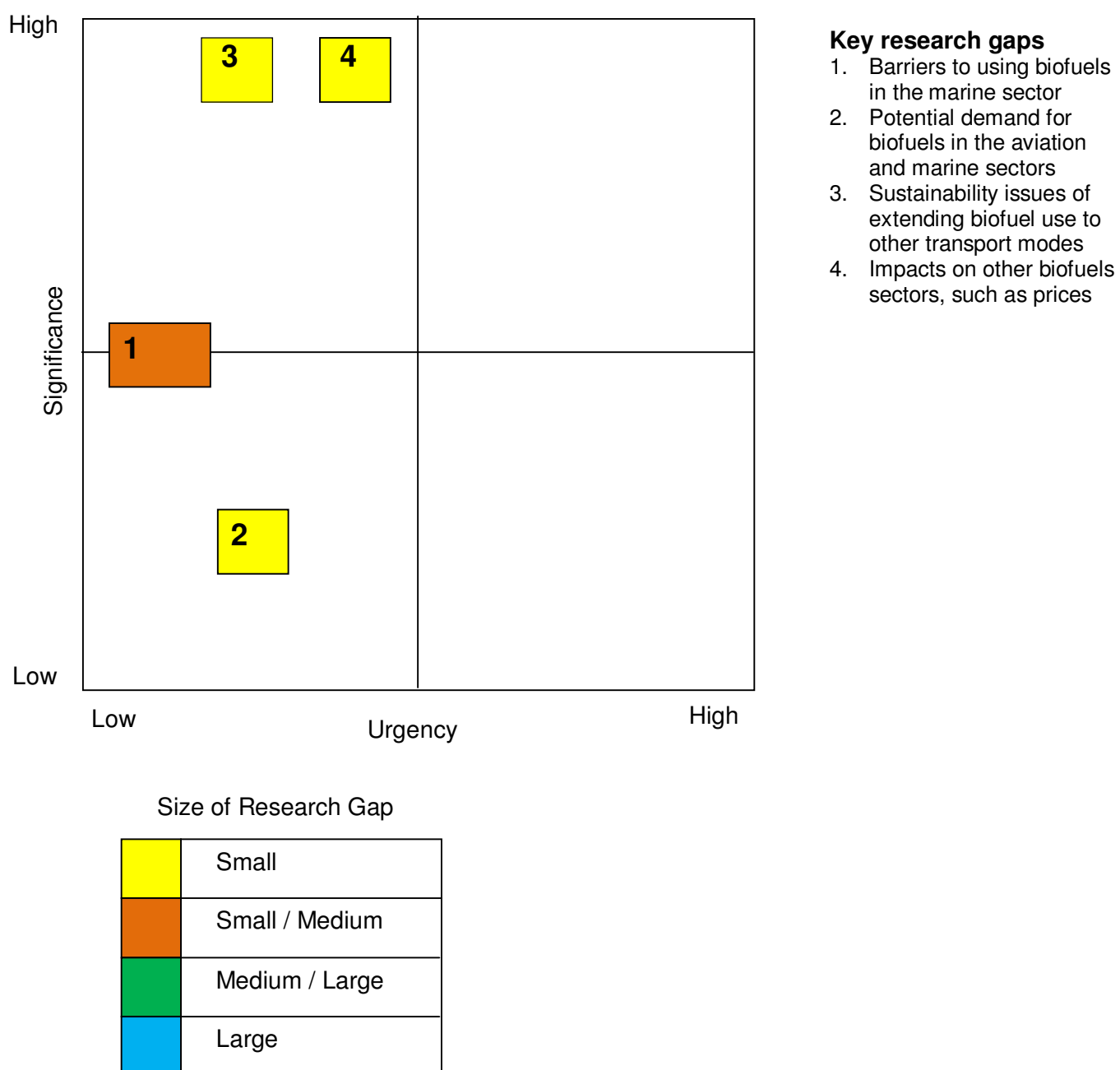
**Key**

<b>Significance</b> – please see matrix	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k * <£100k	<b>National or international i.e.</b> can the work be done in the UK or would it be better done internationally?
<b>Availability of data</b> This will refer to the IPR/availability of R&D already ongoing in the area (e.g. Commercial – restricted; or published/available)			<b>Availability of skill sets</b> *** a number of organisations working in area ** availability restricted to a few groups or only on international scale * skills gap, significant training required	



## 6.2 The extension of biofuels for use in other modes of transport

**Figure 6-2 Matrix prioritising key research gaps for vehicle engines and flex fuel vehicles**



### 6.2.1 Executive Summary

*‘Can biofuels be a viable and sustainable way of reducing GHG emissions in other transport sectors, and what barriers are there?’*

Rail, aviation and shipping all contribute to GHG emissions, with forecasts suggesting that the contribution from the latter two modes will increase significantly. Reflecting this, there has been an increasing interest in measures, which can reduce the GHG impact of these modes.

This chapter considers current and future research in this area and identifies the key research gaps, which need to be filled before we can understand whether biofuels can be a viable and sustainable way of reducing GHG emissions in other transport sectors and the barriers to this.

These key research gaps include:

Research Gap 1: No information was identified on R&D aimed at investigating the ability of the marine sector to utilise biofuels.

Research Gap 2: Little information was identified to indicate the potential demand for biofuels in the aviation and marine sectors. However, a recently commissioned study by the CCC will consider the use of Biofuels and Hydrogen in aviation and include estimates of demand.

Research Gap 3: No evidence has been provided that specifically addresses the issue of sustainability, despite significant concerns and limits on the volume of biofuels that can be produced sustainably.

Research Gap 4: No evidence was submitted in relation to impacts on other biofuel (and bioenergy) sectors, such as prices. This is thought to be mainly because R&D into technical feasibility for other sectors is still at a much earlier stage than for road transport.

A reasonable amount of detail was gathered on current activities being carried out in this area for the aviation industry. Little information was identified for the rail sector (although a number of trials have already been performed internationally and are ongoing in the UK) and no information was received for other transport sectors. For the rail sector, biodiesel does not appear to be a technical challenge but more of a commercial one. For the aviation sector, there is still much research needed or being carried out, although the main issues relate to the fuels themselves rather than modifications to aircraft / their engines. Future advanced HVO (hydrotreated vegetable oil) and BtL biofuels are anticipated to have hardly any limitations compared to conventional diesel and kerosene equivalents. They may even have some advantages – HVO fuels reportedly have a higher energy density, potentially leading to weight reduction and reduced fuel use for in the aviation industry.

### 6.2.2 Context

Emissions from non-road modes can make a significant current contribution to UK CO<sub>2</sub> emissions<sup>52</sup>. Current emissions per year are shown below.

- Aviation (international flights) – 38 Mt CO<sub>2</sub>.
- Shipping – 12 Mt CO<sub>2</sub>.
- Rail – 2 Mt CO<sub>2</sub>.
- Although road transport at 120 Mt CO<sub>2</sub> dominates.

Forecasts for growth in the aviation and shipping sectors are high and this corresponds with an increase in emissions. DfT forecasts<sup>52</sup> suggest that aviation emissions will increase to 60 MtCO<sub>2</sub> in 2050.

Understandably, therefore, there is interest in ways of mitigating these impacts, including the potential for biofuels.

However, outside the area of road transport, there is much less experience and understanding of the impacts of biofuel use in other transport applications. The most experience has probably been gained in the diesel rail sector, which in many countries uses the same fuel as for road transport. However, due to the small size of this sector relatively little dedicated work has been carried out, particularly since the longer term alternative – railway electrification – is more technologically mature and has greater environmental benefits. R&D into aviation biofuels has only relatively recently become significant, but it is rapidly increasing in prominence with several high-profile demonstration flights taking place in the last year.

### 6.2.3 Key research questions

This section explores what research there is on: whether biofuels will be a viable and sustainable way of reducing GHG emissions in other transport sectors, and what barriers are there?

This is underpinned by an analysis of what research there is on:

- 1) The technical, institutional, economic and other barriers to using biofuels in:
  - Aviation.
  - Rail.
  - Shipping.
- 2) What is likely to be the demand for biofuels in these sectors, and what economic and fiscal issues and levers would be required to influence take-up?
- 3) What will be the likely characteristics of biofuels used in these modes of transport? What feedstock will be used, where will it be sourced from, what will be the refinery and infrastructure requirements?
- 4) When are these biofuels likely to come onto the market?

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<sup>52</sup> DfT (2009) UK Air Passenger Demand and CO<sub>2</sub> forecasts.

- 5) What are the sustainability issues of extending biofuel use to other modes of transport, including indirect effects, and also whether there will be enough biomass to extend biofuel use to aviation and still maintain a 10% EU target?
- 6) What will be the impacts on other biofuel sectors – will process increase?
- 7) What will be the impacts on engines?

#### 6.2.4 Research in the area

The status of compatibility and research concerning the use of the main biofuels in the rail, aviation and marine sectors can be summarised as follows:

Whilst there is considerable experience and understanding of the impacts of biodiesel use in road vehicles, there is limited experience on the railways. Tests by operators indicate mixed results – initial engine results from desktop analysis and test bench work shows that current biodiesel is feasible for use in railway traction units engines in lower percentage blends. However, there are potential disadvantages such as increased fuel consumption and decreased power.

Biodiesel: Higher blend (>5%) vehicle compatibility issues are essentially restricted to first generation biodiesel (via esterification of oils), as second generation BtL type fuels are fully compatible with existing specifications. Recent developments in HVO (hydrotreated vegetable oil) fuels are also promising and such hydrotreating processes could deliver higher/more consistent quality biodiesel than conventional esterification processes. Recent trials suggest that modified rail vehicles in the UK may be able to use B20 fuel with relatively few impacts.

Blends in excess of B30 (30% biodiesel content) may increase maintenance costs, although, it is expected that second generation biofuels will be of a higher specification and indeed may prove to be better than fossil fuels.

Biodiesel can influence the emissions from engines and this needs to be considered in light of EU Directive on Non-Road Mobile Machinery stage IIIB or equal legislation. For example, using biodiesel is likely to increase NO<sub>x</sub> emissions but lower particulate emissions, even if tests results vary from railway to railway.

Bio-DME: Bio-DME use for in rail applications is unlikely as DME would be used as a liquid at 5-10 bar, with transport, storage and distribution similar to that of LPG. Rail applications would be significantly limited due to the additional volume and weight of such storage.

For the aviation sector, significant development in aviation biofuels is only relatively recent. The formation of cross-industry initiatives in the last year has led to demonstration flights and a number of US and European research projects on sustainable biofuels have also only recently started.

Aviation biofuels need to be (to cover biofuels use over the next twenty to thirty years) drop-in biofuels that essentially require no aircraft modifications due to their international operation (hence need to be able to use fuel from anywhere in the world) and long lifetimes. Aviation biofuel produced from hydrotreated vegetable oil (HVO) and synthetic kerosene from BtL type processes are the primary viable short-medium term alternatives to conventional jet fuel.

BtL biokerosene: Synthetic kerosene fuels include those produced by CtL (coal-to-liquid), GtL (gas-to-liquid) or BtL (biomass-to-liquid) processes. These fuels appear to have relatively few compatibility issues (other than upgrading aromatics content via blending) and have already achieved Jet-A and Jet-A1 quality certification/approval at both 50% blend and more recently at 100%.

HVO biokerosene: Aviation biofuels produced by hydroprocessing technology are a relatively recent development and have been undergoing tests in recent high-profile demonstrations. Results to date are promising and these fuels are being developed in mind for certification in blends with conventional kerosene. Recent tests of this kind of fuel show reportedly as good or better qualities than Jet A refined from petroleum. It does not freeze at high-altitude temperatures, delivers the same or more power to the engines, and is lighter – an additional advantage that could contribute to lower fuel consumption.

Marine Engines: There appears to be relatively little research in this area. However, there is likely to be similar compatibility issues for current biodiesel fuels used in marine diesel engines. Performance of conventional biodiesel or other biofuels in other marine engines requires further research. Typically large marine engines run on relatively low quality bunker fuel (compared to other forms of transport), however recent amendments in MARPOL VI aimed at reducing air pollution from ships are likely to result in higher quality fuels and more refined engines in new vessels.

The table below lists the work that is being done on these issues at UK, European and international level.

**Table 6-3 Research in the area of biofuels and rail transport**

<b>Funding or research organisation and budget where available</b>	<b>Current status of research – rail</b>
<b>UK</b>	
RSSB and rail industry	RSSB (Rail Safety and Standards Board) and ATOC (Association of Train Operating Companies) co-ordinated bench and service trials of biodiesel fuel with a number of UK rail operators have been run from 2007, with reporting on the results due mid-2009.
ATOC AEA	Research into the technical feasibility of biofuels for rail. Completed 2007.
<b>Europe</b>	
SNCF, DB, CD, MAV	A number of European rail operators have carried out their own bench and field trials on rail vehicles and engines – these include French railway operator SNCF, German railway operator DB, the Czech Operator CD, the Hungarian operator MAV
MTU	To meet the expected rail demand, MTU have already developed an engine that is capable of running on B100.

**Table 6-4 Research in the area of biofuels and aviation**

<b>Funding or research organisation and budget where available</b>	<b>Current status of research – aviation</b>
<b>UK</b>	
Committee on Climate Change (CCC)  E4Tech	<p>Potential for Biofuels for Aviation in UK</p> <p>The review will consider how biofuels could be used in UK aviation in terms of technical feasibility and their wider implications in terms of the economy and sustainability.</p> <p>The research has just started and will be completed end of August 2009. E4Tech Consultancy are undertaking the work.</p> <p>The research is part of the wider CCC Review of Aviation Emissions in the UK.</p>
OMEGA Sheffield, Cranfield, Leeds, Manchester Metropolitan University	<p>Sustainable fuels for aviation</p> <p>The study, which involves several aviation and fuels stakeholders, will evaluate the relative environmental impacts of potential alternative aviation fuels.</p> <p>It will look at kerosene and other fuels derived from fossil fuels; synthetic liquid fuels manufactured from coal, biomass or natural gas; and biofuels made from agricultural crops. It will assess the noise, emission and engine performance of each sustainable fuel.</p>

Funding or research organisation and budget where available	Current status of research – aviation
OMEGA Leeds and Sheffield Universities	Alternative Aviation Fuels data centre  The data centre will include: <ul style="list-style-type: none"> <li>Physical, chemical, operational and environmental properties.</li> <li>The life-cycle analysis (LCA).</li> </ul> The price relative to the price of crude oil. <ul style="list-style-type: none"> <li>Health and safety measures.</li> </ul>
NNFCC	Review of the options for developing aviation fuels from renewable feedstock. <a href="http://www.nnfcc.co.uk/metadot/index.pl?id=4033;isa=DBRow;op=show;dbview_id=2457">http://www.nnfcc.co.uk/metadot/index.pl?id=4033;isa=DBRow;op=show;dbview_id=2457</a>
<b>Europe</b>	
European Commission DGRTD Framework Programme 7 (FP7), Industry co-funding. Total Budget: 9.75 M € EC Grant: 6.82 M €	ALFA-BIRD EC FP7 Research Programme. The Alternative fuels and biofuels for aircraft development started in July 2008, running until June 2012 (see <a href="http://www.alfa-bird.eu-vri.eu">http://www.alfa-bird.eu-vri.eu</a> ).
DGTREN / FP7 Value est. ~3 M Euro	SWAFEA Research Programme (strategic feasibility and impact study on alternative fuels for aviation) started in early 2009.
<b>US</b>	
CAAFI	The Commercial Aviation Alternative Fuels Initiative (CAAFI) is a US air transport industry coalition formed to sponsor research into alternative fuels, including qualification, life-cycle carbon balance and sustainability.
<b>Industry</b>	
Airbus  EU FP7 funded project. 50% EC FP7, 50% Airbus	Airbus' alternative fuels roadmap is focusing on testing of viable alternative fuels such as GTL, paving the way for use of sustainable biofuels when they become available.  Airbus' alternative fuels roadmap is focusing on testing of viable alternative fuels such as GTL, paving the way for use of sustainable biofuels when they become available. Airbus will only consider biofuels that are produced from renewable biomass sources that do not compete with existing food, land and water resources.
Boeing	Boeing is working with airlines and engine manufacturers to gather biofuel performance data as part of the industry's efforts to revise the current American Society for Testing and Materials (ASTM) standards to include fuels from sustainable plant sources. Links to research on sustainable aviation biofuels is available at <a href="http://www.newairplane.com/environment/sustainable-biofuels/">http://www.newairplane.com/environment/sustainable-biofuels/</a>

Funding or research organisation and budget where available	Current status of research – aviation
Rolls-Royce	Testing of samples of the jatropha derived fuel used in the recent Air New-Zealand demonstration flight, as well as wider work on aviation biofuels.
Cross-industry	Several air carriers working to diversify and secure their energy future through participation in the Sustainable Aviation Fuel Users Group (SAFUG).
	Virgin Atlantic, Boeing and GE Aviation carried out in February 2008 a “proof of concept” exercise with a Boeing 747-400 on a short flight from London to Amsterdam, using a biofuel specifically engineered for aviation.
	Air New Zealand and Boeing conducted a sustainable biofuels flight from Auckland using a 747-400 jetliner in November 2008. Conducted in partnership with Rolls-Royce and UOP, a Honeywell company, one of the airplane’s four Rolls-Royce RB211 engines was be powered in part using advanced generation biofuels derived from jatropha.
	Japan Airlines (JAL) conducted a demonstration flight in January 2009 using a sustainable biofuel primarily refined from the energy crop, camelina. It was also the first demo flight using a combination of three sustainable biofuel feedstocks, as well as the first one using Pratt & Whitney engines (on a Boeing 747-300 aircraft).
	Continental completed a two hour test flight out of Houston in January 2009 using a two-engine Boeing 737-800 with one engine powered by a 50-50 blend of regular jet fuel and a synthetic biofuel made from Jatropha and a small contribution (>1%) algae feedstocks. The biokerosene fuel was produced by UOP (a division of Honeywell).

### 6.2.5 Research gaps

Along with road vehicles, in general there appears to be relatively little current publicly-funded research in this area. Most appears to be conducted mainly in-house by industry. As such, it is difficult to obtain detail on the specifics of research topics, timing and budgets, as this information is commercially sensitive. However, more general information is available on the current state of compatibility with different biofuels, from which certain conclusions can be drawn.



Discussions at the project workshop held at the end of February 2009, focused more on the production and quality of the biofuels themselves, rather than on issues concerning technologies. This is mainly because, given the long service lives of aircraft, rail rolling stock and ships, any alternative biofuel really needs to be a 'drop-in' alternative. This view is reinforced by the need for aircraft and ships to be able to handle fuels from anywhere in the world, so variation in fuel quality is not an option.

### **1) What are the technical, institutional, economic, and other barriers to using biofuels in other transport sectors?**

Research is already underway or available for the rail sector, which indicates that biodiesel does not appear to be a technical challenge but more of a commercial one – the rail sector needs the supply and the right price. The Association of Train Operating Companies (ATOC) believes that uptake would be very high if biodiesel was cheaper or at least the same price as gas oil. However, it envisages this would be hard to achieve in the current market place. Research coordinated by RSSB (Rail Safety and Standards Board) on the bench and service trials of biodiesel blends carried out since 2007 is due to report results in mid-2009.

In the aviation sector, research is currently being carried out in the US and in multi-million Euro European EC FP7 and industry co-funded projects (ALFA-BIRD and SWAFEA) that will address this area. The SWAFEA project for example will cover technical, organisational, economic, society, environmental and geopolitical aspects of alternative fuels for aviation.

There is also significant aviation industry activity at present. For example, Airbus has indicated that it is involved in work to optimise fuel formulations for aircraft to meet or exceed standard fuel requirements (flash point, freeze point, etc). This is to be a UK-centred research activity. Boeing is also extremely active in this area and is one of the co-founders of the Sustainable Aviation Fuels User Group (SAFUG), which was formed to accelerate the development and commercialisation of sustainable new aviation fuels.

Safety is seen as a key issue in the aviation sector. Airbus has identified that wider suitability and safety issues related to infrastructure contamination by biofuels must be considered within the scope of any research programme. For example, the contamination of fuel transport infrastructure with fatty acid methyl esters used in biodiesel impacts aircraft safety and is of serious concern to the aviation industry. The mandatory introduction of biofuels to a given sector or the introduction of a new biofuel type would need to include this important safety consideration.

Research Gap 1: No information was found in this study on R&D aimed at investigating the ability of the marine sector to utilise biofuels.

### **2) What is likely to be the demand for biofuels in these sectors, and what economic and fiscal issues and levers would be required to influence take-up?**

The CCC study on the potential for biofuels use in Aviation in the UK is of relevance here. The work will consider biofuels demand scenarios. The research has just started and will be completed at the end of August 2009. While, the SWAFEA project which will cover technical, organisational, economic, society, environmental and geopolitical aspects of alternative fuels for aviation is also likely to provide relevant information.

Airbus has said it believes that second generation/advanced biofuel could provide up to 30 percent of all commercial aviation jet fuel by 2030. Discussion at the stakeholder workshop held in February 2009 also suggested that this level of biofuel would be needed if the aviation sector were to achieve its mid to long term CO<sub>2</sub> reduction targets. Discussion at the workshop also suggested that at moment around 60% of the kerosene used in the UK is already imported.

Research Gap 2: Little information was identified to indicate the potential demand for biofuels in the aviation and marine sectors.

### **3) What will be the likely characteristics of biofuels used in these modes of transport?**

It is already clear (as discussed in 6.2.4) that biofuels for aviation, rail and in many cases, shipping applications, need to be of the 'drop-in' variety of fuels. With the different modes requiring different levels of specification with aviation being the highest.

The aviation industry has already certified synthetic fuels produced by CtL, GtL and BtL type processes for Jet-A and Jet-A1 specification, but BtL fuel technology is still in development and at the moment is prohibitively expensive. Recent research interest has been mainly focused on Hydrotreated Vegetable Oil (HVO) aviation biofuels, which have already been used successfully at various blend levels in demonstration flights over the last year. It seems that HVO biofuels do not have the detrimental side-effects of ester-type biodiesel fuels. Boeing has also stated that the primary focus now is on filling gaps for technical certification, commercial production and distribution, together with sustainable development, economic, environmental and social considerations.

The OMEGA alternative aviation fuels database will consider a range of fuels including:

- Bio-aviation fuels (e.g. soy beans, palm oil, switch grass, Jatropha and algae).
- Butanol, methanol and ethanol.
- Hydrogen.
- Coal to liquids.
- Fischer-Tropsch aviation fuel.
- Gas to liquids.
- Hydrogenation-derived renewable aviation fuel.

### **4) When are these biofuels likely to come onto the market?**

Aviation research in the EU, the USA and across industry is currently addressing this area, as discussed above. However, the large oil companies, like BP, are not prioritising biofuels' development in the aviation sector. This is possibly because aviation fuel is a relatively small part of their business and less profitable than fuels for the road transport sector. Also, there is already significant competition for a limited bioenergy resource. According to Virgin Atlantic, it is the smaller companies that appear to be most interested in specialising in biofuels for aviation as it offers the potential to become a larger part of their business. Having said that, there may be an incentive through the European Union Emission Trading system (EU ETS) to develop and commercialise biofuels, so initial deployment in the aviation sector may not be too far into the future.

### **5) What are the sustainability issues of extending biofuel use to other modes of transport, including indirect effects, and also including whether there will be enough biomass to extend biofuel use to aviation, and maintain a 10% EU target?**

The CCC work will consider the sustainability of biofuels for aviation and demand scenarios.

The OMEGA research into sustainable fuels for aviation will evaluate the relative environmental impacts of potential alternative aviation fuels. It will assess the noise, emission, and engine performance of each sustainable fuel.

At the moment there are few, if any, other viable alternatives for the aviation sector to reduce carbon emissions, but there are other options for road transport in the long-term. If technological barriers to the widespread introduction of high-blend biofuels can be overcome, this will result in competing demand for limited resources from different sectors for bioenergy (including heat and power).

Research Gap 3: No evidence has been provided that specifically addresses the issue of sustainability, despite significant concerns and limits on the volume of biofuels that can be produced sustainably.

#### **6) What will be the impacts on other biofuel sectors – will prices increase?**

No research was identified which addresses this area, principally because R&D into technical feasibility for other sectors is still at a much earlier stage than for road transport.

Research Gap 4: No evidence was submitted in relation to impacts on other biofuel (and bioenergy) sectors, such as prices.

### **6.2.6 Summary and conclusions**

Work is underway to examine the use of biofuels in the rail and aviation sectors, but not in the marine sector. There is therefore a need to look at the barriers to the use of biofuels in this sector, including potential air emissions and other issues which might prevent its uptake. This is considered to be of medium significance but of low urgency. It would involve a small to medium piece of work probably based at one consultancy, but with an international element.

There is a need to examine the potential aviation and rail sector uptake of biofuels when they come onto the market and to look at their characteristics and what affect this may have on other biofuels markets. This is considered to be of low significance and urgency and a relatively small piece of work. However, it will need an appreciation of how much fuel these sectors use and what biofuels and feedstocks are being proposed.

Assessing the sustainability of extending biofuel use to other transport modes is not considered urgent but it is significant in understanding both economic and environmental impacts. This is a comparatively small piece of work because it should be straightforward and could be undertaken by a small team relatively quickly.

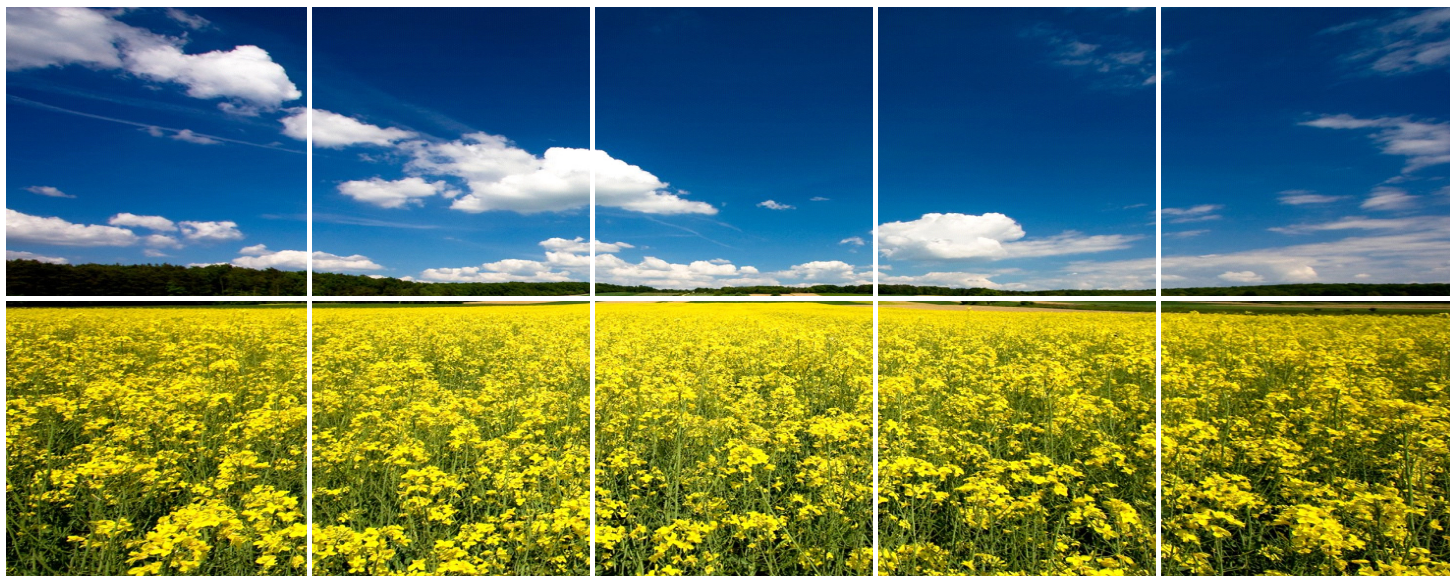
Looking at the impact of demand for biofuels, in the marine, aviation and rail sectors on other vehicle use, including economic impact, is regarded as of medium urgency and high significance. Again, however, this is a relatively small, straightforward piece of work, involving modelling, economic analysis and a relative indication of the sustainability of the use of biofuels in different transport modes.

**Table 6-5 The extension of biofuels for use in other modes of transport – Key findings**

Research Gap	1) Barriers to using biofuels in the marine sector	2) Potential demand for biofuels in the aviation and marine sectors	3) Sustainability issues of extending biofuel use to non-road transport modes	4) Impacts on other biofuel sectors, such as prices
Key related work				
Complexity	**	**	**	**
Time scale	**	*	**	*
Potential costs	**		**	*
National or international?	National	National	International	National
Availability of data	Limited	Available	Varied	?
Availability of skill sets	**	**	**	***

**Key**

<b>Significance</b> – please see matrix	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k * <£100k	<b>National or international</b> i.e. can the work be done in the UK or would it be better done internationally?
<b>Availability of data</b> This will refer to the IPR/availability of R&D already ongoing in the area (e.g. Commercial – restricted; or published/available)			<b>Availability of skill sets</b> *** a number of organisations working in area ** availability restricted to a few groups or only on international scale * skills gap, significant training required	



# Biofuels Research Gap Analysis

## Chapter 7 – Advanced/Second Generation

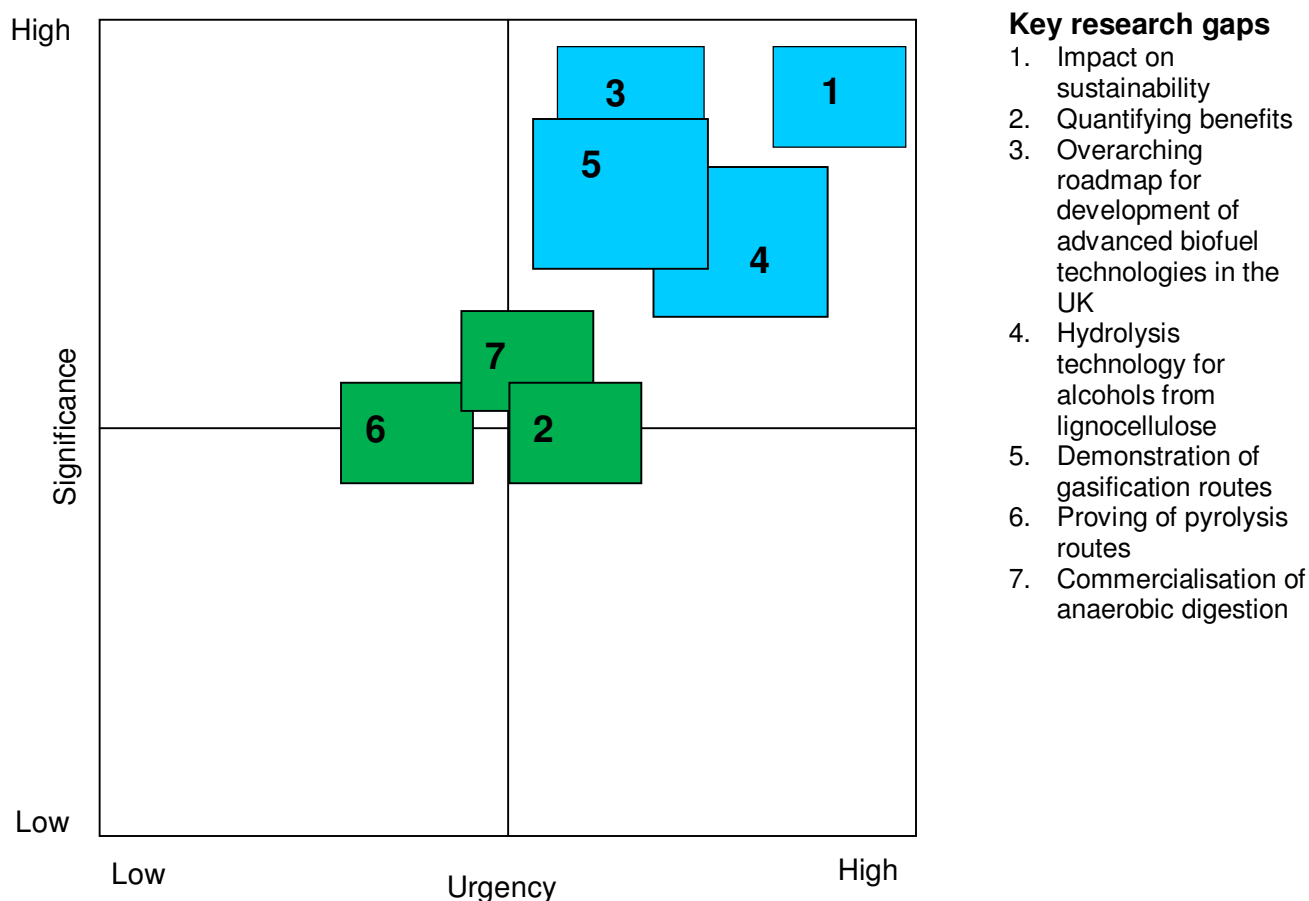






**Final report to the Biofuels Research  
Steering Group**

ED45917  
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## 7 Advanced/second generation biofuel technologies

### 7.1.1 Matrix prioritising key research gaps for advanced/second generation biofuel technologies



Size of Research Gap	
	Small
	Small / Medium
	Medium / Large
	Large

### 7.1.2 Executive Summary

*Whether advanced/second generation technologies are a viable, sustainable and advantageous pathway to meeting the 10% target by 2020, and what Government/EU action is required to bring them on stream?*

Advanced or second generation biofuel technologies are defined as those which convert lignocellulosic<sup>53</sup> materials, as opposed to first generation or conventional processes, which convert food (e.g. sugar/starch) crops; oil plants and animal fats. There are two principal technology routes for producing these advanced/second generation fuels – biological and thermochemical.

These advanced technologies can be viewed as offering a more sustainable alternative to first generation biofuels. They potentially offer higher GHG savings and have the benefit of being able to use a wider range of feedstocks. However, as with first generation technologies, it is essential that feedstock production avoids indirect effects and we need to consider the existing use of the land, especially for food production.

It is essential to understand the role that these technologies can play in meeting the 10% transport target, given that the review of the RED will involve an impact assessment of the minimum GHG saving thresholds to apply, taking into account the availability of first and second generation biofuels with a high level of GHG savings. The European Commission will also take into account the commercial availability of second generation biofuels as part of their review of (amongst others) the feasibility of meeting the 10% transport target sustainably.

This chapter considers current and future research in this area and identifies the research gaps which must be filled before we can understand whether these advanced/second generation technologies are a viable, sustainable and advantageous pathway to meeting the 10% target by 2020, and what Government/EU action is required to bring them on stream.

These research gaps include:

Research Gap 1: Further research needs to be carried out to identify the impacts of second generation biofuels on sustainability. This should link with work being supported by the BBSRC's Sustainable Bioenergy Centre.

Research Gap 2: The benefits of developing second generation biofuels need to be quantified. The aim of such work should be to demonstrate the best second and advanced generation routes for the UK in terms of efficiency of conversion, cost and sustainability, particularly taking into consideration UK infrastructure/facilities (e.g. the chemicals industry and the gas network).

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<sup>53</sup> e.g. *Lignocellulosic* biomass [1] refers to plant biomass that is composed of cellulose, hemicellulose, and lignin

Research Gap 3: There is a need for an overarching roadmap for the development of advanced biofuel technologies in the UK. This should consider what technologies best match the UK's strengths; whether it is possible to leverage funds for advanced biofuels development; and, if so, what is the best way forward to do this? This is the key research gap at present. There are a number of studies being undertaken that should be considered in this research gap, such as the UKERC funded work at Southampton University, and work at NNFFC, the Carbon Trust's Low Carbon Commercialisation Review and the LowCVP's work on the deployment of advanced biofuels.

Research Gap 4: Further work is required to improve the cost and efficiency of hydrolysis technology for alcohols from lignocelluloses. There is a need to assess the potential benefits of lignocelluloses ethanol in the UK. This should examine the potential benefits of production in the UK and whether or not the feedstocks would be better used, for example, in heat and power; and it should also look at the benefits of R&D in developing biotechnology for hydrolysis and the value of this biotechnology market to the UK. Any work on lignocelluloses feedstocks should take the work already ongoing in the US and work being supported by BBSRC into account.

Research Gap 5: There is a need to demonstrate gasification routes. A major barrier to this is the CAPEX and the state aid implications, which need to be addressed before the UK can support a demonstration plant.

Research Gap 6: Further work needs to be carried out on proving pyrolysis routes.

Research Gap 7: There is currently a gap in the commercialisation of anaerobic digestion processes for transport fuels.

Current work on thermochemical conversion processes is concentrated on demonstrating gasification technology and proving pyrolysis technologies. For biological processes, the focus is on reducing costs to an acceptable level and improving efficiency, largely through improvements to the hydrolysis stage. Anaerobic digestion is largely proven, although it is not necessarily economic for some feedstocks.

Work on lignocelluloses feedstocks shows steady progress towards reducing costs and improving yields suitability and pre-treatment. There is also a renewed interest in aquatic species such as algae.

Work to assess the suitability of developing advanced and second-generation biofuel technologies for UK conditions has been done by NNFFC and the Carbon Trust

### 7.1.3 Context

There are two principal technology routes for producing second-generation fuels; biological and thermochemical. As with any nascent area of technology, many variations are being investigated; the main focus however is as follows:

**Biological routes** for alcohol production convert the cellulose and hemicellulose found in lignocellulose materials to simple sugars that are then fermented to become ethanol or butanol. While challenges remain in the fermentation step, the major research challenges are centred on the technologies for hydrolysis, process integration and optimisation. The biological process of anaerobic digestion is also used to convert biological wastes to methane, which can be compressed for vehicle fuel. This concept is already used in Scandinavia and is relatively well proven.

**Thermochemical routes** involve two main processes: gasification and pyrolysis.



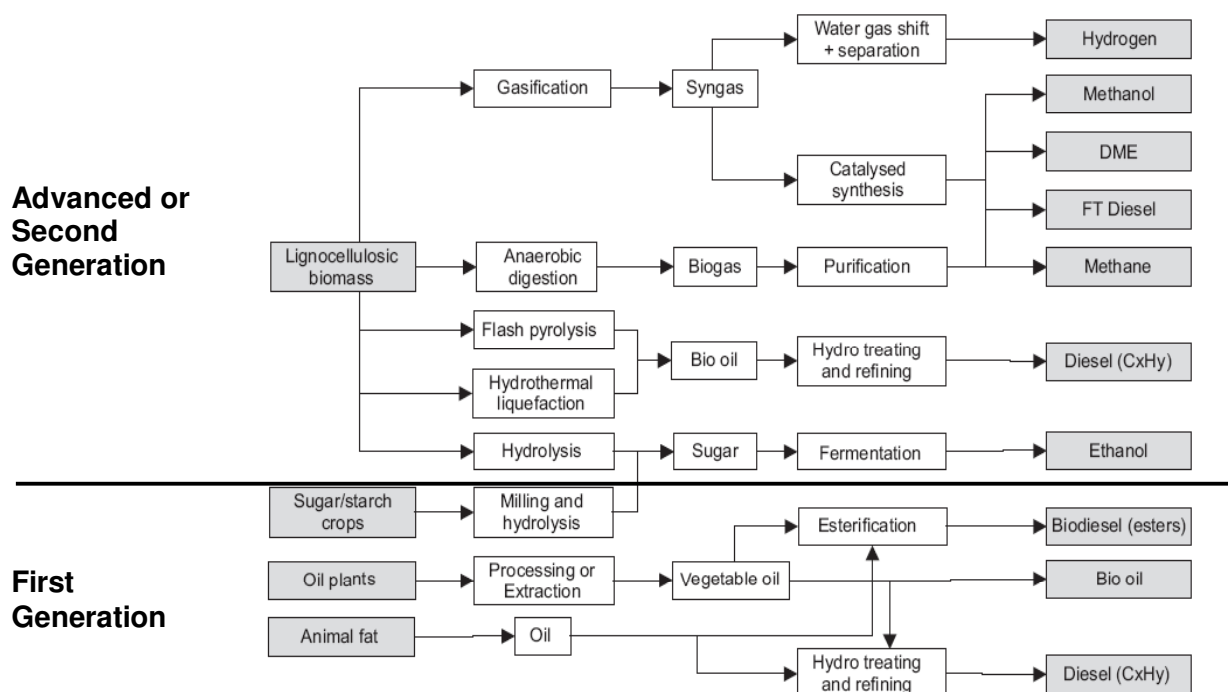
Gasification processes break the biomass into simpler molecules that can be re-combined into methanol, ethanol, methane or alkanes by conventional processes. The reaction conditions and the catalyst selected determine the final product. These routes are based on well understood industrial chemistry and have been applied throughout the last century to produce chemicals and fuels from coal and oil - generally in refinery-scale operations. There are no inherent difficulties in the basic chemistry; however, the main challenges are developing:

- Reliable and suitable biomass gasification technology.
- Installations that are cost effective and at sizes appropriate to biomass.
- The infrastructure necessary to bring the feedstock to the plant in an appropriate form and quality.

Pyrolysis processes break long chain polymers of biomass into complex oxygenated carbohydrates. To make hydrocarbon fuels that can be used in the current UK infrastructure requires the removal of oxygen, which is usually achieved by hydrogenation either in situ or as a separate operation. Pyrolysis is less developed than gasification but its technology has been commercialised for the production of speciality chemicals; however, the subsequent steps are unproven. The challenges are therefore to do with problems of scale and the reliable production of hydrocarbons.

A diagram illustrating examples of first and second generation technologies is shown below in Figure 7-1.

**Figure 7-1 First and second generation/advanced technologies**



Source: Hamelinck C.N. and Faaij A (2006)

In addition to the challenges above there is also the challenge of feedstock production. This involves the development of suitable energy crops such as short rotation coppice, energy grasses and other suitable crops.

There are many good reviews of biofuels production, but the IEA has recently summarised progress (IEA 2008) and the NNFFC has produced an excellent review of the technologies from the UK development viewpoint (NNFFC 2007).<sup>54</sup>

#### 7.1.4 Key research questions

A key overarching research question is: are advanced biofuels a viable, sustainable and advantageous pathway to meeting the 10% target by 2020, and what government and EU action is required to bring them on stream?

Key questions underpinning this include:

- 1) How sustainable will advanced technologies be compared to first generation fuels and current fossil fuels, including impacts on air/water/soil/biodiversity/natural resources/social/food, including indirect land use change and wider indirect effects?
- 2) Compared to first generation fuels and fossil fuels, what are the benefits of the different advanced biofuels, including economic, chemical, sustainability, infrastructure, logistical (etc) issues?
- 3) What are the likely future advanced and/or alternative biofuel technologies?
- 4) What are the technical, institutional, economic, research barriers to advanced biofuels coming on stream? How important is the upfront capital expenditure as a barrier to advanced biofuels development in the UK?
- 5) What would be the required economic, fiscal issues and levers to influence deployment?
- 6) What will be their potential contribution towards the 2020 transport target?
- 7) What advanced technologies are most suited to UK needs and is R&D being done to develop these within the UK? When are they likely to come on the market, and what determines investment in these technologies?

#### 7.1.5 Research in the area

Key research in the area is shown in Table 7-1.

**Table 7-1 Research in the area of advanced/second generation technologies**

Funding or research organisation and budget where available	Current status of research
<b>UK</b>	
NNFFC review (2007)	Liquid Transport Biofuels - Technology Status Report <u>Current work:</u> <ul style="list-style-type: none"> <li>Assessment of suitability of available biomass gasifiers for UK feedstocks (ends May 2009).</li> </ul>

<sup>54</sup> This includes a strength, weakness, opportunity and threat (SWOT) analysis for each technology option, a summary of technology providers and organisations involved in R&D, plus an indication of how close to the market the technologies are. For example, there is a flow chart summarising all development activities in specific key areas such as enzyme development. Finally there is a summary of UK activity in each key area.

Funding or research organisation and budget where available	Current status of research
	<ul style="list-style-type: none"> <li>Anaerobic treatment of packaging waste (ends Q3 2009).</li> <li>Production of biofuels from municipal solid waste. Ends: March 2009.</li> <li>Advanced biofuels roadmap: March 2009. Deliverables: practical strategy/roadmap for the development of advanced biofuels production in the UK.</li> <li>Life-cycle and techno-economic assessment of North East Biomass to Liquids project. Complete.</li> </ul> <p>Past work is provided in Annex 7.</p>
Research councils coordinated approach	<p>Supergen £6.4M phase II to include biofuels <a href="http://www.supergen-bioenergy.net/">http://www.supergen-bioenergy.net/</a></p> <p>TSEC-biosys (£2.3M 2005-2010) A whole systems approach to bioenergy demand and supply in the UK</p>
Sustainable Bioenergy Centre £27M	<p>6 research groups + £7M from 15 industrial concerns. <a href="http://www.bsbec.bbsrc.ac.uk">www.bsbec.bbsrc.ac.uk</a>. Will be examining: Perennial bioenergy crops; Cell wall sugars; Cell wall lignin; Lignocellulosic conversion to bioethanol; Second generation sustainable bacterial biofuels; Marine wood borer enzyme discovery.</p> <p>Three specific studies are important:          Bath University is leading work on sustainability of biofuels and bioenergy for heat and power.          Cambridge University is examining new enzymatic methods to convert lignocellulosic feedstocks to simple sugars (this work includes: development of new enabling technologies for polysaccharide analysis, study of hemicellulose degradation pathways and novel hydrolytic enzyme action, and study of genetic control of hemicellulose synthesis to better inform breeding studies and thus derive better feedstocks and enzymatic degradation systems).          Nottingham University is examining the potential for optimising conversion of cell wall material through modifying fungal enzymes and developing pre-treatment strategies. Work is also ongoing at Nottingham on the optimisation of fermentation.</p>
Integrated Biorefinery Technologies Initiative Club	<p>A partnership between BBSRC and the Bioscience for Business Knowledge Transfer Network aimed at developing biological processes and feedstocks to reduce dependence on fossil fuels.</p>
UKERC (UK Energy Research Centre)	<p>Southampton University is leading UKERC work on bioenergy and is developing a roadmap, which should be published in near future. Three work packages are being funded: Bioenergy scenarios for UK; crop improvement, environmental impacts, land use decisions; and development of a sustainability and MCDA framework for sustainability development (including full supply chain GHG emissions; sustainability criteria). (See UKERC 2007)</p>

Funding or research organisation and budget where available	Current status of research
The Carbon Trust	<p>Idea Assessments These examined the application of the technologies below in the UK, the state of the art internationally, where the development has happened and what UK skills are to develop these areas/technologies: Plant science and agronomy; Biorefineries; Algae; Novel Biofuels; Pyrolysis to transport fuels. These reports are unpublished.</p> <p><u>Pyrolysis challenge (£7-14M)</u> The Pyrolysis Challenge aims to produce oil with the properties required for integration either by modifying the pyrolysis process to produce better quality oil directly; or upgrading the oil before or at the refinery.</p> <p><u>Micro Algae (£10 -16M)</u> – 2 phase approach on fundamental R&amp;D and large-scale production (international). Call for proposals for phase 1 already out.</p> <p><u>Novel biofuels</u> – findings inconclusive as yet <u>DfT committed £3M/year</u> over this and next year to the CT's advanced biofuels accelerator programme.</p> <p><u>Low Carbon Technology Commercialisation Review (LCTCR)</u>. The Carbon Trust is undertaking a review of six technologies, one of which will be ethanol from lignocellulose. The review will address engineering and commercial aspects, the technology status, barriers to deployment and the potential roles for the UK. We understand results will become available in April 09.</p>
LowCVP Biofuels Pathway	Proposed project: Aim will be to provide policy makers with a high level examination of advanced biofuel feedstocks and pathways; their contribution to commercially available biofuels available in the UK by 2020; and the role for the UK.
UK universities	<p>UK universities working on conversion technologies: Manchester (gasification); Aston (pyrolysis); Leeds (pyrolysis), Cardiff (gasification), Cranfield (gasification), Newcastle (gasification, FT).</p> <p>UK universities and research establishments working on other aspects of biofuels: Cambridge (fermentation); Nottingham (optimisation of cell wall degradation); Southampton (Biofuels research map, biofuels crops); Rothamsted (biofuels crops); University of Aberdeen (energy crops); ADAS (energy crops).</p>
North East Biofuels	<p>One North East plus 20 other organisations represent the largest concentration of chemicals processing industry, engineering and supporting sector in UK. <a href="http://www.northeastbiofuels.com/">http://www.northeastbiofuels.com/</a></p> <p>Have committed about 16 M€ on synthetic biofuels, 35 M€ on ethanol from lignocellulosics and 15 M€ on biorefineries (this was part of a wider joint Call with RTD of a total of 57 M€). All areas of advanced and second generation biofuels and energy crops will be supported at demonstration level.</p>

Funding or research organisation and budget where available	Current status of research
Biofuels East	Supporting a virtual 'Advanced Biofuels Hub' on the Biofuels East web site: <a href="http://www.biofueleast.org.uk">www.biofueleast.org.uk</a> , aimed at fostering more collaboration between academia and industry.
FP7	<p>FP7 Biorefinery work is supported by DGRTD. Total funding in FP7 so far is 66.05 M€. There have been three calls to date and emphasis has been very much on second generation, sustainability, co-ordination with south America and support for coordinated actions (networks, information dissemination). Examples (full list of examples is provided in Annex 7)</p> <p>BIOREF-INTEG - Advanced biorefinery schemes integrated into existing industrial fuel complexes (1M Euro)</p> <p>GLYFINERY – Development of use of glycerol from biodiesel in biorefineries. (3.75 M€)</p> <p>GREENSYNGAS – Advanced cleaning devices for production of green syngas (2.72 M€)</p> <p>BIO-HUG – Novel bioprocesses for hemicellulose up grading &amp; 4 more on improved fermentation, genetic modification, improved biochemistry and hydrolysis, use of waste and integration of chemicals production.</p>
Demonstration plants supported by DG TREN	<p><u>Dong energy</u> – 30,000t straw/year, 4,300 tonnes of ethanol 40 M€. Total project cost ~65 M€ Process involves hydrothermal treatment, enzymic hydrolysis &amp; C5 fermentation.</p> <p><u>Finish Waste to bioethanol plant</u> – food industry residues.</p> <p><u>PERSO</u> - 4t/d pilot plant. Organic MSW to ethanol.</p> <p><u>BioSNG</u> – ECN/HGV 1 MW pilot plant. Small scale demo of waste to bioethanol in Finland – ST1 Biofuels – Etanolix 2 units on bakery waste, 1 on potato flakes, Support: 3.2 M€.</p> <p><u>Choren</u> – BtL 7.8 M€.</p> <p><u>BioDME</u>: support 8.2 M€.</p> <p>DG TREN has announced that 4 projects have been selected for support under the 2008 call for work on ethanol from lignocellulose: 8.6-9.1 M€ for each.</p> <p><u>Networks and information supported by DG TREN and RTD:</u>  FP6, ERA-net Bioenergy, bioethanol, Biofuels technology platform secretariat, biogas, development of CEN 335, advanced technologies, dissemination platforms.</p> <p>EU Biofuels Technology Platform further information provided in Annex. launching database of demos and pilot plant soon (before end Feb)  <a href="http://www.biofuelstp.eu/">http://www.biofuelstp.eu/</a></p> <p>BIOMATNET (bioproducts from non-food crops) provides further information on previous Framework support. – lists all FP research projects, technology platforms, Intelligent Energy Europe projects and describes FP7. (Biomatnet – Bioproducts from non–food crops)  <a href="http://www.biomatnet.org/home.html">http://www.biomatnet.org/home.html</a></p> <p>Intelligent Energy Europe Programme. Provision of information and communications on energy efficiency and renewable energy. Funds work</p>

Funding or research organisation and budget where available	Current status of research
	on networks, help in implementing biofuels, networks of suppliers to investigate supply & use, development of clean vehicles, carbon efficient labelling.
<b>US</b>	
US DOE	<p>The US DOE Biomass Program conducts research and development in the four key areas of technology required to produce biomass feedstocks and convert them to useful biofuels and value-added products. These technology areas are: Feedstocks, Processing and Conversion, Integrated Biorefineries, and Infrastructure. See: <a href="http://www1.eere.energy.gov/biomass/biomass_solicitations.html">http://www1.eere.energy.gov/biomass/biomass_solicitations.html</a> biomass production. This work is included in other chapters of the report.</p> <p>The Biomass Program Multi year Action Plan is described in detail in Annex 7 (US DOE, 2008)</p> <p>A joint solicitation from USDA and USDOE was issued covering Feedstocks development, Biofuels and Biobased Products Development, and Biofuels Development Analysis. This is described in detail in Annex 7.</p> <p>The 2010 DOE EERE budget is not yet finalised, but was proposed Feb 23, 2009. The Biomass program utilises a variety of funding mechanisms ranging from cost shares to loan guarantees, to directly funding research and development efforts. <a href="http://www1.eere.energy.gov/biomass/past_solicitations.html">http://www1.eere.energy.gov/biomass/past_solicitations.html</a> includes details on funding amounts for some of the larger projects in the Biomass program portfolio. Examples are provided in Annex 7.</p>
Biosciences energy research Lab, California & BP	<p>BP is investing \$500 million over ten years to establish a dedicated biosciences energy research laboratory attached to the University of California Berkeley and its partners the University of Illinois, Urbana-Champaign and the Lawrence Berkeley National Laboratory. It is the first facility of its kind in the world.</p> <p>The Energy Bioscience Institute would focus initially on three key areas of energy bioscience:</p> <ul style="list-style-type: none"> <li>• Developing new biofuel components and improving the efficiency and flexibility of those currently blended with transport fuels.</li> <li>• Devising new technologies to enhance and accelerate the conversion of organic matter to biofuel molecules, with the aim increasing the proportion of a crop which can be used to produce feedstock.</li> <li>• Using modern plant science to develop species that produce a higher yield of energy molecules and can be grown on land not suitable for food production.</li> </ul>

Funding or research organisation and budget where available	Current status of research
IEA	The IEA Bioenergy Task 39 <sup>55</sup> has recently identified major pilot and demonstration plants and has plotted them on a world map (see: <a href="http://www.abc-energy.at/biotreibstoffe/demoplants.php">www.abc-energy.at/biotreibstoffe/demoplants.php</a> ). Activity on this map is centred mainly on the USA and the EU.
<b>International</b>	
Government of Canada \$19.9M	Funding a Cellulosic Biofuels Network to examine ways to increase efficiency and reduce the economic costs associated with the production of cellulosic ethanol.
IEA	IEA Bioenergy is supporting a number of Tasks relevant to second generation biofuels: Task33 Thermal gasification of biomass; Task 34 Pyrolysis of biomass; Task 39: Commercialising first and second generation liquid biofuels from biomass; Task 42 Biorefineries: co-production of fuels, chemicals, power and materials from biomass.
<b>Industry</b>	
Shell	<p>Shell is active in supporting work on advanced biofuels, particularly on conversion processes for lignocellulosic feedstocks to products; and development of alternative non-crop biomass feedstocks such as micro-algae. Last year Shell quadrupled its rate of investment in biofuels. Research is being carried out both internally and in partnership with universities, commercial entities and the wider public sector. Examples are:</p> <ul style="list-style-type: none"> <li>• support for the Biotechnology and Biological Sciences Research Council's (BSBEC's) work to develop energy crops;</li> <li>• six new agreements between its in-house biofuels research and technology team and groups of experts in academic institutions across the world, including the Centre of Excellence for Biocatalysis, Biotransformations and Biocatalytic Manufacture (CoEBio3) based at Manchester University and the School of BioSciences Exeter University, both in the UK. See <a href="http://www.shell.com/home/content/media/news_and_library/press_releases/2008/biofuels_research_agreements_17092008.html">http://www.shell.com/home/content/media/news_and_library/press_releases/2008/biofuels_research_agreements_17092008.html</a></li> </ul> <p>Other work includes:</p> <ol style="list-style-type: none"> <li>1. Developing ethanol from lignocellulose (straw) using enzymes:</li> </ol> <p>Shell partnership with Iogen (Canada) since 2002; First commercial demonstration plant opened in 2004 (Ottawa). CO<sub>2</sub> profile at this demonstration plant – up to 90% less than gasoline. Full-scale commercial plant under assessment</p> <ul style="list-style-type: none"> <li>• See: <a href="http://www.shell.com/home/content/media/news_and_library/press_releases/2008/iogen_extended_alliance_15072008.html">http://www.shell.com/home/content/media/news_and_library/press_releases/2008/iogen_extended_alliance_15072008.html</a></li> </ul> <ol style="list-style-type: none"> <li>2. Developing high performance synthetic fuel from lignocellulose (wood residue) through gasification and the Fischer-Tropsch process:</li> </ol> <ul style="list-style-type: none"> <li>• Shell partnership with Choren (Germany) since 2005; first commercial</li> </ul>

<sup>55</sup> IEA Bioenergy Task 39 has been set up to commercialise First and Second Generation Liquid Biofuels from Biomass. It is a global network dedicated to the development and deployment of biofuels for transportation fuel use and is part of the [International Energy Agency](http://www.iea.org) (IEA)'s Implementing Agreement on [Bioenergy](http://www.iea.org). Task 39 currently comprises 15 countries or regional associations. See [www.task39.org](http://www.task39.org)



Funding or research organisation and budget where available	Current status of research
	<p>demonstration plant expected to open in 2010 (Freiberg); CO<sub>2</sub> saving compared to diesel at this demonstration plant expected to be up to 90%. Longer term, there is the potential for 'Biomass To Liquids' (BTL) to be used in aviation fuel.</p> <p>See:  <a href="http://www.shell.com/home/content/media/news_and_library/press_releases/2008/visit_merkel_choren_17042008.html">http://www.shell.com/home/content/media/news_and_library/press_releases/2008/visit_merkel_choren_17042008.html</a></p> <p>3. Work on adapting enzymes to improve the conversion of non-food bio-materials into better transport fuels through a collaboration with Codexis (company in Redwood City, California) to convert plant sugars into hydrocarbon molecules using catalysts.</p> <p>4. Joint research and development effort with Virent Energy Systems to convert plant sugars directly into gasoline and gasoline blend components. See:  <a href="http://www.shell.com/home/content/media/news_and_library/press_releases/2008/biofuels_virent_26032008.html">http://www.shell.com/home/content/media/news_and_library/press_releases/2008/biofuels_virent_26032008.html</a></p> <p>5. Marine algae production of vegetable oil for conversion into biofuel. Shell and HR Biopetroleum have formed a joint venture company, called Cellana, which is constructing a pilot facility in Hawaii. An academic research programme will support the project, screening natural microalgae species to determine which ones produce the highest yields and the most vegetable oil. See:  <a href="http://www.shell.com/home/content/media/news_and_library/press_releases/2007/biofuels_cellana_11122007.html">http://www.shell.com/home/content/media/news_and_library/press_releases/2007/biofuels_cellana_11122007.html</a></p>
BP	Joint venture with Verenium to develop and commercialise cellulosic ethanol from non-food feedstocks. \$45M Work based in USA.
BP, Du Pont & ABP	BP, Du Pont and ABP are working on biobutanol.
Industry research in biofuels and other relevant work is summarised in the NNFCC (2007) report and the CT's Ideas Assessment reports.	

### 7.1.6 Research gaps

The following gaps in current research in this area were identified by this study in relation to the following questions.

- 1) **How sustainable will advanced technologies be compared to first generation fuels and current fossil fuels, including impacts on air/water/soil/biodiversity/natural resources/social/food, including indirect land use change and wider indirect effects?**



In general, advanced conversion technologies are thought to be more sustainable than first generation technologies, although there is less experience of these processes than first generation biofuels (UNCTAD 2008). This is because analysis to date shows that they offer improved GHG life-cycle assessment (LCA); and because they extend the range of feedstocks that can be used for conversion to include lignocellulose feedstocks. These feedstocks include woody and fibrous energy crops, wastes and agricultural and farming residues. They are in general cheaper than the feedstocks used for first generation biofuels and consequently more economically sustainable (in theory); but the conversion processes are more complex and expensive. Advanced conversion of lignocellulose crops also allows more of the crop to be used, so that the biomass use and yield of biofuels per ha is greater than for first generation crops.

Use of wastes and residues is thought to be more sustainable because their use does not compete with food crops or other high value crops and decreases land use change. However, there are markets for some of these wastes and residues and the impact on the use of these markets has not been considered in detail.

The USA is aggressively pursuing advanced conversion of lignocellulosic biofuels because of the potential volumes of biomass available, which enable the US to use the biomass available more effectively. A large part of this effort is aimed at developing technologies for conversion of corn stover residues produced when ethanol is produced from first generation technologies. It is likely that there will be more potential lignocellulose feedstock in the UK than first generation feedstock and a strategy to develop advanced conversion is likely to be more sustainable, simply because it enables far greater quantities of biofuels to be achieved.

The US National Biofuels Action plan states that '*A key goal ... is to maximize the environmental and economic benefits of biofuels use by advancing sustainable practices and improvements in efficiency throughout the biofuels supply chain from feedstock production to final use.*' It outlines the requirements of the Renewable Fuel Standard (RFS) programme to promote sustainability by:

- 1) directing that significant reductions in greenhouse gases be achieved for different feedstocks;
- 2) requiring that biofuels production not adversely impact the environment or natural resources;
- 3) focusing on the development of cellulosic and other feedstocks which will promote the sustainable production of biofuels;
- 4) stipulating that every 3 years EPA assesses and reports to Congress on the environmental impacts of biofuel systems.

The programme states that second generation feedstocks developed should 'sustain and enhance water and air quality and other ecosystem services' and that third generation feedstocks should be developed to increase drought and stress tolerance; increase fertiliser and water use efficiencies; and provide for efficient conversion. This focuses the aims of the US programme, which is funded at a level of many millions of dollars. The USDA supports work on biofuels through the Agricultural Research Service (ARS).<sup>56</sup> The Bioenergy Action Plan (2008-2012) aims to enable the integration of sustainable bioenergy production into existing US agricultural systems without disrupting existing agricultural markets for food, feed or fibre. The bulk of ARS research is focused on producing and biorefining cellulosic feedstocks. The USDOE and USDA issued a joint solicitation on research in January 2009. The total funding for this solicitation is \$25M. Of particular relevance is the Biofuels Development Analysis which covers the following themes:

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<sup>56</sup> The USDA also supports work through the Cooperative State Research, Education, and Extension Service (CSREES) at institutions and public, private and non-profit organisations.

- Strategic guidance: development of analysis that provides strategic guidance for the application of renewable biomass technologies to improve sustainability and environmental quality, cost effectiveness, security, and rural economic development.
- Energy and environmental impact: development of systematic evaluations of the impact of expanded biofuel production on the environment (including forest land) and on the food supply for humans and animals, including the improvement and development of tools for life-cycle analysis of current and potential biofuels.
- Assessments of the potential of Federal land resources to increase the production of feedstocks for biofuels and bio-based products, consistent with the integrity of soil and water resources and with other environmental considerations.

In the EU the RED has similar requirements to the US RFS in that it also requires reporting on the impact of biofuels production and the development of advanced biofuels to improve sustainability. Currently, EC FP7 funding on biofuels is very much focused on development of advanced conversion technologies and on understanding and improving the environmental performance of feedstocks for these technologies (e.g. SOILSERVICE is examining conflicting demands of land use, soil biodiversity and sustainable delivery of ecosystem services). Data from the EU and US programmes will clarify whether or not the theoretical sustainability of biofuels is a reality and they should enable this assessment to be made and improved on within the next few years.

Research by the OECD (2008) has looked at the impact of second generation biofuels on food prices. It suggests that the price impact would depend on the amount of feedstock biomass that would be produced on current crop land. If the total production area is significantly expanded, the price effects would be reduced but concerns over negative environmental impacts on sensitive areas and high-carbon soils, including GHG emissions, water use and biodiversity losses could increase.

In the UK there is less work, but a priority of the BBSRC Sustainable Bioenergy Centre is to evaluate the sustainability of the various bioenergy routes. This work is being researched by way of a framework based on the 'Three Pillars' of sustainable development: balancing economic and social development with environmental protection:

- Environmental pillar: addressed via a component entitled 'Life-cycle Analysis' that will provide indicative quantitative and qualitative 'full fuel cycle' appraisals of alternative bioenergy routes. These will include environmental life-cycle assessment (LCA), including the indirect effects of land use changes, and net energy analysis.
- An 'Agricultural Economics' component will be focused at the farm level, where financial and environmental trade-offs, inherent in different crop mix scenarios, will be evaluated using farm system modelling techniques. The identification of economic incentives and barriers to the adoption of new crops and uses of by-products for bioenergy will be enabled by employing the results of in-depth farm surveys covering 250 farmers throughout England.
- The 'Social and Ethical Dimension' will focus on the interface between research and society to map key challenges and opportunities that arise from the wider use of bioenergy. Stakeholder engagement methods will be used to stimulate dialogue amongst different groups on expectations and ethical concerns regarding bioenergy.

These three elements will collectively provide the BBSRC Centre with the capability to appraise the sustainability of bioenergy routes over time. They will evaluate scaled-up, prototypical supply chains stemming from the research programme, and provide evidence in support of policy development.

Other work supported in the UK includes:

RELU,<sup>57</sup> which includes an examination of the environmental impact of crops, that could potentially be used for advanced conversion biofuel technologies.

NERC's TSEC-Biosys: A whole-systems approach to analysing bioenergy demand and supply: this work examines the biomass available in the UK and the environmental implications of biomass energy crops.

Other research has been done on GHG LCA of advanced conversion technologies, but for all of this work there are issues with availability of data on plant performance which make these assessments difficult and subject to uncertainty. For example, NNFCC supported a technical assessment of the North East Biomass to liquid project, which included GHG modelling of the plant and supply chain. The Carbon Trust has supported work to demonstrate the low GHG intensity of pyrolysis.

UKERC has undertaken a life-cycle assessment in the Bioenergy sector, which involved a systematic review. Studies covered a range of bioenergy production systems within the sector, including seven broad methods of liquid transport fuel production and four sources of feedstock for heat and power production from biomass. The study has used a systematic selection and analysis procedure to assess each LCA, collating data on the energy and GHG balances of liquid transport fuels and biomass for heat and power.

Further work is needed to provide the fundamental data for LCA, which should be provided by the USA and EU research and demonstration programmes over the next two to three years. However, until data are available from the current tranche of demonstration plants and feedstock research programmes, it is not easy to estimate the real sustainability of advanced biofuel production.

Impacts on air, water, soil, biodiversity and natural resources are very dependent on the feedstock used and where it is grown (or whether or not it is a residue or waste). Work that has been done on these impacts has been included in the work described in Sections 3.3 and 3.4. There has been some work on the impact of removal of residues from farm land and forestry, which is described in Section 3.5. Further work is needed and there is also a need to provide guidelines on best practice to guide the developers of advanced conversion plants.

Research Gap 1: Further work is required to provide data on the impact of second generation biofuels on sustainability. This work should build on that already ongoing on LCA in the UK, and on UK, EU and US research in the area.

**2) Compared to first generation fuels and fossil fuels, what are the benefits of the different advanced biofuels, including economic, chemical, sustainability, infrastructure, logistical (etc) issues?**

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<sup>57</sup> RELU-Biomass: Social, Economic and environmental implications of increasing rural land use under energy crops

As described above there are a number of potential benefits to be gained from development of advanced biofuels. These include a greater range of feedstocks that can be used; more efficient use of the resource; improved economics; and an improved GHG LCA. There is also the potential that other chemical by-products can be produced. These issues are being considered in the EU and US research programmes mentioned above. In the UK a number of research projects have reviewed the potential for the use of advanced conversion technologies for the UK. This includes work by NNFCC listed in Annex 7, including a review of liquid transport fuels in 2007. This review provides a strengths, weaknesses, opportunities and threats analysis for all advanced conversion technologies for liquid biofuels, including their benefits. Benefits include the greater yield per ha of liquid biofuel; the flexibility of some processes to use more than one source of biomass; improved economics due to lower feedstock costs etc. Logistics and infrastructure requirements may be greater due to the potential improved economics from larger scale plants.

Continuing work includes the NNFCC research on the production of biofuels from municipal solid wastes, which is considering markets for by-products and energy efficiency, and the NNFCC North East Biomass to Liquids (BtL) project that involves technology, economic and greenhouse modelling for a hypothetical BtL plant.

In 2008 the REFUEL project,<sup>58</sup> supported by Intelligent Energy Europe examined various strategies to achieve the EU 2020 target for biofuels using first and second generation biofuels. This work concluded that on an economic basis alone a combination of first generation processing would achieve the target. However, if sustainability, biodiversity, crop prices and longer term requirements for more biofuels were considered, then advanced conversion processing will need to play a greater role. The pros and cons of different policy options are examined, both for first and second generation plants.

The OECD has taken an interest in the subject as well, supporting a round table on the subject in 2007.

Future work will also contribute, for example:

The Economic Policy Program at the German Marshall Fund of the United States has established a Biofuels Project to:

1. explore the various risks and opportunities involved in the production of biofuels;
2. commission research and disseminate cutting-edge data on biofuels;
3. convene to discuss biofuels policies, and, most importantly, to create a set of policy recommendations that offer a viable policy path forward for the United States, the European Union, and other countries.

The NNFCC, EU and the USDOE and USDA work listed under question 1 will be of benefit too.

All of this work points to the potential importance of the development of second generation technologies to support policy, enable greater uptake of biofuels and improve biofuels sustainability. However, until these technologies are demonstrated, the calculations for economic, GHG emissions and sustainability benefits rely on theoretical assumptions. Although these assumptions are plausible, better quantified data is important. Consequently there is a need for quantifiable data from demonstration plant to provide less uncertain data for the LCA, economics and sustainability benefits of second generation processing.

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<sup>58</sup> [www.refuel.eu](http://www.refuel.eu).

Research Gap 2: The benefits of second generation biofuels need to be better quantified, using real data from demonstration schemes. The aim of such work should be to demonstrate the best second generation routes for the UK in terms of efficiency of conversion, cost and sustainability, particularly taking into consideration UK infrastructure/facilities (e.g. the chemicals industry and the gas network).

### **3) What are the likely future advanced and/or alternative biofuel technologies?**

It is difficult to predict which biofuels are likely to be most successful in the UK or EU, although the USA has set upon a path to lignocellulosic bioethanol, in which it has invested over \$1billion. The EU is currently supporting a range of demonstration plants (see Annex 7) for a total cost of 65 M€, including biomass to liquid and straw, waste and food industry residues to ethanol. Recently, it announced support for an additional four lignocellulose to ethanol plants at a level of 8.5-9 M€ each.

In the UK, NNFFC and the Carbon Trust have recently funded technical reviews of advanced conversion technologies and their applicability to the UK, including biomethane and algae. This had lead to the Carbon Trust's pyrolysis challenge (£7-14M). Defra has supported work on the potential for methane production. In addition to this UKERC is supporting Southampton University to develop a roadmap for bioenergy in the UK.<sup>59</sup> Much of this work points to UK strengths in bioscience, crop science, genetic engineering, chemical engineering and environmental impact. In addition there is some experience of advanced conversion techniques, although mainly on the thermochemical conversion side rather than lignocellulosic ethanol; and Aston University heads PYNE, a pyrolysis network supported through the EC's Intelligent Energy Europe programme.

The LowCVP has recently proposed work on a high level examination of biofuel feedstocks and pathways; their contribution to commercially available biofuels in the UK by 2020 and the role for the UK. The LowCVP intends this work to inform policy, funding and support for biofuels in the UK. The Carbon Trust is currently funding a Low Carbon Technology Commercialisation Review (LCTCR) which includes a review of lignocellulose ethanol, which should be available in April 2009. No budgets were available for these projects.

Despite all of this it is still not possible to predict the likely contribution of advanced conversion to the UK 2020 target. The problem is one of economics: the cost of developing these plants is high. Thus, although technically promising, unless consistent R,D &D funding and a consistent policy and support environment is available the plants will not be developed in the UK. This leads to an additional problem in that it is not clear what feedstock development is required if we do not know what technologies will be deployed in the future.

### **4) What are the technical, institutional, economic, research barriers to advanced biofuels coming on stream? How important is the upfront capital expenditure as a barrier to advanced biofuels development in the UK?**

There are many barriers to the development of advanced conversion technologies apart from those mentioned above:

- Strong, consistent policy signals are required to show industry that there is a long-term commitment from policy makers.
- Economics –the investment costs are high and the plants are not economically competitive with alternative (fossil) fuels unless consistent support is available.
- Confusion on which feedstocks are most appropriate.

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<sup>59</sup> This is not yet available and information here is from a report presented by Taylor (2008), which reviews the UK research environment in biofuels.

- Vulnerability to volatile markets – e.g. the splash and dash currently threatening first generation biodiesel in Europe could be echoed in a similar issue for second generation bioethanol.
- Skills gaps – graduates will want to enter a career with a future and need to be assured that there is one in second generation biofuels.
- Public perception, particularly with regard to impact on food production and prices.

The LowCVP will be supporting work in 2009-10 to identify barriers and design solutions to the development and commercialisation of low carbon technologies. This project is expected to be complete by mid 2009.

The EU Bioenergy road map (DG AGRI 2007) and the subsequent impact assessment examine potential for biofuels development in the EU and factors that this development is sensitive to. The US programme also includes analysis of barriers to biofuels, as detailed in the USDOE's Multi-year Programme plan (2008).

## **5) What would be the required economic, fiscal issues and levers to influence deployment?**

Advanced conversion technologies will not just take time and resources to develop: they will take money – and as is indicated by the EU and US programmes this means millions of pounds. Currently the greater part of the funds for developing advanced biofuels are focused on the USA (Boyle 2009), which is in all probability due to the USA's consistent focus in this area for the last decade, together with the establishment of the RFA.

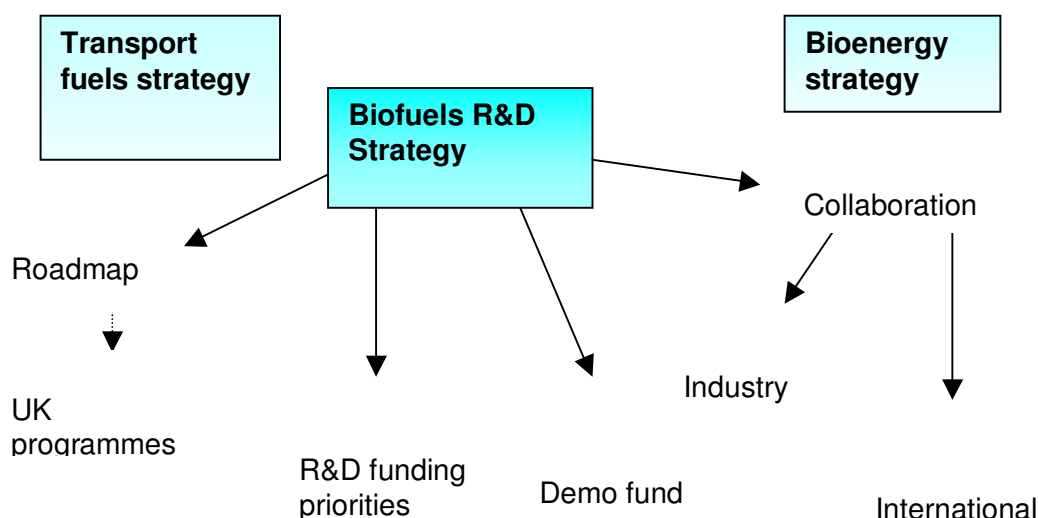
Industry has also invested in development of advanced technologies – BP is investing \$500M over 10 years in its Biosciences Research Laboratory in California; it is also in a joint venture with Verenium to develop and commercialise cellulosic ethanol (\$45 M based in USA); BP, Du Pont and ABP are working on biobutanol; and Shell is working on algal biofuels, supporting BBSRC's BESBEC on energy crops and developing ethanol from straw (see Annex 7). Other industry is participating in the EU's FP7 and in the IEA's Bioenergy Agreement; and industry is involved in demonstration of advanced conversion technologies in the USA and EU. Further involvement of industry in advanced biofuels development is provided in the NNFCC report (2007) and the Carbon Trust's Idea Assessments (see Annex 7).

However, to create an environment in which industry feels it can invest over the longer time period required for development of advanced biofuels in the UK, industry needs a stable long term policy; and it needs to understand the core UK policy for biofuels development. To provide this there is a need for a clear framework for the development of advanced biofuels in the UK, in the form of a Government led roadmap, which will identify key technologies and the route to get there.

Unfortunately this is not currently available, so that at present the UK appears to be considering a wide range of technologies; and the message in terms of future deployment can seem inconsistent. In this environment funds are spread over a wide area of research, while it is not clear if thermal chemical conversion or lignocellulose ethanol is more suited to the UK. Other European countries have tended to focus on one or two technologies and this clear message to industry has helped with deployment. As a result of its lack of overall focus the UK is not involved in demonstrating biofuels at present; nor does it play a major role in the EU's current programme of demonstrations across Europe.

An overarching Government led roadmap would also help unify and add value to the roles of different UK organisations. This could build on the work undertaken by the NNFCC which outlined a practical strategy for the development of advanced biofuels production in the UK, work by UKERC on a roadmap for bioenergy and the future LowCVP Biofuels pathway project.

The potential role of the strategy is outlined below:



Advanced technologies also need to be supported through the innovation chain. There is always a tension between the reluctance of government to pick winners and the need to focus resources in those areas that will deliver the most benefit. To resolve this, the character of the support could be determined by the closeness of the technology to market as follows.

- Market ready – support should be technology neutral and based on carbon performance.
- Near market – support for potential winners.
- Pre-commercial - support portfolio of solutions.

Research Gap 3: There is a need for an overarching roadmap for the development of advanced biofuel technologies in the UK. This needs to consider what technologies best match the UK's strengths; whether it is possible to leverage funds for advanced biofuels development; and, if so, what is the best way forward to do this? There are a number of studies being undertaken at present that should be considered in this research gap, such as the UKERC funded work at Southampton University, and work at NNFCC, the Carbon Trust's Low Carbon Commercialisation Review and the LowCVP's work on the deployment of advanced biofuels.

## 6) What will be their potential contribution towards the 2020 target?

At present there is relatively limited understanding of what advanced biofuels could contribute in the UK. Box 7-1 provides the summary conclusions from the NNFCC (2007) report, which demonstrate that there are a number of options, but not clear information on the contribution advanced biofuels could make. Two studies are ongoing that may clarify this:

- The Sustainable Consumption Institute, University of Manchester, is undertaking a Foresight study to consider alternative scenarios for the future development of a European biofuels sector. The project will provide a structured framework to develop 'baseline' and success scenarios for Europe in 2020. The objective of the study is that it will inform the development of firm strategy and government policy.
- 
- The LowCVP Biofuels Pathway project mentioned above has the aim of providing policy makers with a high level examination of advanced biofuel feedstocks and pathways; their contribution to commercially available biofuels available in the UK by 2020; and the role for the UK.

**Box 7-1: Extract from the summary of the NNFFC (2007) review of the status of liquid transport biofuels:**

Lignocellulosic ethanol production is possibly closer to commercial reality than the Biomass to Liquids (BTL) via the syngas route and the UK could potentially benefit by leveraging US progress in this area. Additionally, a lignocellulosic facility could potentially more effectively share utilities at an existing first generation ethanol production plant thereby reducing investment costs. However, ethanol is a gasoline substitute only and, as noted above, the UK and EU fuels markets are long on gasoline while short of diesel and aviation fuel. The potential to produce an enhanced quality renewable synthetic diesel and/or aviation fuel via the BTL process combined with renewable naphtha (for the production of renewable plastics for example) is therefore attractive. The key barrier to both the lignocellulosic ethanol and BTL routes, however, is high capital investment costs. The pyrolysis process overcomes these at the expense of product quality – pyrolysis oil or bio-oil cannot directly be used as a transport fuel. Research is, though, ongoing to upgrade the low quality pyrolysis oil to a range of standard refinery products.

This is an important area. Although the UK could probably achieve current targets using first generation processing, in the longer term higher levels will only be achieved with the use of lignocellulose feedstocks – and this will not be possible without research and development work now.

**7) What advanced technologies are most suited to UK needs and is R&D being done to develop these within the UK? When are they likely to come on the market, and what determines investment in these technologies?**

The NNFFC (2007) review identified a number of key areas for the UK:

- Synthetic fuels produced via thermochemical biomass to liquid route provide the most suitable fuels blend for the UK. Technology is available on a worldwide basis and is moving to demonstration scale (Choren, Germany; Flambeau, USA; Range Fuels, USA; Stora Enso, Finland). It would be advantageous to locate a BtL facility near Wilton, Teesside, where the UK has important chemical engineering and related experience. Further work is needed in the UK to demonstrate the most appropriate gasification processes, including assessment of the feedstocks that could be used.



- Lignocellulose ethanol production via fermentation is about to be demonstrated in UK, USA and Denmark – commercial demonstration will be vital. In particular the first step in the production of lignocellulosic ethanol is the preliminary hydrolysis step. Commercial development of this step is vital to the success of lignocellulosic ethanol. The USA has a large, well-funded programme on lignocellulosic ethanol which includes significant R&D on hydrolysis, in particular to develop improved enzyme technology and to develop crops that are more suitable for ethanol production. However, this is geared towards US feedstocks; and further work is required. In particular we need to consider the contribution that the UK biotechnology industry can make, particularly to developing microbes and enzymes to improve the efficiency of hydrolysis. In addition there are constraints on the amount of lignocellulose available as a feedstock for bioenergy in the UK; and the relative merits of lignocellulose ethanol against other uses (e.g. heat and power) need to be considered.
- Vegetable oil hydrogenation route - this is commercial now.
- Pyrolysis – this is an emerging technology (and the cheapest process, but it produces the most difficult product to incorporate into the existing pool). Further work is needed to examine the role that pyrolysis might have and the costs and energy benefits of the process in order to prove that it is an appropriate technology for the UK.

The Carbon Trust has undertaken a number of Ideas Assessments that consider the application of the following technologies in the UK: Algae, Novel Biofuels, Pyrolysis to transport fuels. The Assessments considered the state of the art internationally, where the development has happened and what UK skills are required to develop these areas/technologies. The Carbon Trust is further supporting work on pyrolysis, but this technology remains far from the market place. More work is needed to demonstrate what pyrolysis routes are most appropriate for the UK, which feedstocks should be used and the subsequent refining of the products of pyrolysis to appropriate feedstocks for transport fuels.

A number of advanced technologies are currently being demonstrated globally (for example MSW to ethanol). This means that, to some extent, they are already coming to closer to the market. However, market development and investment also depends on a number of other factors, including the price of oil and the cost of feedstock. A rigorous economic assessment of these technologies is therefore required as these factors can also act as barriers to market development. One of the key factors in establishing demonstration of second generation in the UK will be capital expenditure; and, for Government support, the rules of state aid may be an important barrier. To ensure that second generation technologies develop in the UK, Government and EU action in the form of start up grants could be required as well as strong, consistent policy signals on the future need and market for biofuels.

Anaerobic digestion (AD) of organic matter to biogas is also being hailed as a promising advanced technology. In Sweden biogas is cleaned up to produce biomethane used as a transport fuel for fleet vehicles. In the UK AD is used to treat some organic residues and its use could be extended to many other feedstocks. However, the situation regarding anaerobic digestion is not straightforward. While AD of some feedstocks is commercial now (e.g. waste water treatment plant), for other feedstocks (e.g. farm manures and slurries) it is not commercial without financial support. AD produces a biogas that can contain 50% or more carbon dioxide, together with trace contaminants. To be used as a vehicle fuel this biogas needs to go through relatively expensive clean up to produce bio-methane. Thus AD is a promising technology in the UK, but a better understanding of the implications of commercialisation is required. Commercialising AD in the UK will require investment, the development of appropriate plant configuration, and an examination of how the infrastructure for biogas use could be developed (e.g. a separate biogas system for transport or injection into the national gas grid).

Consequently, although there has been important work to assess the suitability and potential of some of the second generation technologies for the UK, more work is needed. This work should focus on establishing the most appropriate technologies for UK feedstocks and refining facilities; an understanding of the potential costs; the need for infrastructure development; improvements in technologies that improve the costs, particularly for the processing of lignocellulose feedstocks; and a better understanding of how the UK sits within development worldwide.

Furthermore, the UK is likely to be limited in terms of indigenous lignocellulose feedstock production, when all demands (including heat and power) are considered. This means that imported feedstocks would be important for production in the UK; or that biofuels would be produced elsewhere and imported.

Taking this into consideration the following gaps have been identified:

Research Gap 4: Further work is required to improve the cost and efficiency of hydrolysis technology for alcohols from lignocellulose. There is a need to assess the potential benefits of lignocellulose ethanol in the UK. This should examine the potential benefits of production in the UK and whether or not the feedstocks would be better used, for example, in heat and power; and it should also look at the benefits of R&D in developing biotechnology for hydrolysis and the value of this biotechnology market to the UK. Any work on lignocellulose feedstocks should take the work already ongoing in the US and work being supported by BBSRC into account.

Research Gap 5: There is a need to demonstrate gasification routes – including a consideration of what feedstock will be used. One major issue in establishing a demonstration in the UK is the capital cost, including the need to clear any Government support through State Aid rules. The possibility of leveraging UK support with international effort should also be examined.

Research Gap 6: Proving pyrolysis routes - this gap lies in proving which pyrolysis routes are viable (economically, environmentally and technically) for the development of UK biofuels.

Research Gap 7: Improved understanding of the implications of commercialisation of anaerobic digestion (AD) for transport fuels.

### **Overall comments**

Through this gap analysis we have identified the following R&D themes as they apply to biofuels:

- Work on thermochemical conversion process is concentrated on demonstrating technology, for biological processes decreasing costs and improving efficiency.
- Feedstocks – steady progress decreasing cost and improving yield, suitability and pre-treatment, renewed interest in aquatic species.

There is little work on:

- Impact of second generation technologies and competition with other uses (US is out to tender on this).
- Infrastructure of feedstock supply.
- Sustainability of feedstock production.

The research suggested that biofuel R&D priorities are dependent on the balance of priorities between policy drivers including:

- i) Carbon saving.
- ii) Fuel supply (security).
- iii) IP development.
- iv) Fuel supply (production).

### 7.1.7 Summary and conclusions

Considerable work is being carried out in the UK in the area of advanced and second generation biofuels, but it is fragmented and there is no overarching policy objective. Furthermore, the results of the research are not always easily available.

There is therefore an urgent and significant need to develop a clear overarching roadmap for the development of these technologies in the UK. This should include an assessment of which are the best routes for the UK, taking into consideration the country's feedstocks, infrastructure and skills. This is a large piece of work in that it needs to bring together all current initiatives, including research funded by the Carbon Trust, the NNFCC, the LowCVP and the UK Research Councils. It should also consider the high cost of development (likely to be hundreds of millions of pounds) and how best to leverage UK resources with those available within the EU.

In addition it also important to examine the sustainability of advanced and second generation biofuels, including land use and other environmental impacts. This is a large and important piece of work, which is urgent and significant.

For individual technologies there are a number of key gaps. These include:

- Hydrolysis technology for alcohols from lignocellulose – an urgent and significant gap if the UK is to develop this technology as improvements this technology are needed to bring the cost down. This work should not only consider the production of lignocellulose ethanol in the UK, but also the potential contribution that the UK biotechnology sector can make to improving lignocellulose ethanol production globally. This work is considered to be a large gap, which reflects the amount of work going on abroad and the need to link into this work rather than duplicate it.
- Demonstration of gasification routes – including a consideration of what feedstock will be used and what route is suitable for the UK. This is an urgent and significant gap, particularly as there are good reasons why thermochemical conversion could be applicable to the UK. The work is large, due to its complexity, its cost, the need to bring together a number of disciplines and the need to interact internationally within the EU.
- Proving pyrolysis routes - this gap lies in proving which (if any) pyrolysis routes are viable (economically, environmentally and technically) for the development of UK biofuels and how they fit into the development of pyrolysis in general. This is considered to be a gap of lower urgency and significance than those above. The work is assessed to be a medium sized gap, predominantly because of the disciplines involved, the difficulty in obtaining some data and the potential need to work at an international level to obtain key information.

- Commercialisation of anaerobic digestion (AD) – this is a technology with great potential. It is already commercially available for some feedstocks but it has so far failed to gain commercial success in many other sectors. Commercialising this technology for these sectors in the UK will require investment, the development of appropriate plant configuration, and an examination of how the infrastructure for biogas use could be developed (e.g. a separate biogas system for transport or injection into the national gas grid). This work is judged to be of lower urgency and significance, primarily because of the time required to commercialise biogas and the absence of any push to implement immediate policy needs. However, the size of the gap is medium to large because of the investment costs, the number of feedstocks and sectors that need to be included and the development of appropriate infrastructure.

The impact of second generation biofuels on sustainability needs to be clearly proved in the medium term and as a result, this work is ranked as of medium urgency and significance. It is a relatively small piece of work, involving developing GHG LCA and other research based on real and improved datasets, which should be available through the initial development work.

The benefits of second generation biofuels also need to be better quantified, using real data from demonstration schemes. This is medium term work, rated as medium urgency and significance. The work should be done using evidence from demonstration plants already in action in countries across the EU.

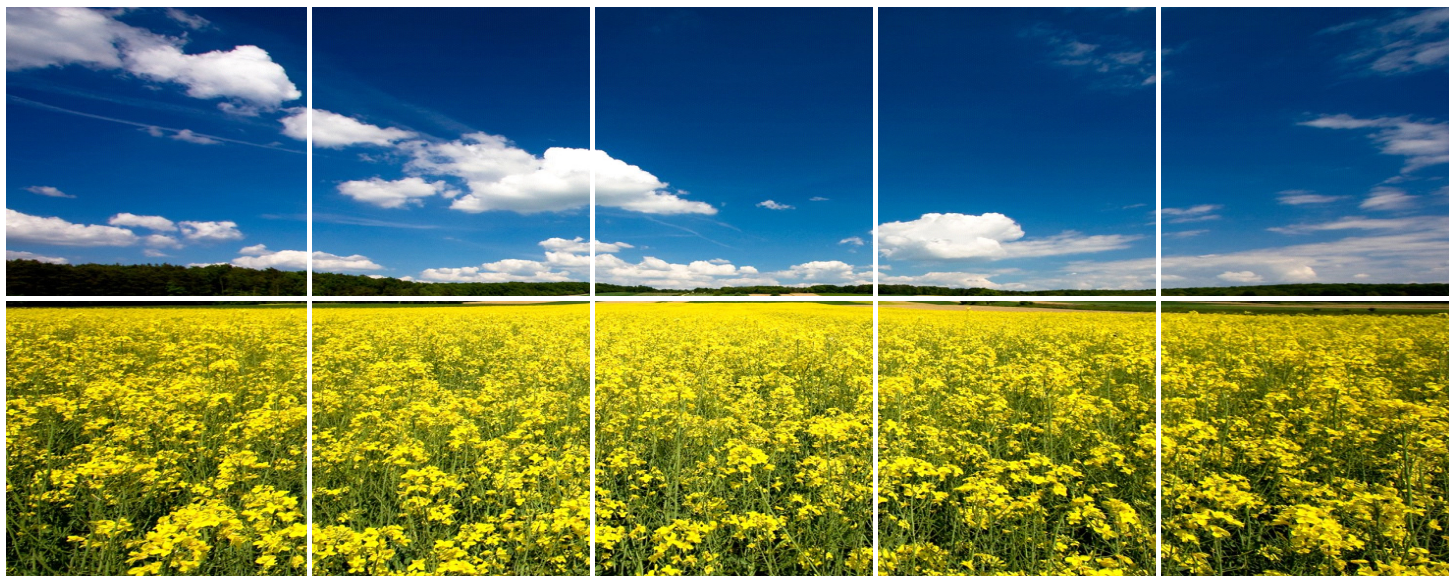
**Table 7-2 Advanced/second generation biofuel technologies - key findings**

Key to ratings on the next page

Research Gap	1) Impact on sustainability	2) Quantifying benefits	3) Overarching roadmap for the development of advanced biofuels in UK	4) Hydrolysis technology for alcohols from lignocellulose	5) Demonstration of gasification routes	6) Proving of pyrolysis routes	7) Commercialisation Anaerobic digestion
Key related work	DoE, FP7, BBSRC	DoE, FP7, BBSRC, EPSRC	Low CVP, NNFCC, the Carbon Trust, BBSRC and UKERC	DoE, FP7	EU FP7, DoE	FP7, CT	EU, USA
Complexity	**	**	***	***	***	***	*
Time scale	**	**	***	***	***	***	**
Potential costs	**	**	*	***	***	***	***
National or international?	UK/EU	UK/EU	National	EU Wide UK/US UK/EU	EU Wide	UK only UK/EU	UK only UK/EU
Availability of data	Published	Published	Lot of information available	Biotech proprietary process published	Details proprietary process published	Science widely published details proprietary	Published
Availability of skill sets	**	**	***	***	***	**	***

**Key**

<b>Significance</b> – please see matrix	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k * <£100k	<b>National or international</b> i.e. can the work be done in the UK or would it be better done internationally?
<b>Availability of data</b> This will refer to the IPR/availability of R&D already ongoing in the area (e.g. Commercial – restricted; or published/available)			<b>Availability of skill sets</b> *** a number of organisations working in area ** availability restricted to a few groups or only on international scale * skills gap, significant training required.	



# Biofuels Research Gap Analysis

## Chapter 8 – Infrastructure

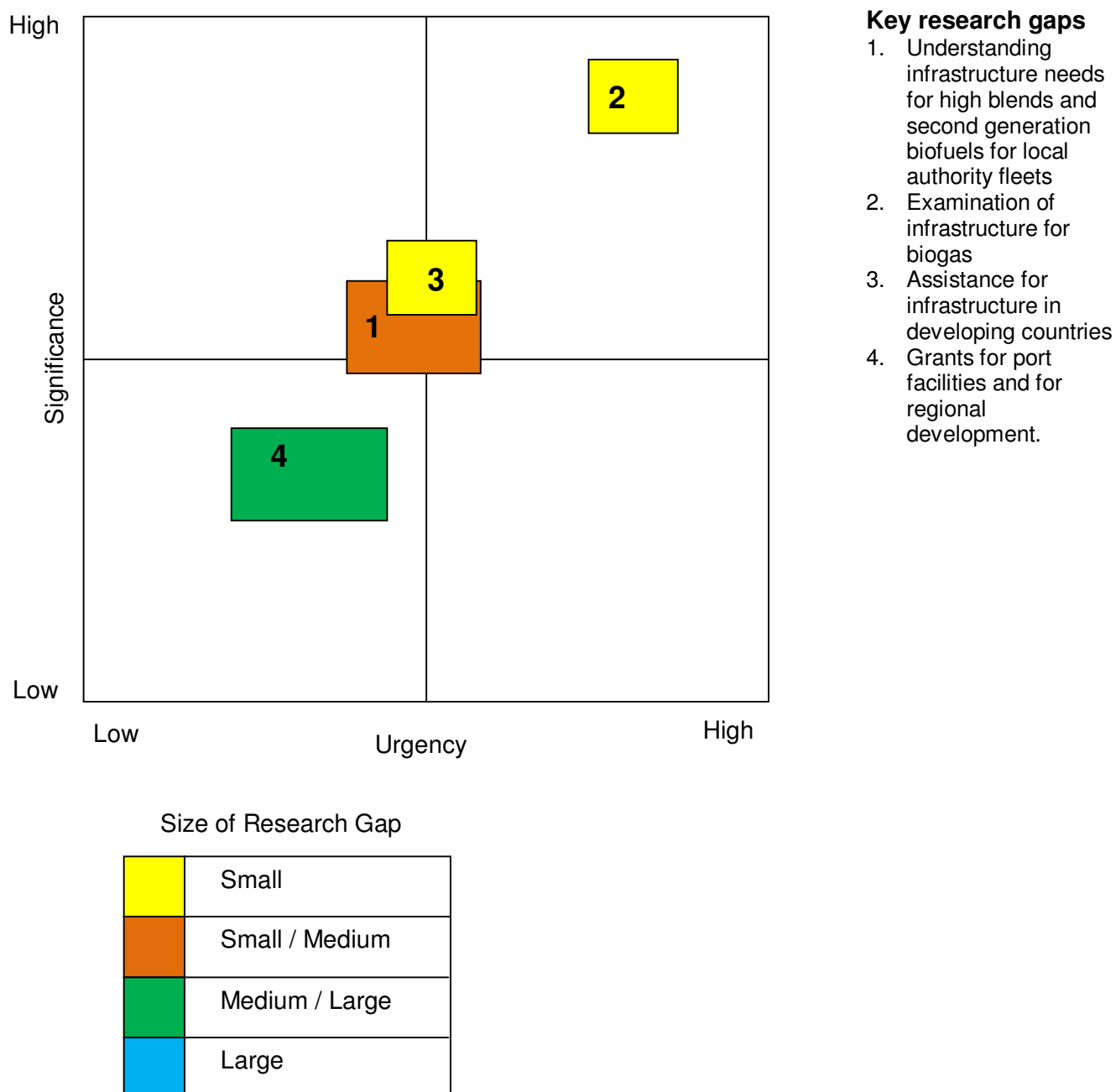


**Final report to the Biofuels Research  
Steering Group**

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## 8 Infrastructure

Figure 8-1 Matrix prioritising key research gaps for infrastructure





### 8.1.1 Executive Summary

*What immediate and future infrastructure is required for increased production/consumption of the different biofuel technologies (e.g. first, second, wastes, aviation, residues, biofuels produced from marginal land, etc).*

The development of infrastructure is important to the uptake of biofuels because it is the interface between the production and use of the biofuels, and also between the supply of feedstock and production of the biofuel. It is thus a key part of the supply chain. In the UK to date infrastructure has not been a major barrier. This is because current biofuels can be blended relatively easily into the regular transport fuel infrastructure and the Government has made grants available for capital investment in refuelling needs.

To meet the UK 10% renewable energy in transport target in the RED, however, there will need to be large-scale increase in biofuel take up. This will include the need to invest in facilities at ports in the UK as well as pipelines, storage facilities, infrastructure at filling stations and development of production facilities for the biofuels. In the next decade there will also be the need for infrastructure to meet the requirements of higher blends or second generation biofuels. This will require more investment in infrastructure than at present. Additionally, there needs to be an understanding of what will be required to develop biogas as a fuel in the UK on any significant scale, including the potential for injection into the gas grid.

This chapter considers current and future research in this area and identifies the research gaps relating to the immediate and future infrastructure requirements.

These are:

Research Gap 1: Further understanding of the infrastructure needs for high blends and second generation biofuels; and for local authority fleets. This includes requirements such as the development of infrastructure to handle bulk and heterogeneous material (such as waste biomass), the development of refineries, storage facilities and pipelines for high blends and the need for advanced biofuel facilities such as pilot and demonstration plants.

Research Gap 2: The conversion of wet organic waste to biogas via anaerobic digestion provides a potential biofuel that is used for transport in other parts of the EU. There is a need to examine the potential for biogas use as a transport fuel in the UK, including the infrastructure requirements associated with the upgrading of biogas to biomethane and how this is delivered to refuelling stations, including the potential for the gas grid.

Research Gap 3: It is probable that the UK will be dependent on imported biofuels for part of its requirement; and it is entirely probable that some of this supply could come from developing countries, allowing their economies to benefit from biofuels development. However, biofuels production may be restricted in developing countries if the need for infrastructure for storage, processing and transport of the biofuels is not addressed. An examination of the gaps in infrastructure which may form barriers to biofuels production in developing countries would usefully inform us on the extent of this issue.

Research Gap 4: Within the UK the need for grants for development of facilities at ports and for storage and pipeline facilities at regional level should be considered. There are important biofuels opportunities in the UK, particularly where there is the potential to take advantage of current facilities at refineries and ports. However, there will be a need to invest in new infrastructure in these areas and an investigation of where it is most advantageous to invest in such facilities would be useful.

### 8.1.2 Context

'Infrastructure' as discussed in this chapter is taken to mean the downstream distribution and supply and any associated infrastructure requirements such as storage, handling, transportation, pipelines, port facilities etc. In addition, there is a requirement to handle large quantities of biomass, whether imported or produced in the UK and the issues associated with the logistics of storage and transport of this biomass (including health and safety) are considerable.

The infrastructure requirements for biofuels are related to the type of biofuel and the level of blend, as indicated in Table 8-1.

**Table 8-1 Infrastructure requirements for biofuels**

<b>Fuel/blend</b>	<b>Infrastructure needs</b>
< 5% blends of first generation fuels	Can be relatively easily integrated into current fuel infrastructure, without the need for specific pipelines, although there are refining, blending, handling and distribution/storage (particularly for bioethanol) considerations and there is a need for the plants that produce the fuels. This has cost implications, particularly for remote areas.
>5% blends of first generation fuels	More significant infrastructure changes are needed to switch to higher blend biofuels, including modifications to engines and other vehicle components, and to storage, distribution and refuelling facilities.
Second generation fuels.	More extensive infrastructure requirements, including the development of demonstration plant associated with supplies at forecourts. For waste or residual biomass, infrastructure will be needed to deal with the collection of dispersed feedstock.
All high blend and second generation biofuels	This will require the introduction of regulatory and standards frameworks and guidance, which are agreed by vehicle manufacturers as well as fuel suppliers.

Although the introduction of biofuels into the UK is a relatively new phenomenon there are already a number of biodiesel only refuelling stations and most forecourts now supply some percentage of biofuel. There have been Government grants to enable this infrastructure to develop. In both the EU and USA, there are standards and guidance available on the storage and handling of biofuels (e.g. NREL 2008, Biofuel Cities 2008) and through the various standards agencies (e.g. CEN in the EU). The key issues which must be taken into consideration for current biofuels, are the degradability of the fuels and the hygroscopic nature of bioethanol, which means they must be stored in watertight tanks. The requirements for biofuels infrastructure in the UK are dependent on where the biofuel is produced or imported. Currently infrastructure for handling, storage and distribution of biofuels is handled by suppliers. The properties of biofuels mean that these storage facilities will need to be separate to those for fossil transport fuels. The requirement to ramp up quantities of biofuels with time may mean that additional storage facilities are required at refineries, and at ports where there is likely to be a large amount of import of biofuel or feedstock (e.g. the Humber) there may be a need to invest in storage facilities. The investment required, sources of finance and long lead time for investment may all be barriers to the rapid development of such facilities. In addition, the introduction of higher biofuel blends, such as E85,<sup>60</sup> would require more investment in infrastructure for storage and distribution.

In Europe, the Dutch Government, Rotterdam city and the Port of Rotterdam have invested heavily in the development of Rotterdam as a biofuels 'hub'. Facilities at the port to encourage biomass import include loading and unloading facilities. Investment in gas and power supply and train/barge transport on site also encourage investment in biofuels plants at the port. This investment has resulted in a considerable increase in biofuels coming into Europe via Rotterdam (an 80% increase in biodiesel in 2008 compared to 2007 and a 50% increase in bioethanol in the same period). This is an example of the development of infrastructure required to encourage successful investment in biofuels.

Elsewhere in the world where large-scale biofuel production takes place there are moves to construct mechanisms for more effective transport of the fuels. For example, pipelines are under construction in Brazil and under consideration in the USA.

The UK has no such proposed investment at present, although there are opportunities at ports such as those on the Humber.

In the future, the development of second generation fuels may lead to more infrastructure needs, particularly if they are dependent on the use of large quantities of biomass produced from dispersed sources, such as residues and wastes. In this case, there will be a need to integrate the collection of the feedstocks with the needs of a potentially large plant. There is a need for the examination of the logistics of supply of dispersed residue and waste feedstocks and the potential to integrate this with existing collection systems for wastes.

### 8.1.3 Key research questions

This section explores what research there is on what upstream and downstream infrastructure is required for increased production/consumption of the different biofuel technologies (e.g. first, second, wastes, aviation, residues, biofuels produced from marginal land, etc).

This is underpinned by an analysis of what research there is on:

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<sup>60</sup> E85 is the term commonly used for ethanol blends at 85% level.

- 1) What are the downstream distribution and supply and upstream infrastructure requirements for increased production/consumption of:
  - First generation
  - Second generation
  - Biofuels for other modes of transport
  - Biofuels with different upstream characteristics (e.g. produced from 'idle land').
- 2) What is the feasibility and cost of these infrastructure requirements?
- 3) What is the role of pilot plants?

#### 8.1.4 Research in the area

Information on research and support for the infrastructure requirements for biofuels is provided in Annex 8. Table 8-2 summarises this information.

**Table 8-2 Summary of work on infrastructure in UK, EU and Internationally**

Funding or research organisation and budget where available	Current status of research
<b>Strategies for infrastructure</b>	
<b>UK</b>	
Highlands and Islands Enterprise	Supported study to examine the costs of the infrastructure requirements for the supply of bioethanol to the Highlands and Islands and remote areas. This included issues such as the difficulty in transporting and storing bioethanol. <a href="http://www.hitrans.org.uk/Documents/documents/RTFORReport2FinalV2.127.11.08.pdf">http://www.hitrans.org.uk/Documents/documents/RTFORReport2FinalV2.127.11.08.pdf</a>
Regional Development Agencies	<ul style="list-style-type: none"> <li>• One North East – has carried out work to examine the potential for developing second generation biofuels alongside the current petrochemical refining facilities already in existence.</li> <li>• Yorkshire &amp; the Humber Regional Energy Forum – commissioned a report in 2007 to evaluate the potential to build biofuels plants in this part of the UK, and assess the potential for the Humber ports to become a biofuels hub.</li> <li>• East of England Development Agency – has encouraged Renewables East to start a 'virtual biofuels hub' to bring academia and industry together to enable biofuels development and has recently launched 'Biofuels East' in support of this.</li> </ul> <p>All of these initiatives could form the focus of a study into the UK's infrastructure needs. Planning plants centrally near ports provides opportunities to share infrastructure needs</p>
London	Mayor has developed a 'Food waste to fuel' alliance to bring together interested parties to provide the infrastructure needed to extract fuel from the city's food waste. This will include five anaerobic digestion plants and bio-diesel refineries. This is part of the £80M that London will spend on projects to reduce waste and generate energy.
National Grid	Has supported work to examine the potential for injection of biomethane into the grid.
Defra – Demonstrator programme	Support for United Utilities project to inject upgraded biogas ('biomethane') into the gas grid.

Funding or research organisation and budget where available	Current status of research
<b>EU</b>	
EBTP	Is examining infrastructure needs for the Vision for Biofuels 2030 targets.
<b>International</b>	
USA	<ul style="list-style-type: none"> <li>• The <a href="#">Infrastructure Requirements for an Expanded Fuel Ethanol Industry</a> by Downstream Alternatives Inc (2002) looked at the infrastructure requirement associated with an expanded biofuels industry in the US (work funded by US DoE).</li> <li>• The Chamber of Commerce led a conference on “Meeting the Infrastructure Challenges to the Expansion of the Biofuels Industry” in September 2007. The proceedings of this conference provide an insight into the infrastructure issues facing expansion of bioethanol.</li> </ul> <p>The Farm Foundation led a conference on “Transition to a Bio-economy: Risk, Infrastructure and Industry Evolution” in collaboration with the USDA’s Office of Energy Policy and New Uses and Economic Research Service. This included calls for a more in-depth study of the issues.</p>
Brazil	Supply infrastructure being planned by Uniduto Logistica, BRESCO, PETROBRAS and America Latina Logistica.
<b>Grants</b>	
<b>UK</b>	
	Has supported the Refuelling Infrastructure Grant Programme since 2006 (currently under review under the State Aid rules). It provided grants of up to 30% towards the capital cost of installing refuelling stations for alternative fuels including biofuels.
<b>EU</b>	
	The EU supports various networks that include examination of the needs for infrastructure for their specific aspect of biofuels (e.g. the Biofuel Cities). Individual countries may have infrastructure grants.
<b>International</b>	
USA	<p>Michigan – the Clean Energy Coalition (CEC) is supporting a Biofuel Infrastructure Grant Incentive Program.</p> <p>Iowa – \$1.52 million in grants for 43 biodiesel and E85 retailers and terminal operators across the state to expand their renewable fuel infrastructure.</p>
Developing countries	India has established special tax measures to encourage the construction of infrastructure for the production of biodiesel. These include a decline in machinery tariffs for foreign projects of less than \$1.1 billion.
<b>Distribution infrastructure for first generation biofuels</b>	
<b>UK</b>	
NNFCC	Supported work on the development of biofuels technologies, which also examines infrastructure requirements.

Funding or research organisation and budget where available	Current status of research
BP	In-house fuel technologists are conducting development work on the impact of higher percentage biofuels on the infrastructure and on vehicles. They are also investigating the impact of advanced biofuel molecules on the infrastructure and vehicles.
EST	Website provides details of where there are biofuel refuelling stations.
<b>EU</b>	
Netherlands	Rotterdam biofuels hub is being developed to encourage biofuels investment.
FP6 and IEE	Projects examining infrastructure: Biofuel-cities, BEST, BIONIC, MEDEGASCAR, SUGRE, PROCURA, PRO-biodiesel and Biodiesel chains.
<b>International</b>	
USA	Research into means for expanding infrastructure (train and/or pipelines). There is R&D in US on materials requirements for infrastructure.
Brazil	Brazil's Government and 2 consortia (led by Petrobras and Cosan) are investing in ethanol pipelines from the ethanol producing areas to where it is used or exported. Cosan is also investing in improving rail freight capacity from ethanol producing areas to the port of Santos.
<b>Distribution infrastructure for second generation biofuels</b>	
<b>UK</b>	
Biofuels East	Examining the issue locally.
National Grid	Has undertaken a study of the potential for a UK-wide biogas network feeding biomethane into the national gas grid (National Grid 2009).
Defra	Is funding United Utilities under the Demonstrator programme. Scheme is to inject biomethane from the Davyhulme treatment works into the grid.
<b>EU</b>	
EBPT	Examined the need to look at how second generation will be developed in Europe and how infrastructure will be needed to support the production and supply of second generation fuels in its roadmap to achieve the Vision for Biofuels (Biofuels technology Platform 2008). Also includes a working group on End Use, which has the aim of identifying what R&D activities with respect to fuel distribution and end use are required to reach the Vision for Biofuels 2030 targets.
<b>International</b>	
US DOT	The DOT has funded a \$700,000 project on the effect of E10, E15 and E20 fuel blends on corrosion and cracking of pipelines. It is anticipated this project will inform the changes that need to be made to mitigate the damage from ethanol to the pipelines and the changes need to design a pipeline that can carry ethanol. Other US plans include a £3.5billion 1,700 mile pipeline from the corn ethanol producing Mid Western states to a fuel terminal in the

Funding or research organisation and budget where available	Current status of research
	Northeast USA. There are also plans to use dedicated train lines to transport ethanol, include a proposed \$150M project in Nebraska.
<b>Feasibility and costs of infrastructure</b>	
<b>EU</b>	
EU	EBTP and other EU funded work provide some costs The EUCAR/JRC/CONCAWE Well to Wheels project includes estimates of the costs of distribution and retail for the first and second generation fuels analysed as well as the addition cost of alternative vehicles.
<b>International</b>	
USA	US Chamber of Commerce supported conference on “Meeting the Infrastructure Challenges to the Expansion of the Biofuels Industry” and the National Bioenergy Knowledge Discovery Framework - ORNL, ANL, INL, UC-Davis and others - are developing a national scale GIS-based framework to assist in analysing the economic and environmental impacts of feedstock, biorefinery, and infrastructure development options.
<b>Pilot plans</b>	
<b>UK</b>	
Shell	Partnering with the Liquid Biofuel Team at the Qingdao Institute of Bioenergy and Bioprocess Technology, Chinese Academy of Sciences, who are focused on research and commercialisation of production of alternative fuels from sustainable and renewable sources. Includes carrying out research into pilot plant design.
<b>EU</b>	
EBTP	EBTP has a list of EU pilot plants.
<b>International</b>	
India	India has pilot plants on transesterification set up by Indian Oil Corporation (R&D), Faridabad; the Indian Institute of Technology (IIT), Delhi; the Punjab Agricultural University (PAU), Ludhiana; the Indian Institute of Chemicals Technology (IICT), Hyderabad; the Indian Institute of Petroleum (IIP), Dehradun; the Indian Institute of Science (IIS), Bangalore; and Southern Railways, Chennai.

### 8.1.5 Research gaps

Research gaps were considered in respect to the key research questions, as follows:

- 1) **What upstream and downstream infrastructure is required for increased production/consumption of the different biofuel technologies (e.g. first, second, wastes, aviation, residues, biofuels produced from marginal land, etc)?**

This study indicates that infrastructure is not always considered in Government biofuels strategies, but it can be an important barrier, particularly for higher blend and second generation biofuels. Although the impact assessment for the RTFO looked at infrastructure requirements for biofuels, long term issues were not covered. This contrasts with work in the USA and Brazil, where biofuels strategies have been developed over a longer period, where there is an established industry and demand, and where there is a stable, long-term policy, which allows for long-term investment. In these countries there are large pipeline projects proposed or under construction and both nations are investigating the potential for dedicated rail freight lines. This is also in part because bioethanol production areas are a long way from where the fuel is refined and used.

In the UK and Europe, the biofuels in use at present are ones that fit easily into the current infrastructure for distribution of vehicle fuels. In the UK, grants have been available to assist with investment in refuelling stations. However, ambitions for second generation fuels in Europe and for higher blends mean that investment is required to ensure that the appropriate infrastructure is available for these fuels. There is some funding in this area from EU governments and industry, but there is a need for a consistent strategy and clear direction before this investment becomes a reality. Sweden has invested to ensure that biogas is successful, but elsewhere in Europe investment is required for biogas infrastructure if this fuel is to be used for transport to any great degree. This includes consideration of how the biogas will be distributed and availability of a fleet operating on biogas.

The successful implementation of second-generation fuels and higher blends requires a high level strategy to ensure that the infrastructure is there to support the use of the fuels. For second generation fuels, there is also a requirement for an infrastructure to collect the feedstock (waste, residue and lignocelluloses crop), which is required for potentially very large processing plants.

Much has been made of the potential for imports, particularly using developing countries to produce feedstocks for first and second-generation biofuels. In these areas, it is likely that the infrastructure for transport and distribution of biofuels will be lacking; in India a key infrastructure requirement that has been identified is the need for soil crushing plants for biodiesel (Gonzales, 2006) and such facilities are also likely to be required elsewhere.

Thus research on this topic area varied. For the UK there has been no study of infrastructure requirements for the UK in response to a large increase in biofuels use. However, work has been supported by the NNFFC on the development of biofuels technologies, which also examines infrastructure requirements. This work points out that some biofuels can be used through existing infrastructure, but that fuels such as biogas would require new gas refuelling infrastructure and purpose built vehicles (Evans 2007). In addition, there is work being done on a regional basis, for example by One North East and for the Yorkshire and Humber Regional Energy Forum (AEA 2007).

The European Biofuels Technology Platform has considered, in its roadmap to achieve the Vision for Biofuels, how second generation will be developed in Europe and the infrastructure required to support the production and supply of these second generation fuels.



The EU has also supported a number of networks designed to share information on the development of biofuels and infrastructure needs. One of the most significant of these is the Biofuels Cities network ([www.biofuel-cities.eu/](http://www.biofuel-cities.eu/)), which provides information on experiences of using biofuels in urban environments. This project lists infrastructure projects being supported in cities around Europe, mainly related to first generation biofuels and biogas, and including work on refuelling infrastructure, biofuel transport, storage and distribution; and it has also produced a review of biofuels and their infrastructure requirements<sup>61</sup>. This network has surveyed stakeholders (Biofuel-cities 2008) and found that key infrastructure barriers for current biofuels (including biomethane) are:

- Insufficient availability of refuelling infrastructure
- High costs to construct or convert refuelling infrastructure
- Insufficient biofuel production capacity and lack of sufficient feedstock for biofuel production units (this point is examined in more detail in chapter 3).

Another EU network, the Euro BEST project, includes examination of the infrastructure needed to support the introduction of bioethanol-fuelled vehicles and flexible fuel vehicles. The network has examined infrastructure available to cars, buses and fleets, together with the experiences of the introduction of ethanol and issues related to infrastructure such as storing and dispensing bioethanol. .

Industry is also undertaking research; for example BP is conducting development work on the impact of high percentage biofuels and advanced biofuel molecules on infrastructure and vehicles.

Although work has been done on biomethane, as indicated in Table 8-2, the UK has only recently begun to consider the potential for the use of this fuel on a widespread basis and in general this has been related to its use for heat or power via the gas grid. This is despite the fact that the UK has one of the best gas (natural gas) distribution networks in Europe.

The work listed above shows that there has been considerable investment in the UK and elsewhere in Europe on infrastructure requirements for first generation biofuels; outside the UK in Europe there has also been work to examine the requirements for biomethane. However, an in-depth examination of the UK's infrastructure requirements for higher blend biofuels and second generation biofuels has not been done; nor have the requirements for extensive distribution of biomethane as a vehicle fuel been examined. In addition the development of facilities for refuelling local government fleets (e.g. buses or refuse collection vehicles), which may be outside the petrochemical companies' remit, needs to be examined at regional level.

Research Gap 1: Further research on infrastructure needs for high blends and second-generation biofuels; and for refuelling facilities for local government fleets.

Research Gap 2: Examination of the need for infrastructure for the use of biogas as a viable transport fuel (i.e. upgrading and transportation of the upgraded biogas to the vehicle fuelling station).

## **2) What is the feasibility and cost of these infrastructure requirements?**

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<sup>61</sup> This mainly covers first generation fuels and biomethane, but there is some discussion of hydrogen, DME and electricity as well (Biofuel cities 2009).

The costs for current biofuels infrastructure requirements are known and costs at the forecourt have been supported through UK and other Government refuelling grants. For high blend and second generation fuels we could find no estimation of infrastructure cost, although the US is supporting work in this area.

Within Europe the European Biofuels Technology Platform has undertaken some research on the costs of biofuels production, including the cost of the conversion process and the infrastructure for storage, distribution, refuelling and use, using data from the EUCAR/JRC/CONCAWE well to wheels project. From its analysis of this, the EBTP recommends the development of standards for second generation fuels to minimise the costs of infrastructure associated with their distribution and storage. It also suggests the consideration of pipelines for distribution of fuels across Europe, although whether or not this is relevant to the UK might be questioned. Similar research has been undertaken in the US (see Table 8-3). It is clear that the work in Europe and the USA will produce useful costs for specific infrastructure that could be used in UK analysis.

Related to this, biofuels plants have been proposed for current petrochemical hubs and key ports in the UK. These plants could provide employment in the north and on the east coast of England, and in Scotland, in areas where some of the infrastructure is already available (e.g. skills in refineries, port facilities). Additional Government grants to develop this infrastructure would make investment in biofuels in these regions more attractive to developers. Regional Development Agencies have realised this and some have funded preliminary studies to examine the opportunities.

There is a need to understand the logistics and constraints related to infrastructure required for second generation fuels. This has not been investigated in depth in the UK (or even at European level, although the EBTP is beginning this examination). If the UK is to successfully develop second-generation plants, it is likely that there will need to be considerable investment in infrastructure at refinery facilities and for collection of the feedstocks for these plants.

The UK could also import biofuels for the UK from developing nations. However, the ability of many of these countries to develop biofuels is restricted by a lack of infrastructure (including transport networks, storage and processing facilities). This issue could be examined with funding from UK aid programmes.

Research Gap: This area links to Research Gap 1, which should include feasibility and costs.

Research Gap 3 Examination of the needs for biofuels-related infrastructure development in developing countries.

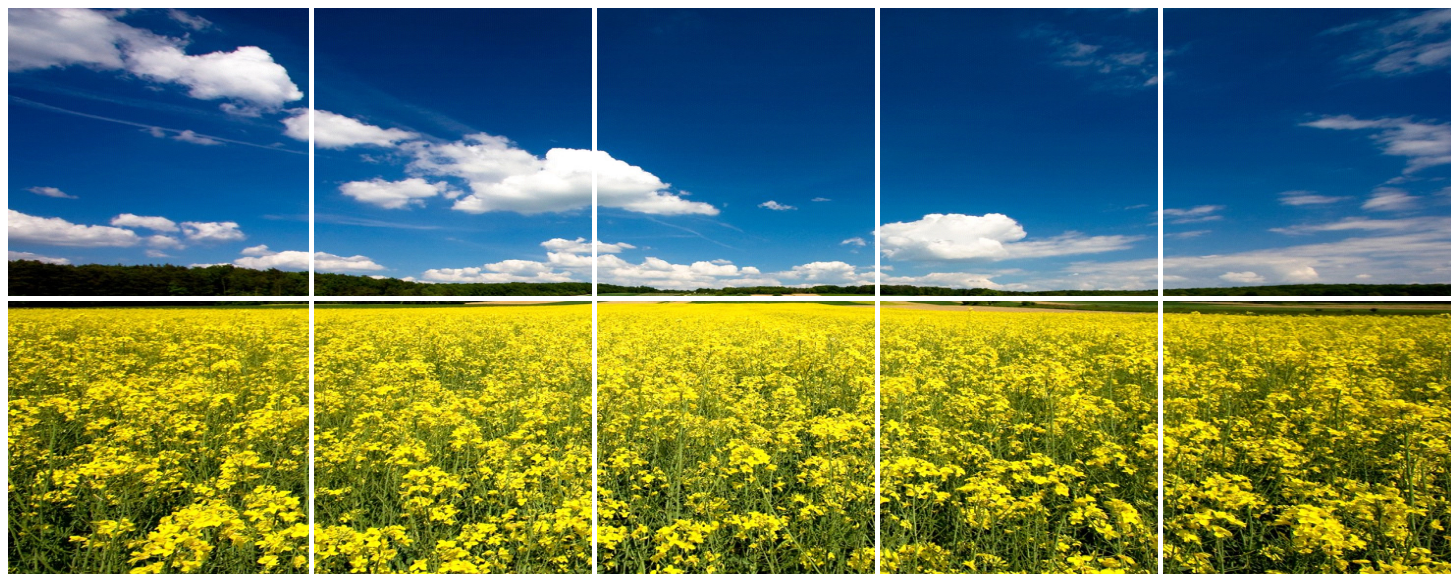
Research Gap 4: Within the UK the need for grants for development of facilities at ports and for storage and pipeline facilities at regional level should be considered. There are important biofuels opportunities in the UK, particularly where there is the potential to take advantage of current facilities at refineries and ports. However, there will be a need to invest in new infrastructure in these areas and an investigation of where it is most advantageous to invest in such facilities would be useful.

**Table 8-3 Infrastructure – key findings**

Research Gap	1) Understanding infrastructure needs for high blends and second generation biofuels.	2) Examination of infrastructure for biogas	3) Assistance for infrastructure in developing countries	4) Grants for port facilities and for regional development
Key related work	US R&D EBTP	Swedish work	UNDP, UNCTAD	Regional Development Agencies
Complexity	*	*	*	*
Time scale	***	***	***	***
Potential costs	*	*	***	***
National or international?	UK/EU	UK	International	UK
Availability of data	Some data available	Available	Available	Available
Availability of skill sets	*	***	**	***

**Key**

<b>Significance</b> – please see matrix	<b>Complexity</b> *** complex, multiple tasks, multiple skills ** moderately complex, requiring some interacting projects and more than one skill set * simple, straightforward task	<b>Time scale</b> *** Long term R&D, taking more than 2 years to complete ** Medium term, taking 1 to 2 years * Short term work, taking up to 1 year	<b>Potential Costs</b> *** > £1 M ** £100k – 999k * <£100k	<b>National or international</b> i.e. can the work be done in the UK or would it be better done internationally?
<b>Availability of data</b> This will refer to the IPR/availability of R&D already ongoing in the area (e.g. Commercial – restricted; or published/available)			<b>Availability of skill sets</b> *** a number of organisations working in area ** availability restricted to a few groups or only on international scale * skills gap, significant training required.	



# Biofuels Research Gap Analysis

## Chapter 9 – Skills

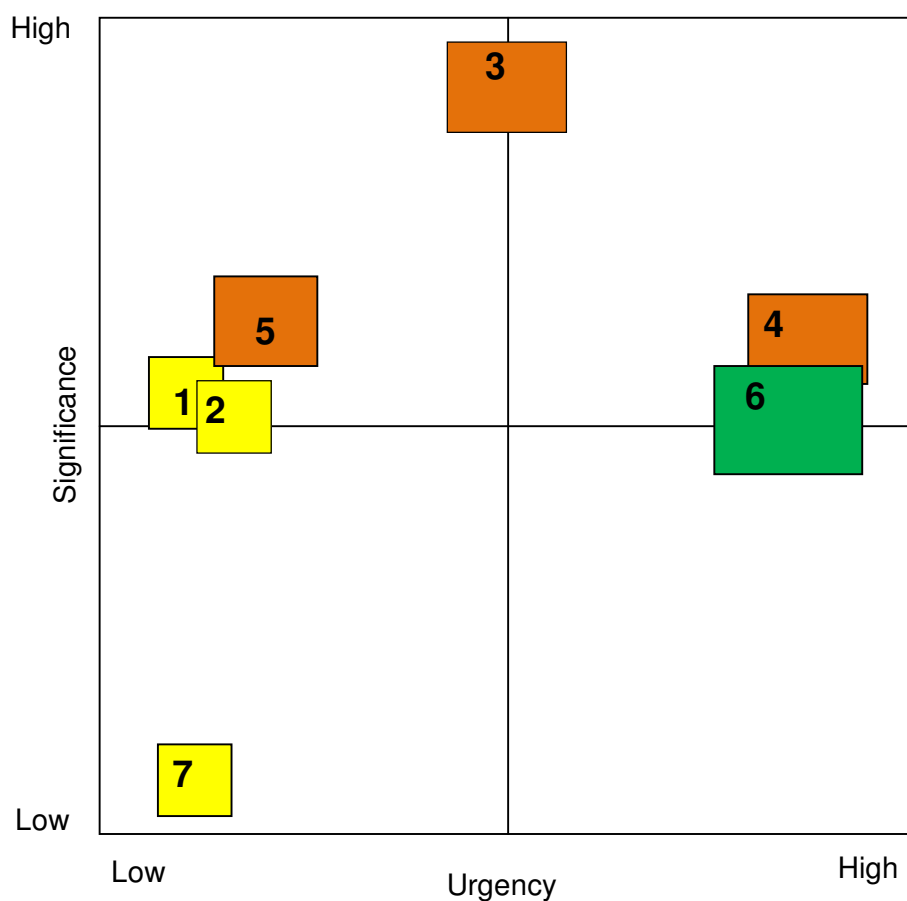


**Final report to the Biofuels Research  
Steering Group**

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## 9 Skills

**Table 9-1 Matrix prioritising key research gaps for skills**



### Key research gaps

#### Gaps for Skills

1. Continuation of funding for fundamental research groups
2. Higher education courses
3. Professional development
4. Technical training 'on the job'

#### Gaps for knowledge transfer and communication s

5. Knowledge transfer
6. Co-operation in research
7. Continue to improve common understanding / removing barriers

### Size of Research Gap

	Small
	Small / Medium
	Medium / Large
	Large

### 9.1.1 Executive Summary

*What skills are required for the UK to meet its 10% renewable transport energy target (and beyond)?*

*What mechanisms for knowledge transfer currently exist?*

In order to develop biofuels in the UK, a range of technical skills is required. It is also important for rapid development of biofuels that knowledge and skills are disseminated effectively and that there is common understanding of biofuels concepts amongst both technical and non-technical audiences.

In the course of this work we have investigated the skills base within the UK and communication and dissemination activities within the UK, in Europe and worldwide. Key gaps identified are:

#### **Skills**

Research Gap 1: Fundamental research groups – these groups train the technologists of tomorrow. The Research Councils are currently funding the work of a number of research groups doing fundamental research. These groups will provide the skilled professional technologists and researchers of tomorrow, so this important role should continue to be funded.

Research Gap 2: Higher Education courses. Biofuels needs to be included within relevant courses and the number of courses being offered needs to be expanded in order to increase awareness and understanding of biofuels.

Research Gap 3: There is a need for professional development. This has more urgent implications and greater significance if biofuels are to be grown at the level required to reach 2020 targets sustainably.

Research Gap 4: There is a need for technical training ‘on the job’. This may prove to be an important issue should the sector rapidly expand.

#### **Communications and knowledge transfer**

Research Gap 5: Knowledge transfer is good in some areas and poor in others. It is suggested that one organisation could act as a central database of information, in order to provide a central focus for information transfer.

Research Gap 6: Co-operation in research. Improved co-ordination of the various government programmes on biofuels and links between researchers of different disciplines to work towards solutions for multi-disciplinary issues is required.

Research Gap 7: Common understanding and removing of barriers to biofuels. The UK is relatively well engaged in these areas. This is therefore a small research gap.

### 9.1.2 Context

In looking at the range of technical skills required to develop biofuels, this study has considered the type of skills required, what skills are currently available in the UK and how these skills might be further developed.

It is also important for the rapid development of biofuels that knowledge and skills are disseminated. This is important for the transfer of technical knowledge between researchers and mechanisms such as Knowledge Transfer networks and International Energy Agency activities. The EU Concerted Action programme has also been investigated to assess its current engagement with biofuels and its future potential.

A significant uptake of biofuels requires a greater general understanding of biofuels. This includes clarification of biofuel wording and descriptions, agreed standards and production of literature explaining the biofuels concepts for both technical and non-technical audiences.

The study has explored how information about biofuels is currently disseminated to potential users and what further work is required in this area.

In addition, this study has also investigated the skills base and communications activities within the UK, in Europe, in the USA and Brazil and looked at international communications and dissemination activities.

### 9.1.3 Key research questions

The main question asked in this part of the study revolves around the type of skills currently needed for the development of biofuels, what will be skills needs in the future, and how information about biofuels is communicated and disseminated.

Key research questions for skills include:

- 1) What skills are required for the UK to meet its 10% renewable transport energy target (and beyond)?
- 2) What is the availability of these skills?
- 3) Are there major skills gaps, and what will be the impact of these gaps upon the UK's ability to meet its biofuels targets?

Key research questions relating to the communication and dissemination of biofuels knowledge include:

- 4) What mechanisms for knowledge transfer currently exist?
- 5) What else could be done to improve communications and knowledge transfer?

### 9.1.4 Research in the area

The key types of organisation targeted for information on skills and communications are shown in the tables below, together with their main area of involvement. Detailed information is provided in Annex 9.

**Table 9-1 Areas of involvement with biofuels skills**

Funding or research organisation and budget where available	Current status of research
Area of involvement with biofuels skills	
UK	
Research Councils and Universities	Development of research skills base, higher education courses.

Funding or research organisation and budget where available	Current status of research
<b>Area of involvement with biofuels skills</b>	
	<p>BBSRC has recently launched the Sustainable Bioenergy Centre, a £20M project, which aims to build bio-energy research capacity. BBSRC also funds a range of studentships. Most are available in any field of bioscience, but in the Targeted Priority Studentships, one of the current priorities is bio-energy.</p> <p>EPSRC funds postgraduate training, including Industrial Case awards and SUPERGEN. NERC leads on TSEC-BIOSYS and ESRC leads the RELU-biomass programme. UKERC funds postgraduate training including energy summer schools for PhDs.</p>
Research Institutes	<p>Government-funded research institutes include Rothamsted Research, the Centre for Ecology &amp; Hydrology, Forest Research, Scottish Association for Marine Sciences, IGER and CSL.</p> <p>The Government has recently funded the Energy Technologies Institute, a public-private partnership working to accelerate the development and commercial deployment of a focused portfolio of energy technologies.</p>
Government Departments and central organisations	<p>Development of UK biofuels and related industries through DECC, Defra, DfT, and BIS.</p> <p>The Carbon Trust has its own programme for biofuels and the work they commission helps to develop skills in these areas e.g, biofuels algal challenge.</p> <p>WRAP is sponsoring a pilot training course in anaerobic digestion.</p>
Regional Development / Energy Agencies and Industry Groups	<p>There are indications that some Regional Development Agencies may be interested in clubbing together with industry to fund apprenticeships in the future.</p>
Private Companies	<p>Oil companies support some work on biofuels in the UK through research council and Government initiatives, and also through direct collaboration with individual university groups.</p> <p>Vehicle manufacturers have some in-house expertise, with staff trained as necessary.</p> <p>Most current biofuels companies tend to train staff 'on the job' rather than fund specific apprenticeships.</p>
<b>Europe</b>	
EU programmes	Biofuels research at the level of individual EU member states.
<b>US</b>	
USDA Food and Agricultural Policy Research	<p>Training program for the emerging bio-economy.</p> <p>The program will train researchers to operate at the interface of</p>



<b>Funding or research organisation and budget where available</b>	<b>Current status of research</b>
<b>Area of involvement with biofuels skills</b>	
Institute	agriculture and energy - a critical place as the agricultural system continues to evolve, with emerging technology, into a broad bio-economy.
USDA AGRI SCIENCES	Integrating agriculture, bioscience and biotechnology concepts in school curriculum: preparing students for careers in agriculture.
<b>International</b>	
Brazil	CENBIO has focused on the development of studies and projects aimed at the use of biomass and promoting the interchange among Brazilian and foreign institutions of technical information and results of biomass technologies.

**Table 9-2 summarises Work in relation to biofuels communications**

<b>Biofuels communications</b>	
<b>UK</b>	
Research Councils and Universities	<p>Information from Research Council-funded programmes is disseminated via meetings and peer reviewed publications.</p> <p>The NNFCC provides independent information and advice on renewable fuels, materials and technologies to agriculture, academia, Government, industry, the media and the public.</p> <p>The Biomass Energy Centre was set up as a 'one stop shop' to provide information to anyone in the UK with an interest in biomass. The centre operates a website, on-line library and helpline.</p> <p>The LowCVP fuels working group is involved in biofuels development and deployment.</p>
Government Departments and central organisations	<p>Information from Defra, DECC and TSB funded work is generally published and available through the relevant website.</p> <p>Work from the Carbon Trust is not currently published.</p>
Knowledge Transfer Networks (KTN)	<p>A number of KTNs have an interest in some aspect of biofuels. For example, the Chemistry Innovation KTN is involved with One Northeast in developing a biofuels project in the region.</p> <p>The Resource Efficiency KTN and the Environmental KTN are sponsoring seminars to inform about bioenergy from waste opportunities.</p> <p>No single KTN is looking at biofuels as a whole.</p>
<b>Europe</b>	
EU Programmes	FP7 projects all have a dissemination element, usually by project website, report and workshop/ seminar.

	FP7 also supports a number of biofuels projects devoted to information exchange. Including: - EU Biofuels Technology Platform. - ERANET- bioenergy.
EU groups	There are a number of European groups disseminating information relating to biofuels for example: Stockholm Environment Institute co-ordinates a network aimed at synthesis, policy analysis and knowledge transfer
<b>International</b>	
UNICA	UNICA aims to provide a broad range of stakeholders with up-to-date information on the contributions of Brazil's, sugar, ethanol and bioelectricity sectors.
IEA	Co-operation, exchange of information and dissemination are central to IEA bio-energy. Work is published and available on the IEA bioenergy website and there is a comprehensive programme of workshops.
GBEP	GBEP aims to foster exchange of information, skills and technologies through bilateral and multilateral collaboration and to identify and overcome barriers to biofuels development.

### 9.1.5 Research Gaps

A number of research gaps have been identified in answer to the following questions:

#### 1) What skills are required for the UK to meet its 10% renewable transport energy target (and beyond)?

The extent to which UK skills are required will depend on whether the UK 10% target is met through biofuel imports or whether it is achieved through UK industry. If it were the latter then engineering and biofuel plant management skills would be required amongst others.

UK research skills in the biofuels area will also be important, but are a separate issue from the UK achieving the 10% target.

#### 2) What is the availability of these skills?

Industrial skills are currently being developed as projects progress. If a sudden increase in these skills was required, for example to meet a 10% target with a significant contribution from UK industry, there would be issues in making enough of these skills available.

The UK Research Councils have recently put in significant effort in building up research skills, particularly through the TSEC and Supergen programmes. However, the UK is currently losing industrial and research skills abroad. This is particularly the case given the current low industrial base in the UK.

Research Gap 1: Fundamental research groups – these groups train the technologists of tomorrow. The Research Councils are funding their work and it is recommended that this funding need to be maintained to continue its role of developing future professionals.

Research Gap 2: Higher Education courses. There needs to be the inclusion of biofuels within relevant courses and expansion of the number of courses being offered, with the intention of increasing awareness of the importance of biofuels.

### **3) Are there major skills gaps, and what will be the impact upon the UK's ability to meet the targets?**

The skills gaps will depend on the UK's aspirations to meet its target through UK activity or whether the targets are met through imports. If we are to meet the target through activity in the UK there are major gaps in industry, in professional development and at managerial level. Currently industry indicates that it is able to meet its needs, but there are few plants in the country. Any expansion may challenge this situation considerably.

At the management level (for example in Local Authorities and among Fleet Managers), a lack of understanding of biofuels and the potential benefits they offer will hinder uptake and therefore the achievement of targets.

This points to two levels of training requirement – that of professional development for workers at the biofuels plants; and a need to train procurement managers to be aware of opportunities and to understand the implications for their fleets.

Research Gap 3: If the UK is to achieve its targets using biofuels produced within the UK there is requirement for professional development, at two levels. These are for professionals with the skills to develop and operate plants; and for managers involved in procurement to understand biofuels and their potential benefits and impacts. This has more urgent implications and greater significance if biofuels are to be grown at the level required to reach 2020 targets sustainably.

Research Gap 4: Technical training 'on the job'. Although current operators indicate that there is no skills shortage at present, issues are likely to arise if the sector expands rapidly in response to the targets.

#### **The promotion of transfer of knowledge:**

### **4) What mechanisms currently exist for knowledge transfer?**

Several mechanisms currently exist for the promotion and transfer of knowledge between research centres including work by the NNFFC and the Biomass Energy Centre; however there is no one specific action focussed on biofuels.

There are several Knowledge Transfer Networks in place providing links between Government and industry where there is a peripheral interest in biofuels, but none directly focus on biofuels. There needs to be a better conduit for information dissemination and a route for funding more demonstration-type schemes.

Research Gap 5: There is a need to provide a specific focus for knowledge transfer for biofuels, using one central organisation to co-ordinate knowledge transfer.

### **5) What else could be done?**

If the UK is to achieve the 10% target in a sustainable manner by 2020 it will require a significant expansion of effort in many areas. Furthermore communication and exchange of information between technical areas will be important and will need to be rapid and effective. To achieve this the current level of co-ordination and communication needs to be developed further. This could be facilitated through the development of a 'Biofuels Energy Centre', to include an information website, which links to other relevant websites and publications. This 'Biofuels Energy Centre' could mirror the Biomass Energy Centre, which provides access to information on all aspects of biomass heat and power, including fuel characteristics, resource and supply, legislation and research and development work as well as links to relevant information on the performance of biomass energy and relevant events. As with the Biomass Energy Centre, such a centre could be operated by an existing organisation that is key to biofuels development.

Improved communications would bring greater visibility to work that is being done, enabling research groups to improve links, encourage the exchange of results, and decrease duplication, while at the same time enabling research to build on work that has already been done. This level of communication will be vital to achieving targets by 2020.

Research Gap 6: There is a need for multi-disciplinary research to provide solutions to the problems outlined in this report. To achieve this there is a need for better co-ordination between UK programmes and for a higher profile within international programmes. There is an opportunity for UK to be more involved in Europe, for example through the European Biofuels Technology Platform (EBTP) and to make more use of ERANET to develop collaborative projects. It is also necessary to explore the need and the opportunities for co-operation with the USA.

Research Gap 7: Common understanding and removing of barriers to biofuels (for example, work on sustainability and life-cycle assessment). The UK is relatively well engaged in these areas. This is therefore a small research gap.

**Table 9-3 UK Skills gaps for biofuels**

Area	Current activity	Gap?	Comments
Fundamental Research Groups	UK Biosciences initiative	x	Need to maintain funding over 5-10 years. Need technology roadmap to focus research.
	SUPERGEN	x	
Higher education courses	Some UK universities offering masters/PhD courses	xx	Need to expand number of universities offering courses and ensure biofuels component in courses. Work is already ongoing to scope out the content of higher education courses at an EU level, and this work should be supported.
Professional development	Small number of 1-2 day courses.	xxx	An urgent need to develop awareness and understanding of biofuels at all levels. Courses could be offered centrally or on a regional basis.
Technical training 'on the job'	Biomass production/processing groups	x	Current funding from Defra needs to be maintained over 5-10 years
	In-company training for	x	Done on an ad hoc basis. Need

Area	Current activity	Gap?	Comments
	specific biofuels projects		will increase and more formal training will be required as additional projects are developed.
	Apprenticeships	xxx	None currently. Scheme could be developed if demand appears.

**Table 9-4 Gaps for knowledge transfer and communications**

Activity Type	Level of UK activity	Gap?	Comments
<b>Knowledge Transfer</b>	Many organisations, not many focussed on biofuels	xx	Can one KTN take lead for biofuels?  Should there be a single UK centre for information dissemination for biofuels?  Maintain involvement with IEA and increase dissemination within UK.
<b>Co-operation in research</b>	Low	xxx	UK programmes could be better co-ordinated. Opportunity for UK to be more involved in EBTP and to make more use of ERANET to develop collaborative projects. Need to explore opportunities for co-operation with USA.
<b>Common understanding/ removing barriers</b>	Increasing, with focus on sustainability, GHG and fuel standards.		UK is well engaged in these areas.

### 9.1.6 Summary and conclusions

There are a number of levels at which skills gaps have been identified in this study. These include:

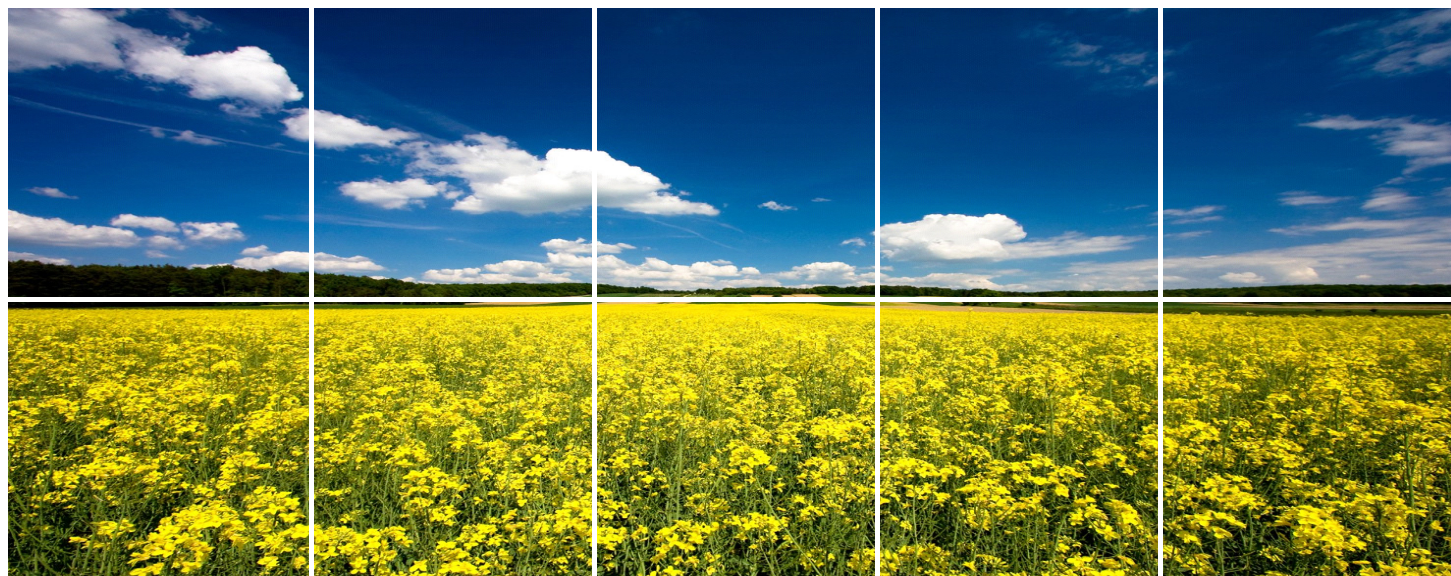
- **Fundamental research groups** – these groups train the technologists of tomorrow. The Research Councils are funding their work and it is recommended that this funding needs to be maintained to continue its role of developing future professionals. This issue has been noted to be of low urgency (in that funding is currently in place) but of greater significance. This is a fairly straightforward issue and the gap is therefore thought to be small.
- **Higher education courses** – there needs to be inclusion of biofuels within relevant courses and expansion of the number of courses being offered, with the intention of increasing awareness of the importance of biofuels. This is not urgent as the demand for

such skills is still small but could be significant in the future. The issue is fairly straightforward and it has been ranked as a small gap, although more effort is required to ensure that the courses are relevant to what is happening within the UK.

- **Professional development** – has more urgent implications and greater significance if biofuels are to be grown at the level required to reach 2020 targets sustainably. Professional training also needs to increase skills training associated with policy sustainability requirements for small-scale producers. Overall this is a more complex area than the two above and has been assessed as a small to medium gap.
- **Technology training ‘on the job’** – respondents noted no problems at present, but issues may arise should the sector rapidly expand. Development of apprenticeships is one way to address this issue. This is not assessed to be urgent at present, but could be highly significant. The size of the gap is judged to be small to medium.

There is also a need to invest in knowledge transfer and improve communications through:

- **Knowledge transfer** – knowledge transfer is good in some areas and poor in others. Sometimes this is because the work is academic with a need to publish in journals, which have a long lead time to publication; sometimes it is because the work is thought to be commercial. If the UK is to achieve what it needs to do rapidly, then better communication of results is required. It is suggested that one organisation could act as a central database of information on biofuels and that communication through the IEA is important, providing the information obtained is disseminated throughout the UK. This is a task for the medium term and is low in significance. It is a medium to small gap, with the challenges mainly lying in the organisation of the centre’s web site and cooperation of academic and commercial institutes.
- **Co-operation in research** – co-ordination of the various government programmes on biofuels and links between researchers of different disciplines to work towards solutions for multi-disciplinary issues is important if the UK is to achieve its targets using UK biofuels. Good co-ordination is already ongoing in some areas (e.g. some of the large research council funded programmes), but needs to be improved in others, particularly to ensure good communication on sustainability issues; and to develop advanced biofuels conversion suitable for the UK. This leads to the conclusion that this is an important medium term issue; and one which is highly significant. It has been judged to be a medium to large gap and will require organisation, multi-disciplinary teams and some investment in international networks.
- **Common understanding and removing barriers to biofuels** – the UK is well engaged in these areas and they are thought to be of lower urgency and significance. The gap here is judged to be small as it can be easily addressed for relatively low cost.



## Biofuels Research Gap Analysis References



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# Biofuels Research Gap Analysis Abbreviations



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## Abbreviations

ACEA – European Automobile Manufacturers' Association  
ACI-NA – Airports Council International–North America (USA)  
AD – Anaerobic Digestion  
AEZ – Agro–Ecological Zoning  
AEZ/BLS – Agroecological Zones/Basic Linked System  
ALFA-BIRD – Alternative Fuels and Biofuels for Aircraft Development (EU)  
ANL – Argonne National Laboratory (USA)  
ASEAN – Association of Southeast Asian Nations  
ASTM – American Society for Testing and Materials (USA)  
ATA – Air Transport Association (USA)  
ATOC – Association of Train Operating Companies (UK)  
BBSRC – Biotechnology and Biological Sciences Research Council (UK)  
BEC – Biomass Energy Centre (UK)  
BEE – Biomass Energy Europe  
BEFS – Bioenergy and Food Security Project (FAO)  
BERR – Department for Business, Enterprise & Regulatory Reform (UK)  
BEST – Bioethanol for Sustainable Transport (EU)  
BIOMATNET – Biological Materials for Non–Food Products (EU)  
BIOREG-INTEG – Development of Advanced BIOREFinery Schemes to be INTEGrated into Existing Industrial Fuel Complexes  
BIO-TOP – Biofuels Assessment on Technical Opportunities and Research Needs for Latin America  
BIS – Department for Business, Innovation and Skills  
BP – British Petroleum  
BRSG – Biofuels Research Steering Group  
BRGA – Biofuels Research Gap Analysis  
BSI – Better Sugar Cane initiative (ISEAL)  
BSPB – British Society of Plant Breeders (UK)  
BtL – Biomass–to–liquids  
BTO – British Trust for Ornithology (UK)  
BUN – Biomass Users Network of Brazil  
C&S – Carbon and Sustainability  
CAAFI – Commercial Aviation Alternative Fuels Initiative (USA)  
CARB – Californian Air Resources Board (California, USA)  
CARD – Center for Agricultural and Rural Development (Iowa State University, USA)

CARENSA – Cane Resources Network for Southern Africa  
 CATARC – China Automotive Technology & Research Center  
 CEC – Clean Energy Coalition (Michigan, USA)  
 CEH – Centre for Ecology and Hydrology (UK)  
 CENBIO – Centro Nacional de Referência em Biomassa (Brazil)  
 CGE – Computable General Equilibrium (models)  
 CGIAR – Consultative Group on International Agricultural Research  
 CI – Conservation International  
 CIRAD – Agricultural Research Centre for International Development (France)  
 CoEBio3 – Centre of Excellence for Biocatalysis, Biotransformations and Biocatalytic Manufacture (University of Manchester and the Exeter University School of BioSciences)  
 COMPETE – Competence Platform on Energy Crop and Agroforestry Systems for Arid and Semi-arid Ecosystems (Africa)  
 CONCAWE – Conservation of Clean Air and Water in Europe  
 CRES – Consortium pour la Recherche Economique et Sociale (Senegal)  
 CSL – Central Science Laboratory (now part of The Food and Environment Research Agency (Fera)) (UK)  
 CSREES – Cooperative State Research, Education, and Extension Service (USDA)  
 CT – Carbon Trust (UK)  
 CTBE – Bioethanol Science and Technology Centre (Brazil)  
 CtL – Coal-to-liquid  
 CURES – Citizens United for Renewable Energy and Sustainability  
 CV – Calorific Value  
 DDGS – Dried Distillers Grains with Solubles  
 DECC – Department for Energy and Climate Change (UK)  
 DEFRA – Department for Environment, Food and Rural Affairs (UK)  
 DEFRA CEOSA – DEFRA Energy Efficiency projects  
 DfID – Department for International Development  
 DfT – Department for Transport (UK)  
 DG ENV – Directorate General for environment, nuclear safety and civil protection (EU)  
 DG RTD – Directorate General for Research (EU)  
 DG TREN – Directorate General for Energy and Transport (EU)  
 DIUS – Department for Innovation, Universities and Skills (UK)  
 DME – Dimethylether  
 EAA – Essential Amino Acids  
 EBAMM – Energy and Resources Group Biofuel Analysis Meta-Model (UC Berkeley, California, USA)  
 EBDI – Ethanol Boosted Direct Injection  
 EBTP – EU Biofuels Technology Platform (EU)

ECCM – Edinburgh Centre for Carbon Management (Scotland, UK)  
ECOWAS – Economic Community of West African States  
EEA – European Environment Agency  
EEDA – East of England Development Agency (UK)  
EISA – Energy Independence and Security Act of 2007 (USA)  
EMBRAPA – Brazilian Agricultural Research Corporation  
EMDA – East Midlands Development Agency  
ENEP – European Network of Environmental Professionals  
ENGVA – European Natural Gas Vehicle Association  
EPSRC – Engineering & Physical Sciences Research Council (UK)  
ERDF – European Regional Development Fund  
ERIA – Economic Research Institute for ASEAN and East Asia  
ESD – Energy for Sustainable Development  
ESMAP – Energy Sector Management Assistance Programme (World Bank and UNDP)  
EST – Energy Saving Trust (UK)  
EU CAR – European Council for Automotive R&D  
EU CEN – European Standards Organisation  
EU ETS – European Union Emissions Trading Scheme  
FAA – Federal Aviation Administration (USA)  
FAO – Food and Agriculture Organisation of the United Nations  
FAPRI – Food and Agricultural Policy Research Institute (Iowa State and the University of Missouri, USA)  
FCO – British Foreign and Commonwealth Office  
FERA – The Food and Environment Research Agency (UK)  
FFV – Flex-fuel Vehicle  
FP – Framework Programme (EU)  
FQD – Fuel Quality Directive (EU)  
FSC – Forestry Stewardship Council  
FSE – Food Security and the Environment (programme of the Freeman–Spogli Institute for International Studies (FSI) at Stanford University, USA)  
FSI – Freeman–Spogli Institute for International Studies (Stanford University, USA)  
GBEP – Global Bioenergy Partnership  
GDP – Gross Domestic Product  
GE – General Electric  
GEF – Global Environment Facility  
GEFSEC – Secretariat of the GEF  
GHG – Greenhouse Gas  
GIS – Geographical Information Systems  
GM – Genetic Modification



REET – Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation

GTAP – Global Trade Analysis Project

GTAP-E – An Energy–Environmental version of the GTAP Model

GtL – Gas-to-liquid

HGV – Heavy Goods Vehicle

HVO – Hydrotreated Vegetable Oil

IBE – Institute of Business Ethics (UK)

IBEP – International Bioenergy Platform (FAO)

IBF – International Biofuels Forum

IBI – International Biochar Initiative

ICAR – Indian Council of Agricultural Research

ICCO – International Cocoa Organisation

ICONE – Institute for International Trade Negotiations (Brazil)

ICRAF – International Centre for Research in Agroforestry

ICRISAT – International Crops Research Institute for the Semi-Arid Tropics

IEA – International Energy Agency

IEE – Intelligent Energy Europe

IEED – International Institute for Environment and Development

IFAD – International Fund for Agricultural Development (UN)

IFEU – Institute for Energy and Environmental Research (USA)

IFOAM – International Federation of Organic Agriculture Movements

IFPRI – International Food Policy Research Institute

IIASA – International Institute for Applied Systems Analysis

IICT – Indian Institute of Chemicals Technology

IIP – Indian Institute of Petroleum

IIS – Indian Institute of Science

IIT – Indian Institute of Technology

ILUC – Indirect land-use change

IMF – International Monetary Fund

IMPACT – International Model for Policy Analysis of Agricultural Commodities and Trade

INMETRO – National Institute of Metrology, Standardisation and Industrial Quality (Brazil)

IPC – International Food and Trade Policy Council

IPCC – Intergovernmental Panel on Climate Change

IPR – Intellectual Property Rights

ISCC – International Sustainability and Carbon Certification (Germany)

ISEAL – International Social and Environmental Accreditation and Labelling

ISRA – Institut Senegalais de Recherches Agricoles (Senegal)

IUCN – International Union for Conservation of Nature

IUW – Institute for Environmental Economics and World Trade  
JNCC – Joint Nature Conservation Committee (UK)  
JRC – Joint Research Centre (EU)  
KTN – Knowledge Transfer Network  
LAMNET – Latin American Thematic Network on Bioenergy  
LCA – Life-cycle Assessment/Analysis  
LCFS – Low Carbon Fuel Standard (California, USA)  
LCTCR – Low Carbon Technology Commercialisation Review (Carbon Trust, UK)  
LCVP – Low Carbon Vehicle Partnership  
LPG – Liquid Petroleum Gas  
LUC – Land–use change  
LULUCF – Land Use, Land–Use Change and Forestry  
M&E – Monitoring and Evaluation  
MARPOL – International Convention for the Prevention of Pollution from Ships, 1973  
MCDA – Multiple Criteria Decision Aid  
MIT – Massachusetts Institute of Technology (USA)  
MNP – Netherlands Environmental Assessment Agency  
MoU – Memorandum of Understanding  
MTBE – Methyl Tertiary Butyl Ether  
N – Nitrogen  
NASA – National Aeronautics and Space Administration (USA)  
NBB – National Biodiesel Board (USA)  
NEPIC – North East Process Industries Cluster (UK)  
NERC – Natural Environment Research Council (UK)  
NGO – Non governmental organisation  
NGV – Natural Gas Vehicle  
NL – Netherlands  
NNFCC – National Non–Food Crops Centre (UK)  
NOx – Nitrogen Oxide  
NRDC – Natural Resources Defense Council (USA)  
NREL – National Renewable Energy Laboratory (USA)  
NSAPI – National Skills Academy for Process Industries (UK)  
ODI – Overseas Development Institute  
OECD – Organisation for Economic Cooperation and Development  
OSR – Oilseed rape  
OTAQ – United States Environmental Protection Agency Office of Transportation and Air Quality  
PAU – Punjab Agricultural University (India)

PEFC – Programme for Endorsement of Forest Certification Schemes (Switzerland)

PPO – Pure Plant Oil

QUEST – Quantifying and Understanding the Earth System

R&D – Research and development

RA – Rainforest Alliance

RAEL – Renewable and Appropriate Energy Laboratory (UC Berkeley, California, USA)

RDA – Regional Development Agency (UK)

REAP – Renewable Energy Assessment Project (USDA)

RED – The Renewable Energy Directive (EU)

REDD – Reduced Emissions from Deforestation and Degradation (UN)

RELU – Rural Economy and Land Use Programme (UK)

RFA – Renewable Fuels Agency (UK)

RME – Rape Methyl Ester

RSB – Roundtable on Sustainable Biofuels

RSPB – Royal Society for the Protection of Birds (UK)

RSPO – Roundtable on Sustainable Palm Oil

RSSB – Rail Safety and Standards Board (UK)

RTFO – Renewable Transport Fuel Obligation (UK)

SAFUG – Sustainable Aviation Fuel Users Group

SEE – Energy Secretariat of the São Paulo State (Brazil)

SEERAD – Scottish Executive Environment and Rural Affairs Department

SME – Soybean Oil Methyl Ester

SME(s) – Small and Medium Enterprises

SOFA – The State of Food and Agriculture Report (FAO)

SRC – Short Rotation Coppice

SUPERGEN – Sustainable Power Generation and Supply

SWAFEA – Sustainable Way for Alternative Fuel and Energy in Aviation

TSB – Technology Strategy Board (UK)

TSEC–BIOSYS – Towards a Sustainable Energy Economy Initiative (UK)

TTR – Transport & Travel Research (UK)

UKERC – UK Energy Research Centre

UN – United Nations

UNCTAD – United Nations Conference on Trade and Development

UNDP – United Nations Development Programme

UNEP – United Nations Environment Programme

UNEP DTIE – United Nations Environment Programme Division of Technology, Industry and Economics

UNEP STAP – United Nations Environment Programme Scientific and Technical Advisory Panel

UNEP–WCMC – United Nations Environment Programme World Conservation Monitoring Centre

UNICA – Brazilian Sugarcane Industry Association

UNICAMP – Universidade Estadual de Campinas (Brazil)

UNIDO – United Nations Industrial Development Organisation

US EPA – United States Environmental Protection Agency

USDA – United States Department of Agriculture

USDOE – United States Department of Energy

USDOE EERE – United States Department of Energy – Energy Efficiency and Renewable Energy

USDOT – United States Department of Transportation

VROM – Dutch Ministry of Housing, Spatial Planning and the Environment (Netherlands)

WAB – Research Programme on Scientific Assessment and Policy Analysis for Climate Change (Netherlands)

WI – Wuppertal Institute for Climate, Environment and Energy (Germany)

WRAP – Waste and Resources Action Programme (UK)

WTO – World Trade Organisation

WWF – World Wildlife Fund

ZALF – Leibniz Centre for Agricultural Landscape Research (Müncheberg, Germany)



# Biofuels Research Gap Analysis Annexes



**Draft report to the Biofuels Research  
Steering Group**

ED45917  
Issue Number 3  
30<sup>th</sup> July 2009

## Annex 1 – Methodology

The project involved a four-stage process. The first stage involved the identification of organisations involved in research or in funding research into biofuels in the areas of interest to the BRSG. These areas of interest are detailed below:

- Indirect effects
- Other environmental issues
- Biofuels and food
- Other social and economic impacts
- Market forces / trade issues
- Vehicle capability
- Advanced / second generation biofuel technologies
- Infrastructure – downstream distribution and supply, and upstream
- Skills

Contact was then made with these organisations. This was through an email accompanied by a letter of introduction and a list of consultation questions agreed with the BRSG. The consultation questions were divided into two sections. The first section covered the research the organisations were currently undertaking and planning, the second section aimed to gather their wider knowledge and views. Where appropriate telephone interviews / meetings were also held.

The information collected from the responses to the consultation questions and telephone interviews/ meetings was logged into an access database. With the organisations being grouped by topic areas and sectors.

The database enable a summary of current research of each areas to be developed, and therefore enabled the identification of gaps in knowledge and in evidence in the topic areas of interest to the DfT.

This initial assessment of research gaps was held at a workshop on the 24<sup>th</sup> February 2009. The objectives of the workshop were to 'peer review' the initial findings and identify any further areas which needed to be considered.

These findings were then taken on board in this, the final report of the project.

## **Annex 2 – Chapter 2**

**Results of Questionnaires and Interviews of Indirect Land Use Change Research**

Interviewee	Organisation	Organisation Type	Projects	References	Webpages
Hans Böttcher Dr Gunter Fischer	IIASA Forestry Programme, Institute for Applied Systems Analysis	Global	<ul style="list-style-type: none"> <li>QUEST/Quatermass: QUEST Theme 3</li> <li>Biomass Energy Europe (BEE)</li> <li>Aware of EU7 project: PROSUTE project (Development and application of a standardized methodology for the prospective sustainability assessment of Technologies)</li> </ul>		<ul style="list-style-type: none"> <li><a href="http://quest.bris.ac.uk/research/themes/QUATERMASS.html">http://quest.bris.ac.uk/research/themes/QUATERMASS.html</a></li> <li><a href="http://www.eu-bee.info">www.eu-bee.info</a></li> <li><a href="http://www.iiasa.ac.at/cgi-bin/finder?login:%5Efischer%24:15:383">http://www.iiasa.ac.at/cgi-bin/finder?login:%5Efischer%24:15:383</a></li> <li><a href="http://www.iiasa.ac.at/Research/LUC/uc07/index.html">http://www.iiasa.ac.at/Research/LUC/uc07/index.html</a></li> </ul>
Name withheld	UNEP	Global	<p>UNEP led 'Assessments and Guidelines for Sustainable Liquid Biofuels Production in Developing Countries'. Executing agents FAO and UNIDO.</p> <p>Evidence base (or state of knowledge) document on the relationship between biofuels, climate change mitigation and biodiversity (expected publication June 2009)</p>	<p>Please refer to the 'GEF Scientific and Technical Advisory Panel' when citing any of the above information. Our main focal points for further information are:</p> <p>Prof. N.H. Ravindranath (Panel Member, Climate Change) Dr A.R.D. Taylor (STAP Secretary)</p>	<ul style="list-style-type: none"> <li><a href="http://www.unep.org/">http://www.unep.org/</a></li> <li><a href="http://www.globalenvironmentfund.com/">http://www.globalenvironmentfund.com/</a></li> <li><a href="http://gefonline.org/projectDetailsSQL.cfm?projID=3224">http://gefonline.org/projectDetailsSQL.cfm?projID=3224</a></li> <li><a href="http://stapgef.unep.org/activities/technicalworkshops/biofuels">http://stapgef.unep.org/activities/technicalworkshops/biofuels</a></li> <li><a href="http://www.thegef.org/uploadedFiles/Documents/Council_Documents_(PDF_DOC)/GEF_31/C.31.Inf.7%20STAP%20Biofuels%20Recommendations%20to%20GEF.pdf">http://www.thegef.org/uploadedFiles/Documents/Council_Documents_(PDF_DOC)/GEF_31/C.31.Inf.7%20STAP%20Biofuels%20Recommendations%20to%20GEF.pdf</a></li> </ul>
Dr Helen Watson	University of KwaZulu Natal, SA	Africa (Academic)	<p>COMPETE – Competence Platform on Energy Crop and Agroforestry Systems for Arid and Semi-arid Ecosystems- Africa</p> <p>CARENSA- Cane Resources Network for Southern Africa</p>		<p><a href="http://www.compete-bioafrica.net/">http://www.compete-bioafrica.net/</a></p> <p><a href="http://www.carensa.net/">http://www.carensa.net/</a></p>
Dr Rainer Janssen	WIP, Germany	Africa (Academic)	<ul style="list-style-type: none"> <li>COMPETE – Competence Platform on Energy Crop and Agroforestry Systems for Arid and Semi-arid Ecosystems- Africa</li> <li>BEST – Bioethanol for Sustainable Transport</li> <li>CO<sub>2</sub> Star</li> <li>ECHI-T</li> <li>LAMNET – Latin American Thematic Network on Bioenergy</li> <li>BIO-TOP Biofuels Assessment on Technical Opportunities and Research Needs for Latin America</li> </ul>		<p><a href="http://www.compete-bioafrica.net/">http://www.compete-bioafrica.net/</a></p> <p><a href="http://www.best-europe.org">www.best-europe.org</a></p> <p><a href="http://www.co2star.eu/">http://www.co2star.eu/</a></p> <p><a href="http://www.wip-munich.de/echi-t/echi-t.html">http://www.wip-munich.de/echi-t/echi-t.html</a></p> <p><a href="http://www.bioenergy-lamnet.org/">http://www.bioenergy-lamnet.org/</a></p> <p><a href="http://www.wip-munich.de/projects.htm">http://www.wip-munich.de/projects.htm</a></p>



Interviewee	Organisation	Organisation Type	Projects	References	Webpages
Dr Abigail Fallot	Forum for Agricultural Research in Africa (FARA), Africa	Africa (NGO)			<a href="http://www.catie.ac.cr/ProyPorPais.asp?CodIdio=ENG&amp;CodMagazin=102">http://www.catie.ac.cr/ProyPorPais.asp?CodIdio=ENG&amp;CodMagazin=102</a> <a href="http://www.catie.ac.cr/ProyPorPais.asp?CodIdio=ENG&amp;CodMagazin=107">http://www.catie.ac.cr/ProyPorPais.asp?CodIdio=ENG&amp;CodMagazin=107</a> <a href="http://www.catie.ac.cr/ProyPorPais.asp?CodIdio=ENG&amp;CodMagazin=106">http://www.catie.ac.cr/ProyPorPais.asp?CodIdio=ENG&amp;CodMagazin=106</a>
Prof. Arnaldo Walter	University of Campinas, Brazil	Brazil (Academic)			
Prof. Lin Erda	Chinese Academy of Agricultural Sciences, China	China (Academic)	<b>EU-China Partnership on Climate Change</b>  <b>UN-China Partnership</b>		<a href="http://ec.europa.eu/environment/climat/china.htm">http://ec.europa.eu/environment/climat/china.htm</a>
Dr Jan-Eric Peterson	European Environment Agency, EU	EU (Government)	JRC collaboration		<a href="http://www.eea.europa.eu/">http://www.eea.europa.eu/</a>
Luisa Marelli	EU Joint Research Centre	EU (Government)			<a href="http://www.eea.europa.eu/">http://www.eea.europa.eu/</a>
Dr Angela Karp	Rothamsted Research, UK	EU (Academic) - UK	<p>The following is a list of projects in which Rothamsted have be involved:</p> <ul style="list-style-type: none"> <li>• BB/F006039/1:INIT:From data to knowledge/ the ONDEX System for integrating Life Sciences data sources</li> <li>• BB/E006833/1: BBSRC Crop Science Initiative: Accelerating breeding for biomass yield in short rotation coppice willow by exploiting knowledge of shoot development in Arabidopsis</li> <li>• BB/E014682/1: BBSRC Optimising the development of the energy grass Miscanthus through manipulation of flowering time.</li> <li>• RCUK: RELU-Biomass: Social, Economic and environmental implications of increasing rural land use under energy crops</li> <li>• NERC: TSEC_Biosys: A whole-systems approach to analysing bioenergy demand and supply</li> <li>• SUPERGEN: Fuel specification and matching to conversion processes</li> <li>• Defra Contract NF0424: Improving short rotation coppice through breeding and genomics 2003-2008,</li> <li>• Defra Contract NF0104: Field-scale impacts on biodiversity from new crop 2006-2008,</li> <li>• BBSRC Sustainable Bioenergy Centre (BSBEC) Perennial Bioenergy Crops Programme</li> </ul>		<a href="http://www.relu-biomass.org.uk">http://www.relu-biomass.org.uk</a> <a href="http://www.tsec-biosys.ac.uk">http://www.tsec-biosys.ac.uk</a> <a href="http://www.supergen-bioenergy.net/">http://www.supergen-bioenergy.net/</a>
Prof Paul Mitchell	University of Aberdeen, UK	EU (Academic) - UK	Land use and climate change modelling and effects on biofuel crop development. Previous involvement with IPPC/EU/ESERC/NERC		
Prof. Rik Leemans	University of Wageningen, The Netherlands	EU (Academic)	Research linked to the international global change programmes		<a href="http://www.esa.wur.nl/UK/Staff/Leemans/">www.esa.wur.nl/UK/Staff/Leemans/</a> <a href="http://www.ipcc.ch">www.ipcc.ch</a> <a href="http://www.essp.org">www.essp.org</a> <a href="http://www.maweb.org">www.maweb.org</a> <a href="http://www.greenfacts.org">www.greenfacts.org</a> <a href="http://www.itc.nl">www.itc.nl</a>

Interviewee	Organisation	Organisation Type	Projects	References	Webpages
					<a href="http://www.f1000.biology.com">www.f1000.biology.com</a>
Dr Guido Reinhardt	IFEU Institute for Energy and Environmental Research, Germany	EU (Academic)			<a href="http://www.ifeu.de/english/">http://www.ifeu.de/english/</a>
Prof Andre Faaij Dr Edward Smeets	University of Utrecht, The Netherlands	EU (Academic)	<p>The following is a list of projects in which Utrecht has been involved:</p> <ul style="list-style-type: none"> <li>• Biomass Energy Europe (BEE)</li> <li>• EU Refuel Project</li> <li>• FAO Bioenergy and Food Security Project</li> <li>• IEA Task 40 Sustainable International Bioenergy Trade</li> <li>• BIOSAFOR - Biosaline (Agro)Forestry</li> <li>• COMPETE – Competence Platform on Energy Crop and Agroforestry Systems for Arid and Semi-arid Ecosystems- Africa</li> </ul>		<a href="http://www.eu-bee.com/">http://www.eu-bee.com/</a> <a href="http://www.refuel.eu/home/">http://www.refuel.eu/home/</a> <a href="http://www.fao.org/nr/ben/befs/">http://www.fao.org/nr/ben/befs/</a> <a href="http://www.fairbiotrade.org/">http://www.fairbiotrade.org/</a> <a href="http://www.oasefoundation.eu/project/67">http://www.oasefoundation.eu/project/67</a> <a href="http://www.compete-bioafrica.net/">http://www.compete-bioafrica.net/</a>
Dr Goran Berndes	Chalmers University of Technology, Sweden	EU Academic			<a href="http://www.chalmers.se/ee/EN/personnel/berndes-goran">http://www.chalmers.se/ee/EN/personnel/berndes-goran</a>
UWE Fritsche	Öko Institute, Germany	EU (Consultancy)	<p>German Biofuels Certification Project</p> <p>WBGU "GHG Balances and cumulated primary energy demand of bioenergy conversion pathways including possible land use changes"</p> <p>Review of Bioenergy Life-Cycles: Results of Sensitivity Analysis; prepared for UNEP-DTIE, final draft January 2009 (forthcoming)</p>		<a href="http://www.iscc-project.org/index_eng.html">http://www.iscc-project.org/index_eng.html</a> <a href="http://www.wbgu.de/wbgu_ig2008_ex04.pdf">http://www.wbgu.de/wbgu_ig2008_ex04.pdf</a>  <a href="http://www.bioenergywiki.net/index.php/Joint_International_Workshop_Mapping">http://www.bioenergywiki.net/index.php/Joint_International_Workshop_Mapping</a>
Prof. N.H. Ravindranath	Indian Institute of Science, India	India (Academic)	<p>SCOPE Project - Team global assessment of GHGs emissions for biofuels - Study of 10% petroleum substitution with biofuels by 2030 - Land use for crops and GHG emissions from land conversion (SCOPE project).</p> <p>Global Environmental Facility – contributing to GEF biofuels sustainability assessment.</p> <p>UNEP STAP (Scientific and Technical Advisory Panel) review of the implication of biofuels on CO<sub>2</sub> emissions and biodiversity.</p> <p>Also involved in India based university research initiatives</p>		<a href="http://www.icsu-scope.org/">http://www.icsu-scope.org/</a> <a href="http://www.gefweb.org/default.aspx">http://www.gefweb.org/default.aspx</a> <a href="http://www.unep.org/Documents.multilingual/Default.asp?DocumentID=43&amp;ArticleID=203&amp;l=en">http://www.unep.org/Documents.multilingual/Default.asp?DocumentID=43&amp;ArticleID=203&amp;l=en</a> <a href="http://ces.iisc.ernet.in/ravi/">http://ces.iisc.ernet.in/ravi/</a>
Prof. Jerry Melillo	Marine Biological	USA (Academic)	Component part of MIT Joint Program on the Science and Policy of Global Change		<a href="http://globalchange.mit.edu/files/document/MITJSPGCRpt168.pdf">http://globalchange.mit.edu/files/document/MITJSPGCRpt168.pdf</a>

Interviewee	Organisation	Organisation Type	Projects	References	Webpages
	Laboratory, USA		Also aware of: Carnegie Global Ecology Program at Stanford University  SCOPE		<a href="http://dge.stanford.edu/DGE/CIWDGE/research/projects/">http://dge.stanford.edu/DGE/CIWDGE/research/projects/</a>  <a href="http://www.icsu-scope.org/">http://www.icsu-scope.org/</a>
Prof. Rattan Lal	Ohio State University	USA (Academic)			
Name withheld	DoE, USA	USA (Government)			
Name withheld	DoE, USA	USA (Government)			
Dr Joseph Fargione	The Nature Conservancy, USA	USA (NGO)	<p>The following lists work undertaken by The Nature Conservancy (<a href="http://www.nature.org/?src=logo">http://www.nature.org/?src=logo</a>):</p> <ul style="list-style-type: none"> <li>• Fargione JE, J Hill, D Tilman, S Polasky, P Hawthorne. 2008. Land clearing and the biofuel carbon debt. <i>Science</i> 319: 1235-1238</li> <li>• Clark CM, EE Cleland, SL Collins, JE Fargione, L Gough, KL Gross, SC Pennings, KN Suding, and JB Grace. 2007. Environmental and plant community determinants of species loss following nitrogen enrichment. <i>Ecology Letters</i> 10: 596-607</li> <li>• Baez S, J Fargione, DI Moore, SL Collins, JR Gosz. 2007. Nitrogen deposition in the northern Chihuahuan desert: Temporal trends and potential consequences. <i>Journal of Arid Environments</i> 68: 640-651</li> <li>• Diaz S, J Fargione, FS Chapin III, D Tilman. 2006. Biodiversity loss threatens human well-being. <i>PLoS Biology</i> 4: 1300-1305</li> <li>• Diaz S, D Tilman, J Fargione, et al. 2005. Biodiversity and the regulation of ecosystem services. In Millennium Ecosystem Assessment editors. <i>Ecosystems and Human Well Being: Current State and Trends</i>. Island Press, DC, USA</li> <li>• Fargione J, and D Tilman. 2005. Diversity decreases invasion via both sampling and complementarity effects. <i>Ecology Letters</i>, 8: 604-611</li> <li>• Fargione J, CS Brown, and D Tilman. 2003. Community assembly and invasion: An experimental test of neutral versus niche processes. <i>Proceeding of the National Academy of Sciences</i>, 100: 8916-8920</li> <li>• Fargione J, and D Tilman. 2002. Competition and coexistence in terrestrial plants. Pages 156-206 In U. Sommer and B Worm editors. <i>Competition and Coexistence</i>. Springer-Verlag, Berlin, Germany</li> <li>• Tilman D, J Fargione, B Wolff, C D'Antonio, A Dobson, R Howarth, D Schindler, W Schlesinger, D Simberloff, and D Swackhamer. 2001. Forecasting agriculturally driven global environmental change. <i>Science</i> 292: 281-284</li> </ul>		

## Annex 3 – Chapter 3

Region	R&D	Topics covered
<b>Soil Quality</b>		
	FAO 2007b	Carbon loss and sequestration in soils
	Smeets et al 2004	Deforestation is thought to be responsible for 43% of total erosion
	UN 2007	Positive and negative impacts on soil
Europe	EEA 2007	Biofuel crops and soil
UK and Internationally	Rowe et al 2007	Environmental Impact of Lignocellulosic crops
Europe	FP7 EU project	Soil service
US	USDA CSREES	Field Study to Develop Sustainable Production Practices for Energy-Cane to Reduce Soil Erosion and Agro-chemical Loss in Drainage Runoff
US	USDA ARS	Enables new optimal practices and systems that maximize the sustainable yield of high-quality bioenergy feedstocks.
US	Ohio University	Soil quality
<b>Water Quality</b>		
	Delucchi 2004, Nelleman et 2007	
	Webb et al 1998	Application of nitrogen fertiliser
US	Simpson et al 2007	Impacts of fertiliser
US	Ohio Institute	Water quality
Brazil	Casson 2003	
Scotland	SEERAD 2006	Biomass production impacts
<b>Water resources</b>		
	EEA 2006	Impacts of irrigated land
	UN 2007	Impacts of agriculture on water shortages
International including US, Europe, China and India	De Fraiture et al 2007	Increased use of water for biofuels crops
USA	Kreider and Curtiss 2007	Use of water for biofuels crops
	Morton et al 2006	Impact of deforestation the rainforest and longer term impacts on the rainfall cycle
UK	Lyons et al 2001	Impacts of short rotation coppice
	Smeets et al 2004	Evapotranspiration by eucalyptus

Region	R&D	Topics covered
Far East and Asia	Hooijer et al 2006 African biofuels Network 2007	Impacts of drainage for wetlands. Including aeration of peat material and then to oxidation resulting in CO <sub>2</sub> emissions.
	Muckel 2004	Improper drainage of acid sulphate soils
	Mitchell et al 2007	Wetlands, flooding and importance for soil structure
International	Tricker et al 2008	Water Use increases due to Bioenergy Plantations
<b>Air quality</b>		
International Malaysia and Indonesia	Peskett et al 2007	Burning used for clearing and air quality
International Far East	Wetlands International 2006	Peatland burning including health consequences
General	FAO 2003	Particulate matter released from land clearance by fire
International China, Indonesia and Brazil	ODI Peskett et al 2007	Use of fire to clear new land can cause air pollution
Brazil	Ometto et al, 2004	Ethene emissions, smog and respiratory problems
Sao Paulo	Arbex (2004)	Health impacts of burning sugar cane
	AQEG (2007)	Particulate matter and warming and cooling effects
US	Kojima and Johnson 2005	Ethanol mills and means of addressing NO <sub>x</sub> impacts
Scotland	SEERAD 2006	Biomass production impacts

## Annex 4 – Chapter 5

### Research on market and trade issues

The following lists of organisations, projects and related document references are ordered according to the four research areas given in Section 5.1.4. Note that these are illustrative and not comprehensive, we do not include here studies on market potential of specific biofuel technologies.

#### Modelling of Biofuels Markets

##### *GTAP*

Global Trade Analysis Project, is coordinated by the [Center for Global Trade Analysis](#), which is housed in the [Department of Agricultural Economics](#) at [Purdue University](#). There is much research using the GTAP global model to assess the impacts of policies and other changes on production, land use, prices, and trade. The main research is carried out at Purdue University and LEI among other institutes such as Energy Biosciences Institute. Agricultural Economics Research Institute (LEI), The Hague have built a global CGE, using GTAP, that models the effects of policy changes in the EU and their effects on a number of parameters including world prices, trade, land use, farm incomes and subsidies needed to meet mandated targets.

GTAP resources are given in the consultation database. See also:

[https://www.gtap.agecon.purdue.edu/resources/res\\_list.asp](https://www.gtap.agecon.purdue.edu/resources/res_list.asp)

##### *IIASA*

A global spatial and integrated agro-ecological and socio-economic assessment of biofuel development study to be released in March “Biofuels- Avoiding the Pitfalls and Mobilizing the Potentials”. The study was commissioned by the OPEC Fund for International Development. The study is based on an integration of the FAO/IIASA AEZ ( Agro-Ecological Zone methodology) and IIASA BLS( Basic Linked System of the world agricultural economy and trade model). Future work is planned for more detailed national and regional studies.

##### *OECD/FAO Aglink-Cosimo*

Used by Defra to model impacts of biofuels policies, and by DfT to analyse the impact of policy mandates on the biofuels markets and wider agricultural market impacts. However, this model currently provides results only at the EU15 level and is not UK specific. The DfT work with this model does not plan to focus on the industry specifics as in the breakdown of questions outlined above.

#### International Research

##### *Biomass Technology Group*

Netherlands based consultancy group operating worldwide in fields of sustainable energy production from biomass and waste. BTG (2008) includes an assessment of WTO rules as a barrier to sustainability criteria and certification, which draws on work on the Dutch case undertaken by of Bossche, Schrijver et al (2007) and Bronckers, Verberne et al (2007).

BTG (2008) Sustainability Criteria & Certification: Systems for Biomass Production, report for DG Tren of European Commission.

##### *Biofuels Technology Platform (aka Biofuels TP)*

<http://www.biofuelstp.eu/biofuelsmarkets.html>

The Biofuels TP was launched in 2006 to increase biofuel use in the EU and worldwide. It has a wide-ranging remit and is covered in other parts of this report, but Working Group 5 looks at the marketing of biofuels, the obstacles and opportunities therein. The European Biofuels Technology Platform is supported by a Secretariat, which is funded in part by the European Commission (FP6). The Secretariat is coordinated by the Swedish Energy Agency (STEM, Eskilstuna, Sweden) in association with Fachagentur Nachwachsende Rohstoffe e.V (FNR, Gülzow, Germany)".

The members of WG5 are from private sector and trade associations

#### *Carensa*

Network of researchers, policy-makers, and industry representatives demonstrating the role of sugarcane resources in supporting sustainable energy solutions and improving economic competitiveness within the sugar industry and its affiliates in southern Africa. This network was previously funded by EC and now coordinated by Francis. X. Johnson (Stockholm Environment Institute). It has produced a number of reports on the global market for bioethanol and policy case studies.

<http://www.carensa.net/index.htm>

#### *Elobio: Biofuel policies for dynamic markets*

The ELOBIO project is an EU-wide project with seven partners, funded through Intelligent Energy – Europe. The participants are:

[ECN](#) (Energy research Centre of the Netherlands/Energieonderzoek Centrum Nederland)

[VITO](#) (Vlaamse instelling voor technologisch onderzoek N.V.)

[CLN](#)

[CIEMAT](#) (Centro de Investigaciones Energeticas, MedioAmbientales y Tecnologicas)

[COWI](#) (COWI A/S)

[IIASA](#) (International Institute for Applied Systems Analysis)

[CHALMERS](#) (Chalmers tekniska högskola AB)

It is a policy-orientated project which looks at how biofuel policies may impact other markets and how to develop 'low-disturbing' policy options.

Work Package 2 is led by VITO and covers an inventory of existing biofuel policies. The results are published in Inventory of biofuel policy measures and their impact on the market by Pelkmans, Govaerts and Kessels of VITO, available at

[http://www.elobio.eu/fileadmin/elobio/user/docs/Elobio\\_D2\\_1\\_PolicyInventory.pdf](http://www.elobio.eu/fileadmin/elobio/user/docs/Elobio_D2_1_PolicyInventory.pdf)

This looks in particular at Government Intervention, with Table 1 outlining the key measures and where they are in place (e.g. EU15, EU27, individual countries). It also covers certain countries in more depth and provides an overview of biofuel development outside the EU.

Work Package 4 is led by COWI and is policy development and evaluation,.

Work Package 7 is led by ECN and assesses potentials, impacts and costs at the identified best policies.

There is a strong emphasis on stakeholder input throughout the project.

[\(http://www.elobio.eu/\)](http://www.elobio.eu/)

#### *German Marshall Fund*

The Economic Policy Program at the German Marshall Fund of the United States has established a Biofuels Project to: 1. explore the various risks and opportunities involved in the production of biofuels; 2. commission research and disseminate cutting-edge data on biofuels; 3. convene in neutral yet dynamic settings to discuss biofuels policies, and, most importantly, to 4. create a set of policy recommendations that offer a viable policy path forward for the United States, the European Union, and other countries.

*ICONE (Institute for international trade negotiations - Private sector sponsored)*

Brazilian project for the promotion of ethanol as an internationally traded commodity. Having the creation of an ethanol world market as a goal, ICONE started a project in a partnership with the [UK Embassy in Brasilia](#) and financed by [Global Opportunity Fund](#) of the [Foreign & Commonwealth Office](#). ICONE will be working in conjunction with an UK based company, [E4tech](#). It has an objective to outline the key conditions that are necessary for the development of an effective global ethanol trading mechanism. The conditions are linked to: (i) strengthening the supply and demand, (ii) building financial structures that will create liquidity and reduce uncertainty in the bio-ethanol commodity market and (iii) improving trade policies.

<http://www.iconebrasil.com.br/en/?actA=14&areaID=10&secaoID=75>

*IEA Bioenergy Task 40:*

Task 40 addresses Sustainable Bioenergy Trade: Securing Supply and Demand. It contributes to the development of sustainable biomass markets in the short and on long term and on different scale levels (from regional to global). For reports see: <http://www.bioenergytrade.org/t40reportspapers/index.html>

See also:

Literature review of lessons learned from European Bioenergy Policies (Martin Junginger, 2007). Including key lesson on continuity of policy support.

<http://igitur-archive.library.uu.nl/chem/2008-0423-200511/NWS-E-2007-122.pdf>

Workham and Rosillo Calle (2008) On "Biofuels: Investor Confidence and Corporate Responsibility. A Case Study of Exxon Mobil, Royal Dutch Shell and British Petroleum" (Unpublished report).

*International Food & Agricultural Trade Policy Council (IPC)*

International organisation promoting trade and development policies in food and agriculture. Their discussion paper (IPC, 2006) outlines key issues that require clarity in the biofuels and trade area.

IPC (2006) WTO Disciplines and Biofuels: Opportunities and Constraints in the Creation of a Global Marketplace, IPC and Renewable Energy and International Law (REIL)

[http://www.agritrade.org/Publications/wto\\_biofuels.html](http://www.agritrade.org/Publications/wto_biofuels.html)

*McKinsey*

Caesar W., Riese, J. & Seitz, T. (2007) Betting on Biofuels, Report for McKinsey Quarterly,

*OECD (see also Aglink model)*

Trade and Agriculture Directorate has produced a number of studies on bioenergy including policy and economic issues of biofuels. Key publications are:

OECD (2008) Biofuel Support Policies: An Economic Assessment, OECD, July 2008. For list of reports see:

[http://www.oecd.org/document/25/0,3343,en\\_2649\\_33785\\_39633881\\_1\\_1\\_1\\_1,00.html](http://www.oecd.org/document/25/0,3343,en_2649_33785_39633881_1_1_1_1,00.html)

OECD (2006) Agricultural Market Impacts of Future Growth in the Production of Biofuels, Working Party on Agricultural Policies and Markets, OECD.

<http://www.oecd.org/dataoecd/58/62/36074135.pdf>

*Parliament of Australia*

Webb, R. (2008) The Economic Effects of an Ethanol Mandate, Department of Parliamentary Services.

<http://www.aph.gov.au/library/pubs/rp/2007-08/08rp18.pdf>



Purdue University

Purdue University specialists have written a number of papers on the economics of biofuels including:

Hertel et al (2008) Biofuels and their By-Products: Global Economic and Environmental Implications, Department of Agricultural Economics, Purdue University.

<https://www.gtap.agecon.purdue.edu/resources/download/3974.pdf>

Ethanol Pricing Issues for 2008 by Wallace E. Tyner, Frank Dooley, Chris Hurt, and Justin Quear Purdue University

The Economics of Biomass Collection, Transportation, and Supply to Indiana Cellulosic and Electric Utility Facilities by Sarah C. Brechbill and Wallace E. Tyner, Purdue University

Biofuels for all? Understanding the global Impacts of Multinational Mandates by Thomas W. Hertel, Wallace E. Tyner and Dileep K. Birur, Center for Global Trade Analysis Department of Agricultural Economics, Purdue University

"Biofuels, Policy Options, and Their Implications: Analyses Using Partial and General Equilibrium Approaches," by Tyner, Wallace and Taheripour, Farzad. 2007 Papers

*SRI Consulting*

US company undertaking research in biofuels market issues including a process economics program. <http://www.sriconsulting.com/>

*UNCTAD Biofuels Initiative*

The Initiative seeks to add value by providing interested countries with access to sound economic and trade policy analysis, capacity building activities and consensus building tools. UNCTAD has implemented biofuels assessment studies for several developing countries that have requested it. There are plans for 2009 to review investments in biofuels to understand investment trends and defaults".

<http://www.unctad.org/Templates/Page.asp?intItemID=4344&lang=1>

*University of California Berkeley*

UC Berkeley linked to the Energy Biosciences Institute and University of Illinois. Experts including Prof Zilberman focus on the economics of biofuels. Papers include:

Turner, B. T., Plevin R.J., O'Hare, M. & Farrell, A.E. (2007) Creating Markets for Green Biofuels: Measuring and improving environmental performance, Institute of Transportation Studies, UC Berkeley Transportation Sustainability Research Center.

Zilberman, David, and Deepak Rajagopal. Review of Environmental, Economic and Policy Aspects of Biofuels. The World Bank, Policy Research Working Paper Series: 4341 (2007).

Utrecht, the Netherlands: Department of Science, Technology and Society, Copernicus Institute.

See publication list:

[http://www.metis.modules.uu.nl/umetiprd/pk\\_apn.onderzoek?p\\_url\\_id=5716](http://www.metis.modules.uu.nl/umetiprd/pk_apn.onderzoek?p_url_id=5716)

UK Based Government and Academic Research

*DECC*

Market analysis and technology analysis being done through NNFFC (see notes on NNFFC). Ongoing research interests include incentivising second generation biofuels (follow on from the NNFFC barriers of biofuels work) and economic study of how to meet biofuels targets after 2020.

#### *Defra*

Key studies:

Deconti, M. (2008) Estimating the Cost Effectiveness of Biofuels, Defra Economics Group, April 2008.

<http://www.defra.gov.uk/ENVIRONMENT/climatechange/uk/energy/renewablefuel/pdf/biofuels-080414-2.pdf>

Deconti, M. (2008) Estimating the Value for Money of Government Support for Biofuels, Defra Economics Group, April 2008.

Pfuderer, S. & del Castillo, M.(2008) The Impact of Biofuels on Commodity Prices, Defra Agricultural Economics Unit, April 2008.

#### *RFA*

RFA provides monthly and annual reporting (due in January 2010) on progress of the RTFO. In addition the RFA reports annually as part of the post regulatory impact assessment process. Apart from providing figures for quantity of biofuels the annual report examines economic and social impacts as well as progress towards sustainability. Part of this work will involve a number of discreet studies examining the data in more depth.

University of Essex

European level research headed by Mark Harvey

1. Collaborative partnership between social scientists in Essex and Manchester and the Bioscience for Business Knowledge Transfer Network. (October 2008 to March 2010). ESRC Research Award

2. Foresight for European Biofuel Futures – A 2020 Vision (December 2008-09)

#### UK Industry and Independent Agency Research

#### *LowCVP*

A number of relevant reports including:

“Impact of the RTFO on UK businesses” in collaboration with the RFA. It will aim to assess how UK companies, and the agricultural sector, have been affected by the introduction of the RTFO. LowCVP propose to undertake a review of business effects to inform the RFA’s preparation of its annual report. It will involve a survey of LowCVP members and other businesses.

#### *NNFFC*

Various projects investigating biofuels market, giving economic evaluations of a number of new technologies and informing investment decisions. Outlined in consultation database.

#### *RNCOS*

An industry research firm that has published market analysis aimed at industry, e.g. UK Biofuel Market (2006) and Biofuels Outlook (2007).

#### *Vireol plc*

**Annex 5 Detail of R&D on sustainability and supply chains.**

Region	R&D on sustainability certification	Funding or research organisation and budget where available.
UK	Monitoring and analysis of RTFO	RFA
	Definitions of degraded and idle land	Over the next 12 months the RFA are considering work on definition of idle and marginal land and the potential for intensification – this work would include case studies on avoidance of ILUC.
	Implementation of RED and decisions on the future of RED and RTFO various Government Departments will be involved in this work over next 18 months.	RFA, DfT, Defra/DECC
	Rural Economy and Land Use (RELU) Programme, funds work on social and economic impacts of land use in rural areas of UK. Includes a project on social, economic and environmental implications of increasing rural land use under energy crops (at Rothamsted, funding £898k). This work has developed a framework (encompassing social, environmental and economic consequences) for Sustainability Appraisal (SA) of the conversion of land to energy crops (SRC and Miscanthus). The project represents a useful analysis of the UK situation regarding these crops and uses fundamental principles for assessing sustainability and provides useful data for development of sustainability monitoring for the UK, particularly for biodiversity. Completion date 2008.	Work done by Rothamsted and jointly managed by ESSRC and BBSRC £898k
	BBSRC is participating in an ERA ARD Net (ERA - European Research Area, ARD - Agricultural Research for Development) Call on a project entitled 'Is bioenergy an opportunity or threat to the rural poor?' BBSRC will be the lead organisation for the management of the UK dimension of the call which will consist of funding from BBSRC, ESRC, NERC and DFID. This work will provide information for sustainability certification, but not directly contribute to the development of sustainability schemes.	BBSRC

Region	R&D on sustainability certification	Funding or research organisation and budget where available.
	BBSRC will be working on environmental sustainability of biofuels. The work will involve several quantitative appraisal methods, such as environmental life-cycle assessment (LCA), including the indirect effects of land use changes, and net energy analysis. The environmental (specifically carbon) implications of selected biofuel routes will be mapped. Whole work programme complete by 2014. Total funding for the work on biofuels at Nottingham is £6.78M, but this includes work in several other areas.	University of Nottingham, funded by BBSRC and industry.
	Oxfam – do not support R&D but are concerned with land rights and social impacts and gather experience on these areas as well as lobbying to improve the situation.	
EU - EC	Support for the development of sustainability criteria within the Renewable Energy Directive (work currently being recruited. Project will continue for next two years) ~200k plus work by JRC	DGTREN
	Sustainability certification and socio-economic implications, to include Latin America and/or African ACP and/or Asia. Work to include: analysis of trading regimes for biomass and possible future trends on the basis of new legislation and emerging economies; identification of opportunities and limitations in the development of certification schemes in terms of social sustainability; assessment of links between socio-economic effects of biomass with water use, biodiversity loss, soil erosion etc.; assessment of public perception of the use of biomass for biofuels	DGRTD Framework Programme 7 (FP7), current call: KBBE 2009-3-4-01

Region	R&D on sustainability certification	Funding or research organisation and budget where available.
	COMPETE – supports work on bioenergy across Africa, including support for workshops on sustainability and data gathering for criteria important to sustainability	EC Framework
EU - EEA	Has done work on impact of EU biofuels policy rather than on sustainability certification or monitoring. Working with JRC to model biomass for energy globally. This work will include water use and biodiversity. JRC have a biofuels task force involved in integrated assessment of impacts of Biofuel Directive (mainly modelling work, not development of sustainability criteria, but this work will demonstrate the key impacts that need to be addressed, e.g. impact of fertiliser application, additional planting of specific biofuels crops etc.). The EEA has produced two reports: Estimating the environmentally compatible bioenergy potential from agriculture <sup>62</sup> How much bioenergy can Europe produce without harming the environment? <sup>63</sup>	
Germany	German standard has been developed and includes requirements for protection of natural habitats and GHG reduction potentials (these are more stringent than the EU RED requirement). Soy and palm oil biodiesel are excluded.	
	Development of a monitoring system on the impacts of biofuels development. Will be developing a pilot methodology for implementation of sustainability for specific African countries.	GTZ/PROBEX (Programme for basic energy and conservation in Southern Africa)
	Sustainability scheme has been defined for the BioNachV regulation <sup>64</sup> , and further work is under consideration to support it (e.g. further work on indirect land use change and on biodiversity)	

<sup>62</sup> EEA (2007).

<sup>63</sup> EEA (2006)

<sup>64</sup> Germany's biofuel quota law.

Region	R&D on sustainability certification	Funding or research organisation and budget where available.
	<p>German International Sustainability and Carbon Certification (ISCC project<sup>65</sup>, managed by Méo consultancy. Pilot project on the certification of sustainable biofuel production – the creation of a certification system for Europe, Brazil, Argentina, Malaysia and Indonesia to enable the verification of sustainability and reduction of GHG emissions, using mass balance monitoring along the supply chain and independent verification. Project focuses on development and practical test of a certification system that takes account of the needs of industry and society. Trial phase testing independent certification and auditing is complete. A two year pilot project is underway, incorporating 6 work packages:</p> <ul style="list-style-type: none"> <li>- Selecting an appropriate certification method to ensure sustainability along the entire value chain (national and international processes)</li> <li>- Verification of GHG emissions along the value chain</li> <li>- Establishing instruments for verification monitoring</li> <li>- Developing a meta system in order to integrate other certification systems</li> <li>- Developing and implementing minimum standards for certification, each tailored to the region and resource in question</li> <li>- Examining the interaction of the different system components</li> </ul>	<p>The German Agency for Renewable Resources (FNR). Project co-ordinator: Méo consulting.</p>
	<p>Leibniz Centre for Agricultural Landscape research e.V. (ZALF) Proposed work on socio-economics relevant to biofuels – this work will include a sustainability impact assessment for an African case study region to include assessment of implications of biofuels for livelihood, environment, regional economy, and implications for food security. The work will also include the development of a decision support model for farmers and local authorities in these regions on the planting and cultivation of biofuels crops.</p>	<p>GTZ and German ministry for Economic Cooperation and Development (BMZ)</p>
	<p>General work in Germany also includes work on the modelling of Indirect Land Use Change (ILUC) at the Öko Institute. This work is covered in the chapter on indirect effects of biofuels.</p>	

<sup>65</sup> See: [http://www.iscc-project.org/e711/element712/090218\\_ISCCBro\\_en\\_eng.pdf](http://www.iscc-project.org/e711/element712/090218_ISCCBro_en_eng.pdf)

Region	R&D on sustainability certification	Funding or research organisation and budget where available.
NL	<p>Implementation of trial projects to produce biomass more sustainably, in cooperation with producing countries.</p> <p>Implementation of Cramer sustainability criteria within the framework of RED will include:</p> <ul style="list-style-type: none"> <li>- Implementation of trial projects to produce biomass more sustainably, in cooperation with producing countries.</li> <li>- Innovation focuses on second and third generation biofuels, as well as new energy crops and techniques that are less competitive with agriculture and vulnerable nature areas (e.g. cultivation in salty areas or poor soils).</li> <li>- An international monitoring system set up for macro-monitoring of both direct and indirect effects of biomass production and consumption.</li> </ul> <p>There is support for pilot project on the import of sustainable biomass from developing countries and large producing countries.</p>	Dutch Government
	Development of internationally accepted methodologies and systems to monitor indirect effects. Currently exploring research options and possibilities for international cooperation.	Dutch Environment Ministry (VROM)
	CEN TC383 – Dutch Government are supporting this EU-wide development of sustainability standards for biofuels. This work is divided into six working groups including WG5 on verification and auditing.	NEN (Dutch standards institute)
Sweden	CARENSA project, aimed at synthesis, policy analysis and North-South-South knowledge transfer: <a href="http://www.carensa.net">www.carensa.net</a> 500k Euro 2002-2006. <sup>66</sup> Did not develop sustainability criteria or certification, but examined the experience of sugar cane producers in Africa and the experience of improving best practice (e.g. use of water resources, air emissions, social issues and the use of co-products).	Stockholm Environment Institute, funded by EC 500k Euro

<sup>66</sup> Cane Resources Network for Southern Africa (CARENSA) final report for EC Fifth Framework Research Programme. Contract number: A-4-2001-10103

Region	R&D on sustainability certification	Funding or research organisation and budget where available.
	Sweden-Brazil sustainable ethanol initiative (including environmental and social criteria). A list of principles have been agreed (including GHG calculation methodology guided by RTFO methods). The scheme will have independent third party verification and will include a chain of custody (track and trace) audit. SEKAB covers cost of verification, but remaining costs are paid by producer. See: <a href="http://www.sustainableethanolinitiative.com/">http://www.sustainableethanolinitiative.com/</a>	SEKAB (renewable fuel supplier)
UN	Has examined 'fair certification schemes' (2008), to balance positive benefits with risks of discrimination for some producers, as part of its BioTrade initiative. <sup>67</sup> The main Operational objective for UNCTAD is to promote and support the organization of decentralized roundtables. Plans for 2009: Continue work on certification	United Nations Conference on trade and development (UNCTAD)
	UNEP is active in the area of biofuels and biofuels certification through the RSB and FAO but has not created a separate sustainability initiative. The organisation of workshops and project work is undertaken only in order to bring further data and analysis to the table. Examples are the UNEP workshops with the RSB, IUCN, and FAO on high conservation value areas. Future work: <b>"Establishing Sustainable Liquid Biofuels Production Worldwide"</b> (A Targeted Research Project) supported by GEF Trust Fund (through GEF Scientific and Technical Advisory Panel, <a href="http://stapgef.unep.org/">http://stapgef.unep.org/</a> ). July 08-Sep 10 <sup>68</sup> Aim: To identify and fully assess innovative, cost-effective, and sustainable systems for the production of liquid biofuels for transportation and stationary applications, in order to enable the GEF to set clear policies and priorities in this area and embark on investment-oriented projects.	United Nations Environment Programme (UNEP)  UNDP are assisting with the GEF Trust fund project. Other funding for this project comes from GTZ. \$460k

<sup>67</sup> See [www.biotrade.org](http://www.biotrade.org) which includes information on the BioTrade facilitation programme. This initiative has been operating since 2002. It is supported by the Governments of NL and Switzerland, as well as other national and international organisations. It works in selected countries in Latin America, Asia and Africa. The initiative covers all biomass trade, not just biofuels. It is particularly concerned with the impact on biotrade on biodiversity and although it is not a certification scheme, it has developed a verification framework to help member countries move towards compliance with the basic principles and criteria (see, for example UNCTAD BioTrade Initiative: BioTrade principles and criteria (2007), which sets out a set of 7 principles for sustainable biotrade and a list of criteria for each one; and the BioTrade Initiative and Verification working document (2006) available from the BioTrade web site).

<sup>68</sup> This work has been developed as a response to an earlier series of consultations and workshops within the GEF partnership see e.g. <http://stapgef.unep.org/activities/technicalworkshops/biofuels>, and the GEF Council paper that established the policy for GEF actions in this field: [http://www.thegef.org/uploadedFiles/Documents/Council\\_Documents\\_\(PDF\\_DOC\)/GEF\\_31/C.31.Inf.7%20STAP%20Biofuels%20Recommendations%20to%20GEF.pdf](http://www.thegef.org/uploadedFiles/Documents/Council_Documents_(PDF_DOC)/GEF_31/C.31.Inf.7%20STAP%20Biofuels%20Recommendations%20to%20GEF.pdf)



Region	R&D on sustainability certification	Funding or research organisation and budget where available.
	<p>Includes:</p> <ul style="list-style-type: none"> <li>- Development of a methodology for data gathering following the ISO 14040 series for LCA (full life cycle from cradle to grave, i.e. including upstream and downstream processes).</li> <li>- Life-cycle GHG emissions assessment of typical production practices of different crops in representative developing countries (regional approach)</li> <li>- Spreadsheet-based calculation tool for energy and GHG balances</li> <li>- Recommendations for improving production practices</li> <li>- Guidelines for developing certification systems (Development of guidance to help define sustainable biofuels strategies)</li> </ul> <p>Total funding: \$2.36M, \$460,000 on sustainability section.  <b>“Evidence base (or state of knowledge) document on the relationship between biofuels, climate change mitigation and biodiversity”</b> To be completed mid 2009.  Funds: \$30k.</p>	
USA	<p>Ongoing work on:</p> <ul style="list-style-type: none"> <li>- Improved Uses and Values for the By-products of the Developing Biofuels Industry</li> <li>- Social Implications of Alternative Farming Systems</li> </ul>	USDA
	<p>Council for Sustainable Biomass Production<sup>69</sup> is a north American initiative to develop voluntary sustainability principles for biomass. These will apply to biofuels from lignocellulosic processes. Will develop principles, guidelines and/or measures to address core issues.  Is working with RSB.</p>	Not certain, but USDA and USDOE are both on steering committee.
	<p>Sustainable Biodiesel Alliance – has issued sustainability criteria</p>	
	<p>ANSI - national sustainable agriculture standard that includes development of a biofuel section.</p>	Leonardo Academy leading with multi-stakeholder approach

<sup>69</sup> See [www.cspb.org](http://www.cspb.org)

Region	R&D on sustainability certification	Funding or research organisation and budget where available.
	<p>The California low carbon fuel standard (LCFS) establishes GHG emission reduction requirements and is examining sustainability issues associated with land use change.. The target is to develop a plan for incorporating sustainability metrics into the LCFS by December 2009. Issues to be addressed in this process include, among others, a discussion of: the definition of sustainability, what metrics will be reviewed for including the LCFS, a framework for how sustainability metrics will be incorporated and enforced in the LCFS, and a schedule for finalizing sustainability criteria and metrics by no later than December 2011.<sup>70</sup></p> <p>The ARB will work together with other State agencies, national and international organizations, non-government organizations, and other interested parties to develop an appropriate sustainability strategy.</p> <p>The draft Investment plan (to be confirmed) suggests '\$19 million for non-GHG reduction categories (e.g., workforce training, sustainability, public education and outreach)'.</p>	California Air Resources Board (ARB)
	<p>Biofuel sustainability task force (<a href="http://www.biodiesel.org/resources/sustainability/default.shtm">www.biodiesel.org/resources/sustainability/default.shtm</a>). Main role is to support industry to develop sustainable biofuel (as seen through improved life-cycle GHG emissions), but it is also looking at the issues of indirect land use change and working with RSB. One of the main functions NBB has is to promote biodiesel and provide guidance to its members on best practice and it has launched a web site on sustainability (<a href="http://www.biodieselsustainability.org">www.biodieselsustainability.org</a>). Has developed a list of principles for sustainable biodiesel and will develop guidance statements for each principle to be used by industry to develop best management practice.</p>	National Biodiesel Board.

<sup>70</sup> Taken from: California Environmental Protection Agency Air Resources Board (2008)

Region	R&D on sustainability certification	Funding or research organisation and budget where available.
	<p>Winrock international will be doing work to support effective sustainability standards. The work will seek to collate and disseminate existing information and data related to biofuel sustainability and will explore inter alia:</p> <ul style="list-style-type: none"> <li>• The potential of management tools to measure and monitor sustainability parameters at different scales.</li> <li>• The impacts and implications of national adoption of criteria specific to sustainability standards</li> </ul> <p>This work will deliver a report on Building Capacity to Monitor Standards for Biofuels. The work will also develop Country Profiles, which will summarise the impact evaluations for 3 countries (Brazil, Indonesia and US) will illustrate how the criteria used in various sustainability standards, if applied, could impact quantities of biofuels produced, GHG emissions and other parameters.</p>	Packard Foundation (\$250,000 - 1 year)
Brazil	<p>Sustainability certification is one of Brazil's key priorities. The Brazilians have established a Program of Biofuels Certification, developed by INMETRO and are working with US National Institute of standards and EU CEN initiatives to develop standards for sustainable biofuels.</p> <p>Have developed a first version of proposed criteria and principles. Once this is approved a pilot phase will be developed. Decisions will be made in the first quarter of 2009.</p> <p>EMBRAPA (Brazilian Research Centre for Agriculture) is co-ordinating Agro-Ecological zoning for sugar cane at national level (zoning refers to guidance for licensing and credits concessions). This study should have been complete by September 2009, but the delivery has been delayed.</p> <p>Other work by EMBRAPA includes examination of sustainability of small production systems, the potential to recuperate degraded areas, sustainability of production systems and environmental quality policies.</p> <p>Defra supported a review of sustainability of ethanol production in Brazil (undertaken by UNICAMP)<sup>71</sup></p>	EMBRAPAs work is funded by the Brazilian Ministry of Agriculture.
International	<b>RSB</b> – Roundtable on sustainable biofuels – has developed a series of principles and criteria for biofuels ('Version Zero') and is examining a 'scorecard concept'. Has consulted	Various (including UNEP, Swiss Confederation,

<sup>71</sup> Analysis of Environmental and Social Impacts of Bio-ethanol Production in Brazil, funded by UK Embassy, in Brasília, with funds of the UK's Department for Environment, Food and Rural Affairs (Defra). The work was done in 2008 by University of Campinas (UNICAMP).

Region	R&D on sustainability certification	Funding or research organisation and budget where available.
	<p>on this on international basis: meetings have been held in USA, Brazil, Africa, Caribbean, South America, Europe and East Asia and obtained feedback on how the standard needs to be interpreted on a regional context.</p> <p>Other funding comes from fees from participants.</p> <p>Workplan for 2009 is published on the web site (<a href="http://cgse.epfl.ch/">http://cgse.epfl.ch/</a>). This includes:</p> <ul style="list-style-type: none"> <li>- Development of Version 1 principles and criteria, benchmarked against other standards and pilot testing of Version 1.</li> <li>- Chain of custody research</li> <li>- Creation of certification scheme.</li> <li>- Collaboration with key stakeholders (including ISO and CEN)</li> </ul>	Petrobras, Michelin, Daimler, Novozymes, EV/UP).. Recent grant from Packard Foundation (\$1.6M).
	<p><b>ISEAL:</b> Develops and maintains Codes of Practice for social and environmental standards to ensure credibility in all stages of their development and implementation. Has become the international normative reference for social and environmental standard-setting practices.</p> <p>Will launch an Impacts Code in 2010, which will establish what impacts standards systems should means and how to ensure comparability and consistency of results.</p> <p>The ISEAL Verification Code will be launched in 2012 and will define best practice for auditing, certification and accreditation in social and environmental contexts.</p>	Various including Dutch Ministry for Development Cooperation, HIVOS, ICCO, Overbook Foundation, Ford Foundation, Packard Foundation and GTZ.
	<b>Roundtable on Sustainable Palm oil, Better Sugar Initiative and Roundtable on Responsible Soy.</b> All of these agreements are developing sustainability certification for crops relevant to biofuels	Participants.
	<b>Global Bioenergy Partnership has 2 taskforces: GHG and sustainability</b>	
	<b>Jatropha Sustainable Biofuels Alliance</b> – aim is to support development of Jatropha as a sustainable biofuel. Also works with the RSB as the Jatropha Working Group. This alliance also keeps a record of Jatropha projects worldwide. Will examine the viability of Jatropha on marginal land and the GHG balance of applications.	Members (500Euro joining fee).
	<b>International Energy Agency</b> – Bioenergy Agreement Task 40 (Sustainable International Bioenergy Trade) – information exchange including workshops and publications on trade and sustainability certification. Workplan for 2010 –2012 currently under discussion.	Participating nations

Region	R&D on sustainability certification	Funding or research organisation and budget where available.
	<b>Mali Folkecenter</b> Malian NGO committed to sustainable development of rural populations. Working on sustainable production of Jatropha. Work completed in 2010. Funding: 300 000 EUR by SHGW (Green Forest Foundation, the Netherlands) and DOEN Foundation (also the Netherlands), and for 300 000 EUR by AMADER (the Malian rural electrification agency created in the frame of a World Bank programme)	Dutch and Malian organisations and World Bank.
	<b>CURES</b> (Citizens United for Renewable energy and Sustainability) Impact evaluations of a sample (8) of small to medium scale biofuels projects, run by NGOs or SMEs, mostly looking at a social – economic impacts of the rural households + looking at a few environmental effects. Has worked with RSB on sustainability certification.	International Network of NGOs.
	The Sustainable Biomass Utilization Vision in East Asia under ERIA (Economic Research Institute for ASEAN and East Asia): Research within individual academic member institutions now underway and will explore sustainability metrics in a regional context	
	InterAmerican Development Bank has created a scorecard based on version zero of the Roundtable on Sustainable Biofuels. The World Bank is also developing a draft with WWF.	
Industry	We know that industry are involved in sustainability certification through membership of various initiatives, such as the RSB, BSI and RSPO; we also know from various sources that some companies are establishing internal procedures to source sustainable biofuel (e.g. Greenergy are supporting work on the development of practical measures to manage ILUC) and that they are undertaking or commissioning their own work on GHG emissions methodologies, but we received very little direct information from industry on its work, due to the confidential nature of much of this work (industry is particularly sensitive about discussing the work they are supporting on GHG LCAs, particularly when it may give them a competitive advantage, and on discussing which regions they are working with to develop biofuels feedstocks).	Industry.  Greenergy
	Shell has a detailed policy for sustainable sourcing of feedstock. Shell, BP and Petrobras are working together to address sustainability and are participating in the RSB. Many of the oil suppliers are investing in second generation biofuels <sup>72</sup> or in more sustainable feedstock for first generation fuels (e.g. Jatropha or algae).	Shell, BP and Petrobras
	Neste Oil is studying the whole production chain in terms of sustainability. The goal is to understand all the effects of biofuel production (direct and indirect) and then create a	Neste oil

<sup>72</sup> See REO research (2008) Biofuels and sustainability: an investor perspective.

Region	R&D on sustainability certification	Funding or research organisation and budget where available.
	system that mitigates unwanted effects.	

## **Annex 5 – Chapter 6**

Region	Current status and R&D on vehicle engines and flex-fuel vehicles	Funding or research organisation and budget where available.
UK	<p>The Low Carbon Vehicle Partnership has commissioned work on 'Market opportunities for high blend biofuels and biomethane'. This study commenced in September 2008 and is being performed by a consortium of TTR and Fleetsolve. The purpose of this study is evaluate the market opportunities for high blend (&gt;10% by volume) liquid and gaseous biofuels and recommend the most appropriate mechanisms to stimulate take-up. The study is intended to inform policy-makers by illustrating the benefits of specific high blend liquid and gaseous fuel uses in market niches and clear advice on the status of technical issues. The study will also produce recommendations on how to stimulate uptake. The final report for the work is scheduled for May 2009 and may yield a series of recommendations for market interventions to support alternative fuelled vehicles.</p> <p>Specifically, the study aims to develop evidence based answers to a number of questions, with those particularly relevant to the vehicles area including:</p> <ul style="list-style-type: none"> <li>• What are the areas of consensus and areas of uncertainty about use of high blend liquid and gaseous biofuels (potentially by vehicle sector)?</li> <li>• What technologies do vehicle manufacturers currently have which may point towards certain high blend products?</li> <li>• Does the proliferation of different liquid biofuel blend proportions help or hinder the penetration of these fuels?</li> </ul> <p>In addition, a number of more technical questions on fuels are raised in the study scope:</p> <ul style="list-style-type: none"> <li>• How would a UK standard for high blend liquid and/or gaseous biofuels relate to European standards (should these exist)?</li> <li>• Is there a need to develop a specification for different liquid biofuel blends; B25, B30 etc, or a need for one specification for a single blend? Does the absence of an agreed high blend specification hinder take-up? and</li> <li>• What might be the impact of changing specifications for EN590 fuel allowing the use of 30% biodiesel within current guidelines?</li> </ul> <p>The study is intended to inform policy-makers by illustrating the benefits of specific high blend liquid and gaseous fuel uses, providing clear advice on the status of technical issues and providing recommendations on how to stimulate uptake. The study is also intended to promote engagement and understanding across different sectors of the vehicle and fuel industry.</p>	LowCVP (core funding from DfT/BERR)
	Birmingham University are carrying out R&D on the impact of DMF on Engine Performance and Emissions as a New Generation of Sustainable Biofuel.	EPSRC funded, £500k



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	<p>AEA are working with the Environment Agency on the 'Design &amp; Evaluation of a Bio-diesel Trial'. The contract is a two-year trial aimed at providing an independent assessment of the viability and advantages of using B22 biodiesel relative to ULSD. A selection of 75 vehicles from four depots of the EA's fleet are running on biodiesel (produced from recycled vegetable oil), and the carbon savings, are being evaluated using life-cycle analysis.</p> <p>This project brings together several teams from across AEA contributing expertise in different, complementary, areas. Tasks have involved assessing the driveability of the vehicles in the trial through driver feedback, assessing the impact of the B22 fuel on the repair and maintenance of the vehicles, and undertaking detailed emissions testing to evaluate the impact of the B22 fuel on emissions other than CO<sub>2</sub>. Vehicles include Land Rovers, Ford Transits, Transit Connects and Vauxhall Combo vans. Ninety per cent of them are beyond their warranty period, so there is little risk of refuted warranty claims on the basis of fuel specification. The project has been run from April 2007, due to complete in July 2009.</p>	<p>Environment Agency funded project, budget: £105,000</p>
<b>EU - EC</b>	<p>The Volvo Group is the coordinator for the European project BioDME, which started in September 2008. BioDME is a unique cooperative project involving the automotive industry as well as fuel producers and distributors regarding the fuel DME. The project will demonstrate the entire technology chain, from biomass to trucks powered by DME fuel, including fuel distribution and filling stations. The overall project objective is to demonstrate production of environmentally optimised synthetic biofuel from lignocellulosic biomass at industrial scale. In order to check technical standards, commercial possibilities and engine compatibilities the bio-DME will be tested in a fleet consisting of 14 Volvo trucks.</p>	<p>Total budget: 28.4 M€ The project is co-financed by the partners of the consortium, EU's Framework Programme 7 (FP7) (8.2 M€) and the Swedish Energy Agency (9.6 M€).</p>
<b>EU – CEN</b>	<p>In the European Standards Organisation (CEN) the oil industry is working with the manufacturers /biofuel suppliers to allow greater percentages of biofuels to be incorporated in conventional petrol and diesel and to set quality standards that can be used in vehicle design.</p>	<p>Industry</p>
<b>USA</b>	<p>US Defence Advanced Research Projects Agency: \$14.9M to Science Applications International Corp and \$19.9M for General Atomics: research into algae based jet fuels. Runs to mid-2010.</p>	<p>US Dept. of Defence</p>
	<p>The US Department of Energy (USDOE) are carrying out a wide range of biofuels R&amp;D. Research in the vehicles area includes:</p> <ul style="list-style-type: none"> <li>• Developing safety standards for E85 fuel dispensing systems</li> <li>• Testing of intermediate blends to assess impacts on small engines and vehicle performance, emissions, durability, and other factors.</li> <li>• Assessing FFV (flex-fuel vehicle) technology development for mileage and emissions impacts and providing data to vehicle manufacturers.</li> <li>• Evaluating options for improving performance of/optimising FFVs for ethanol use.</li> <li>• Validating market data on fuel use as a function of vehicle performance, fuel cost, and availability.</li> </ul>	<p>US Dept. of Energy (USDOE)</p>

Region	Current status and R&D on vehicle engines and flex-fuel vehicles	Funding or research organisation and budget where available.
	CARB (Californian Air Resources Board) has \$25m over next 2 years on development and implementation of activities related to E85 e.g. project including infrastructure financing. \$2m on performance testing of vehicles on biodiesel and \$1m for in-house testing (over 4 to 5 years).	California Air Resources Board (CARB)
<b>Industry</b>		
<i>BP</i>	Have in-house fuel technologists conducting development work on the impact of higher percentage biofuels on the infrastructure and on vehicles.	BP
<i>Corning</i>	Corning are currently carrying out joint work with the biodiesel board on alkali ash specification for safe operation of DPFs.	Corning/EBB
<i>DAF</i>	DAF's testing and validation of biodiesel (-blends) are related to reliability of engine operation and potential function impacts. They are testing current specifications and the potential next step (confidential to DAF). Generally due to the chemical instability of the first generation biodiesels (fatty acid methyl esters) DAF would prefer to replace them by the more stable hydrogenated biodiesel and second generation biodiesels. Further DAF would prefer one well specified biodiesel blend (e.g. B7 ) to optimise engine emissions and durability.	DAF
<i>Daimler</i>	<p>All trucks from Mercedes-Benz produced since 1988 are approved for operation with EN14214 biodiesel at any concentration up to and including 100%. Van range limited to a maximum of 5%. Daimler also conducted a trial operating in Germany using Pure Plant Oil but will not be extending it or recommending its use as a vehicle fuel.</p> <p>New Mercedes-Benz trucks and buses are optionally available with extra equipment for biodiesel, and retrofitting is possible for vehicles already in operation to minimise the impacts of biodiesel use on general operation and maintenance.</p>	

Region	Current status and R&D on vehicle engines and flex-fuel vehicles	Funding or research organisation and budget where available.
<i>Ford</i>	<p>Ford have been developing vehicles to run on renewable biofuels, such as bioethanol, for many years and flexi-fuel vehicle (FFV) models that can run on high ethanol blends up to E85 have been available for some years in the US. In the UK they have supplied Ford Focus FFVs mainly to fleets located close to the UK's bioethanol pumps such as Avon &amp; Somerset Police, the Environment Agency and National Farmers' Union. Ford are supporting a variety of current work in the biofuels area and as part of the ACEA group, provide input into various biodiesel working groups, primarily concerned with developing tests to assess the performance of engine oils when exposed to biodiesel fuel dilution. Current projects that Ford is supporting include:</p> <p><b>A)</b> a project with Bath University which is investigating the effect of biodiesel on fuel and oil properties including: 1) Oxidation rates, 2) Soot to oil transfer rates, 3) Recovery rates</p> <p><b>B)</b> internal research into the compatibility of our vehicle fleet with bio-diesels from varying feed stocks (RME, SME, etc) and increasing ratios of biodiesel, up to B30.</p> <p><b>C)</b> an E85 ethanol project with Somerset council &amp; BP as part of the BEST project to assess the potential to extend oil service intervals for ethanol vehicles. The objective of the work is to better understand the compatibility of vehicles to increasing levels of biodiesel content in diesel fuel.</p> <p>Bath University project expected completion date: 2012 Internal research expected completion date: 2010 E85 Project 2011</p> <p>More work is also needed in understanding the effects of different biodiesel feed stocks on the stability of the biodiesel.</p>	<p><b>A)</b> Work is part government funded</p> <p><b>B)</b> Internal research is funded by Ford</p> <p><b>C)</b> E85 research is part of the BEST project</p>
<i>GM</i>	<p>GM has conducted fleet trials of B30 on Vivaro van, following prior engineering validation. The fleet now has extended B30 use throughout its Vivaro vehicles under controlled conditions only (e.g. fuel source, servicing, etc). Confirmed full compatibility is only possible with approved European B30 standard.</p> <p>GM's passenger car engineering vehicle fleet in Germany is currently carrying out a long term trial of E10 and B10, in order to build confidence prior to possible future introduction of such fuel on the market. The anticipated outcome is confirmation of vehicle compatibility with E10 and B10 when all related vehicle evolutions are implemented.</p> <p>GM also has various experts in the US, Sweden, etc. carrying out research in conjunction with academic institutions into various aspects of bio-fuels. However, GMUK is not currently closely involved in this work.</p>	

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<i>PSA</i>	<p>For more than ten years, PSA Peugeot Citroën has been committed to promoting the use of ethanol in petrol up to 10%. This blending process can be achieved without adjusting the current engine technology. It already supplies flex-fuel ethanol vehicles (up to E85) into US, Brazil and European markets. It has also approved use of high quality B30 blends in a number of regions for use in vehicles powered by its HDi family of diesel engines (introduced in 1998), without any maintenance concerns.</p> <p>PSA believes the future belongs to second-generation biofuels (Gas to Liquid fuels produced from biomass, residues or, for example, algae) that do not compete with food production. In this context, PSA Peugeot Citroën is working to adapt (/optimise) its engines to these second-generation non-fossil fuels while respecting limits on pollutant emissions. This research is anticipated to come into industrial production by 2020.</p> <p>In China, the Group is conducting biodiesel research with the China Automotive Technology &amp; Research Center (CATARC). In Latin America, PSA Peugeot Citroën has initiated a series of trials with Ladetel, a Brazilian clean technologies laboratory specialized in biofuels, to assess the performance of Brazil's B30 biodiesel.</p>	PSA
<i>Ricardo</i>	<p>Research R&amp;D carried out by Ricardo includes:</p> <ol style="list-style-type: none"> <li>1. Ethanol boosted gasoline technologies;</li> <li>2. Diesel engine operation on high biodiesel content (up to B30) and impact on emissions (regulated &amp; unregulated);</li> <li>3. Existing engine technology using virgin vegetable oil (VVO).</li> </ol> <p>Future R&amp;D is likely to focus on future engine technologies and how they will operate on high bio-content fuels (no further specific programmes in place yet)</p>	1) & 2) Technical collaborations and internal Ricardo funding 3) DfT
<i>Saab</i>	<p>Saab is a leader in flexible-fuel and turbocharging technology, previously breaking new ground with it BioPower 100 Concept. This was the first production-based turbocharged engine to be optimised for pure E100 ethanol. Saab's objective was to show how "rightsizing" through turbocharging can give "large" engine power from small displacement engines. Pure ethanol, with its high 106 RON octane rating, allows higher compression ratios for more power than is normally possible with turbocharging, without harmful knocking (self-ignition). Fuel consumption is higher with E100 because of ethanol's lower energy density, but Saab believes that E100 fuel consumption can move closer to gasoline levels with the future addition of direct injection and lean-burn technology.</p>	Saab/GM

Region	Current status and R&D on vehicle engines and flex-fuel vehicles	Funding or research organisation and budget where available.
<i>Scania</i>	<p>Scania's recommendation is that either 5% FAME fuel mixed in standard diesel (according to EN590) or 100% FAME fuel (according to EN14214) may be used, provided a number of conditions are observed. These include more frequent oil and fuel filter changes. Other biofuels, such as PPO (Pure Plant Oil), are not approved. Issues Scania is researching include:</p> <ol style="list-style-type: none"> <li>1) Problems with bacterial growth in biodiesel and the issue of sourcing good quality fuel;</li> <li>2) The need to replace fuel filters very regularly at first when converting across to biodiesel (due to re-suspension of deposits in the fuel lines by biodiesel, which is a more effective solvent);</li> <li>3) Use of E95 in converted diesel engineered buses (the thermal efficiency of the engine is comparable to a diesel, 43% compared to 44%), and solving the lubrication issues (the ethanol used for diesel combustion contains 5-7% additives that improve ignition and lubrication). This technology was originally introduced for city buses, but is now working on extending it to trucks as well. In the last 15 years they've put 600 ethanol buses on the road (mostly in Sweden).</li> </ol>	Scania
<i>Volvo</i>	The Volvo Group is the coordinator for the European project BioDME, see above.	See above.
<i>VW</i>	<p>Volkswagen Group has experience with the development of cars capable to run on biofuels, especially ethanol, due to their production site in Brazil. VW approves the use of diesel fuel containing up to five per cent biodiesel (B5) in all of its diesel vehicles. VW does not approve the use of B30 biodiesel in any of its vehicles, but a limited number of vehicle models are approved to run on 100 per cent Rapeseed Methyl Ester (RME) biodiesel (only when complying to the standard DIN EN 14214). Blends greater than B5 are not currently compatible for its vehicles with DPFs or PD engine variants.</p> <p>Volkswagen has been working on concepts for the industrial production of next-generation biofuels since the year 2000, and has co-operated with other carmakers, biotech companies and oil corporations in the process. In collaboration with Choren, as well as other partners, Volkswagen has already developed its SunFuel, a fully synthetic diesel fuel produced using a biomass-to-liquids (BtL) process. The goal now is to forge stronger ties between industry and the scientific community so as to come up with environmentally less damaging alternatives to petroleum as a source of energy.</p>	VW, other

**Summary of the current status of R&D for biofuels for use in other modes of transport**

Region	R&D on extension of biofuels for use in other modes of transport	Funding or research organisation and budget where available.
UK	RSSB (Rail Safety and Standards Board) and ATOC (Association of Train Operating Companies) co-ordinated trials of biodiesel fuel with a number of UK rail operators have been run from 2007.	RSSB and rail industry.
EU - EC	ALFA-BIRD EC FP7 Research Programme. The Alternative fuels and biofuels for aircraft development started in July 2008, running until June 2012 (see <a href="http://www.alfa-bird.eu-vri.eu">http://www.alfa-bird.eu-vri.eu</a> ). ALFA-BIRD aims at developing the use of alternative fuels in aeronautics. ALFA-BIRD gathers a multi-disciplinary consortium with key industrial partners from aeronautics (engine manufacturer, aircraft manufacturer) and fuel industry, and research organization covering a large spectrum of expertise in fields of biochemistry, combustion as well as industrial safety. The consortium will develop the whole chain for clean alternative fuels for aviation. The most promising solutions will be examined during the project, from classical ones (plant oils, synthetic fuels) to the most innovative, such as new organic molecules. Based on a first selection of the most relevant alternative fuels, a detailed analysis of up to 5 new fuels will be performed with tests in realistic conditions.	DGRTD Framework Programme 7 (FP7), Industry co-funding. Total Budget: 9.75 M € EC Grant: 6.82 M €
	SWAFEA Research Programme (strategic feasibility and impact study on alternative fuels for aviation) started in early 2009. The project aims to establish a comparative analysis (including technical compatibility) of alternative fuel options, plus the environmental and business case, providing input to policy makers and a roadmap.	DGTREN / FP7. Value est. ~3 M Euro
USA	The Commercial Aviation Alternative Fuels Initiative (CAAFI) is a US air transport industry coalition formed to sponsor research into alternative fuels, including qualification, life-cycle carbon balance and sustainability. CAAFI sponsors include: Airports Council International-North America (ACI-NA), Aerospace Industries Association (AIA), Air Transport Association (ATA) and the Federal Aviation Administration (FAA). CAAFI participants are evaluating alternative fuels in four areas: 1) Certification and Qualification, 2) Research & Development, 3) Environment, and 4) Economics, Business and Policy.	

Region	R&D on extension of biofuels for use in other modes of transport	Funding or research organisation and budget where available.
Industry		
<i>Airbus</i>	<p>Airbus' alternative fuels roadmap is focusing on testing of viable alternative fuels such as GTL, paving the way for use of sustainable biofuels when they become available. Airbus will only consider biofuels that are produced from renewable biomass sources that do not compete with existing food, land and water resources. To this end, Airbus recently announced a partnership with Honeywell Aerospace; UOP, a Honeywell Company; International Aero Engines (IAE); and JetBlue Airways. The objective is to pursue development of a sustainable second-generation biofuel for use in commercial aircraft and to evaluate the challenges for obtaining approval for this fuel by standards organisations. Airbus believes that second-generation bio-fuel could provide up to 30 percent of all commercial aviation jet fuel by 2030.</p> <p>Airbus' alternative fuels roadmap is focusing on testing of viable alternative fuels such as GTL, paving the way for use of sustainable biofuels when they become available. Airbus will only consider biofuels that are produced from renewable biomass sources that do not compete with existing food, land and water resources.</p>	<p>Airbus, other industry</p> <p>EU FP7 funded project. 50% EC FP7, 50% Airbus</p>

Region	R&D on extension of biofuels for use in other modes of transport	Funding or research organisation and budget where available.
<i>Boeing</i>	<p>Boeing is working with airlines and engine manufacturers to gather biofuel performance data as part of the industry's efforts to revise the current American Society for Testing and Materials (ASTM) standards to include fuels from sustainable plant sources.</p> <p><i>Summary of research:</i> All information approved for external release related to Boeing Commercial Airplanes activities on sustainable aviation biofuels is available at <a href="http://www.newairplane.com/environment/sustainablebiofuels/">http://www.newairplane.com/environment/sustainablebiofuels/</a> and includes a number of test-flights with airlines participating in the Sustainable Aviation Fuel Users Group (SAFUG), detailed below.</p> <p><i>Anticipated outcome:</i> Commercial scale sustainable aviation biofuel feedstock projects complete funding rounds, announcements of first commercial scale sustainable aviation biofuel production project plans , technical certification of sustainable aviation biofuels for operational use in commercial airplanes, public policy approval for production and use of specific sustainable aviation biofuels in meeting economic, environmental and social sustainability guidelines</p> <p><i>Timing:</i> Boeing are working to achieve initial use of commercial sustainable aviation biofuels in commercial airplanes in 2013, and anticipate indefinite ongoing R&amp;D related to emerging gaps, obstacles and opportunities required to continue the advancement of viable commercial markets for sustainable aviation biofuels.</p>	Boeing, Airlines, UOP
<i>Rolls-Royce</i>	<p>The direct involvement of Rolls-Royce in bio-fuels research has been limited to the testing of samples of the jatropha derived fuel used in the recent Air New-Zealand demonstration flight. The Company has indicated publicly that it is prepared to test and evaluate candidate bio-fuels (and other alternative fuels) against the industry specifications for jet turbine fuel. Rolls-Royce is a partner in the European ALFA-BIRD and SWAFEA programmes. Rolls-Royce is also a participant in the management of the internationally agreed aviation fuel specifications.</p>	



Region	R&D on extension of biofuels for use in other modes of transport	Funding or research organisation and budget where available.
<i>Cross-industry</i>	Several air carriers working to diversify and secure their energy future through participation in the Sustainable Aviation Fuel Users Group (SAFUG). The group was formed to accelerate the development and commercialisation of sustainable new aviation fuels. As well as Boeing and Honeywell's UOP, airlines supporting the initiative include Air France, Air New Zealand, ANA (All Nippon Airways), Cargolux, Gulf Air, Japan Airlines, KLM, SAS and Virgin Atlantic Airways. Collectively, they account for approximately 15 percent of commercial jet fuel use. With support and advice from the world's leading environmental organizations, the World Wildlife Fund (WWF) and Natural Resources Defence Council (NRDC), the SAFUG makes commercial aviation the first global transportation sector to voluntarily drive sustainability practices into its fuel supply chain. Various demonstration flights have been operated successfully over the last 18 months on varying blends of biofuels, and include:	Various industry organisations including members of the SAFUG
	Virgin Atlantic, Boeing and GE Aviation carried out in February 2008 a "proof of concept" exercise with a Boeing 747-400 on a short flight from London to Amsterdam, using a biofuel specifically engineered for aviation. The flight used a 20% biofuel /80% kerosene blend in one of the aircrafts four engines. It was the first time a commercial jet has flown on a sustainable, plant-based fuel mixture: in this case, a blend that included oils from Babassu nuts extracted from indigenous Brazilian plants, and coconuts from the Philippines. The biofuel demonstrations are part of a broader industry-wide effort to identify and commercialise renewable fuel sources for commercial aviation.	
	Air New Zealand and Boeing conducted a sustainable biofuels flight from Auckland using a 747-400 jetliner in November 2008. Conducted in partnership with Rolls-Royce and UOP, a Honeywell company, one of the airplane's four Rolls-Royce RB211 engines was be powered in part using advanced generation biofuels derived from jatropha. Advance testing by Rolls-Royce for the Air New Zealand flight showed that the jatropha based biofuel met all critical specifications, including a freeze point at -53 degrees Fahrenheit (-47 degrees Celsius) and a flash point at 100 degrees Fahrenheit (38 degrees Celsius). The blended fuel met the essential requirement of being a drop-in fuel, meaning its properties will be virtually indistinguishable from conventional fuel, Jet A1, which is used in commercial aviation today. The biofuel was produced by UOP's green jet fuel processing technology based on hydroprocessing methodologies that are commonly used to produce transportation fuels.	

Region	R&D on extension of biofuels for use in other modes of transport	Funding or research organisation and budget where available.
	<p>Japan Airlines (JAL) conducted a demonstration flight in January 2009 using a sustainable biofuel primarily refined from the energy crop, camelina. It was also the first demo flight using a combination of three sustainable biofuel feedstocks, as well as the first one using Pratt &amp; Whitney engines (on a Boeing 747-300 aircraft). The results of the flight are expected to conclusively confirm the second-generation biofuel's operational performance capabilities and potential commercial viability. A blend of 50% biofuel and 50% traditional Jet-A jet (kerosene) fuel was tested in one of the aircraft's four Pratt &amp; Whitney JT9D engines. No modifications to the aircraft or engine were required for biofuel, which is a 'drop-in' replacement for petroleum-based fuel. The fuel was produced using UOP's hydroprocessing technology. UOP Renewable Energy and Chemicals have indicated this drop in replacement fuel eliminates the need for costly changes to the fuels infrastructure and transportation fleet and the technology could be utilized to begin making an impact on the aviation fuel supply in as little as three years.</p> <p>Continental completed a two hour test flight out of Houston in January 2009 using a two-engine Boeing 737-800 with one engine powered by a 50-50 blend of regular jet fuel and a synthetic biofuel made from Jatropha and algae feedstocks. The biokerosene fuel was produced by UOP (a division of Honeywell) by their hydrotreatment type process and has reportedly as good or better qualities than Jet A refined from petroleum: It does not freeze at high-altitude temperatures, delivers the same or more power to the engines, and is lighter, as well<sup>73</sup>. UOP state they can turn almost any plant oil into the alternative jet fuel.</p>	

<sup>73</sup> See article from Scientific American Magazine: <http://www.sciam.com/article.cfm?id=air-algae-us-biofuel-flight-on-weeds-and-pond-scum>

## **Annex 6 – Chapter 7**

Region	R & D on Advanced Technologies	Funding or research organisation and budget where available
UK	<p><b>NNFCC review (2007):</b> Liquid Transport Biofuels - Technology Status Report</p> <p><u>Current work:</u></p> <ul style="list-style-type: none"> <li>Assessment of suitability of available biomass gasifiers for UK feedstocks (ends May 2009). Deliverables: A technical and economic review and evaluation of new and existing gasification technologies; identify and assess technologies with the potential to produce syngas suitable for conversion to liquid transport fuels from types of biomass and wastes likely to be available in the UK.</li> <li>Anaerobic treatment of packaging waste (ends Q3 2009). Deliverables: potential for AD to deal with a mixed food waste stream containing plastic; best practice for dealing with contamination by conventional plastics.</li> <li>Production of biofuels from municipal solid waste Ends: March 2009. Deliverables: critically examination of the options for producing energy and fuels from indigenous UK wastes (i.e. anaerobic digestion, thermochemical conversion, and energy from waste technologies such as pyrolysis and direct combustion). Issues considered will include costs, energy efficiency and markets for by-products.</li> <li>Advanced biofuels roadmap: March 2009. Deliverables: practical strategy/roadmap for the development of advanced biofuels production in the UK, emphasising technologies based on thermochemical conversion. A series of commercial demonstration activities and projects are expected to be initiated as an outcome of this programme.</li> <li>Life cycle and techno-economic assessment of North East Biomass to Liquids project. Complete. Deliverables: Technology, economic and greenhouse gas modelling for a hypothetical BtL plant based in North East England. Includes sensitivity analysis with respect to key technical parameters, especially plant size. Will model the whole supply chain from an LCA and economic viewpoint.</li> </ul> <p><u>Past work includes:</u></p> <ul style="list-style-type: none"> <li>Lignocellulosic Ethanol Report and fact sheet (20908);  <a href="http://www.nnfcc.co.uk/metadot/index.pl?id=7607;isa=DBRow;op=show;dbview_id=2539">http://www.nnfcc.co.uk/metadot/index.pl?id=7607;isa=DBRow;op=show;dbview_id=2539</a>  <a href="http://www.nnfcc.co.uk/metadot/index.pl?id=7883;isa=DBRow;op=show;dbview_id=2539">http://www.nnfcc.co.uk/metadot/index.pl?id=7883;isa=DBRow;op=show;dbview_id=2539</a></li> <li>Biochemical opportunities summary report and fact sheet (2008)  <a href="http://www.nnfcc.co.uk/metadot/index.pl?id=7934;isa=DBRow;op=show;dbview_id=2539">http://www.nnfcc.co.uk/metadot/index.pl?id=7934;isa=DBRow;op=show;dbview_id=2539</a></li> </ul>	<b>NNFCC</b>

Region	R & D on Advanced Technologies	Funding or research organisation and budget where available
	<a href="http://www.nnfcc.co.uk/metadot/index.pl?id=7884;isa=DBRow;op=show;dbview_id=2539">http://www.nnfcc.co.uk/metadot/index.pl?id=7884;isa=DBRow;op=show;dbview_id=2539</a> • Biorefinery opportunity in North East (report): <a href="http://www.nnfcc.co.uk/metadot/index.pl?id=7752;isa=DBRow;op=show;dbview_id=2539">http://www.nnfcc.co.uk/metadot/index.pl?id=7752;isa=DBRow;op=show;dbview_id=2539</a> • AD feasibility + Calculator <a href="http://www.nnfcc.co.uk/metadot/index.pl?id=7198;isa=DBRow;op=show;dbview_id=2539">http://www.nnfcc.co.uk/metadot/index.pl?id=7198;isa=DBRow;op=show;dbview_id=2539</a> <a href="http://www.nnfcc.co.uk/metadot/index.pl?id=7197;isa=DBRow;op=show;dbview_id=2539">http://www.nnfcc.co.uk/metadot/index.pl?id=7197;isa=DBRow;op=show;dbview_id=2539</a>	
UK	<b>Research Councils coordinated approach.</b> Total funds: <b>£38.8M</b>	
	– Supergen <b>£6.4M</b> phase II to include biofuels <a href="http://www.supergen-bioenergy.net/">http://www.supergen-bioenergy.net/</a>	<b>EPSRC</b>
	TSEC-biosys ( <b>£2.3M</b> 2005-2010) A whole systems approach to bioenergy demand and supply in the UK	<b>NERC</b>
	<b>Sustainable Bioenergy Centre £27M</b> – 6 research groups + £7M from 15 industrial concerns. <a href="http://www.bsbec.bbsrc.ac.uk">www.bsbec.bbsrc.ac.uk</a> . Will be examining: Perennial bioenergy crops; Cell wall sugars; Cell wall lignin; Lignocellulosic conversion to bioethanol; Second generation sustainable bacterial biofuels; Marine wood borer enzyme discovery.	<b>BBSRC</b>
	<b>Integrated Biorefinery Technologies Initiative Club.</b> A partnership between BBSRC and the Bioscience for Business Knowledge Transfer Network aimed at developing biological processes and feedstocks to reduce dependence on fossil fuels. Is supporting international Bioenergy collaboration by funding a UK element of research led by the European Bioenergy ERA-NET scheme. Has funded a mission to Brazil. Is funding work on biobutanol.	<b>BBSRC</b> (IBTI) - £5M 5 year

Region	R & D on Advanced Technologies	Funding or research organisation and budget where available
	<p><b>UKERC (UK Energy Research Centre)</b>  Supports Energy summer school for PhDs  Southampton University leading on bioenergy and is developing a roadmap, which should be published in near future. 3 work packages are being funded: Bauen: Bioenergy scenarios for UK; Taylor: crop improvement, environmental impacts, land use decisions; WP3: Clift: development of a sustainability and MCDA framework for sustainability development; full supply chain GHG emissions; sustainability criteria.  No publications are available from web site, but Dr Taylor provided latest journal publications for her work package.</p>	Cross research council <b>TSEC</b> (Towards a sustainable energy economy) initiative
UK	<b>The Carbon Trust</b>	
	<p><b>Idea Assessments</b>  These examined the application of the technologies below in the UK, the state of the art internationally, where the development has happened and what UK skills are to develop these areas/technologies: Plant science and agronomy; Biorefineries; Algae; Novel Biofuels; Pyrolysis to transport fuels. These reports are unpublished.</p> <p><b>Pyrolysis challenge (£7-14M)</b>  The Carbon Trust has identified pyrolysis oil from sustainable sources of biomass as having the potential to produce low-cost fuels with low system greenhouse gas (GHG) emissions - if it can be integrated into a conventional refinery. However, the properties of the oil produced from current fast pyrolysis processes are far from suitable for direct integration. The Pyrolysis Challenge aims to produce oil with the properties required for integration either by modifying the pyrolysis process to produce better quality oil directly; or upgrading the oil before or at the refinery.  Through applied research and development, the expected outcomes of the <b>Pyrolysis Challenge</b> include:</p> <ul style="list-style-type: none"> <li>• Proof of scientific and engineering principle for a novel process for low-cost and low GHG intensity upgrading of biomass pyrolysis oil</li> <li>• Complete characterisation of the upgraded oil, including details of characterisation processes and the impact of different feedstocks</li> <li>• An assessment of the likely commercial and environmental value of any associated co-products and processes for their exploitation</li> <li>• Development of a large lab-scale or small industrial demonstration unit</li> </ul>	<b>Carbon Trust</b>

Region	R & D on Advanced Technologies	Funding or research organisation and budget where available
	<ul style="list-style-type: none"> <li>Modelling of the full scale process economics, whole system GHG intensity and key technical parameters</li> </ul> <p><b>Micro Algae (£10 -16M):</b> – 2 phase approach on fundamental R&amp;D and large scale production (international). Call for proposals for phase 1 already out.</p> <p><b>Novel biofuels</b> – findings inconclusive as yet DfT committed <b>£3M/year</b> over this and next year to the CT's advanced biofuels accelerator programme.</p> <p><b>Low Carbon Technology Commercialisation Review (LCTCR).</b> The Carbon Trust are undertaking a review of six technologies one of which will be ethanol from lignocellulose. The review will address engineering and commercial aspects, the technology status, barriers to deployment and the potential roles for the UK. We understand that results will become available in April.</p>	
UK	<b>Others</b>	
	<b>LowCVP Biofuels Pathway</b> Proposed project: Aim will be to provide policy makers with a high level examination of advanced biofuel feedstocks and pathways; their contribution to commercially available biofuels available in the UK by 2020; and the role for the UK. This is to inform policy and the funding and support landscape for biofuels in the UK. This project has yet to be scoped. Budget unknown.	<b>Low CVP</b>
	UK universities working on conversion technologies: Manchester (gasification); Aston (pyrolysis); Leeds (pyrolysis), Cardiff (gasification), Cranfields (gasification), Newcastle (gasification, FT).	
	<b>North East Biofuels:</b> One North East plus 20 other organisations represent the largest concentration of chemicals processing industry, engineering and supporting sector in UK. <a href="http://www.northeastbiofuels.com/">http://www.northeastbiofuels.com/</a>	
EU	<p>Have committed about <b>16 M€</b> on synthetic biofuels, <b>35 M€</b> on ethanol from lignocellulosics and <b>15 m€</b> on biorefineries (this was part of a wider joint Call with RTD of a total of 57 M€). All areas of advanced and second generation biofuels and energy crops will be supported at demonstration level.</p> <p><b>FP7 Biorefinery</b> work is supported by DGRTD Total funding in FP7 so far is <b>66.05 M Euro</b>. There have been three calls to date and emphasis has been very much on second generation, sustainability, co-ordination with south America and support for coordinated actions (networks, information dissemination). Examples: (figures are EU support only):</p>	DG TREN & RTD FP7 and predecessors

Region	R & D on Advanced Technologies	Funding or research organisation and budget where available
	<p>ALFA Bird – consortium to develop alternative fuels in aeronautics. 6.82M Euro</p> <p>BEE- Biomass Energy Europe</p> <p>BIOREF-INTEG - Advanced biorefinery schemes integrated into existing industrial fuel complexes (1M Euro)</p> <p>BIOTOP - Assessment of technical &amp; Research needs for Latin America (1M Euro)</p> <p>GLYFINERY – Development of use of glycerol from biodiesel in biorefineries. (3.75 M Euro)</p> <p>GREENSYNGAS – Advanced cleaning devices for production of green syngas (2.72 M Euro)</p> <p>PLANTPOWER – Living plants in microbial fuel cells for in situ bioenergy production (4M Euro)</p> <p>PROPANERGY – Bioconversion of glycerine into value added productions and biogas at pilot plant scale (1.82 M Euro)</p> <p>SUPER METHANOL – Reforming of crude glycerine to produce methanol for re-use in biodiesel plants. (2.09M Euro)</p> <p>SUSTOIL – Biorefinery for integration into existing oil production transesterification plants. (1M Euro)</p> <p>SOILSERVICE – Examining conflicting demands of land use, soil biodiversity &amp; sustainable delivery of ecosystem services (3.48 M Euro)</p> <p>4F CROPS – Future crops for food, feed, fibre and fuel. (1M Euro)</p> <p>AQUATERRE – EU network for biomass and waste re-utilisation for bioproducts (0.775M Euro)</p> <p>CROPSZINDUSTRY – Non food crops to industry (1M Euro)</p> <p>DISCO – Targeted discovery of novel celluloses and hemi celluloses (2.99M Euro)</p> <p>ENERGY POPLAR – Enhancing poplar for energy (2.99 M Euro)</p> <p>FORBIOPLAST - Forest resource sustainability through bio-based development (4.3 M Euro)</p> <p>NEMO – Novel high performance enzymes for bioethanol production (5.8 M Euro)</p> <p>RENEWALL – Improving plant cell walls for use as renewable industrial feedstock (5.74 M Euro)</p> <p>SWEETFUEL – Sweet sorghum as energy crop (2.97M Euro)</p> <p>AGFOODTRADE – New issues in agriculture, food and bioenergy trade (2.87M Euro)</p> <p>HYPE – High efficiency bioprocess technology for lignocellulose ethanol (3.66 M Euro)</p> <p>BIOSYNERGY - Aims to integrate synthesis processes (to obtain transportation fuels and green platform chemicals), and energy production (power, CHP) by application of innovative synergetic biorefinery concepts, using advanced fractionation and conversion processes, and combining biochemical and thermochemical pathways. (7M Euro)</p> <p><b>FP 6 – 54.07M Euro</b></p>	



Region	R & D on Advanced Technologies	Funding or research organisation and budget where available
	<p>NILE: New improvement for ligno cellulosic ethanol  CHRISGAS – Clean hydrogen rich synthesis gas  RENEW – Renewable biofuels for advanced power trains  BIOCAT – Catalyst development for biomass flash pyrolysis  ThermalNET – Integrated network on thermal biomass to heat, power and transport fuels  Co-production of biofuels – Includes utilisation of lignocellulose.  BABILAFUENTE - Production of 200M t of bioethanol from cereals &amp; lignocellulose.  BIO-HUG – Novel bioprocesses for hemicellulose up grading &amp; 4 more on improved fermentation, genetic modification, improved biochemistry and hydrolysis, use of waste and integration of chemicals production.</p> <p><b>Demonstration plants supported by DG TREN</b>  <u>Dong energy</u> – 30,000t straw/year, 4,300 tonnes of ethanol 40M Euro. Total project cost ~65M Euro Process involves hydrothermal treatment, enzymic hydrolysis &amp; C5 fermentation.  <u>Finish Waste to bioethanol plant</u> – food industry residues.  <u>PERSO</u> - 4t/d pilot plant. Organic MSW to ethanol.  <u>BioSNG</u> – ECN/HGV 1 MW pilot plant. Small scale demo of waste to bioethanol in Finland – ST1 Biofuels – Etanolix 2 units on bakery waste, 1 on potato flakes, Support:3.2 M Euro  <u>Choren</u> – BtL 7.8 M Euro  <u>BioDME</u>: support 8.2 M Euro</p> <p><b>DG TREN</b> have announced that <b>4 projects</b> have been selected for support under the 2008 call for work on ethanol from lignocellulose: <b>8.6-9.1M Euro</b> for each.</p> <p><b>Networks and information supported by DG TREN and RTD:</b>  <b>FP6</b>, ERA-net Bioenergy, bioethanol, Biofuels technology platform secretariat, biogas, development of CEN 335, advanced technologies, dissemination platforms.  <b>EU Biofuels Technology Platform</b> : mission is to contribute to the development of cost competitive world class biofuel technologies and a healthy biofuels industry supplying sustainable biofuels in EU through a process of guidance, prioritisation and promotion of R,D &amp;D. Secretariat: FNR (Birger Kerckow) Operates through a series of working groups on specific key</p>	

Region	R & D on Advanced Technologies	Funding or research organisation and budget where available
	<p>topics.</p> <p><u>Strategic Research agenda document</u>: 3 main area of technology development are critical: Feedstocks (managing competition for land &amp; resources &amp; for different bioenergy/biomass applications e.g. heat or materials versus biofuels)</p> <p><u>Conversion technology</u>: energy efficient &amp; reliable biomass to fuel</p> <p><u>Logistics &amp; end use technologies</u> – Optimising fuel engine environmental and energy performance &amp; ensuring compatibility with existing &amp; future infrastructure &amp; vehicles.</p> <p>Strategic Deployment Document: 5 recommendations: • Coherent, long term and harmonised political and open market framework to secure confidence of investors in capital-intensive innovative technologies. • Joint public/private financing for R&amp;D and Demonstration of new biofuel production routes and end-use applications. • Biofuel quality standards based on sound science, while not creating unnecessary barriers for biofuels deployment. • Social awareness and acceptance gained by open communication on benefits as well as on potential limitations of biofuels. • A simple, coherent and global certification system to ensure environmental, economic and social sustainability of biofuel production chains.</p> <p><b>EU Biofuel Technology Platform</b> will be launching database of demos and pilot plant soon (before end Feb)</p> <p><a href="http://www.biofuelstp.eu/">http://www.biofuelstp.eu/</a></p> <p><b>BIOMATNET</b> (bioproducts from non-food crops) provides further information on previous Framework support. – lists all FP research projects, technology platforms, Intelligent Energy Europe projects and describes FP7. (Biomatnet – Bioproducts from non-food crops) <a href="http://www.biomatnet.org/home.html">http://www.biomatnet.org/home.html</a></p> <p><b>Intelligent Energy Europe Programme.</b> Provision of information and communications on energy efficiency and renewable energy. Funds work on networks, help in implementing biofuels, networks of suppliers to investigate supply &amp; use, development of clean vehicles, carbon efficient labelling.</p>	
USA	<p>The US DOE <b>Biomass Program</b> conducts research and development in the four key areas of technology required to produce biomass feedstocks and convert them to useful biofuels and value-added products. These technology areas are: Feedstocks, Processing and Conversion, Integrated Biorefineries, and Infrastructure. See: <a href="http://www1.eere.energy.gov/biomass/biomass_solicitations.html">http://www1.eere.energy.gov/biomass/biomass_solicitations.html</a> A current example is: Demonstration of Integrated Biorefinery Operations (Funding: Up to \$40,000,000 per award; Open Date: 12/22/2008; Close Date: 04/30/2009). The Biomass Program funds work on sustainability through life-cycle biomass production. This work is included in other chapters of the report.</p>	<b>DOE \$1billion</b>

Region	R & D on Advanced Technologies	Funding or research organisation and budget where available
	<p>The <b>Biomass Program Multi year Action Plan</b> (US DOE, 2008) has 2 aims:</p> <ol style="list-style-type: none"> <li>1. Through RD&amp;D, make cellulosic ethanol cost-competitive, at a modelled cost for mature technology of £1.33/gallon by 2012 and ~£1.20/gallon by 2017</li> <li>2. Help create an environment conducive to maximizing the production and use of biofuels by 2017 and displacing 30% of 2004 gasoline use by 2030.</li> </ol> <p>In January 2009 a <b>joint solicitation from USDA and USDOE</b> was issued covering:</p> <p>(A) FEEDSTOCKS DEVELOPMENT</p> <p>R,D &amp;D activities regarding feedstocks genetic, and feedstock logistics (including the harvest, handling, transport, pre-processing, and storage) relevant to production of raw materials for conversion to biofuels and bio-based products.</p> <p>(B) BIOFUELS AND BIOBASED PRODUCTS DEVELOPMENT.</p> <p>Research, development, and demonstration activities to support: (i) the development of diverse cost-effective technologies for the use of cellulosic biomass in the production of biofuels and bio-based products; and (ii) product diversification through technologies relevant to production of a range of bio-based products (including chemicals, animal feeds, and co-generated power) that potentially can increase the feasibility of fuel production in a biorefinery.</p> <p>(C) BIOFUELS DEVELOPMENT ANALYSIS.</p> <p>(i) STRATEGIC GUIDANCE: Development of analysis that provides strategic guidance for the application of renewable biomass technologies to improve sustainability and environmental quality, cost effectiveness, security, and rural economic development.</p> <p>(ii) ENERGY AND ENVIRONMENTAL IMPACT: Development of systematic evaluations of the impact of expanded biofuel production on the environment (including forest land) and on the food supply for humans and animals, including the improvement and development of tools for life-cycle analysis of current and potential biofuels.</p> <p>(iii) ASSESSMENT OF FEDERAL LAND: Assessments of the potential of Federal land resources to increase the production of feedstocks for biofuels and bio-based products, consistent with the integrity of soil and water resources and with other environmental considerations.</p> <p>The 2010 DOE EERE budget is not yet finalized, but was proposed Feb 23, 2009. The Biomass program utilizes a variety of funding mechanisms from ranging from cost shares to loan guarantees, to directly funding research and development efforts. <a href="http://www1.eere.energy.gov/biomass/past_solicitations.html">http://www1.eere.energy.gov/biomass/past_solicitations.html</a> includes details on funding amounts for some of the larger projects</p>	

Region	R & D on Advanced Technologies	Funding or research organisation and budget where available
	<p>in the Biomass program portfolio.</p> <p><b>\$272M</b> - 4 commercial-scale biorefineries over 4 years</p> <p><b>\$17 M</b> - 5 projects to develop efficient fermentative organisms to convert biomass to ethanol</p> <p><b>\$9.7M</b> - 4 projects to demonstrate thermochemical conversion of residues to biofuel</p> <p><b>\$114M</b> over 4 years to support small scale cellulosic biorefineries</p> <p><b>\$33.8 M</b> over 4 years to develop improved enzyme systems.</p> <p><b>\$375M</b> - 3 bioenergy research centres: Oak Ridge, University of Wisconsin, Lawrence Berkeley National Lab</p> <p><b>Currently 6 demo plants supported:</b> AKICO, Florida \$33 M, BlueFire Ethanol, California \$40 M, Broin Companies, Iowa \$80M, logen Idaho \$80M, Abengoa, Kansas \$76M, Range Fuels \$76M</p> <p><u>Abengoa</u> – 700t/d corn stover, wheat straw milo stubble and switchgrass.</p> <p><u>AKICO</u> – 13.9 M gals of ethanol + CHP . Feedstock= wood, garden and vegetable waste.</p> <p><u>BlueFire</u> – sited on landfill, 19M gals ethanol/y Feedstock: 700 t/d of sorted green and wood waste from landfills.</p> <p><u>Broin</u> – 125 Mgals of which 25% will be cellulosic from 842t/d corn fibre, cobs and stalks.</p> <p><u>logen</u> – 18 M gals ethanol/y - 700 tons per day of agricultural residues including wheat straw, barley straw, corn stover, switchgrass, and rice straw as feedstocks</p> <p><u>Range Fuels</u> 40M gals ethanol + 9 Million Gallons methanol/y. The plant will use 1,200 tons per day of wood residues and wood based energy crops</p> <p>International collaboration</p> <ol style="list-style-type: none"> <li>1) GBEP GHG Accounting and Sustainability Working Groups</li> <li>2) US Biomass Research and Development Board</li> <li>3) Roundtable on Sustainable Biofuels</li> <li>4) Council on Sustainable Biomass Production</li> </ol>	

Region	R & D on Advanced Technologies	Funding or research organisation and budget where available
US	<p>Biosciences energy research Lab, California</p> <p><b>BP</b> is investing \$500 million over ten years to establish a dedicated biosciences energy research laboratory attached to the University of California Berkeley and its partners the University of Illinois, Urbana-Champaign and the Lawrence Berkeley National Laboratory. It is the first facility of its kind in the world.</p> <p>The Energy Bioscience Institute would focus initially on three key areas of energy bioscience:</p> <ul style="list-style-type: none"> <li>• Developing new biofuel components and improving the efficiency and flexibility of those currently blended with transport fuels</li> <li>• Devising new technologies to enhance and accelerate the conversion of organic matter to biofuel molecules, with the aim of increasing the proportion of a crop which can be used to produce feedstock</li> <li>• Using modern plant science to develop species that produce a higher yield of energy molecules and can be grown on land not suitable for food production</li> </ul>	BP \$500 million over 10 years
Canada	Funding a Cellulosic Biofuels Network to examine ways to increase efficiency and reduce the economic costs associated with the production of cellulosic ethanol.	Government of Canada \$19.9M
IEA	IEA Bioenergy is supporting a number of Tasks relevant to second generation biofuels: Task33 Thermal Gasification of biomass; Task 34 Pyrolysis of biomass; Task 39: Commercialising first and second generation liquid biofuels from biomass; Task 42 Biorefineries: co-production of fuels, chemicals, power and materials from biomass.	
<b>Industry</b>		
	<p><b>Shell</b> are active in supporting work on advanced biofuels, particularly on conversion processes for lignocellulosic feedstocks to products; and Development of alternative non-crop biomass feedstocks such as micro-algae. Last year Shell quadrupled its rate of investment in biofuels. Research is being carried out both internally and in partnership with universities, commercial entities and the wider public sector. Examples are:</p> <ul style="list-style-type: none"> <li>• support for the Biotechnology and Biological Sciences Research Council's</li> <li>• (BSBEC's) work to develop energy crops;</li> <li>• six new agreements between its in-house biofuels research and technology team and groups of experts in academic institutions across the world, including the Centre of Excellence for Biocatalysis, Biotransformations and Biocatalytic Manufacture (CoEBio3) based at Manchester University and the School of BioSciences Exeter University, both in the UK. See</li> </ul>	

Region	R & D on Advanced Technologies	Funding or research organisation and budget where available
	<p><a href="http://www.shell.com/home/content/media/news_and_library/press_releases/2008/biofuels_research_agreements_17092008.html">http://www.shell.com/home/content/media/news_and_library/press_releases/2008/biofuels_research_agreements_17092008.html</a></p> <p>Other work includes:</p> <ol style="list-style-type: none"> <li>1. Developing ethanol from lignocellulose (straw) using enzymes: <ul style="list-style-type: none"> <li>• Shell partnership with Iogen (Canada) since 2002; First commercial demonstration plant opened in 2004 (Ottawa). CO<sub>2</sub> profile at this demonstration plant – up to 90% less than gasoline. Full-scale commercial plant under assessment</li> <li>• See: <a href="http://www.shell.com/home/content/media/news_and_library/press_releases/2008/iogen_extended_alliance_15072008.html">http://www.shell.com/home/content/media/news_and_library/press_releases/2008/iogen_extended_alliance_15072008.html</a></li> </ul> </li> <li>2. Developing high performance synthetic fuel from lignocellulose (wood residue) through gasification and the Fischer-Tropsch process: <ul style="list-style-type: none"> <li>• Shell partnership with Choren (Germany) since 2005; first commercial demonstration plant expected to open in 2010 (Freiberg); CO<sub>2</sub> saving compared to diesel at this demonstration plant expected to be up to 90%. Longer term, there is the potential for 'Biomass To Liquids' (BTL) to be used in aviation fuel.</li> <li>• See: <a href="http://www.shell.com/home/content/media/news_and_library/press_releases/2008/visit_merkel_choren_17042008.html">http://www.shell.com/home/content/media/news_and_library/press_releases/2008/visit_merkel_choren_17042008.html</a></li> </ul> </li> <li>3. Work on adapting enzymes to improve the conversion of non-food bio-materials into better transport fuels through a collaboration with Codexis (company in Redwood City, California) to convert plant sugars into hydrocarbon molecules using catalysts.</li> <li>4. Joint research and development effort with Virent Energy Systems to convert plant sugars directly into gasoline and gasoline blend components. See: <a href="http://www.shell.com/home/content/media/news_and_library/press_releases/2008/biofuels_virent_26032008.html">http://www.shell.com/home/content/media/news_and_library/press_releases/2008/biofuels_virent_26032008.html</a></li> <li>5. Marine algae production of vegetable oil for conversion into biofuel. Shell and HR Biopetroleum have formed a joint venture company, called Cellana, which is constructing a pilot facility in Hawaii. An academic research programme will support the project, screening natural microalgae species to determine which ones produce the highest yields and the most vegetable oil. See: <a href="http://www.shell.com/home/content/media/news_and_library/press_releases/2007/biofuels_cellana_11122007.html">http://www.shell.com/home/content/media/news_and_library/press_releases/2007/biofuels_cellana_11122007.html</a></li> </ol>	

Region	R & D on Advanced Technologies	Funding or research organisation and budget where available
	<b>BP:</b> Joint venture with Verenium to develop and commercialise cellulosic ethanol from non-food feedstocks. \$45M Work based in USA.	
	<b>BP, Du Pont and ABP</b> are working on biobutanol.	
	Industry research in biofuels and relevant work is summarised in the NNFCC (2007) report and the CT's Ideas Assessment reports.	

## Annex 7 – Chapter 8

### United Kingdom

We found no central study of the infrastructure requirements for the UK in response to a large increase in biofuel use. However, there is some work being done on a regional basis, particularly in areas where the petrochemicals industry is strong or where there are significant proposals for biofuels plants. There is interest and opportunity in the North East to develop second generation biofuels along side the current petrochemical refining facilities already in existence (and work has been done to examine this opportunity e.g. by One North East 2007). On the East coast the Humber ports could become a biofuels hub (there are a number of companies interested in building biofuels plants in this location). To understand the needs and opportunities associated with this, the Yorkshire and the Humber Regional Energy Forum commissioned a report in 2007 to evaluate the situation in their region (AEA 2007). This report concluded there were opportunities for development of first and second generation biofuels at or near the port, but that there was a need to invest in infrastructure such as storage facilities and to develop transport routes to cope with any large-scale expansion in the future. The East of England Development Agency has also spotted the potential of biofuels in its area and encouraged Renewables East to start of 'virtual biofuels hub' to bring academia and industry together to enable biofuels development and has recently launched 'Biofuels East' in support of this. All of these initiatives could form the focus of a study into the UK's infrastructure needs. Planning plants centrally near ports provides opportunities to share infrastructure needs (Black & Vetch 2008).

Work has been supported by NNFFC on the development of biofuels technologies, which also examines infrastructure requirements. This work points out that some biofuels can be used through existing infrastructure but that fuels such as biogas would require new gas refuelling infrastructure and purpose built vehicles (Evans 2007). This report also comments on the infrastructure needs for other biofuels.

The Government has supported a Refuelling Infrastructure Grant Programme since 2006, which is currently under review under the State Aid rules. This provided grants of up to 30% towards the capital cost of installing refuelling stations for alternative fuels including biofuels. In addition the Energy Savings Trust (EST)'s web site provides details of where the refuelling stations.

In response to our survey BP and Shell both indicated that they are including infrastructure in their programmes:

- BP's in-house fuel technologists are conducting development work on the impact of higher percentage biofuels on the infrastructure and on vehicles.
- Additionally, BP are investigating the impact of advance biofuel molecules on the infrastructure and vehicles.
- Shell is partnering with the Liquid Biofuel Team at the Qingdao Institute of Bioenergy and Bioprocess Technology, Chinese Academy of Sciences, who are focused on research and commercialisation of production of alternative fuels from sustainable and renewable sources. This work includes carrying out research into pilot plant design.



## **European Union**

We obtained limited information on infrastructure development in the EU.

We have already discussed the plans of the **Rotterdam** port to become a biofuels hub.

There are a number of relevant EU funded networks and projects that include an element of work on infrastructure:

The EU funded **Biofuels-Cities network** is a 2.5M Euro FP6 funded network, which runs from 2006 to 2009. It aims to:

- build a European Partnership for exchange and networking on biofuels application;
- independently assess research & development and demonstration projects on biofuels and sustainable mobility policies;
- offer support through information, events, tools, and publications

The Biofuel-Cities guidance brochure covers infrastructure (Biofuel-cities 2008). The network also summarises work on the introduction of biofuels in cities throughout the EU, such as experience of (for example) the introduction of biofuel and biogas bus fleets, including infrastructure development. As part of its work it has undertaken a survey of stakeholders that indicated that infrastructure barriers were seen as significant by respondents (Biofuel-Cities 2008a). The key barriers for infrastructure were listed as:

- Insufficient availability of refuelling infrastructure
- High costs to construct or convert refuelling infrastructure
- Insufficient biofuel production capacity and lack of sufficient feedstock for biofuel production units

The solutions to these barriers were seen to lie within Government policy (i.e. refuelling infrastructure should be stimulated financially or mandated by Governments).

The 8M Euro **BEST**<sup>74</sup> project includes examination of the infrastructure needed to support the introduction of bioethanol fuelled vehicles, so that the market for bioethanol vehicles becomes self-supporting. The project includes information on refuelling stations and incentives in participating countries. This project runs from 2006 to 2009.

There are opportunities to exchange information on infrastructure development and needs through Intelligent Energy Europe (IEE) and it is likely that there are national programmes to support infrastructure development for biofuels, but we have no information on these. IEE funded projects include:

**Bionic** – Biofuels networks in the community – examines biofuel supply and use in transport specifically from the perspective of local authorities [www.bionic-project.eu](http://www.bionic-project.eu) 2007-2010 1.4M Euro, lead by Merseyside Passenger Transport Executive.

**Madegascar** – market development of gas driven cars, including supply and distribution of natural gas and biogas [www.madegascar.eu](http://www.madegascar.eu) 2007-10 1.4M Euro.

**SUGRE** - Sustainable Green Fleets. Includes information on viability of cleaner fuels for vehicle fleets and refuelling issues. [www.Sugre.info](http://www.Sugre.info) 2006-08 2.5M Euro

**PROCURA** – Green fleet procurement models - aimed to overcome market barriers for large-scale procurement for alternative fuel vehicles. [www.procura-fleets.eu](http://www.procura-fleets.eu) 2006-08 1.75M Euro<sup>75</sup>

<sup>74</sup> Bioethanol for sustainable transport, see: [www.best-europe.org/](http://www.best-europe.org/)

<sup>75</sup> The web site includes: a manual for infrastructure development; training guidelines for the maintenance and support of alternative fuel vehicles; a user manual for fleet owners on alternative fuel vehicles.

**Pro Biodiesel** which examined the non-technical barriers to biodiesel. (2006-7, 770k Euro)  
**Biodiesel chains**, which examined promotion of favourable conditions to establish biodiesel markets and concluded that investment in infrastructure remains a key issue.  
[www.cres.gr/biodiesel](http://www.cres.gr/biodiesel) (2006-7, 760k Euro).

In the longer term there is a need to look at how second generation will be developed in Europe (for example will there be second generation 'hubs'?) and how infrastructure will be needed to support the production and supply of second generation fuels.

The **European Biofuels technology platform** ([www.biofuelstp.eu/](http://www.biofuelstp.eu/)) examined this need in its roadmap to achieve the Vision for Biofuels (Biofuels technology Platform 2008). In this it examined strategic deployment and indicated:

- There will be a need to develop infrastructure to handle bulk and heterogeneous material
- For the development of advanced biofuels facilities: 'The development of innovative processes involves an access to large pilot facilities. It is necessary to facilitate the access to demonstration plants and pilot-scale facilities for R&D work'; and 'It is important to establish an infrastructure linking academic research to large scale facility operations in order to improve available knowledge.'
- 'Additional investments for biomass planting, harvesting, transportation and soil conditioning systems as well as additional infrastructure and engine development are going to require further investments. As a reference, an investment cost in the range of 400-600 million € for a 105-120 thousand tons per year BtL plant (next generation lignocellulosic biomass conversion) was reported in a 2006 study coordinated by the German Energy Agency.'

The EU Biofuels Technology Platform also includes a working group on End Use, which has the aim of identifying what R&D activities with respect to fuel distribution and end use are required to reach the Vision for Biofuels 2030 targets.

**EU Biogas work:** Sweden has taken a different route to the UK, in that it has developed biogas a vehicle fuel, particularly for larger vehicles such as buses and HGVs. Biogas has been combined with natural gas to enable this use to be 'kick started' and biogas has now overtaken the use of natural gas as a vehicle fuel. The needs for infrastructure include upgrading of biogas (in Sweden much of the biogas used is land fill gas). Over the past few years several European countries have allowed injection of biogas to their gas grids. These countries include Sweden, Switzerland, Germany, France and the Netherlands. Each of these countries has national standards for gas injection into the mains system. This means that there is now information on the cost of upgrading and injection into the mains and the costs of biogas vehicles (Jönsson, 2004, quoted in AEA 2007a). The Trendsetter (2003) report provides a good summary of the best upgrading solutions in terms of vehicle fuel, electricity generation, heat recovery and gas grid injection; and BERR has supported work to examine the potential for upgrading in the UK (Panthol 2007). The European Natural Gas Vehicle Association (ENGVA) website <http://engva.org> provides information on the infrastructure needs for natural gas fuelling stations.

## United States

- A U.S. Department of Transportation (DOT)-led group is studying the feasibility of transporting ethanol in pipelines, as part of the Biofuels Action Plan (2008). The DOT has also funded a \$700,000 project on the effect of E10, E15 and E20 fuel blends on corrosion and cracking of pipelines. It is anticipated this project will inform the changes that need to be made to mitigate the damage from ethanol to the pipelines and the changes need to design a pipeline that can carry ethanol. Other US plans include a £3.5 billion 1,700 mile pipeline from the corn ethanol producing Mid Western states to fuel terminal in the Northeast USA. There are also plans to use dedicated train lines to transport ethanol, include a proposed \$150 M project in Nebraska.
- The [Infrastructure Requirements for an Expanded Fuel Ethanol Industry](#) by Downstream Alternatives Inc (DAI) in 2002 was a detailed look at the infrastructure requirement associated with an expanded biofuels industry in the US (work funded by US DoE).
- There have been two recent conferences of interest:
- US Chamber of Commerce led a conference on “Meeting the Infrastructure Challenges to the Expansion of the Biofuels Industry” in September 2007. The proceedings of this conference provide an insight into the infrastructure issues facing expansion of bioethanol.<sup>76</sup>
- Farm Foundation led a conference on “Transition to a Bio-economy: Risk, Infrastructure and Industry Evolution” in collaboration with the USDA’s Office of Energy Policy and New Uses and Economic Research Service. This included calls for a more in-depth study of the issues.<sup>77</sup>
- The CRS produced a report for US Congress – “[Ethanol and Biofuels: Agriculture, Infrastructure, and Market Constraints Related to Expanded Production](#)” 2007, which outlines the current supply issues facing biofuels industries, including infrastructure constraints. Interestingly this report gives an indication of the cost of installing fuel pumps for high blend ethanol: ‘If a new E85 pump and underground tank are necessary, they can cost as much as \$100,000 to \$200,000 to install. However, if existing equipment can be used with little modification, the cost could be less than \$10,000.’

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<sup>76</sup> See for example:

Union Pacific – Presentation on “[Meeting the Infrastructure Challenges to the Expansion of the Biofuels Industry](#)”  
 Magellan Midstream Partners – “[Ethanol Transportation and Distribution](#)”  
 General Motors – “[GM and Biofuels](#)”  
 Oak Ridge National Laboratory – “[Logistics of Biomass Supply](#)”

<sup>77</sup> For more information see:

Infrastructure for the Bio-economy - [Frank Dooley](#), Purdue University  
 Transportation Infrastructure for the Bio-economy - [Paul Hammes](#), Union Pacific  
 Legal Structures and Issues for the Bio-economy [Mark J. Hanson](#), Stoel Rives LLP

- The Clean Energy Coalition (CEC), Michigan is supporting a Biofuel Infrastructure Grant Incentive Program to offer financial incentives to increase biofuel infrastructure (ethanol and biodiesel) in Michigan. For 2008 & 2009, they offer infrastructure incentives for E85 (85% Ethanol) conversions through a grant from the Michigan Department of Labor & Economic Growth Energy Office. Additional support for 2008 and 2009's project has been provided by the Corn Marketing Program of Michigan. The objective of the programme is to increase biofuel infrastructure along major highway corridors and in urban areas throughout Michigan with incentives for installing such infrastructure at retail locations.
- Similar grants are available in Iowa: \$1.52 million in grants for 43 biodiesel and E85 retailers and terminal operators across the state to expand their renewable fuel infrastructure. Financial assistance of up to 50 percent of the cost to install, replace or convert fuel equipment, or \$30,000 for a combination of equipment at any one retail motor fuel location is available. Out of the 43 awards, 15 were for E85 dispensers and 13 were for biodiesel dispensers, including the state's first biodiesel blender pump planned at Pioneer's Rest Area in Dubuque, Iowa. Twelve tank wagons and three biodiesel terminals were also awarded funding.

## **International**

### **New Zealand Ministry of Transport**

- Report on "[Enabling Biofuels: Biofuels Distribution Options](#)", (Hale and Twomey, 2006). This identifies the infrastructure changes that would be required for the introduction of biofuels, and discuss constraints that may restrict biofuel uptake. Biofuel volume expectations are derived based on various constraints. The implications of various biofuels policy options are assessed for the likely impact on biofuel use.

### **Brazil**

- Bioethanol Science and Technology Centre (CTBE), Brazil - located in Campinas, State of São Paulo, Brazil has recently been formed with funding from the Brazilian Ministry of Science and Technology. Among the facilities currently under development at the Centre is a pilot plant for process development, which includes bagasse pretreatment, enzymatic hydrolysis, fermentation, and distillation laboratories, supported by all necessary analytical instrumentation.
- The following extracts from <http://sugarcaneblog.wordpress.com> detail development of supply infrastructure in Brazil:
  - The Brazilian company Uniduto Logística will begin building the first phase of a major Brazilian ethanol pipeline in April 2010, with operations due for 2011-2012. The pipeline will run from Brazil's main sugarcane-producing region in São Paulo state to the port of Santos. The first phase has a budget of 1.8 billion reais (€603 million) to build 600km of pipeline. Uniduto was created jointly by 12 groups including Cosan S Indústria e Comércio, Copersucar, São Martinho and Crystalsev to develop, build and operate an alcohol transportation system by ducts.
  - Another ethanol pipeline is also under development. BRESCO, a start-up company that has an aggressive international strategy, will start construction of a separate pipeline within the next year. Third, as if that was not enough, state-owned oil company, PETROBRAS, has over \$1 billion in investments planned, ranging from the construction of new pipelines to expansion of waterways for fuel transport.
  - Brazil's largest independent logistics company, América Latina Logística (ALL) has signed a long-term contract with leading sugar and ethanol group Cosan. The two companies announced investments of over \$500 million to expand

rail freight capacity for the transport of bulk sugar and other sugarcane by-products to the Santos port. Cosan is the world's largest logistics player in sugar exports, with static storage capacity of 435,000 tonnes and annual shipment capacity of 8.5 million tonnes of sugar and grains. According to Reuters, the agreement with ALL would enable Cosan to raise its shipment capacity to 15 million tonnes. Cosan signed in October a different agreement with ALL to move ethanol by train to Santos.

## **India**

- Gonsalves (2006) says that for Indian to establish biofuel trade, the infrastructure for biofuel transport, store, blend and distribute biofuel must be created from scratch and he identifies the major issues to be a lack of infrastructure in seed collection and oil extraction. As India already produces ethanol from sugar cane the infrastructure requirements for bioethanol are not so great.
- India has pilot plants on transesterification set up by Indian Oil Corporation (R&D), Faridabad; the Indian Institute of Technology (IIT), Delhi; the Punjab Agricultural University (PAU), Ludhiana; the Indian Institute of Chemicals Technology (IICT), Hyderabad; the Indian Institute of Petroleum (IIP), Dehradun; the Indian Institute of Science (IIS), Bangalore; and Southern Railways, Chennai.
- India has also established special tax measures to encourage the construction of infrastructure for the production of biodiesel. These include a decline in machinery tariffs for foreign projects of less than \$1.1 billion

## **Developing countries**

Very little could be found on developing countries, but work for the Gallagher review indicated that infrastructure could be a major issue. This included transportation infrastructure, fuelling stations, oil crushing facilities and flex-fuel power trains. Of these transportation infrastructure and processing facilities are probably of immediate importance. It is known that the palm oil industry in Africa has not been able to invest in up to date processing facilities and so cannot produce palm oil with the efficiency of the Far East (AEA 2008).

## **Annex 8 – Chapter 9**

## **Skills building in the UK**

### **Research Councils**

The Research Councils support a full spectrum of energy research and postgraduate training and seek to expand UK university and institute research capacity in energy related areas. The Research Councils' Energy Programme builds on a substantive portfolio of activities bringing together researchers from many disciplines to tackle the research challenges involved in developing and exploiting energy technologies and understanding their environmental, economic and social impact.

Research supported includes areas of direct relevance to the economics of renewable energy (e.g. improving energy yield from second-generation biofuel crops) through to underpinning support that has an impact on the economics of renewables (e.g. development of technologies, siting of facilities, environmental impacts, economic models, social aspects).

The provision of skills is key to the continued economic viability of the renewables sector. Funding from the Research Councils maintains and develops the skills base in renewable energy through a combination of both responsive and strategic approaches across all of the main renewable energy themes. The Research Councils all support studentships in renewable energy and the number of students has increased markedly since 2004, in particular through Towards a Sustainable Energy Economy (TSEC) and the Sustainable Power Generation and Supply (SUPERGEN) consortia.

The Research Councils recognise the importance of strong partnerships and engagement with research users such as industry and government in order to meet their needs and increase knowledge transfer and economic impact. The business focus that industry partners bring includes the long-term economic viability of renewable energy in the UK. The Research Councils' Energy Programme is also one of the funders of the Energy Technologies Institute, a public-private partnership working to accelerate the development and commercial deployment of a focused portfolio of energy technologies.

BBSRC has recently launched the Sustainable Bioenergy Centre. This is a £20M project based at a number of UK universities that aims to build bio-energy research capacity, particularly in the field of underpinning research on biological issues of relevance bio-energy. BBSRC also aims to collaborate on International bio-energy projects where these present opportunities for the UK science base, and to contribute to cross council initiatives where it can add value to these.

BBSRC fund a range of studentships. Most are available in any field of bioscience, but in the Targeted Priority Studentships, one of the current priorities is Bio-energy.

BBSRC funds a number of schemes in collaboration with business. Most of these are open to any business in the biosciences area.

EPSRC supports SUPERGEN bio-energy. The aim of SUPERGEN is to encourage the development of sustainable power generation and supply. The bio-energy consortium contains both academic and industrial partners and both develops the skills base at universities and Government research establishments, and encourages information exchange and dissemination. SUPERGEN has recently been extended, and now includes transport biofuels and biorefineries as priority areas. Wider dissemination of information is via the Bioenergy Research Forum, which runs occasional seminars for the bioenergy community.

EPSRC funds postgraduate training, including Industrial Case awards. 44 new centres for doctoral training were announced in December 2008, including hydrogen and fuel cells, chemical synthesis, technologies for low carbon future, Bioprocessing Engineering.

NERC leads on TSEC-BIOSYS, which aims to adopt a whole systems approach to bio-energy. The project brings together 12 UK and European research Institutes to look at economic, social and environmental implications of large scale bio-energy development.

NERC also sponsors National Science and Engineering week- including energy from waste seminar. The purpose is to interest young people in becoming involved in these areas.

ESRC lead the RELU-biomass programme, which brings together 5 leading UK research organisations to look at the impacts of conversion of land to energy crops production. They also commission individual projects as required.

### **Government Funding**

Defra funds a large range of research projects in support of policy development and UK competitiveness within its areas of remit. This research helps maintain UK skills in universities and public and private research institutes. In addition Defra specifically supports development of grower skills for energy crops production and supply, and dissemination of information through publications and the Biomass Energy Centre. Defra is also involved in demonstration of waste to energy projects, and biofuels would be eligible for this scheme.

DECC lead on work on the Renewable Energy Strategy. They are also undertaking work in related fields such as Industrial Biotechnology, to identify what economic conditions are required to catalyse the bio-based production of speciality, fine and platform chemicals and where the market opportunities might lie to achieve higher than today uptake of IB within the UK chemicals sector. Also in renewable materials and biorefineries, which includes biofuels particularly from a LUC and competition for resources perspective. Skills would be transferable to biofuels.

DIUS sponsors the TSB Low Carbon Energy Technologies Programme. This is a programme which could potentially support near market biofuels development in the UK. The current view of the TSB is that they are not supporting biofuels projects because a) there are more pressing issues whilst the larger biofuel debate goes on and 2) when the bio fuels are developed it is only really a relatively minor activity to convert vehicles to ensure compatibility - the changes needed are generally known based on current biofuels development. If the UK start developing completely new biofuels then there may be some activity needed and TSB will review.

The Carbon Trust have their own programme for biofuels, and the work they commission helps to develop skills in these selected areas. E.g. Biofuels Algae Challenge and Pyrolysis Challenge. The Carbon Trust are doing a Low Carbon Technology Commercialisation Project, with one of the technologies considered being next generation biofuels. This is a detailed engineering commercial review of near commercial technology which will recommend how Government should consider dealing with innovation. This may help with the debate on how to promote/ fund the uptake of next generation biofuel technology in the UK. CT work is not fully published and we recommend a wider dissemination of the information from their programmes.

Waste and Resources Action Programme (WRAP) is sponsoring a pilot training course on anaerobic digestion (AD) for electricity generation. The course is designed to increase the quality and robustness of emerging AD projects in the UK and is targeted at operators, waste management companies, farmers, compost producers and the food processing industry.



## Research Institutes

A number of Universities have built up expertise in bio-energy, with 14 different universities responding to the consultation. Several are recognised at an international level, e.g. Aston University for pyrolysis and Imperial College for policy issues, Leeds for combustion, Tyndall Centre for Climate Change Research at Manchester. This skills base is dependent on continued Research Council and UK Government and EU support, with areas of research often determined by the funding bodies and subject to fixed term programmes. Output is usually published in peer reviewed journals, and availability to a wider audience is recommended.

Government Funded Research Institutes such as Rothamsted Research, the Centre for Ecology and hydrology, Forest Research, Scottish Association for Marine Science, IGER and CSL have built up expertise in energy crops and their utilisation. This is a world class skills base, dependent on continued Research Council and Government support. Output from Forest Research is now available through biomass energy centre. Output from other institutes is usually published in peer reviewed journals, and availability to a wider audience is recommended.

A number of consultancies have built up a skills base in biofuels, on the basis of both Government Programmes and private industry work. The availability and dissemination of information from this work depends on whether it was conducted for a public client (usually published) or a private client (usually confidential).

NGO research. There is a considerable skills base around the areas of expertise of the NGO, which can be a useful resource. Examples are RSPB, BTO and OXFAM, The Nature Conservancy. This research is often published. Opinion is also disseminated to the public through subscription magazines and websites. NGO can therefore have powerful influence on public opinion.

## Private companies

Oil companies support some work on biofuels in the UK through research council and Government Initiatives, and also through direct collaboration with individual University Groups. However, research is conducted on a global basis, and currently centres for biofuels research are not within the UK.

Currently skills development in biofuels is through recruitment, training, ongoing experience and via open innovation with external partners.

It is the view of Shell that long-term funding of R&D is essential in creating a critical mass of expertise and experimental resources. The establishment of centre(s) of excellence in biofuel R&D in the UK is required, and the research councils and Governmental bodies should join forces and work together to ensure that the UK's world leading science base in biological and chemical disciplines is more effectively linked and supported. This is necessary to ensure that policies and funding are aligned and supportive of a common vision.

The point was made that it is difficult to recruit and retain staff with expertise in biofuels, as there are many more opportunities in this field in Europe and the USA.

Vehicle manufacturers generally have some in-house expertise in biofuels, with staff trained as necessary. However, main research effort is not in the UK. Main interest is in performance of biofuels in vehicle engines with respect to performance, maintenance and emissions. They perceive a need to inform potential users about biofuels, and SCANIA have developed their own guidance on biofuels use.

Biofuels production companies - there was little response from this sector on skills development. Those who responded have recruited and trained staff as required for their biofuels plant.

### **Skills development and information dissemination at the Regional level**

RDAs have a remit for regional development. As such they are keenly interested in opportunities to develop and maintain skills in the region, with a view to increasing both quantity and quality of employment opportunities. As such, individual RDAs have interest in biofuels where they believe there is an opportunity for their region, often in supporting existing business capabilities. For example, in EEDA they are involved in development of novel energy crops, in YH/NE they are hoping to develop existing chemical manufacturing skills to develop biofuels conversion plant, in west Midlands the emphasis is on developing new low carbon vehicles.

Large projects are usually funded by a mixture of Central Government funding and EU Funding, often through the European Regional Development Fund (ERDF), in combination with large companies with a local presence.

There is a wide variation between the regions in their knowledge of and involvement in biofuels. Some examples of biofuels initiatives are given below.

#### **EEDA**

The Innovation in Crops project led by the University of East Anglia to implement the InCrops Enterprise Hub over the 2008-2013 period. Project has 13 partners in the region and aims to develop and exploit novel crops for non-food uses.

#### **East Midlands Development Agency (EMDA)**

EMDA is ensuring appropriate support is available for Further Education Colleges and Skills Providers to provide suitable training within the region in energy technologies.

Energy Connections Programme is a new way to encourage mutually beneficial international collaboration in the energy sector. The programme aims to bring together companies from around the globe to collaborate with industry and educational bodies in the East Midlands for mutual benefit. This collaboration could, for instance, take the form of companies partnering together to advance innovate energy technology projects; or of universities and companies working together to find placements for students, either as part of work experience within undergraduate degrees or to place post-graduate students working on projects. The programme will involve more than 50 companies in the East Midlands, as well as universities and colleges.

There is an opportunity for further work on skills development and information dissemination at the regional level, but this will depend on the region identifying biofuels as an attractive investment option for the region. The NW region has warned that the biofuels market there is in difficulties due to the ready availability of cheaper biofuels and biofuel feedstock imports.

North East Process Industries Cluster (NEPIC) have identified a shortage of both specific skills and competencies and upcoming talent in the Process Industry. This will also affect the nascent biofuels industry. NEPIC is working to address both regional skills shortages and to set up a National Skills Academy for Process Industries (NSAPI).

Respondents did not comment on the type of skills training required for biofuels. Two surveys into this question were identified, and brief summaries of the results are given below.

ThermalNet, a bioenergy R&D network conducted a two-part survey on the supply and demand for higher education and training in the bioenergy field in Europe. Respondents said that there is currently a shortage of applicants with bioenergy know how, and they anticipate this will continue in the next 5-10 years. Respondents believed that higher education courses for students, preferably including industrial placements, and short seminars for industry were required address this gap.

US Association of Energy Engineers carried out a survey amongst its members relating to green jobs and energy independence. Respondents felt that the Biofuels and renewable energy sector is facing a serious shortage of qualified professionals in the next 5 years and that there was a need for national and state training for "Green Jobs" to address job shortages that are impairing growth in green industries, such as energy efficient buildings and construction, renewable electric power, energy efficient vehicles and biofuels development.

At the workshop there was general agreement that the type of training required would be higher education (masters degrees) for a wider discipline such as 'low carbon energy technologies' that would include biofuels. This could follow a degree in a related discipline such as engineering or natural science or environmental science and should include industrial placement.

There is also a need for ongoing professional development, which would be shorter courses to address the need to increase awareness amongst managers of biofuels and the opportunities they present to help with company climate change and energy objectives.

There was agreement that there would be a shortage of trained bioenergy professionals if UK biofuels targets are to be met through development of a UK biofuels industry. The point was made, however, that currently a large proportion of biofuels is imported, and that the UK obligation could continue to be met in this way. If there is no substantial UK biofuels industry, then trained professionals will not be required. In fact, the current trend of young professionals to obtain jobs in Europe and the USA is likely to continue.

## **UK**

### **Government Funded R&D**

Information from Research Council funded programmes such as RELU, TSEC and SUPERGEN is disseminated via meetings and peer reviewed publications to the research community. However, there is an opportunity to make this work more easily available via the programme websites, and possibly through a biofuels resource centre.

Information from Defra, DECC and TSB funded work is generally published and available through the relevant website, but again it would be more easily accessible through a biofuels resource centre.

Work from the Carbon Trust is not currently fully published. Access to this work by a wider audience would be welcome.

## KTNs

The objective of a Knowledge Transfer Network is to improve the UK's innovation performance by increasing the breadth and depth of the knowledge transfer of technology into UK-based businesses and by accelerating the rate at which this process occurs. The Network must, throughout its lifetime, actively contribute and remain aligned to goals of the sponsoring organisation, the Technology Strategy Board. An important part of KTN work is to provide a forum for a coherent business voice to inform government of its technology needs and about issues, such as regulation, which are enhancing or inhibiting innovation in the UK.

A number of KTNs currently have an interest in some aspects of biofuels:

- Chemistry Innovation Knowledge Transfer Network (CIKTN)- in the biofuels area CIKTN is involved with One Northeast in developing a biofuels project in the NE Region. It ran a workshop on development of measurements and standards for biofuels.
- Bioscience for Business KTN is developing the Integrated Biorefining Technologies Initiative. Working to define the RD&D needs of biorefineries for industrial implementation. Initial funding from BBSRC to look at how bioscience developments from the research programme can be progressed to deployment.
- Low carbon and Fuel cell KTN- biomethane community aims to act as one voice for the biomethane (from AD) community and to provide an information exchange forum.
- Resource Efficiency KTN and Environmental KTN are sponsoring seminars to inform about bioenergy from waste opportunities

However, no one KTN is looking at biofuels as a whole, or representing the needs and views of the biofuels community to Government. There is an opportunity to focus KTN effort in this area to bring forward biofuels projects. However, as mentioned earlier, TSB does not currently see biofuels as a priority area so the prospects of a biofuels KTN is uncertain

NNFCC provide independent information and advice on renewable fuels, materials and technologies to agriculture, academia, Government, industry, the media and the public. This is done by:

- Dissemination of technical and policy research
- Biofuels and biorefineries are major topic areas within NNFCC portfolio. Research is published and available on the NNFCC website, and disseminated via workshops and newsletter.
- Encouraging industrial partnerships
- Run free seminars to introduce industry/academics. Currently facilitating and promoting biofuels demonstration projects.
- Information dissemination on biofuels events
- Events are run by many different organisations relating to aspects of biofuels. NNFCC publish a listing of relevant events.

Biomass Energy Centre was set up as a 'one stop shop' to provide information to anyone in the UK with an interest in biomass derived solid, liquid and gaseous fuels and associated conversion technologies. The BEC currently focuses on wood fuel supply and heat production. The Centre operates a website, on-line library and helpline.

LowCVP Fuels Working Group is involved in biofuels development and deployment. They currently fund work from core funds in relevant areas, with a wide portfolio of projects across many important areas of biofuels. They recognise that the programme needs to complement others in the sector such as the NFCCC and Concawe and new entrants in the sector including TSB, ETI, RFA and Carbon Trust. LowCVP have a remit to provide a forum for stakeholders to share knowledge and information. They carry out this important dissemination function through the Working Groups, extensive industry contacts, open meetings, publications and website.

Scientific Societies Several in related areas run dissemination events in biofuels area. Such seminars tend to relate to the specific interests of members and are prolific at the moment because of the current high profile of biofuels. Useful to disseminate facts about biofuels. e.g. Society of Chemical Industry.

Societies also run exchange studentships, some of which can relate to biofuels, e.g. NEST-Excellence Group in Thermal Power and Distributed generation at the Mechanical Engineering Institute, Federal University of Itajubá at Itajubá, Minas Gerais, Brazil have a link with Durham University through a Royal Society Exchange Project related to the modelling and test of biomass gasifiers/internal combustion engine systems.

In summary, there are a number of organisations working to disseminate information in the bioenergy area in the UK. It would be helpful if one communication conduit between Government and Industry were dedicated to biofuels, and one organisation took on the task of collecting and disseminating published information on biofuels.

## Europe

Framework Programme (FP7) is the main instrument through which R&D projects are supported at the European level. FP7 projects encourage industrial participation, particularly from SMEs. There are a number of projects on all aspects of biofuels. All projects have a dissemination element, usually by project website, report and workshop/ seminar. FP7 also supports a number of biofuels projects devoted to information exchange and dissemination and to policy development. The most relevant to biofuels are:

### EU Biofuels Technology Platform

The Mission of the European Biofuels Technology Platform is to contribute to the development of cost-competitive world-class biofuels technologies and a healthy biofuels industry supplying sustainable biofuels in the European Union, through a process of guidance, prioritisation and promotion of research, development and demonstration. It has a wide membership amongst the European biofuels industry and offers the opportunity for discussion, information exchange and communication of needs in Biofuels research to the EU and National governments. The EBTP is producing a map of EU biofuels projects.

### ERANET – bioenergy

The objective of the project is to establish co-operation between national bioenergy research programmes in the member states. Specific aims are:

- exchange of information and best practices on national programmes
- identify administrative or legal barriers that could hinder transnational co-operation
- to enable exchange of personnel
- to set up pilots of joint work programmes.

ERANET are currently investigating the prospects for SNG, and for co-operation on biorefinery

### **Biofuel Cities European Partnerships Consortium.**

A one-stop-shop for information and exchange on the broad scale application of liquid and gaseous biofuels. implementing biofuels standards in Europe.<http://www.biofuel-cities.eu/index.php?id=4255>

### **Joint research centre**

Involved in a range of biofuels projects on behalf of the EC. Much information published on the website.

### **International Scientific Cooperation Projects**

Examples relevant to biofuels are:

- the Cane Resources Network for Southern Africa (CARENSA), led by the Stockholm Environment Institute- working with a range of EU, African, Brazilian and international partners to share information.
- the Competence Platform on Energy Crop and Agroforestry
- Systems for Arid and Semi-arid Ecosystems – Africa (COMPETE). Aims to evaluate current and future potential for the sustainable provision of bioenergy in Africa and to facilitate South-South technology and information exchange from key countries Brazil, Mexico, India, China and Thailand by establishing the Competence Platform to ensure effective dissemination and knowledge exchange inside and outside the network.

### **Intelligent Energy Europe (IEE2)**

- IEE2 focuses on removing barriers to the take-up of energy efficient technologies and renewables. It is a non-technological funding programme. It co-finances international projects, events and the start-up of local or regional agencies. Areas of relevance are:
- Promotion of new and renewable energy sources for electricity, heat and biofuels (ALTENER)
- Energy aspects of transport, fuel diversification, biofuels and energy efficiency (STEER)
- UK partners benefit from the experience of working at a European level, from networking opportunities and from developing new working relationships. The UK also benefits from the knowledge gained by UK participants and from the removal of the barriers to renewables and energy efficiency measures generally.

There are a number of European groups disseminating information relating to biofuels, such as:

European Renewable Raw Materials Association- seeks to promote and develop the market-led use of renewable raw materials and resources. As part of this it is actively involved in establishing standards for renewable raw materials and in disseminating information and know-how at a European and international level. Participants are 5 national agencies, including the NNFFC from the UK.

FNR- German Renewable Resources Agency- Provides a BtL information platform (a website). The aim of the BTL information platform (BTL-IP) is to simplify the exchange of information between the institutions and companies that are involved in the development of BTL fuels and to improve dissemination to all relevant companies

Energy research Centre of the Netherlands - maintains the Phyllis database, which contains information on the composition of biomass and waste.

Stockholm Environmental Institute- co-ordinates a network previously funded by EC aimed to synthesis, policy analysis and North-South-South knowledge transfer. Work is ongoing and many documents are available on the website for downloading

## **USA**

There is a very large program of biofuels R&D in the USA. The Biomass R&D Board was created to co-ordinate programs within and among agencies and departments relating to bio-energy, and has representatives from all relevant major US Departments and Agencies. The National Biofuels action Plan has been produced by the Board and covers all aspects of the bio-energy supply chain. Regarding skills development it states that 'Progress against these tight timelines (for biofuels development) will require an adequate supply of skilled technicians, builders, and managers. Human capital development will be important to maintain the pace of biofuels production capacity growth. To meet this challenge, government agencies will need to work collaboratively with university and other partners to assess workforce development needs and respond with well-crafted technical training and advanced science education programs.

The Biomass multi-year program plan highlights that stakeholder communications and outreach, strategic partnerships, and government policy and regulation are important to the development of bio-energy industries. Communication is a common theme, with information dissemination planned for all stakeholders and the public, closer working relations with state and regional organisations and discussion and development of biofuels standards at both national and international level.

Much information is published and available via the relevant websites.

## **Brazil**

CENBIO was set up by an agreement among the Ministry of Science and Technology (MCT), the Energy Secretariat of the São Paulo State (SEE), the São Paulo University (USP) and the Biomass Users Network of Brazil (BUN). CENBIO was established with the main goal of promoting the development of research activities and the disclosure of scientific, technologic and economic information to make feasible the use of biomass as an efficient energy source in Brazil.

In order to achieve these goals, for over ten years, CENBIO has been focused on the development of studies and projects aiming at the use of biomass, and promoting the interchange among Brazilian and foreign institutions of technical information and economic, social and environmental results of biomass technologies uses for energetic ends. Sharing knowledge and spreading information on the perspectives of biomass technologies development have been accomplished by countless articles, the organization of seminars, this website and the Revista Brasileira de Bioenergia.

The Brazilian Sugarcane Industry Association (UNICA) aims to provide consumers, government officials, NGOs, the business community and the news media with up-to-date, detailed information on vital social, economic and environmental contributions of Brazil's sugar, ethanol and bioelectricity sectors. UNICA is not a research organisation, but rather carries out communication and dissemination functions. Areas of activity are: Sustainability, Agro-environmental Protocol, Multi-stakeholder certification initiatives, land use changes in Brazil, biofuels and food, agricultural improvements on sugar cane, Environmental and Social Impacts of Bio-ethanol Production in Brazil.

Many of the papers from Brazil are in Portuguese. The potential to work through UNICA to obtain a greater coverage of available Brazilian research could be explored.

## **International**

### **Bilateral agreements**

The UK has MoU on energy R&D with the USA and China. Opportunities for collaboration on biofuels research under these agreements could be explored.

**International Information Exchange networks** IEA bio-energy aims to accelerate the use of environmentally sound and cost competitive bio-energy on a sustainable basis, thereby achieving a substantial contribution to future energy demands. IEA bioenergy relies on co-operation between participating countries in each task. There are currently 13 tasks, and all are relevant to biofuels, with tasks 39 and 42 most directly supporting biofuels development. Co-operation, exchange of information and dissemination are central to the ethos of IEA bio-energy. Work is published and available on the IEA bioenergy website and there is a comprehensive programme of workshops. In addition, the task is increasingly being asked for advice in policy development and participation in International fora. Historically, the UK has had a high level of participation in IEA Bioenergy, and participants have found that involvement in the tasks is useful and rewarding. Continued participation is recommended, and there is opportunity for greater feedback and dissemination of output throughout the UK research community.

#### **International bioenergy working groups**

Aim to achieve common understanding of bio-energy terms, and to implement common standards and methodologies where appropriate. Aim is to maximise environmental benefits and increase ease of trade in biofuels.

There has been a proliferation various fora and working groups at both National and International level. There is now a need to rationalise the information flow between these groups to ensure that information/ requirements are fed from the local to national to international level and back again in the most effective and constructive way. It is important to ensure that Industry is involved in these discussions, but also that particular industry interests are not allowed to dominate the outcomes. The two most relevant groups for biofuels currently are:

Global Bioenergy Partnership (GBEP) has a high rate of participation from the major countries and organisations involved in biofuels throughout the world. It is thus able to promote global high-level policy dialogue on bioenergy and facilitate international cooperation. At the moment it is particularly active in working to harmonise approaches to sustainability and GHG methodologies for biofuels. It also aims to foster exchange of information, skills and technologies through bilateral and multilateral collaboration and to identify and overcome barriers to biofuels development. GBEP is working with other biofuels initiatives including FAO International Bioenergy Platform (IBEP), International Biofuels Forum IBF) and UNCTAD Biofuels Initiative.

Roundtable on Sustainable Biofuels- is attempting to develop a globally-applicable standard for sustainable biofuels. This is being done by wide consultation, including stakeholder workshops and teleconferences and one to one phone calls. The RSB remains committed to incorporating and recognizing other sustainability standards work, and to harmonizing and reducing any eventual reporting burdens as much as possible.  
<http://energycenter.epfl.ch/biofuels>



AEA group  
329 Harwell  
Didcot  
Oxfordshire  
OX11 0QJ

