# Biofuels for Road Transport

Biomass is a potential source of renewable energy for the UK. The carbon dioxide ($CO_2$) absorbed from the atmosphere during the growth of biofuel is released back to the atmosphere when the biofuel is burned. Hence the combustion of biomass does not directly add to the level of carbon dioxide in the atmosphere. However, there are emissions of carbon dioxide (and other greenhouse gases) from the production of crops and the manufacture and distribution of biofuels so the use of biofuels results in some net emission of carbon dioxide (and other greenhouse gases). The net $CO_2$ emissions vary with the biofuel and way it is produced but with the best options they can be very low.

Biofuels offer lower overall $CO_2$ emissions than conventional fossil fuels. HMG estimate that adding 5% of bioethanol and FAME (biodiesel) to petrol and diesel could save up to 1 of the current 32.5 million tonnes of carbon emissions from road transport.

The Government's 2003 Energy White Paper highlighted that biomass could be used to reduce emissions of carbon dioxide from heat and power generation and/or road transport. The future balance between these two uses will be determined by the reaction of growers, farmers, fuel producers, fuel suppliers and fuel users to Government policy, based on the economics of biofuels. The Royal Commission for Environmental Pollution has already supported the use of biomass for power generation and the Government has set up a Biomass Study Task Force, led by Sir Ben Gill, to examine the power generation option in detail. Hence this paper, by the Low Carbon Vehicles Partnership's Fuels Working Group, concentrates on the use of biomass for transport fuels.

## Background

HMG has decided to put the UK on a path to reduce UK emissions of carbon dioxide in 2050 to around 60% of the 1990 level. Road transport will have to contribute towards meeting this target. For 2020 the transport sector's contribution is a reduction of around 2 to 4 MteC below the level predicted with current policies. Government expects to achieve this by a combination of improved vehicle efficiency and biofuels, probably as a 5% blend in petrol and diesel.

The Government is already encouraging the use of biofuels for road transport. Budget 2004 confirmed that the current 20 pence per litre duty incentive in favour of both biodiesel and bioethanol will be maintained until at least 2007 and that the Government will discuss the application of enhanced capital allowances (ECA) to support investment in the most environmentally beneficial biofuels processing plants with stakeholders. Further work on the details of an ECA scheme was announced in Budget 2005. In addition the 2004 Energy Act contains enabling legislation for the introduction of a Renewable Transport Fuels Obligation (RTFO) which could require companies to provide biofuels as a given percentage of their total sales. The basis and feasibility of a RTFO has been examined by a Government inter-Departmental group drawn from HMT, DfT, DEFRA and DTI.  Their report is expected to be published in late 2005.

The EU Biofuels Directive 2003/30/EC set indicative goals for biofuels use of 2% of road fuel energy content by the end of 2005 and 5.75% by the end of 2010.  A wide rage of gaseous and liquid road fuels derived from biomass can be used to meet the indicative goals.  Each member state has to set its own targets.  For 2005 the UK has set a target well below the indicative figure in the Biofuels Directive.  No UK figure has been set for 2010 yet.

Well to Wheels studies indicate that the low carbon options for future road transport fuels are:-

- hydrogen made from renewables (wind, wood, etc), nuclear power or fossil fuels with carbon sequestration, especially when used in fuel cell vehicles.
- biofuels made from conventional crops (wheat, sugar beet, rape seed, etc), energy crops (short rotation coppicing, miscanthus, etc) and organic wastes.
- battery powered vehicles (dependent on a supply of low carbon or renewable electricity and advances in battery technology)

The carbon saving and cost varies significantly between the various options and it is too early in the development of many of the technologies to be able to pick the long-term winner(s).  For biofuels the net greenhouse gas emissions will vary with the crop or waste chosen as the feedstock, the agricultural system used to grow it, the conversion technology used to process it and how efficiently the biofuel is used. Some biofuels are available now.

Hydrogen from a low carbon or renewable source is widely considered to be the best long-term option.  Governments, motor manufacturers, component suppliers, oil companies and other companies are already investing in the development of hydrogen powered fuel cell vehicles and pilot hydrogen filling stations.  However some biofuels can deliver similar carbon dioxide savings and so could be a good long-term option in their own right. They also provide an alternative should the hydrogen option not overcame the significant technical and cost challenges it faces.

## Biofuels

Biofuels can be produced from traditional food crops (the conventional biofuels in the table below), from waste organic material (the established biofuels) and from energy crops/ waste using new technology (the advanced biofuels).  Some examples are given in the table below.

## Examples of Biofuels and their Production Processes

| | Biofuel | Crop / Feedstock | Production Process |
|---|---|---|---|
| **Conventional** | Ethanol | Sugar beet, sugar cane, wheat, maize, etc | Fermentation |
| | ETBE | Made from bioethanol | Reaction with isobutene |
| | FAME (Biodiesel) | Rape, soya, palm, used cooking oil, etc | Trans-esterification with methanol |
| | Diesel | Rape, soya, palm, etc | Refinery hydrotreater |
| **Established** | Biogas (Methane) | Waste, etc | Anaerobic digestion |
| **Advanced** | Ethanol | Straw, Wood, etc | Enzyme hydrolysis followed by fermentation |
| | Hydrogen | Short rotation coppice, miscanthus, straw, waste | Gasification, shift reaction |
| | DME | Short rotation coppice, miscanthus, straw, waste | Gasification, chemical synthesis |
| | Methanol | Short rotation coppice, miscanthus, straw, waste | Gasification, chemical synthesis |
| | FT diesel | Short rotation coppice, miscanthus, straw, waste | Gasification, chemical synthesis (Fischer Tropsch synthesis) |

Conventional biofuels are currently used in a number of countries so experience to guide their successful introduction in the UK is available. FAME, in particular, is relatively easy to incorporate into diesel blends. Ethanol requires special handling and distribution due to its high blending vapour pressure and affinity for water. ETBE, which is made from bioethanol, eliminates these problems but raises concern over water contamination, similar to that experienced with MTBE in the USA. However ETBE is safely used in many countries, including France, and could be used to replace current MTBE production.

Advanced biofuels are produced from non-food feedstocks and waste through processes currently under development, such as ethanol production from straw and wood, or diesel production from wood using gasification and the Fischer-Tropsch process (known as Biomass to Liquids (BtL)). These processes are predicted to give better quality fuels or extend the range of biomass that can be processed or give a better well-to-wheels reduction in greenhouse gases or a combination of these. Advanced biofuels will not be constrained by a limit on the bio-content which presently operates through fuel quality standards – see below.

Established biofuels from non-food sources include biogas made by anaerobic digestion of organic waste. E4tech's December 2003 report for DfT identified that converting the organic fraction of the UK's municipal solid waste, sewage sludge and farm slurries plus captured landfill gas could supply 13% of the UK's road transport needs. It is currently unclear whether the biogas (55-70% methane plus carbon dioxide and other gases) is best used directly to raise power or cleaned up, compressed and stored for use in specially converted natural gas powered vehicles. Further information will be available in late-2005 when a revised European Well-to-Wheels study will cover this pathway.

## Availability of Technology

The technology for producing biofuels from biomass could become available in the following time frame.  The timeframe could be altered by Government support for development of the new processes or by advancement in the technology of conventional biofuel production:-

2000-2010 Conventional biofuels, biogas, FAME from vegetable oil and bioethanol from wheat, sugar beet, etc, are available now.  Other processes are at the demonstration or pilot plant phase.  First commercial plant converting straw to bioethanol will be commissioned towards the end of this period.  Refinery conversion of vegetable oil to diesel will be proven. Combining liquid biofuel and electricity production will be used to improve the carbon efficiency of utilising biomass.

2010-2025 Fuels, electricity and chemicals are available from a range of energy crops, waste and biomass. Processes to convert lignocellulose to bioethanol are available, initially with straw as the feedstock.  Biomass to liquids (FT diesel) technology should also becomes available post 2015 along with improved power generation from gasification of biomass.  The biofuels content of petrol and diesel may be increased from the current 5% by volume.

2025-2050 The future cannot be predicted, but it is possible that hydrogen be will be produced from biomass and that a hydrogen fuel distribution infrastructure put in place.    Another scenario would be that biofuels improve so much that hydrogen does not take-off or co-exists with biofuels in road transportation.

## Biofuel production

In the short/medium term conventional biofuels (bioethanol and FAME) are likely to form the bulk of biofuels used in road transport.  They will be produced either in the UK from conventional crops (wheat, sugar beet, oil seed rape plus other oilseeds) and perhaps straw or imported. Replacing 5.75% of the energy content of current UK petrol and diesel sales with bioethanol and FAME from conventional crops would require around 1.75 million hectares of land – see Appendix.  This area could be reduced by converting the wheat and sugar currently exported to biofuels.  For example the UK usually exports around three million tonnes per annum of wheat which could be used to produce about one million litres of bioethanol, if incentivised to remain in the UK for bioethanol production.

Before 2010 the conversion of straw to bioethanol will be demonstrated at the commercial scale.  Converting unprocessed rape and other vegetable oils to diesel in a refinery hydrotreater will also have been demonstrated at the commercial scale, provided suitable incentives are in place.  HMG is currently considering how to introduce “input taxation” on biofuels to help. The commercial demonstration will confirm the energy/carbon balances and economics of these options.  Converting waste streams to biofuels may also make a contribution in the future.

After 2010 a range of advanced biofuels processes, currently being developed, may become commercially available based on low value/high volume energy crops. Current wells to wheels studies predict that these advanced processes may offer a larger reduction in emissions of carbon dioxide and a greater reduction in carbon dioxide per hectare of land used to grow biomass. The advanced processes will largely be based on the energy crops currently being encouraged in the UK for power production, but may also include a considerable contribution from waste organic matter. The economics of these options have still to be confirmed by commercial operation

## Limitations

### *Fuel Standards*

Only a maximum of 5% ethanol by volume or 15% of ETBE (a ether made from ethanol) can be blended into conventional petrol and 5% of FAME into diesel without potentially invalidating vehicle warranties or exceeding the limits in the European / British standards for petrol and diesel. The limits for ethanol and ETBE are also in the EU Fuels Directive 2003/17/EC and the UK Motor Fuels (Composition and Content) Regulations. The limits are based on a variety of factors compatibility of materials, effect of trace by-products from biofuel manufacture, etc. Over time the limits may be changed by CEN, the European Standards Organisation, provided there is a consensus.

Other countries already operate with higher limits for ethanol eg the USA has a limit of 10%. Hence some cars sold in Europe are capable of operating with a higher ethanol concentration in petrol. However ethanol use above 5% could not be easily adopted for general use in the UK or the EU until the current fleet has been turned over.

The use of flexible fuelled vehicles (FFVs), which are specially designed to utilise a range of biofuel concentrations in either petrol or diesel, provide an alternative approach. Ford sells an ethanol FFV Focus in Sweden. Saab and Volvo plan to introduce ethanol FFVs this year.

The limits on FAME concentration in diesel do not apply to most of the advanced processes under development or the possible option of converting vegetable oil to diesel in a refinery hydrotreater. For example the BtL option produces a very high quality diesel which can be used in any concentration in conventional vehicles.

### *Available Land*

The UK can only devote a limited area to the cultivation of crops for biofuels. The total land area of the UK is around 24 million hectares (ha). In 2002 DEFRA estimated that about 6.5 million ha was arable land made up of around:-

- 4.5 million hectares under arable cultivation,
- 0.7 million hectares “set-aside” (reduced in subsequent years)
- 1.2 million hectares under grass less than 5 years old so could theoretically be brought back into use for growing crops, although there may be major cultural and environmental constraints including a significant reduction in animal husbandry.

A further 11 million hectares is specified to be grazing land for livestock including rough grazing. Around 5.6 million hectares in improved grazing which is intensively managed and low in biodiversity. This is theoretically suitable for arable or perennial energy crops, but in practice it is very unlikely that farmers would plough up grassland to plant an arable crop as this would be a reversal of current trends of agricultural specialisation. (Note using some of the UK's long established grassland to grow biofuels would affect the carbon stored in the soil and could result in releases of $CO_2$ sufficient to wipe out the $CO_2$ saving from biofuels over a number of decades.)

Forest or woodlands cover 2.8 million hectares. The remainder of the UK's land area is taken up by towns, roads, recreation, semi-natural environments, e.g. sand dunes, grouse moors and non agricultural grasslands, and inland waters.

Hence there are about 2 million hectares of arable land available in the UK to grow biofuels, without affecting current food production. However, in practice environmental constraints (see below) will reduce the area available to 1-2 million hectares. This will limit the amount of conventional biofuels that can be grown in the UK to around 5-10% of road fuel use. This would enable the maximum currently permitted by UK and European fuels standards, 5% by volume of bioethanol and FAME, to be added to petrol and diesel respectively. This would require 1.2 million hectares of arable farmland.

The Biofuels Directive 2003/30/EC indicative target for 2010 of supplying 5.75% of the energy content of road fuels is also within reach with UK production of bioethanol and FAME. This will require around 1.75 million hectares of arable farmland.

As UK FAME production requires more land than bioethanol production, the area required for biofuel production will increase if the demand for diesel continues to rise and the demand for petrol continues to fall. The area required for the UK production of bioethanol and FAME could be reduced, by using the wheat and sugar currently exported for the production of bioethanol and, in the future, the conversion of straw to bioethanol.

Competing with land for energy crops to generate electricity could reduce potential UK production. It may be possible to alleviate this to some extent by developing "bio-refineries" to extract a range of products from the woody plant material before the residue is burnt. Further work is required to explorer this possibility.

In their study for DfT, E4Tech estimated that around a third of UK road fuels could be replaced by biofuels by using advanced biofuels production processes which give a higher yield of road fuels per ha, more land (4 million ha) and converting waste streams. Hence imported biofuels would be needed if the UK wanted to move to very high usage of biofuels.

## Cost

The cost of the domestic and overseas produced biofuels is around 2-4 times the price of conventional road fuels so some intervention in the market will be required to stimulate the widespread introduction of biofuels in the competitive UK road fuels market. This could be a duty differential, the current policy, and/or a Renewable Transport Fuels Obligation under the 2004 Energy Act. Both these options have advantages and disadvantages.

Like other many other ways of reducing $CO_2$ emissions from road transport, the cost per tonne of carbon saved with biofuels is high. No precise figures are available but published studies give a range of values eg Sheffield Hallam's January 2003 study for DEFRA quotes £600-1200/teC for FAME from oilseed rape, British Sugar (private communication) estimate £450-500/teC and the December 2003 JRC/Concawe/Eucar Well-to-Wheels study quotes £570-900/teC for FAME and £660-£1500/teC for bioethanol. These figures are much higher than options in other sectors including the EU Emissions Trading Scheme where the current price of carbon is around £20/te carbon and HMT's illustrative cost of saving carbon of £70/teC in 2000 rising to £100/teC in 2030.

## Environmental Impact

Annual crops (cereals and oilseeds) and perennial energy crops (miscanthus and SRC willow) are different in terms of area under cultivation, inputs required, harvesting practices, etc. For example miscanthus and SRC willow require low inputs of fertilisers and crop protection products compared with annual crops. Hence their environmental impacts cannot be easily compared.

Cereals and oilseeds are already grown extensively in the UK and their final use for food or biofuels should be regulated in the same way. However significantly increased production of wheat, oilseed rape, sugar beet, SRC willow and miscanthus will alter the intensity and diversity of agricultural land use in the UK countryside, with possible effects on:-

- Biodiversity (Biodiversity Action Plan priority species and habitats; Sites of special scientific interest and farmland birds)
- Water quality (affected by inputs of agrochemicals)
- Soil quality/erosion
- Landscape character

Additionally, perennial woody biomass crops grow on the same soil for 15-20 years and may have additional specific issues, for example effects on the water table.

Some of these effects will be positive, while others will be negative. Overall, it is impossible to predict what the net effect will be at local, regional or national scales. However, we can anticipate that further intensification of arable crop production – for example by growing biofuel crops on set-aside that is currently uncropped – would probably have negative impacts, while areas dominated by intensive grasslands would probably benefit from the introduction of woody biomass crops. There should therefore be a strategic environmental assessment of the possible effects on habitats from changing crop growth in the UK before biofuels are adopted on a large scale.

Perennial biomass crops may become increasingly important as biofuel feedstocks during the next few years. Currently there is a requirement within the Energy Crops Scheme for all plantations of SRC willow and miscanthus over five hectares to undergo an environmental impact assessment (EIA) before grant funding is agreed. This may limit the density of perennial biofuel crops in some areas. However, the area of arable biofuels, such as wheat and oilseed rape, is not regulated and will be determined largely by agronomic and market factors. (NB HMG does not intend to limit production to the catchment area of the biofuel plant for arable crops.) The Partnerships recommends that the Government should monitor changes in the area of the various biofuel crops grown in the UK in order to predict any adverse environmental impacts and, if necessary, put in place mitigation measures to prevent these impacts from occurring.

It is likely that genetic modification (GM) will be used in the future to improve yield and quality traits of crops used as biofuel feedstocks. The Partnership recognises (and supports) that the environmental bio-safety requirements for deliberate release of GM crops are currently assessed in the same way for both human consumption and industrial use. This means that, provided that growers of GM crops comply with national regulations on good agricultural practice and GM crop release requirements, growing GM crops for biofuels should cause no additional environmental impacts compared with 'conventional' crop management.

A biofuels accreditation scheme is required to ensure that biofuels are produced in a sustainable way and that the greenhouse gas savings from the various options are identified.  The farm to wheels greenhouse gas savings for imported biofuels should include emissions from transporting the biofuel to ensure that the comparison with UK produced biofuels is fair.  The scheme needs to be non-bureaucratic and internationally accepted so that imported and domestically produced biofuels are covered.  The development of a biofuels accreditation scheme should not be used to delay the development of biofuels in the UK.

Under international rules the carbon dioxide emitted from biofuels used in road transport is assumed to be zero.  The emissions from growing biofuels and from their production are allocated to the agricultural and, if appropriate, industrial sectors.  This gives imported biofuels an apparent advantage in their contribution to total UK greenhouse gas emissions.  However the objective is the global reduction in greenhouse gas emissions so it is important that biofuels “farm to wheels” emissions are fully established and options assessed on a global basis.

## Future Work

The paper, and work conducted to date by the Fuels Working Group highlights a number of key points that indicate the future direction of partnership activity in this area:

1. The carbon saving achieved by different biofuels various significantly depending upon the type of fuel and method of production. The LowCVP's Fuels Working Group's (FWG) Well- to-Wheels (WTW) study examining production of bioethanol from wheat showed carbon savings of between 7 and 77% were possible depending upon the production process. Advanced biofuels may achieve higher savings than these.
    - LowCVP should seek to ensure that WTW carbon saving considerations are incorporated within allocation of Government grants/incentives, development of the fuel duty regime and possibly the renewable transport fuels obligation
    - After the revised JRC/Concawe/Eucar European WTW has been published the LowCVP FWG should consider whether further work is required to explain the differences between published WTW studies

2. Enabling legislation for a Renewable Transport Fuel Obligation was included in the 2004 Energy Act.
    - The Partnership should work closely with HMG on its feasibility study on the Renewable Transport Fuels Obligation to ensure that a broad range of stakeholder opinions are heard.

3. The use of Conventional Biofuels is presently constrained by supply. However, European fuel quality standards, which limit the proportion of conventional biofuels allowed in petrol and diesel, could become a significant constraint post 2010. The long-term appropriateness of the current standards needs to be reviewed.
    - The Partnership should encourage The UK BSI to ask CEN, the European Standards Organisation, to examine whether the present 5% limit on bioethanol and FAME in petrol and diesel is still appropriate or whether modifications to biofuel quality specifications could enable limits to be increased without affecting vehicle reliability. A positive response would help persuade the European Commission to consider changing the Fuels Directive.
    - The Partnership should encourage all stakeholders to collect evidence of both successful operation and problems with biofuels blended into both petrol and diesel. The evidence would help CEN decide on whether a change in the current specifications is justified.
    - The Partnership should examine ways of accelerating the development and supply of biofuels through support for R&D, fiscal and other incentives

4. An accreditation scheme to mitigate social and environmental impacts of large-scale production of biofuels and to ensure manufactured fuels achieve quantifiable carbon savings is needed in the medium/long term. Initially, a single, voluntary UK scheme should be developed to ensure that biofuels are grown and manufactured in a sustainable manner. However the development

of an accreditation scheme should not be used as a barrier to establishing a UK market for biofuels. As an international market for biofuels develops an equivalent CEN or ISO scheme will be needed.

- The Partnership should work to introduce a single, credible, voluntary standard for biofuel supply in the UK incorporating, as far as possible, existing schemes and systems.

5. The Partnership should encourage DEFRA to carry out a strategic environmental assessment of the possible effects on habitats from changing crop growth in the UK, before biofuels are adopted on a large scale. The purpose of the strategic environmental assessment should be to produce an overview of where, when and under what conditions possible problems could occur, e.g. what would be the environmental impact of converting the majority of set aside land to biofuels production? It should not lead to restrictions on individual farmers, especially those growing arable biofuels like wheat and rape. It should also suggest possible mitigation strategies for averting these impacts, e.g. changes to agri-environment schemes to include support for environmental management of biofuels grown on set aside. Much of this research has already been done so it should not be onerous to pull together into a more formal strategic assessment.

5. The Partnership should encourage DEFRA to monitor the area of biofuels crops grown in the UK and the environmental impacts/benefits of these crops when grown under normal agronomic conditions. A dramatic increase in demand for biofuels is likely to lead to longer term shifts in farming patterns and it will be critical to monitor these trends so that we can anticipate the environmental consequences, whatever they may be.

**January 2005**

### Table - Biofuels required to meet the 2010 Indicative Value of 5.75% by energy content of EU Directive 2003/30/EC

| **Fuel** | **Sales** (Nov 03–Oct 04) Mte/a | **Energy Content** GJ/te | **Energy** PJ/a | **5.75% of Energy** PJ/a | **Biofuels Required** Mte/a |
|---|---|---|---|---|---|
| Petrol | 19.165 | 43.99 | 843 | 48.5 | |
| Diesel | 18.570 | 42.82 | 795 | 45.7 | |
| Total | | | | **94.2** | |
| Bioethanol | | 26.8 | 48.5 | | 1.81 |
| Biodiesel | | 36.8 | 45.7 | | 1.24 |
| Total | | | **94.2** | | **3.05** |

### Table – UK land area to produce the 5.75% by energy content of biofuels required to meet the 2010 Indicative Value in EU Directive 2003/30/EC

| **Fuel** | **Crop** | **Biofuels Required** | **Biofuels Yield** | **Land Required** |
|---|---|---|---|---|
| | | Mt/a | ha/te | million ha |
| Bioethanol | 50% from Wheat | 0.91 | 0.398 | 0.36 |
| Bioethanol | 50% from Sugar Beet | 0.90 | 0.255 | 0.23 |
| FAME | Rape Seed | 1.24 | 0.924 | 1.15 |
| Total | | **3.05** | | **1.74** |

Notes

1. This corresponds to an average biofuel yield of around 1.75 tonnes per hectare which is the middle of the 1.5 to 2.0 tonnes per hectare range quoted by BABFO.

2. The data used above is from wells to wheels studies published for Sheffield Hallam and ICCEPT and DTI's estimate of fuel sales