Report prepared for DEFRA, Organics,
Forestry and Industrial Crops Division

Liquid biofuels – prospects and potential impacts on UK agriculture, the farmed environment, landscape and rural economy.

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SUMMARY

Remit

CSL was commissioned by the Organics, Forestry and Industrial Crops Division (OFIC) of DEFRA during September 2002 to "Assess the economic aspects of biofuel production, the potential for expansion of UK liquid biofuel production and impacts on available land use and the potential environmental impacts of a large scale increase in crops destined for liquid biofuel production." Greenhouse gas and air quality issues were not considered as part of this study as these topics are currently being reviewed elsewhere.

Biofuels and substitution targets

The European Commission has proposed that EU members should move towards development of biofuels and have proposed indicative targets of 2% replacement by 2005 (in blends or as a total replacement fuel) rising by 0.75% per annum to a target of 5.75% replacement by 2010. In the international market, biodiesel (derived commercially from either rape or soy oil) and bioethanol (currently derived commercially from fermentation of maize or sugar cane) dominate as the most technically feasible and commercialised alternative renewable fuel sources that perform at least as efficiently as their petrochemical counterparts. Biodiesel production in the UK currently relies on use of waste vegetable oils as a low-cost feedstock under current fiscal duty rates. The cost of production of crop-derived biofuels is 2-3 times that of mineral fuels and without a fiscal advantage biofuels will not compete with fossil fuels.

Biodiesel can be made from a wide range of vegetable oils, including rape oil and competitors oils such as soy, sunflower and palm oil. It can also be derived from animal fats, grease and tallow. However, there are additional technical problems when using waste oils and animal fats for biodiesel production and difficulties achieving the EU biofuel specifications, which will limit inclusion of oils derived from such feedstocks to use in blends with biodiesel from 'fresh oil' or mineral diesel. Biofuels have a number of environmental advantages apart from reducing CO_2 emissions; biodiesel is rapidly biodegraded and possesses very low toxicity to mammals and water borne species. In addition it contains no sulphur and does not contribute to SO_2 emissions. On combustion, ethanol is reported to produce less formaldehyde (cited as a carcinogen) than fossil diesel.

UK fuel use

Road transport accounts for 76% of UK fuel use, 64% of which is petrol/gasoline, but the use of diesel and diesel car sales are increasing. Currently around 44.8 M tonnes of fuel are used in the UK per annum for transport. Based on a 2% growth prediction, fuel use is predicted to be 40.3 M tonnes by 2005 and 44.5 M tonnes by 2010. Based in the EC indicative targets, this gives a target for substitution of 806,000 tonnes in 2005, rising to 2.56 M tonnes in 2010.

Biofuel potential in the UK

Oilseed rape is the crop most likely to provide large volumes of competitively priced oil for biodiesel production in the UK for the foreseeable future. Average yields across the UK are typically around 3 tonne/ha, though the best growers can achieve

around 4 t/ha. Current UK rape oil production is estimated at 450,000 tonnes, and UK crushing capacity exceeds UK crop potential.

One tonne of rapeseed produces 0.38 tonne of Rape Methyl Ester (RME) (Biodiesel). Based on an average UK yield of 3 t/ha, this gives a potential RME production potential of 1.14 tonne per ha of oilseed rape in the UK. Typical costs of RME production available in the public domain are in the range 27-32 pence/litre, though some industry figures are reportedly higher than this.

Bioethanol can be produced from three types of feedstock: sugar, starch and cellulose. The choice of feedstock depends on technical and economic considerations. Costs of production are very sensitive to the costs of feedstock. In theory, assuming 100% efficiency, fermentation of starch should yield around 57% ethanol by weight, and sugars 54% by weight.

Starch derived bioethanol

The main UK starch bearing crops suitable for ethanol production are wheat and potatoes, wheat is preferred on a cost and long-term storage basis as ethanol yields per unit area are very similar (wheat is capable of producing 2.6 –3.2 t ethanol/ha). It is estimated that bioethanol could be produced from wheat at around 29 pence/litre.

Sugar derived bioethanol

Ethanol production from sugar beet is likely to be seasonal (lasting around 4 months in the autumn/winter period). Sugar beet is capable of producing around 3.8-4.3 tonne/ha of ethanol. Estimates of costs of ethanol production from sugar beet vary widely but recent estimates suggest a cost of 39 pence/litre at current (relatively high) beet costs of £31/tonne. The future for sugar beet production in the UK is likely to be severely affected by revision of the EU Sugar Regime, which will open up EU markets to overseas imports. The future of sugar beet as a long-term UK biofuel feedstock is therefore uncertain.

Cellulose derived bioethanol

Lignocellulose refers to the intimate mix of lignin and cellulose found in plants. To ferment the cellulose it must be broken down into its constituent sugars whereby lignin is left as a by-product. This could be burnt to produce energy for further ethanol production. Cereal straw and wood (waste and short rotation coppice (SRC)) are considered to be suitable potential commercial sources of lignocellulose. Miscanthus, the relatively new energy grass crop, also has potential as a source of cellulose for bioethanol production. US estimates of the cost of producing ethanol from poplar (SRC) vary between 15 and 19 pence/litre. It is difficult to readily translate these figures to the UK due to differences in for example the costs of borrowing, fiscal rates and differences in costs of materials etc. Limited European data suggests higher costs currently, around 71 pence/litre, though these could fall with expected technical improvements.

By-products

In meeting biofuel substitution targets, some consideration needs to be given to the effects of by-products flooding onto the market, glycerol in the case of bioethanol production and rapemeal in the case of biodiesel production. While rape meal could easily be absorbed into the animal feed market, world trade agreements covering limits on generation of soy meal equivalents from industrial crops, unless renegotiated, may restrict this use. Without the development of other markets, rape meal could end up being burnt as a fuel, reducing returns to processors, and inflating the price of biodiesel production. Glycerol production could cause problems for the oleochemicals market, causing over supply of glycerine and a drop in returns. It may be possible to convert the derived glycerine to fuel, but more work is required to find suitable alternative uses.

Recycling of both crop and by-products into the production chain and using the derived biofuel in the crop production process significantly improves the energy balance of biofuel production.

Meeting the EU indicative targets
Based on the targets for a 2% substitution of road transport fuels by 2005, in the short term it is likely that only biodiesel production will be sufficiently well developed commercially in the UK to contribute significantly towards this target. It is likely that international trade in refined liquid biofuels will be limited in the short to medium term due to the scarcity of supply and demands from home markets. The target for replacement of 2% of transport fuels could be met from growing just over 0.6 million hectares of oilseed rape. This could be grown either a) on set-aside utilising land deemed surplus to current requirement or b) on arable land, either diverting the same crops currently grown for food use to fuel use, or alternatively replacing other food crops in the rotation. (*Growing of industrial/fuel crops on set-aside land may be curtailed under current proposals being debated as part of the mid-term review of Agenda 2000*).

At the current rate of set aside (10%) 0.8 million hectares is removed from agricultural production. Substitution of 2% of 2005 fuel demand by biodiesel could be met by growing over 0.6 million hectares of oilseed rape on all but the lightest of this land without affecting current UK farming practice or rotations.

To meet UK rape oil demands (approx. 1 million tonne OSR per annum) as well as substitute for 2% of UK transport fuel requirement, the current rape area (allowing for use of waste vegetable oil) would have to increase by 153%. Oilseed rape production is currently optimised (in agronomic terms) in areas of high oilseed productivity. Any expansion in the oilseed area is likely to occur in areas already dominated by rape, as the economics and competitiveness of oil seed crops in the rotation is dependant on yield performance. This would lead to shorter rotations between rape crops. Growth in the oilseed rape area is most likely to be at the expense of second wheats on heavy and medium textured land and other spring break crops and winter bean crops on medium-textured land. In the former case this would move towards a better balance between cereal and non-cereal crops in the landscape. Minimum tillage and seed broadcasting techniques would need to be refined to ensure timely oilseed rape establishment. In all cases yields of oilseed rape would need to be maintained at a high level to ensure economic viability even if additional revenue for fuel crop production was made available to growers.

In reality, such an expansion in OSR cropping is unlikely to be achieved in practice. What is more likely is that a proportion of the conventional crop will be sold speculatively for fuel use where the price is favourable. On balance, it is most likely that 2% replacement of the diesel market alone is achieved by 2005. Farmers will be reluctant to reduce rotational intervals between oilseed rape crops for fear of developing pest and disease problems and reducing yield and profitability. A significant price premium would be required to encourage such a shift and it is currently not clear whether this will be available to growers, and how much of any money derived from reductions in duty will be passed down to primary producers.

The target for replacement in 2010 is an even more difficult task and requires innovative solutions. It is assumed that there will be little increase in the volume of waste oil recycled (around 100,000 tonnes RME equivalent) and little opportunity to increase home-produced RME beyond about 600,000 tonnes for the reasons outlined above. Without significant import of vegetable oils for biodiesel production, the bulk of the target would have to be met from bioethanol production. Of the feedstocks available, the most likely sources in the UK, after use of cheaply sourced suitable waste materials, would be wheat and perhaps sugar beet plus lignocellulose derived from short rotation coppice (SRC) and wood waste. *(It is assumed that by 2010 the development of industrial plant and processes for dealing with lignocellulosic materials would be refined and commercialised and that costs of production would be comparable with ethanol derived from other sources).*

Wheat is a valuable commodity and it is assumed that no more than around 5% of the UK cereal crop (equivalent to current UK cereal surplus) will be available for bioethanol production. This would be capable of producing 435 thousand tonnes of ethanol. Further cereal demand for ethanol production would have to be imported or sourced from the UK at a premium.

The UK sugar beet area has reached up to 205,000 hectares in the past under limits imposed by quota restrictions. However, this probably represents the area of optimal production in the UK. Assuming this area is retained (and there is some uncertainty about this with the ongoing deregulation of the EU Sugar Regime) and represents the maximum area that could be devoted to ethanol production, this has the potential to produce around 830,000 tonnes of ethanol per year.

The predicted total production of biofuels derived from oilseed rape, wheat and sugar beet sources falls short of the total required to meet the 2010 target for fuel replacement. A significant proportion would have to be derived from novel sources such as SRC or wood waste etc. It is estimated that around 30,000 tonnes of bioethanol could be produced in the UK from forest thinnings and waste wood, leaving a requirement to source around 0.5 million tonnes equivalent of fuel (20% of the target requirement). SRC and/or potentially Miscanthus could produce this from around 250 thousand hectares of production.

At current levels of support, the economics of perennial energy crop production are marginal compared with returns from combinable crop rotations. It is unlikely that lignocellulosic feedstock crops will be grown in significant quantities on arable land if access to production on set-aside is removed. With suitable support, it is more likely that lignocellulosic crops will replace land currently in grass where land can be mechanically harvested and cultivated. There are currently 1.2 million hectares under rotational grass. Given the current downturn in dairy and extensive meat production systems, production of liquid biofuels, bioenergy crops or a combination of the two could offer a potential alternative enterprise for rural economies.

Landscape

Most energy crops will be grown in rotation as part of a mix of several crops on the farm. Introduction of perennial crops like SRC and Miscanthus requires careful planning. Most biofuel feedstock crops would not add to the variation in structure of the landscape, as they are already present on large areas. SRC adds structural diversity to agricultural landscapes with its tall nature and regular planting. This impact can be minimised where deemed necessary by designing plantation to fit into existing landscapes. Planting which obscures views could cause problems but SRC is unlikely to have any significant negative visual impact in lowland areas. Miscanthus is a non-native with an unfamiliar growth habit in the UK countryside. It is not dissimilar in character to that of forage maize, though it is taller. In plantations it is likely to have a significant visual impact in the countryside.

Traffic impacts

Conventional arable crop biofuel feedstocks will have little impact on the movement of crops, which would have been moving off farm anyway. Growing of crops specifically for lignocellulose on arable farms may reduce transport pressure at the peak crop harvest time as harvest of perennial lignocellulosic crops takes place during late winter. Traffic is likely to concentrated around large biofuel plants, but these are most likely to be established in an urban setting.

Impacts on the farmland environment

Biofuel production from a broad mix of arable crop feedstocks diverted from food use will have a neutral effect on the farmed environment, though there could be a move towards reducing agrochemical inputs where quality of product is less of an issue. There is likely to be little overall impact from swapping cereals for rape and vice versa. However, any replacement of spring sown break crops by an expanding winter oilseed rape area would be undesirable for crop diversity and conservation of farmland birds, many of which utilise stubbles overwinter. In the longer term, as technology improves, cereal straw and other arable crop wastes could also provide raw materials for ethanol production without affecting the farmed environment significantly. Growing biofuel crops on otherwise un-cropped land, or SRC in predominantly grassland areas are likely to have more significant impacts on the local environment.

Replacement of set-aside - environmental impacts

If the required additional crop production was met on set-aside land, the majority of naturally regenerated set-aside would disappear. The replacement with oilseed rape would on balance be environmentally detrimental, due to the resulting increase in intensification of nitrogen and pesticide use, and reduction in habitat diversity, though a few species would probably benefit. However, oilseed rape has a less negative environmental profile than some other crops, and imaginative mitigation measures could help to minimise environmental damage. These could include measures to avoid large-scale block–cropping and introduction of a percentage of non-crop habitat.

Expansion of perennial lignocellulosic crop production - environmental impacts
Impacts of SRC and Miscanthus cropping are relatively benign, fertiliser use is modest, and pesticide requirements are also likely to be low, risks of soil erosion, phosphate losses and nitrate leaching are also low. The impacts on biodiversity and landscape will depend on the species and scale of planting. Willows are native and willow coppice support a wide variety of birds, mammals, invertebrates and other plants, especially if managed sympathetically.

Oilseed rape allergies
Oilseed rape pollen is allergenic, but data on the incidence of sensitisation is conflicting. Allergy to rape pollen is uncommon, even in intensive areas of production, and is most commonly associated with individuals with multiple sensitivities showing a broad cross sensitivity to birch and grass pollen allergens. During the flowering period it is difficult and rare to achieve pollen-loading levels sufficient to cause allergic reactions close to dwellings, sensitivity is therefore most acute during peak flowering periods or in close proximity to fields. Volatile chemicals associated with oilseed rape may have an impact on sensitive individuals but there is little evidence that such compounds reach sufficient concentrations in air.

Impacts on the rural economy
The greatest effects on the rural economy are likely to be realised where cropping takes place on otherwise unproductive land, effects are relatively neutral and difficult to determine where one crop substitutes for another. Expansion of oilseed rape onto set-aside and expansion of SRC onto grassland are used as examples where impacts could be anticipated.

Note: assessment of the impact of an enterprise on the rural or urban community commonly focus on the economic output (gross or net) of the crop production system or processing plant and/or on resulting employment in the wider economy. Changes in prices or costs of processing etc have a significant impact on output and employment. Such changes are difficult to predict as they arise from a complex interaction of many variables. The value of any production/functions or 'rural multiplier' commonly used in such analyses will therefore change over time.

The direct effects of biofuel feedstock production are likely to be realised in the rural community but effects related to biofuel production are most likely to affect the urban community, as processing and logistics considerations will most likely lead to production facilities being sited near existing crushing or refining plants.

Rural impacts of biodiesel production on set-aside
A plant producing 125,000 tonnes per annum of biodiesel would employ around 43 staff. To produce 125,000 t of diesel 329,000 tonnes of rapeseed would be required. Assuming improved yields (4t/ha) this would require 82,000 ha. Growing rape on this area of land (rather then leaving it as set-aside) would create 82 extra jobs (one for every 1000 hectare of crop grown, equivalent to 0.65 jobs/1000 tonne of biodiesel). When the oilseed rape multiplier effect associated with the added value of this farm activity is considered, the total number of jobs created rises to 144 (equivalent to 1.15 jobs/1000 tonne of biodiesel). This is lower than the figures presented in some other studies, but agrees with figures presented by parts of the biofuel industry using a similar methodology. There is considerable variation in

estimates of employment creation, probably related to use of different multipliers. German and Irish studies suggest job creation figures in the economy of around 10-16 additional jobs/1000 tonnes of production. Using an appropriate rural multiplier, it is estimated that £0.7 million would be generated in the rural economy per 1000 tonnes of RME production.

Rural impacts of SRC production on grassland

One way in which bioethanol production could significantly influence rural communities is if biofuel feedstock production expands from conventional crop sources to lignocellulose production in areas with currently little or no arable production, for example those with significant areas of extensive livestock production.

A plant producing 135,000 tonne of ethanol would require around 750,000 tonne of wood feedstock. This equates to the production from around 71,500 ha of SRC. Equivalent annual values of revenue from SRC (adjusting for the 3 year harvest interval) currently range between £203-400/ha at current values and support payment rates (assuming the crop is eligible for arable area support payments – which may not be the case on much of the UK grassland area). Once established, SRC is less labour intensive than the management of sheep/livestock enterprises. Therefore it is possible that moving to cropping with SRC could reduce direct employment or reduce the workload on livestock farms.

Using multipliers developed for the forestry and sheep sectors, it is estimated that the total benefits to the rural community arising from the cultivation of 71,500 ha of SRC would be £26-74 million. Using a gross margin for sheep (average lowland and upland) of £315-325/ha, this would equate to generation of £45-58 million for the same area of grassland supporting sheep. The generation of biofuels would appear to add greater value to the rural economy in some cases; however, this is based on the assumption that SRC will receive AAPS support payments. Without access to such payments SRC production is much less profitable than extensive livestock enterprises. A recent study has demonstrated that in the absence of subsidy payments SRC is the more profitable of the two enterprises, provided at least 8 tonnes of dry matter is produced at a chip price of £35/tonne, which should be achievable in the UK uplands with appropriate inputs. The study also concluded that SRC production could be supported with lower subsidy payments than those currently paid to sheep producers. Access to such subsidy payments will be necessary if the government wishes to stimulate production of SRC outside of the current arable area for either biofuel or bioenergy production.

Prospects

The EC targets for fuel replacement can potentially be achieved using UK-sourced crops, however there are a number of International Trade Agreements, the outcome of the Mid-Term Review of Agenda 2000, impacts of reform of the Sugar Regime as well as impacts of changes in raw material cost and competitor oils which will all have an impact on the type of feed stocks used for biofuel production in the future, many of which are difficult to predict. In addition, any diversion of crop feedstocks from food use to biofuel production in excess of that surplus to UK demand will have an impact on the balance of trade. There are currently few barriers to development of the UK biodiesel industry other than the fiscal duty rates applied. A reduction in this to ensure parity with fossil diesel for biodiesel produced from fresh vegetable oil would result in a rapid uptake. With restrictions on use of set-aside for industrial cropping, some of this duty cut would have to filter down to rapeseed growers to encourage a shift to increased rape production.

In the longer term, a wider basket of fuel feedstocks is likely to be required to meet replacement biofuel targets for 2010 and there is a need to stimulate the bioethanol industry. It is unlikely that the total potential demand for biofuels will be met by use of arable crops alone, for the reasons outlined earlier. At least a 20% deficit on the 2010 target is envisaged and this may be even greater if the UK sugar beet crop area declines and this bioethanol feedstock is not replaced by imported sugar processing waste etc. Fermentation of lignocellulose feedstocks for bioethanol could provide a solution, but steps will have to be taken in the near future to help develop the technology. In addition, a political decision will be required to encourage (if deemed desirable) development of crops such as SRC on land that is currently only eligible for support through livestock-related payments. This would have to be backed up by a detailed analysis of the potential impacts on the environment and rural economy.

Liquid biofuels – prospects and potential impacts on UK agriculture, the farmed environment, landscape and rural economies.

1.0 REMIT

CSL was commissioned by the Organics, Forestry and Industrial Crops Division (OFIC) of DEFRA during September 2002 to "Assess economic aspects of biofuel production, the potential for expansion of UK liquid biofuel production and impacts on available land use and the potential environmental impacts of a large scale increase in crops destined for liquid biofuel production."

1.1 Areas of study

Economics/Agriculture;

- Assessment of the UK potential for biofuel production (both biodiesel and bioethanol).
- Assessment of the implications for farm incomes and the wider rural economy.
- The likelihood of importation of biofuels or biofuel feedstocks from Continental Europe.

Environmental (excluding green house gas and air quality issues)

- Potential impacts on landscape and land use.
- Potential impacts on crop inputs including agrochemicals, fertiliser and pesticide use.
- Potential health issues (allergens etc)

2.0 BACKGROUND

As a signatory to the Kyoto Protocol in 1997, the UK agreed to reduce greenhouse gas emissions by 12.5% (compared to 1990 levels) by 2008-2012 as part of a wider EU burden sharing commitment to reduce emissions by 8% over the same period. CO_2 accounts for 80% of UK greenhouse gas emissions.

Road transport accounts for around 20% of the UK's CO_2 emissions (DETR) and emissions are directly proportional to the amount of fuel consumed. Growth in traffic and limited improvements in overall fuel efficiency* over recent decades means that road transport is the fastest growing source of CO_2 emissions, with petrol-fuelled cars accounting for around 57% of emissions in recent years (DETR). As part of a balance of CO_2 abatement measures across a number of industries the Government is committed to developing a less polluting transport system.

2.1 Draft EU Commission directives and proposals

The European Commission has proposed that EU member states should move towards development of biofuels and have proposed indicative targets of 2% replacement by 2005 (in blends or as a total replacement fuel) rising by 0.75% per annum to a target of 5.75% replacement by 2010. The Commission's longer-term objective is to replace

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* Increases in engine fuel efficiency have been negated to some extent by preference for power steering and air conditioning as well as regulated emissions, noise and safety standards (DETR)

20% of conventional fuels by 2020 (EC 2001). The 2% target for 2005 corresponds to around 5 million tonnes of oil equivalent (Mtoe) across the EU for which reduction in duty could be considered under a pilot phase of development.

2.2 Alternative fuels

In the international market, biodiesel (derived commercially from either rape or soya oil) and bioethanol (currently derived commercially from maize or sugar cane) dominate as currently the most technically feasible and commercialised alternative renewable fuel sources. Lifecycle greenhouse gas emissions from biodiesel and bioethanol are claimed to be 55 and 60% lower than conventional petrol fuel (ECOTEC 2002)

Biodiesel can actually be made from a wide range of vegetable oils, including rape oil competitors such as soy, sunflower and palm oil. It can also be derived from animal fats, grease and tallow. The source oil is esterified by mixing the oil with an alcohol (usually methanol) in the presence of a sodium or potassium catalyst. The ester produced takes its name from the source material (i.e. rape biodiesel = Rape Methyl Ester (RME)). There is very little difference between such esterified vegetable oils allowing them to compete in the biodiesel market.

A key advantage of biodiesel over conventional diesel is that it is rapidly biodegradable (95% degraded in soil in 21 days) and possesses very low toxicity to mammals and is much safer to water borne species than fossil diesel (Körbitz 1998). In addition it contains no sulphur (so reducing sulphur dioxide emissions from road transport). It is also a very effective lubricant which can be added to ultra-low sulphur diesel (at 2% inclusion or greater) to compensate for losses in lubricity associated with ULSD (Dunn *et al.,* 2002). Pure RME has a higher flash point than fossil diesel, which makes it safer to transport (Körbitz 1998), though this is affected by residual levels of methanol in RME. In most cases the contaminating methanol should be removed and recovered during distillation.

2.3 Standardisation and efficiency

NORM and DIN specifications for biodiesel have encouraged engine manufacturers to accept RME biodiesel, though in many circumstances manufacturers, including major truck manufacturers, will only guarantee support and warranty cover where fuels containing no more than 5% biodiesel are used. Biodiesel in Europe is produced under the Austrian Biofuels Institute specification E DIN 51606. The new EU standard pr EN14214 should reinforce this. Research is concentrating on improving efficiency and producing fuels with recognised specifications as cheaply as possible.

Biofuels perform as efficiently as their petrochemical counterparts, though a range of efficiency from –1 to +14% is reported from a review of relevant literature (Walker *et al.* 2002*)* Ethanol as a petrol additive is reported to increase power and efficiency by around 2% (HGCA 1993).

2.4 Waste oils and fats

Used frying oils and fats (tallow) can be used as biodiesel feedstocks. Restrictions on inclusion of used frying oils in animal feed has reduced the value of such waste and used vegetable oil has ended up being dumped in landfill (though there will be restrictions on dumping of liquid oils in landfill from 2003). ACORN (Affiliated Cooking Oil Reclaimers Nationwide) report a fall from 24p/l to 13p/l. Some waste fat is being disposed of in drains, SAC reports that East of Scotland Water spends £2.3m/year on clearing drains of congealed fats. Based on EC estimates it is calculated that 0.5 million tonnes of biofuels could be generated from used vegetable oil (ECOTEC, 2002), however industry does not foresee a potential for much more than 100,000 tonnes/annum being produced in the UK in future (ECOTEC, 2002).

Post BSE legislation which prohibits inclusion of animal products in animal feed has resulted in large quantities of tallow with few outlets. As a stopgap in the short term, the UK has asked for a derogation to allow animal products to be used in animal feed for a limited period. In 1995 the UK exported approximately 7,000 tonnes of tallow, though exports are now restricted. Although tallow is a cheap raw material there are technical problems with using it for biodiesel production and in achieving the EU specifications, particularly those related to cloud point, cold filter plugging point and viscosity. The refining plant required to process animal fats is less complex than that dealing with 'fresh' oilseed rape oil (which runs on a continuous basis) but the process is more labour intensive.

2.5 Fuel Duty

The cost of production of biofuels is 2-3 times that of mineral fuels and without a fiscal advantage biofuels will not compete. Chevron has developed a long-range oil price model, which predicts how future fossil oil prices will be affected by costs of securing and extracting new or existing oil stocks. Predictions suggest that at current costs of production, alternative fuels are unlikely to compete until the conventional oil price exceeds $40 US/barrel (£26 or 41.5 euro at current rates of exchange) the current oils price is around $29 per barrel. It is anticipated that this is unlikely to be achieved until around 2050. Current figures for cost of biodiesel production (see later sections) suggest that even a rise in mineral diesel price of this magnitude is insufficient to ensure biodiesel could compete with mineral diesel without additional fiscal support).

In the 2002 budget, biodiesel was awarded a 20p cut in duty over that for ultra low sulphur diesel as a stimulant to develop the biodiesel industry. As an 'other fuel substitute' bioethanol is currently be taxed at the ULSP rate. However, the Chancellor announced in the Autumn 2002 budget statement that duty on bioethanol would also be cut by 20p/litre.

The permissible levels of duty levied on biofuel production across the EU will be reviewed at the end of 2003. EU member states may currently apply to the Commission to reduce levels of duty levied on biofuels, or request exemption from duty altogether.

Other European Union members have levied reduced rates of tax on biofuels (Italy), or exempted them altogether (France, Germany and Spain).

Table 2-1 Hydrocarbon Duty Rates from 17 April 2002

	Pence per litre
Light oils	
Ultra low sulphur petrol (ULSP)	45.82
Unleaded petrol (non ULSP)	48.82
Leaded petrol	54.68
(Bioethanol (*Autumn 2002 budget statement*))	25.82)*
Heavy oils	
Ultra low sulphur diesel (ULSD)	45.82
Conventional diesel	51.82
Biodiesel	25.82

Source: UK Treasury

* To be confirmed following Autumn 2002 Budget statement

3.0 CURRENT TRANSPORT FUEL USE AND FUTURE TRENDS

According to Datamonitor reports, the UK fuel retailing market reached a volume of 36.6 billion litres in 2001, and is forecast to reach 39.6 billion litres in 2006 (a 6.4% increase based on a compound annual growth rate of 1.6% (current rates are around 1.6-1.7% per annum)).

Earlier estimates by the DTI identified that 44.8 million tonnes of petroleum products are used for transport with the following breakdown.

Table 2-2 Breakdown of fuel use by mode of transport

% of UK petroleum use	
49	Petrol
27	DERV
16	Air transport
4.5	Water transport
3.5	Railways

Source: DTI

Conversion of one million tonnes of rape (double the current UK national area) into RME could only supply 3% of the above DERV market (see later sections on biodiesel for calculation of RME output from oilseed rape).

According to Datamonitor Statistics on UK Fuel Retailing, transport fuels in the UK are the most expensive in Europe. Between 1996 and 2000, unleaded petrol prices increased by 6.6% and diesel by 6.8%. Hypermarkets account for the largest share of UK fuel retail sales with 26.7% of all sales.

3.1 Diesel use

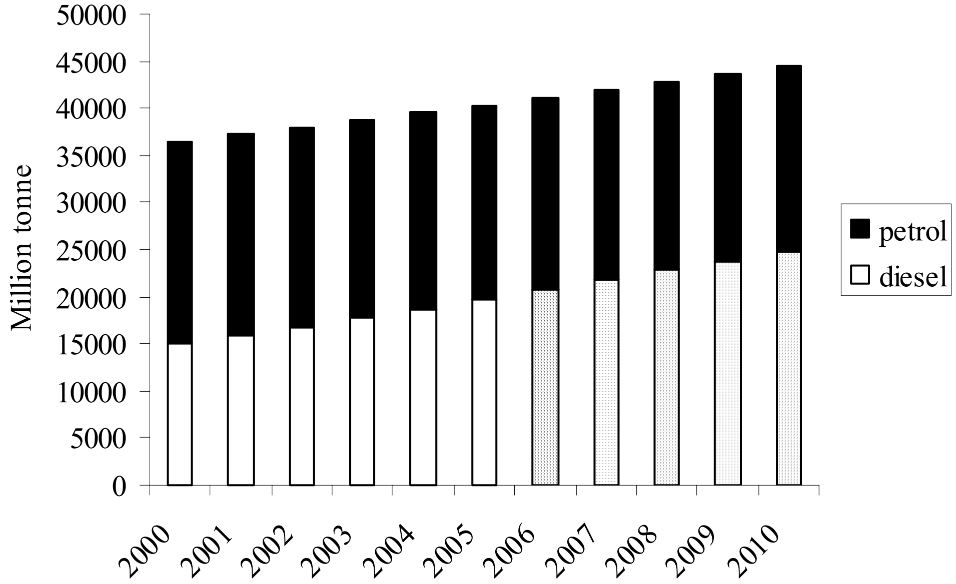
Diesel use is on the increase in the UK, with 15 million tonnes consumed in 2000 (Frost and Sullivan Report 2001). The sale of diesel cars is increasing at a greater rate than that of petrol-fuelled cars (after a decline in recent years). Diesel-powered car sales account for around 14% of UK new car sales, compared to the European average of 32% (Frost and Sullivan Report 2001). On the European Mainland, diesel is significantly cheaper than petrol.

The majority of diesel fuel is used primarily by Heavy Goods Vehicles followed by Light Goods Vehicles (HGV's, LGV's and diesel-powered cars were responsible for 23, 6.5 and 7% respectively of CO_2 emissions from road transport in 1996 (DETR)).

3.2 Petrol use

The UK Motor Spirit Trade forward predictions for petrol use show a continuing decline in the petrol market up to 2005, with the decline increasing over time as diesel use increases as a proportion of the total fuel market. Extending on the predicted average decline over the 2000-2005 period (0.9% per annum), by 2010, the market for petrol is likely to be in the region of 19.6 million tonnes per annum. For total fuel consumption a growth of 2% per annum is assumed from a baseline in year 2000 when 15 million tonnes of diesel was consumed according to industry statistics (Frost and Sullivan Report 2001).

Fig 3-1 UK Fuel Market Forecast (Million tonnes)



Source: Petrol data - Snapshot International UK Motor Spirit Market Forecast 2001-2005 (open white bars) and forward prediction for 2010 based on 2001-2005 trend (shaded bars). Diesel use based on assumed growth of 2% in fuels market above 2000 baseline of 15 million tonnes.

Based on the above calculations, petrol and diesel consumption in 2005 and 2010 is estimated to be as shown in Table 3-1.

Table 3-1 Estimated fuel consumption in 2005 and 2010 and potential EU targets for biofuel replacement (thousand tonnes)

	2005		2010	
	Total	2%	Total	5.75%
All fuels	40317	806	44514	2560
Diesel	19773	395	24877	1430
Petrol	20545	411	19636	1129

Based on the European Commissions proposals for biofuel uptake, the Commission estimates that within 15 years, 10% of agricultural land could be devoted to biofuel production to help meet such targets (Anon 2002). The potential for UK crops to supply the predicted UK target demand is discussed in later sections.

3.3 Future factors which may affect fuel use

The future wide commercialisation of lean-burn, direct fuel injection petrol engines could improve fuel efficiency (by up to 20+ % according to ESSO), as could the development of lighter vehicles by development of new lightweight materials. This and other potential technological developments would need to be balanced against the predicted continued increase in road traffic. A full analysis of such impacts is beyond the scope of this current study.

4.0 BIODIESEL

4.1 UK production

In 2001, over 23,000 ha of oilseed rape was grown on UK farms for biodiesel production, though virtually all was processed in mainland Europe on an ‘equivalence trade basis’. Until recently UK biodiesel production was limited to 200 tonnes. The reduction in duty from April 2002 is likely to increase this significantly.

4.2 European and American production

In mainland Europe around half a million tonnes of biofuels were used for transport in 2001. With political support, biofuel production and use in other EU states has grown rapidly. In comparison it is estimated that 2 million tonnes of biodiesel was produced from soy bean oil in the US in 2000 (Terry de Winne, Biofuels Northern Ireland).

Clearly the technology is well developed and commercialised

4.3 RME yields

Oilseed rape is the crop most likely to provide large volumes of competitively priced oil for biodiesel producton in the UK for the foreseeable future

The climate in the UK favours Oilseed rape production and yields are amongst the highest in the world. Yields are typically around 3 tonne/ha, though yield potential appears to have stagnated in recent years. High oil contents are achieved in the UK and a consistent quality is achieved which is suitable for biodiesel production. The UK is the third largest producer of rape in Western Europe and rape oil production is estimated at 450,000 tonnes based on 40% oil content. UK Crushing capacity is currently greater than UK crop production potential and rape is imported and crushed for food use.

Oil is extracted by conventional mechanical and solvent extraction. One tonne of rapeseed provides the following (Walker, 1995)

1 t rape → 0.41 t crude oil → 0.4 t refined oil → 0.38 t RME (0.88 g/ml) = 432 litres

Based on an average UK yield of 3 t/ha, this gives a potential RME production potential of 1.14 t per ha of oilseed rape. Current best practice in Germany is reported to be achieving an oil yield of 2 t/ha from oilseed rape (ECOTEC 2002). Given that the oil content of rape commonly ranges from 40 to 43%, this suggests yields of around 4.5 t/ha are achieved. This is exceptional and would equate to an RME yield potential of around 1.8 t/ha (based on the above efficiency of RME production). Winter rape yields in Germany are more typically 3.0-3.2 t/ha according to official statistics, similar to those of the UK. Based on the above efficiencies, it is likely that in the long term national oilseed yields could be raised to the best yields achieved now of around 4-4.5 t/ha giving an RME yield potential of between 1.5 and 1.7 t from 1 ha of rape.

4.4 Costs of production and competitors for oilseed and biodiesel supply

Current costs of biodiesel production from oilseed rape in the UK are estimated to be around 30p/litre at 2002 prices (Walker *et al., 2002*), but this will depend on costs of raw materials. The British Association for Biofuels and Oils (BABFO) calculated UK costs of biodiesel production to be around 32.9 p/litre in the mid 1990's (Kasterine and Batchelor 1998) at a rapeseed cost of £130/tonne (current rape costs are closer to £150/tonne ex farm). The price is very sensitive to the cost of rape seed which makes up the bulk of the costs of production (Table 4-2). Estimates of costs of production vary widely (Kasterine and Batchelor 1998), depending on costs of raw, materials, the value assigned to by-products and the scale of operation etc, but the more recent commercial development of biofuels should provide better estimates of the actual costs involved. Recent industry figures suggest production costs in the range 27.2-31.8p/litre depending on rapeseed cost (Mortimer et al., 2002 based on earlier reports from Cargill by P Smith).

Table 4-2 Biodiesel production costs (pence/litre)

	Cost/litre RME
Capital cost	8.3
Operating costs	1.2
Power	0.3
Maintenance	0.8
Miscellaneous	0.9
Working capital	1.6
Rapeseed	37.7
Returns from by-product sales:	
Meal	16.0
Glycerine	4.0
Balance	**30.8**

Source: SAC (Unpublished)

Table 4-3 Costs of rape-biodiesel production in comparison with typical mineral diesel-fuel cost (to nearest pence/litre).

	Biodiesel (Pence/litre)	Mineral diesel (Forecourt pence/litre)
Production cost	31	10
Excise duty	26	46
Distribution and marketing	7	7
VAT (17.5%)	11	11
Retail margin + VAT	6*	5
Total costs	***81***	***79***

* includes 5p/l providing 15% return on capital plus 1p VAT

Source: Walker et al.,2002

Clearly there is only a small difference between the forecourt costs of biodiesel and mineral diesel, due to the current lower duty rate levied on biodiesel. This differential can be reduced further where waste oil is also utilised, particularly as the cost of the waste oil has also declined (discussed above). A 10% inclusion of waste vegetable oil purchased at 15p/ litre is enough to diminish the differential between the two. However, some of this benefit can be offset by the increased amount of processing required when handling feedstocks of varying quality and specification. Maximising the amount of low-cost used frying oil or tallow can reduce the price, but including large quantities may make it difficult to achieve the EU biodiesel standard, as viscosity, cloud point and cold-filter plug-point parameters of the resultant methyl ester are affected by inclusion of such materials.

The vast majority of rape imported into the UK is from France and Germany (418 thousand tonnes in 2001/02). Outside the EU, smaller but significant tonnages are imported from Australia and Poland. France and Germany are likely to be the main competitors to UK sourced rape for biodiesel production, but import of biofuels is not seen as a threat currently (Section 6.3.2). Low cost competitor oils could be a threat and will compete on a base cost basis.

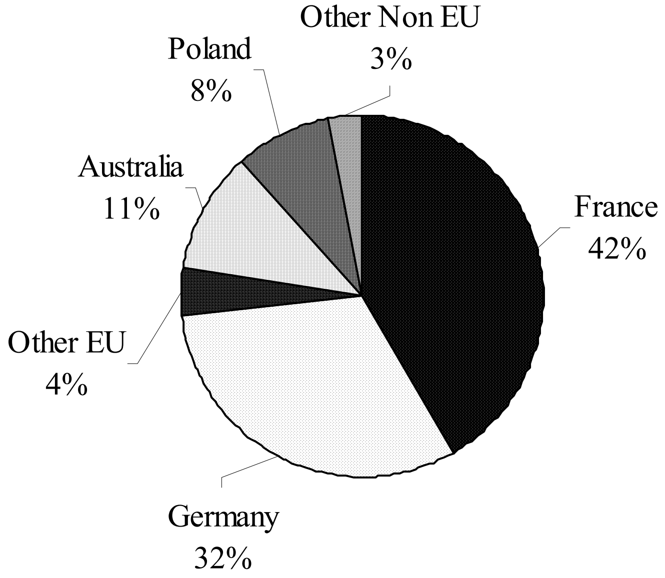
Table 4-1 UK rapeseed imports and exports 2001/02 season (tonnes)

	Imports	Exports
EU	442,442	48,224
Non EU	127,045	23

Source: Home Grown Cereal Authority

Fig 4-1

Proportion of UK rapeseed imports by country of origin (2001/02)



4.5 *Biodesel plant gestation*

Development and commissioning of an RME refining plant takes at least two years. Costs of building a plant for production of 'fresh' RME depend on scale of production ranging from £400 thousand for output of 300 tonnes of RME per annum, £800 thousand for 8000 tonnes RME/annum and £8 million for 100 thousand tonnes RME/annum (Oelmuhle Leer Connemann 1999 (cited by Terry de Winne, Biofuels Northern Ireland)).

4.6 By-products of RME production

4.6.1 Glycerol

Glycerol is produced as a by product of the biodiesel manufacturing process (at the rate of 100 kg/ tonne of RME (from Mortimer et al., 2002)). The majority of which is disposed of as glycerine as a low-value by-product of further processing. There is a glut of glycerine since biodiesel production took off in mainland Europe (T de Winne, UK Allied Biodiesel Industries (response to Mortimer et al 2002 draft report)). Unless glycerol can be processed locally then there are few options other than disposing of it as waste, composting or recovering the fatty acids as low value heating fuel.

The European oleochemicals association Apag has expressed concern at the amount of glycerine that will be produced when biodiesel production is scaled up. Apag represents 36 producers and suppliers of fatty acids, glycerine, alcohols, metallic soaps and fatty nitriles. Apag assert that increased competition in the glycerine market would also harm markets for competing products such as sorbitol, glycols and many polyols from petrochemical feedstock. Since fatty acids and glycerine are manufactured in a fixed ratio, a drop in glycerine prices would force oleochemical producers to increase the prices of fatty acids and their derivatives. This will lead to a general increase in prices for oleochemical products used in many day-to-day products. Clearly there will be a need to resolve this problem.

4.6.2 Rape meal

The primary outlet for rape meal is as a protein source in animal feed. However exceeding 1 million tonnes of soya meal equivalent of meal derived from industrial oilseed crops requires the EU to take ‘corrective actions’ under the Blair House Agreement. This equates to production from around 1 million ha of rape across the EU (Batchelor *et al.* 1996). Without re-negotiation on this point, other alternative uses for rape meal will be required to keep the price of RME as low as possible. However, the current move away from a crop specific support to more of a generalised area based support payment across all arable crops may ease pressure on transatlantic trade agreements.

There is potential to incorporate significantly more rape meal into UK animal diets. Currently, restrictions on availability and high price compared to alternatives limit its use by the industry. The UK currently produces 1.5 million tonnes of rapeseed meal and 570,000 tonnes is used annually by feed manufacturers in the UK (Statpub, 2000). Much of the UK produced rapemeal is exported to the rest of Europe. Demand for rapemeal is controlled by price, which is in turn controlled by supply that is currently limited.

Ration inclusion ratios (R & H Hall, 2002)

The maximum levels of “00” rapeseed meal that can be fed to cows without causing problems has not yet been determined, but as a rough guide up to 5kg/day can be fed to a dairy cow. Rapeseed meal can be added at inclusion rates of 20% to calf diets without affecting palatability.

Inclusion of 20-30% rapeseed meal in rations can be fed to pregnant and lactating ewes as well as growing/finishing lambs.

Rapeseed meal should not be included at rates greater than 5% for piglets, and 15% for finishing pigs. For sows it should not exceed 10%

Recommended inclusion rates for poultry diets ranges from 3% to 15%. For laying hens it should not exceed 6% because of problems with fish taint in eggs.

The UK feed industry could accommodate a doubling of rapeseed meal supply, especially the dairy straights market, as there is still much scope to increase the amount of rapeseed meal in dairy rations (I. Bending, personal communication).

Alternative uses of rapemeal

Other alternative uses for rape meal (Batchelor *et al.* 1996) include use as a fuel, animal bedding, horticultural compost and use in seed coatings and baits but all represent low value returns compared to use as a feed supplement. Higher value market outlets for the mid-term have yet to be developed but include use as a fertiliser, use in microbial culture media, wood composites, supplementation of mushroom composts, use as a spill absorbent. Likely market volumes and likelihood of success need to be researched. In the longer term, applications in the biodegradable plastics, coatings and adhesive market are possible, though these will be subject to competition from other renewables. Some potential markets for speciality product such as pesticides derived from glucosinolates are also possible.

4.7 Other markets

Biodiesel has number of uses other than as a road transport fuel and biodiesel can also substitute for these markets. These markets include use as a heating oil (350,000 tonnes/annum of biodiesel in the EU in recent years). RME may also have applications in the solvents, lubricant and hydraulic fluid sectors, but as with biodiesel, RME-derived products are likely to be more expensive than their mineral-derived counterparts and will need specific advantages to develop any significant market penetration.

5.0 BIOETHANOL

Bioethanol is the term given to ethanol produced from fermentation of plant carbohydrates. Bioethanol can be used as a 100% renewable fuel substitute or as a petrol additive.

Ethanol is less volatile than petrol which may potentially lead to problems with starting engines in cold weather (temp below 4.4ºC). However, once running, ethanol has a high octane number (91-105), this improves engine efficiency. Use of pure ethanol increases the power output of engines by 5-10%, but it is thought that the potential margin for improvement could be of the order of 30% (Holman et al, 1991).

Sulphur dioxide and aromatic emissions from ethanol engines are insignificant and carbon monoxide emissions have been reported to be 30% lower and nitrogen oxides up to 15% lower than from comparable petrol engines. However, a disadvantage is reported to be the emission of formaldehyde and acetaldehyde (potential carcinogens). However**,** the California Environmental Policy Committee in a review of air quality impacts of ethanol concluded that while use of ethanol compared with fossil-diesel does result in slightly increased levels of acetaldehyde, this is more than offset by reductions in formaldehyde, a contaminant many times more harmful. Depending on the feedstock crop material, carbon dioxide emissions associated with the whole life cycle analysis of ethanol could be 23% higher than those of petrol due to the high energy inputs of modern agriculture, particularly those arising from fertiliser use (However there is currently some debate over such calculations and energy values for fertiliser inputs are being revised downwards). The energy balance can be improved significantly by better use of wastes from ethanol production (i.e. burning for fuel generation) and re-cycling of fuel into the chain of productions (see later sections)

5.1 Bioethanol as a petrol additive

Bioethanol can be added to petrol at inclusion rates of 5%, 10% or 22%. No engine modifications are required at an inclusion rate of 5%. Bioethanol acts as an oxygenate, increasing the oxygen content of the fuel which improves combustion, resulting in increased efficiency and reduced emissions. At present the main oxygenates used by the fuel trade are methyl t-butyl ether (MTBE) and ethyl t-butyl ether (ETBE). The former is made from isobutylene and methanol. The latter can be produced from ethanol. The use of ethanol as an oxygenate confers some disadvantages compared to other oxygenates. Petrol/alcohol blends absorb water and if the water content reaches 0.5% the petrol and alcohol starts to separate. It is therefore more convenient to use ETBE derived from bioethanol as an addictive for petrol. This has been done by the fuel companies Elf and Total in France (to level of 5% and 10%) (Todd, 1993).

5.2 Bioethanol as a total fuel

Using ethanol as a fuel presents a problem due to its low cetane number, which confers poor ignition characteristics. In order to use unmodified ethanol the engine would require modification in order to allow the use of diesel oil as a pilot for combustion where ethanol would substitute for 75-95% of diesel.

5.3. Current bioethanol production in the UK, Europe and US

In the UK 450-500 thousand tonnes of wheat is used annually in the brewing industry for spirit production. However, currently no crops are registered for bioethanol production on set-aside and no bioethanol is currently being produced. In 1998, in the EU as a whole 2 billion litres of bioethanol was produced, but only 5% was used as fuel (GIFNFC 2002). In comparison, 4.4 billion litres of bioethanol was produced in the US in 1999 and production is planned to rise with the help of reduced duty rates. Twelve billion litres of bioethanol is produced from sugar cane in Brazil (45% of demand). All cars in Brazil are modified to run on a 24% bioethanol/petrol blend.

In recent years France has produced 344 thousand tonnes and Germany 130 thousand tonnes of bioethanol. Spain has rapidly expanded its bioethanol production capacity and plans to produce 300 tonnes per annum by 2004

5.4 Green Fuels Challenge - Pilot projects

To stimulate development of bioethanol from ligno-cellulose materials (and certain other alternative fuels including hydrogen, methanol, biogas, pyrolysis of organic or waste feedstocks and novel treatment of organic oils (excluding esterification)) the UK Treasury has pledged to provide duty reductions or exemptions for pilot projects developing such fuels. However it is unlikely that such exemptions would apply to bioethanol produced from sugar or starch sources, where technology is already well developed.

5.5 Feedstocks for bioethanol production

Bioethanol can be produced from three types of feedstock: sugar, starch and cellulose. The choice of feedstock depends on technical and economic considerations. Currently the fermentation process to produce bioethanol relies on the use of the yeast *Saccharomyces cerevisae* that is only able to utilise simple sugars. Carbohydrate and cellulose bearing materials need to be processed to break them down to their constituent sugar units that can then be utilised by the yeast.

Typically, in theory, assuming 100% efficiency, fermentation of starch should yield around 57% ethanol by weight, and sugars 54% by weight, the remaining substrate being lost via respiration as CO_2. In practice, the efficiency of fermentation is closer to 85-95% (Marrow, Coombs and Lees, 1987).

5.5.1 Starch feedstocks

The main UK starch bearing crops suitable for ethanol production are wheat and potatoes (wheat is preferred to barley because of higher starch yields/unit area). One tonne of wheat produces around 670 kg of fermentable sugar while one tonne of potatoes only yields around 180 kg of fermentable sugar due to the low dry matter content of potatoes. The rates of ethanol production per unit area of crop are very similar for wheat and potato crops (Table 5-5) which makes potatoes an expensive source of ethanol. This difference in efficiency favours the use of cereal on both a cost of production and practical basis, with much higher costs of transport and storage etc associated with potatoes. At current levels of efficiency, the fermentation process transforms 50% of the fermentable sugar into ethanol. An advantage of using cereals as a feedstock is their high dry matter content (around 85%), lower costs of transport and suitability for low cost, long-term storage (important for continuity of supply).

Prior to fermentation (enzymic hydrolysis) there are two options;

- The grain may be milled and separated into starch and other by-products (fibre and gluten) whereby only the starch enters the hydrolysis process;
- The grain may be milled and mixed with water (to form a slurry); the slurry enters hydrolysis and separation of by-products occurs at the end of the process.

The first process requires a larger initial investment, but can reduce the processing costs. If starch separation occurs at the start it would be possible to divide the starch in two fractions (high quality and value and lower quality one). The high quality fraction could be sold for the food industry or for other industrial uses (natural polymers) the low quality fraction could be used for the production of ethanol.

In order to use wheat for ethanol production the starch has to be extracted and broken down to sugar. This occurs with a two-step process of enzymatic hydrolysis:

- Liquefaction: the prepared feedstock is mixed with water to form a slurry, then a liquefying enzyme (alpha amylase) is added. This breaks down the starch molecules into non-fermentable sugars (dextrins);
- Saccharification: this process breaks down the dextrins into fermentable sugars using a second enzyme (Houghtron-Alico, 1982).

5.5.2 Costs of ethanol production from wheat

An economic analysis for the costs of producing ethanol from wheat (updated from Batchelor et al, 1994 and Warren et al, 1994 for current grain prices) is given in Table 5-1, assuming a current wheat price of £55/tonne (Sept 2002) and animal feed prices (based on rapemeal and soya meal) of £90/tonne.

The costings are based on a plant producing 30 million litres which equates to 100,000 litres of anhydrous ethanol and 90 tonne of distillers dried grains with solubles (DDGS) per day. This plant would have a grain requirement of 260 tonne of wheat per day and 78,000 tonne of wheat per annum.

Table 5-1 – Costs of ethanol derived from wheat grains (pence/litre)

	*30 m litres/year**
Capital costs	10.4
Wheat (£65/t)[a]	16.9
Other raw materials	
Energy	4.7
Staff	2.2
Maintenance	0.7
Administration	0.7
Interests on capital	1.1
Total annual costs	**36.7**
By-product income	
DDGS (£90/t)	8.1
Net cost	**28.6**

* given ethanol density of 0.78g/ml this would equate 23,000 t/year.

[a] Including haulage charge at £10/tonne (25 mile haul)

Source: based on SAC data, (Walker *et al.* 2002)

The above figure is highly sensitive to feedstock price. Grain price is currently at a low at around £55/tonne, at £70/tonne the costs of ethanol rises to 32 per litre. British Sugar estimates the cost at between 32.5-39.9p/l (British Sugar, 2002 (unpublished)), but this will be influenced by price of grain used in the calculations. On an area basis, typical UK wheat crops are capable of producing between 60 and 70% of the ethanol yield of sugar beet crops (see Table 5-5).

5.5.3 Costs of ethanol production from sugar beet

The low dry matter content of sugar beet (20-24%) and contamination of harvested beets with stones and soil makes transport very expensive. As beets (or the juices) cannot be economically stored long term (due to rotting of beets and fermentation of juices), ethanol production from sugar beet is likely to be seasonal (lasting around 4 months in the autumn/winter period). Sugar feedstock can be delivered to the distillery as beets, molasses or concentrated beet juice. To extract sugar the beets need to be cleaned prior to sugar juice extraction. White sugar is extracted and crystallized leaving molasses as a by-product. Crystallization removes only 50% of the sugar in the juice. Molasses are recycled several times until is no longer economically viable to extract more sugar. If the molasses are used for bioethanol production, typically only 50% of the sugar content is removed by crystallisation. Sugar beet gives a relatively high ethanol yield per unit area (see table 5-5).

Data on costs of processing beet into ethanol are difficult to obtain. Batchelor, Nielsen and Pedersen (1996) provide an estimate of £20-23p per litre. However this is based on a beet price of £18-21 per tonne. The current price of beet is around £29 per tonne, which represents a significant increase (38-60%). The price of the feedstock accounts for over 50% of the cost of production and has a significant impact on the final costs. Marrow et al., (1990) estimated the costs of producing ethanol from sugar beet at 39p/l (at a sugar beet price of £31/t).

The main by-products from ethanol production are beet tops (at the farm level), beet pulp and vinasse. Beet tops and pulp can be fed to animals, vinasse can be mixed with the pulp or used as potash fertiliser.

5.5.3.1 The future for sugar beet production in the UK

The future for sugar beet production in the UK is going to be severely affected by the Everything But Arms (EBA) agreement which will impact on the EU sugar regime. The EBA (as amended on February 2001 by the EU General Affairs Council) will introduces a gradual liberalization of the EU sugar markets, through relaxation of quotas and tariffs on sugar imports from Less Developed Countries (LDCs) (Table 5-2).

The initial import quota concerns only raw cane sugar for refining; however by 2009 complete liberalization of the sugar market will occur, including free access to the EU for processed white sugar from outside the EU.

Table 5-2 Tariff and quota reductions on sugar imports associated with the EBA agreement

Date	*Tariff quota*	*Reduction in tariff*
01/07/01	74,185	
01/07/02	85,313	
01/07/03	98,110	
01/07/04	112,827	
01/07/05	129,751	
01/07/06	149,214	20%
01/07/07	171,596	50%
01/07/08	197,395	80%
01/07/09	Complete liberalisation	100%

Source: Royal Agricultural Society of the Commonwealth, 2002.

As ethanol is produced using by-products from sugar refining, then any decline in the overall profitability of sugar production will impact on UK ethanol production capabilities. It is likely that in the near future UK sugar beet production will come under pressure as profitability declines due to lower returns on harvested crop in the face of competition from imports. In such circumstances any ethanol production from by-products of sugar refining will rely increasingly on imported feedstocks. Such production could supplement ethanol produced from other feedstocks.

5.5.4 Lignocellulose feedstocks

Lignocellulose refers to a mix of lignin and cellulose contained in plant parts, and the lignin protects the cellulose from degradation. To start fermentation the cellulose must be broken down into its constituent sugars. The lignin cannot be used and is left as a by-product of fermentation. The lignin waste could be burnt to produce energy for the production of ethanol. The typical composition of various lignocellulosic materials is shown in Table 5-3.

Table 5-3 Typical composition of lignocellulosic materials

Source	*Cellulose*	*Hemicellulose*	*Lignin*
Softwood	35-40	25-30	25-30
Hardwood	45-50	20-25	20-25
Miscanthus	45-50	20-25	10-17
Straw	33-40	25-30	10-17

Source: Marrow *et al*, 1987, Marrow, 1990.

Lignocellulose feedstocks include wastes (straw, forestry residues) or materials that could be specifically grown for biomass production for either direct burning (for heat/power generation) or ethanol production (SRC, Miscanthus). The cellulose and the hemicellulose are encased by lignin, which inhibits enzymatic hydrolysis. To overcome this the lignocellulosic material has to be pre-treated. This can be chemical, physical or via steam-treatment with alcohol/water mixtures. The cellulose is hydrolysed (by either acidic or enzymatic action) to break the cellulose down to glucose.

5.5.4.1 Short Rotation Coppice (SRC) and Miscanthus

SRC and Miscanthus have a very similar material composition, (see Table 5-3). SRC provides higher dry matter yields of around 36 t/ha, but is only harvested every 4 years. Miscanthus gives lower dry matter yields (10-12 t/ha) but is harvested every year for up to 15 years. Both SRC and Miscanthus are currently being grown for biomass energy production.

Estimates for the cost of production of ethanol from yellow poplar are available for the USA (NREL) and vary between $ 1.44-1.14 per gallon (15-19p/litre). Future predictions estimate that by 2015 the cost could drop to 0.76c per gallon (10p/litre). It is difficult to readily translate these figures to the UK due to differences in for example the costs of borrowing, fiscal rates and differences in costs of materials etc. An estimate of the costs of ethanol production from wood feedstock for the European situation is given in Table 5-4. The costs relate to a plant capable of producing 136,000t/yr and 76,000t/yr for acid and enzymatic hydrolysis respectively. These figures are much higher than the US data suggests.

Table 5-4 Costs of ethanol production from wood sources (new/waste)

	Acid hydrolysis (pence/litre)	Enzymatic hydrolysis (pence/litre)
Production cost	46-58.5	73.5
By-products credit	8.5-23.5	2.5
Net cost	35-46.5	71

Source: Marrow, 1990

5.5.4.2 Forestry waste, wood processing waste and straw

Agricultural and forestry waste products suitable for the production of ethanol include straw, forestry waste and wood processing wastes. Domestic wastes, paper wastes and other wastes currently require expensive selection and separation of the useful material (Marrow *et al*, 1987).

Forestry waste could be supplied from managed forests (‘lop and tops’ – branches and tops which account for 10-25% of tree mass). However significant amounts of wastes are required to produce one tonne of ethanol (Table 5-5) and given the low density of supply (0.2-3.9 t/km^2, average 3.4 t/km^2) (Marrow and Coombs, 1990) too little material could be readily sourced to supply a 500 thousand litre/day ethanol plant (which would require 0.75 Mt/yr of wood). Even with a high density of supply the estimated ethanol yield potential per hectare remains low (Table 5-5).

Wood wastes from the processing industry present the same problem. The density of surplus (currently mostly being sold or used as a fuel at the point of production) amounts to 5t/km^2 in some areas, but the ethanol yield per hectare is low (0.5-0.8 l for softwood and 1.1-1.5 l for hardwood).

An estimate of the cost of ethanol production from wood, wood waste and SRC is given in table 5-4. High costs arise because only 45% of the dry matter is fermentable sugar that is recovered with only 55% efficiency.

The by-products of lignocelluloses processing come from hemicellulose and lignin. An increase in the relative value of the by-products is necessary to improve the economics of ethanol production.

- Xylose is produced as a by-product from hemicellulose, it can be sold into the molasses market (as animal feeding) or converted to furfural (a selective solvent used in petroleum refining).
- Extracts from lignin could be used as plastic extenders, in adhesives, as surfactants, asphalt extenders and rubber reinforcers. Alternatively it could be dried and burnt to increase energy recycling.

5.6 Comparison of bioethanol output from different feedstocks

The feedstock requirement for 1 tonne of ethanol production and the typical potential ethanol supply from 1ha of each feedstock is given in table 5-5. Clearly the high sugar and starch content feedstocks give the highest outputs, but the practical problems of storing potatoes and sugar beet cost-effectively long term after harvest rules them out of all but seasonal processing. Wheat is a very effective feedstock and costs of production compare favourable with those of sugar beet feedstocks. However, the energy balance also needs to be considered (see next section) where lignocellulosics have an advantage. Utilisation of the whole crop can significantly improve the energy balance. Work in the USA demonstrates that ethanol can be produced very cheaply from SRC and ethanol outputs/unit crop area can be close to half of those achieved with wheat grain feedstocks.

5.7 Energy balance

If biofuels production is pursued in order to increase sustainability then it is necessary to determine the balance of the energy contained in the biofuel compared to that required to grow and produce it. A means of doing this is to assess the Net Energy Ratio (NER) where

$NER=e_{lbf}/e_{ff}$

e_{lbf} is the energy in the liquid bio-fuel and e_{ff} is the energy equivalence of the fossil fuel inputs used to grow, harvest and process the fuel. Values less than one indicate that the energy yield of the resulting biofuel is less than that of the energy used to producing the fuel. Conversely, values greater than one indicate that the fuel yields more energy than that used to produce it.

The NER value is very dependant on subjective assessment of individual parameters, so it is important to bear in mind that this provides an indicative value only and values in the literature vary significantly. The values presented in Table 5-6 come from a broad study carried out on behalf of the EC.

Table 5-5 Tonnes of feedstock crop required to produce 1 tonne of ethanol and typical yields of ethanol per hectare of feedstock crop.

Ethanol Feedstock (typical field yield)	*Feedstock requirement per tonne of ethanol produced (tonne)*	*Estimated ethanol yield from typical UK crops (kg/ha/yr)*
1. STARCH CROPS		
Potatoes (40 t./ha)	11[a]	3600
Wheat (8 t/ha)	2.5-3.0 [a]	2600 - 3200
2 SUGAR CROPS		
Sugar beet (48 t/ha)	11-12.5 [a]	3800- 4300
3 LIGNOCELLULOSIC		
<u>*Grown*</u>		
SRC*	5.5-7.5[b]	1,200-1,650
Miscanthus (10-12 t/ha)	5.5-7.5 [c]	1,400-2,000
<u>*Waste*</u>		
Hardwood	5.5-7.5 [b]	5-6
Softwood	6.25-9.75 [b]	3-5
Straw	4.25-6.25 [b]	750-1050

*SRC is harvested every 4 years; the yield indicates the equivalent annual ethanol production potential per hectare.

Source: [a] Derived from Marrow, Coombs and Lees 1987, [b] derived from Marrow and Coombs, 1990. [c] estimated based on material composition

Table 5-6 NER values for different feedstock/processes for ethanol production (not accounting for waste disposal).

Feedstock/process	*NER*
Beet/fermentation/ethanol	1.0-1.07*
Wheat/fermentation/ethanol	0.82-0.96*
Wheat/fermentation/ethanol (straw fired)	2.51*-3.08
Wood/fermentation/ethanol (acid hydrolysis)	1.28-1.38
Wood/ fermentation/ethanol (enzyme hydrolysis)	1.25-1.48
Straw/fermentation/ethanol (acid hydrolysis)	1.87-2.36
Straw/fermentation/ethanol (enzyme hydrolysis)	1.79-2.35

Source: Coombs, 1996 except * Armstrong *et al*. 2002

Production of ethanol from wheat grains is relatively energy inefficient compared to production from sugar beet or lignocellulosic materials. However, if cereal straw is also used in the process then the energy efficiency is greatly improved. In all cases, if the biofuel is used to fuel the crop production phase, then further improvements in efficiency are obtained. Recently derived NER values for RME range from 1.59-2.08 (Table 5-7).

Table 5-7 NER values for RME production (not accounting for waste disposal).

Data source:	NER
Armstrong *et al.,* 2002	1.59
Mortimer *et al.,* 2002	1.85-2.08
Richards, 2000	1.78

Much of the energy input into biofuel production is related to energy associated with production of the fertiliser used to grow the crop (42% of energy input for biodiesel production (Mortimer *et al.,* 2002)). The energy input associated with this aspect is currently the subject of considerable debate. Where straw or other by-products are also recycled as part of the production process then improvements in efficiency are achieved (e.g. Table 5-6). Where rape straw is also used in the processing of RME (straw-fuelled) then the NER improves to NER values as high as 3.7 (Richards, 2000). Using biofuel in the crop production chain would improve efficiency further.

6.0 POTENTIAL FOR BIOFUEL PRODUCTION IN THE UK

The current areas and yield potential of UK arable crops likely to be used as biofuel feedstocks is detailed in Table 6-1, along with current areas of non-cropped land (set-aside). Also included is an estimate of UK production as a proportion of UK demand. Some caution is required in interpretation where raw materials are imported for re-exportation as processed product etc (e.g. oilseed rape).

Table 6-1 Areas of major arable crops in UK (2001) with potential as biofuel feedstocks and area of set-aside

	Area ('000 ha)	Production ('000 tonnes)	Average UK yield ('97-'01) t/ha	Production as % of supply for use in UK
Total cereals	3014	18,990	-	
- of which wheat	1635	11,570	7.62	85 %
Oilseed rape	404	1,038	2.98	83 %
Oilseed rape on set-aside	48	121	2.84	-
Sugar beet	177	8,180 (1.2 Mt sugar)	53.22	63 %
Potatoes (maincrop)	158	6,354	42.04	85 % (raw + processsed)
Set aside	800	-		
Total UK cropped area	4454	-		

Source: Derived from DEFRA Statistics

6.1 2005 liquid biofuel target

Based on the targets for a 2% substitution of road transport fuels by 2005, in the short term it is likely that only biodiesel production will be sufficiently well developed commercially in the UK to contribute significantly towards this target. The areas of oilseed rape production required to meet the target from UK-produced RME are given in table 6-2.

The target for replacement of 2% of fuels with renewable fuels could be met from growing over 600 hectares of oilseed rape. Two scenarios are considered:

A) Production takes place on set-aside utilising land deemed 'surplus to current requirement'
B) Production occurs on arable land assuming growing of industrial crops on set-aside land is curtailed (as proposed under current proposals being debated as part of the mid-term review of Agenda 2000)

Table 6-2 Areas of oilseed rape production required to meet 2005 renewable fuel targets from UK-produced RME

	Fuel Use ('000 tonnes)	2% RME ('000 tonnes)	OSR Area equivalent (fresh oil alone) ('000 ha)	OSR Area equivalent (100,000 tonne met from waste oil) ('000 ha)
All fuels	40317	806	707	619
Diesel only	19773	395	346	258

The area of set-aside in the UK has ranged between 300 and 800 thousand hectares in recent years in response to changes in the designated area of set-aside required to regulate supply of cereals. Currently the rate of set aside is 10%, which releases around 800 thousand hectares from agricultural production. The target for replacement of 2% of fuels with renewable fuels could be met from growing over 600 hectares of oilseed rape on set-aside land in the UK without affecting current UK farming practice or rotations [though oilseed rape production would be limited on the lightest textured soils where oilseeds do not perform well]. There would be environmental consequences potentially arising from loss of natural regeneration set-aside and additional nitrogen and pesticide input etc, these effects are discussed in more detail in section 8. A further consideration is implications for world trade arising from increased rape meal production (see section 4.6.2) despite the obvious value to EU livestock. If problems materialise then alternative non-feed markets may need to be found for the meal.

A further problem for the future of industrial cropping on set-aside is the outcome of the mid-term review (MTR) of Agenda 2000. Currently the European Commission proposes, as part of current consultations, that the rules which allow non-food crops to be grown on set-aside are scrapped and replaced by a 'carbon credits' scheme whereby an aid payment of 45€ (approx £27) will be paid for 'energy crops' up to a maximum guaranteed area of 1.5 million ha. The eligible area would be shared out between member states in proportion to historical production of energy crops on set-aside. This would disadvantage the UK where energy crop production currently lags behind that of our European neighbours. On this basis, any crops grown for energy above any 'carbon-credit allocated area' would have to compete on an equal footing with crops for conventional market outlets.

Implementation of the MTR proposals as they stand would have a significant impact on biofuel crop production in UK rotations. To continue to meet UK rape oil demands in the food sector as well as contribute to replacement of 2% of the UK's transport fuels, the rape area would have to increase by 153%. On arable land where root or horticultural crops cannot be grown, oilseed rape is the most profitable break crop and dominates the break crop acreage. The current Maximum Guaranteed Area ensures some control over production by scaling back support payments where the target maximum area is exceeded, within this market constriction, oilseed rape production is currently optimised (in agronomic terms) in areas of high oilseed productivity. It is likely that any expansion in the oilseed area would occur in the areas currently dominated by rape, as economics and competitiveness in combinable crop rotations is dependant on yield performance compared with returns achievable from cereal cropping. This is likely to lead to shorter rotations between rape crops, leading perhaps to two rape crops in a rotation of 5 or 6 courses. It is possible to grow rape continuously, as was done by ADAS at High Mowthorpe in North Yorkshire for 8 years. Yields were comparable with conventional crops in most years, but higher inputs of herbicide and pest control were required in later years. It is questionable whether continuous rape production would be desirable, economically it would be less favourable than where 1st wheats were grown in the rotation.

In the absence of set-aside for expansion, any growth in the oilseed rape area is most likely to be at the expense of second wheats on heavy and medium textured land as well as other spring break crops and winter bean crops on medium-textured land. Oilseed rape is unlikely to make inroads on light soils. In the former case this is likely to move towards a better balance between cereal and non-cereal crops in the landscape. This could result in wheat/rape rotations of perhaps as close as 1 in 2 on heavy soils, where minimum tillage and seed broadcasting techniques would need to be refined to ensure timely oilseed rape establishment. In other cases, a second oilseed rape crop could be incorporated into the rotation to displace winter sown beans or spring break crops. This scenario is less desirable, resulting in reduced crop diversity, and effects on success of farmland birds where overwinter stubbles are replaced (section 8). In all cases yields of oilseed rape would need to be maintained at a high level to ensure economic viability in both of the above cases even if additional revenue for fuel crop production was made available to growers.

In reality, it is unlikely that the above scenario is likely to be realised to a significant extent in practice. An extension of oilseed rape cropping to the extent required to meet the proposed 2005 target from RME alone is likely to be difficult to achieve in practice. What is more likely is that a proportion of the conventional crop will be sold speculatively for fuel use where the price is favourable. On balance, it is most likely that 2% replacement of the diesel market alone is achieved by 2005. Farmers will be reluctant to reduce rotational intervals between oilseed rape crops for fear of developing pest and disease problems and reducing yield and profitability. A significant price premium would be required to encourage such a shift and it is currently not clear whether this will be available to growers, and whether any money derived from reductions in duty will be passed down to primary producers. If the proposed renewable fuel targets are to be met for 2005 and beyond, then a broader mix of fuels needs to be considered. The target for replacement in 2010 is an even more difficult task and requires innovative solutions and reconsideration of means of achieving the targets if they prove unsuitable.

6.2 2010 liquid biofuel target

For 2010, the proposed targets for fuel replacement are detailed in table 6-3. It is assumed that there will be little increase in the volume of waste oil recycled, and little opportunity to increase RME production beyond that achieved by 2005 for the reasons outlined above.

Table 6-3 2010 predicted fuel consumption and targets for renewable substitution

	Fuel Use (‘000 tonnes)	5.75% (‘000 tonnes)
All fuels	44514	2560
Petrol	19637	2417
Diesel only	24877	1430

The target represents a considerable task and without significant import of vegetable oils for biodiesel production, the bulk of this would have to be met from bioethanol production. Of the feedstocks available, the most likely sources in the UK, after suitable waste materials, would be wheat (where straw is recycled in the plant to improve energy ratios etc) and perhaps sugar beet plus lignocellulose derived from short rotation coppice and wood waste. It is assumed that by 2010 the development of plants and processes for dealing with lignocellulosic materials would be refined and commercialised and that costs of production would be comparable with ethanol derived from other sources.

Wheat is a valuable commodity and it is assumed that no more than around 5% of the UK cereal crop (equivalent to current UK cereal surplus production) would be available for bioethanol production, capable of producing 435 thousand tonnes of ethanol (assuming average grain yields of 8 t/ha).

The UK sugar beet area is regulated by quota and has reached 205,000 ha in previous years. This represents the area of optimal sugar beet production for the UK and it is unlikely that there would be a significant potential for expansion above this area due to soil limitations for beet production. Sugar beet is already grown in a 1 in 4 rotation with cash crops such as potatoes or root vegetables, which limits the potential for further expansion within the rotation. Assuming this beet area is maintained (and there is some uncertainty about this (see section 5.5.3.1)), this could potentially produce around 830,000 tonnes of ethanol.

The predicted total production of biofuels derived from oilseed rape, wheat and sugar beet still falls short of the total bioethanol feedstock required to meet the target for fuel replacement and a significant proportion of biofuel requirement would have to be met from novel sources such as short rotation coppice or wood waste etc. A possible breakdown for supply of bioethanol is given in table 6-4.

It is estimated that around 30,000 tones of bioethanol could be produced in the UK from forest thinings and waste wood etc (based on reworking of values in Marrow and Coombs, 1990). This leaves a requirement to source around 0.5 million tonnes equivalent of fuel, or 20% of target requirement. SRC and/or Miscanthus could make a contribution to this and would require around 250 thousand hectares of production.

Table 6-4 Possible scenario of crop feedstock areas required to achieve 2010 targets for renewable fuels

	Biofuel yield (tonnes)	Approx feedstock area (ha)
RME		
From waste oil	100,000	
Fresh oil	600,000	350,000[a]
Bioethanol		
Waste wood	30,000	
Sugar beet	830,000	205,000
Wheat/straw[c]	435,000	150,000
SRC/Miscanthus [b]	500,000	250,000
	2,495,000	955,000

[a] Assumes high conversion rate of 1.7 t RME/ha rape production
[b] Assumes high conversion rate of 2 t ethanol/ha of crop production
[c] Assumes high conversion rate of 2.9 t ethanol/ha of crop production

Currently, the economics of perennial energy crop production are marginal compared with returns from combinable crop rotations and they would not compete with rotations capable of growing cash crops like potatoes and sugar beet. As such, it is unlikely that lignocelulosic feedstock crops would be grown in significant quantities on current arable land if access to production on set-aside was removed. With suitable support, it is more likely that lignocellulosic crops would replace land currently in grass in situations where land could be mechanically harvested and cultivated. In the UK there are currently 1.2 million hectares under rotational grass and 5.6 million hectares under long-term grass production. Given the current downturn in dairy and extensive meat production systems, production of liquid biofuels, bioenergy crops or a combination of the two could offer a potential alternative enterprise for rural economies dependent on such enterprises. The move from grassland to lignocellulosic biomass cropping would have landscape and environmental impacts, but siting plantations as extensions to existing woodland (enabling dual use of SRC and waste wood) etc could be advantageous.

Recent trends towards lowering of stocking densities and environmental support schemes could help stimulate opportunities for farm diversification. Initial studies on the suitability of SRC production in the Welsh uplands, using slurry to fertilise the saplings has proved promising (Randerson *et al*., 1997). A financial comparison of sheep and SRC production in the uplands of Wales (Heaton, Randerson and Slater 1999) indicated that in the absence of subsidy payments, SRC production could be more profitable than sheep farming, assuming a yield of over 8t/annum could be achieved (with a value of £35/tonne). This is a low yield that should be achievable even on upland sites. British Biogen are currently lobbying government to pay subsidies equivalent to those paid for sheep production to farmers wishing to switch to SRC production. A modelling study by Heaton, Randerson and Slater (1999) indicated that provided 10 t/ha of dry matter could be produced then SRC would actually require less subsidy than the same area of land used for sheep production. If such advice is accepted and acted upon, then this could provide the incentive required to expand SRC areas and improve the potential of the UK meeting targets for renewables.

Without access to areas of land outside the current arable area, and with restrictions on use of set-aside for biofuel production, it will prove difficult to meet the indicative targets established by the EU for biofuel substitution in 2010 by using UK produced feedstocks alone. This would be exacerbated if sugar beet production declined in the UK as a result of the future liberalisation of EU sugar markets. Unless a sugar refining capability is retained in the UK, to provide by-products for bioethanol production, then even larger areas of lignocellulose production would be required to meet the indicative targets and/or better means would have to be found of collecting and transporting crops wastes (e.g. cereal straw etc) to processing plants so that they could be better exploited.

6.3 Potential for imports

6.3.1 Vegetable oils and grains

According to FEDIOIL statistics (IENICA 2000), the EU as a whole is currently virtually self sufficient in production of rape and sunflower derived oils, with limited import into the EU of processed oils from these crops. Around 300 thousand tonnes of rape, and 2 million tonnes of sunflower are imported into the EU for crushing. The bulk of the EU vegetable oil deficiency is met by importation of groundnut, copra, palm, castor and maize oils for speciality or specific uses. In some cases these, could substitute for rape depending on price and supply. There is potential for increasing sunflower oil production in several of the accession states, which could significantly increase exportable supplies of this competitor feedstock.

There may be some opportunities for niche marketing of crops to meet feedstock demands or shortfalls. For example 100 ha of spring barley grown on set-aside in East Anglia was recently shipped to Spain for bioethanol production, providing growers with a £6/tonne premium over conventional feed market outlets.

6.3.2 Trade in biofuels

It is likely that international trade in refined liquid biofuels is likely to be limited in the short to medium term due to the scarcity of supply and demands from the domestic market (Biogen/ABF/British Sugar 2002).

The largest producers of biodiesel are currently France and Germany, while Spain and France dominate the ethanol production market (Table 6-5). Ethanol production in Spain has increased dramatically since the data in table 6-5 was compiled, facilitated by investment by the Abengoa company in new production plants, which now has a 15% world market share in ethanol production. In Germany, biodiesel production in 2002 was reported to have grown to 625 thousand tonnes, and the forecast for 2003 is for 1 million tonnes (Walker *et al.*, 1992).

Table 6-5 Biodiesel and Bioethanol production in Europe (2000)

	Biodiesel production (million tonnes)
France	328,000
Germany	246,000
Italy	78,000
Austria	27,600
Belgium	20,000
Total:	700,600
	Bioethanol production (million tonnes)
France	91,000
Spain	80,000
Sweden	220,000
Total:	191,000

Source: EurObserver (EU institute on renewable energy)

7.0 POTENTIAL EFFECTS OF BIOFUEL CROP PRODUCTION ON THE RURAL LANDSCAPE

7.1 Crop

Visual Impact

Renewable energy crop production is compatible with food crop production where crop species are common. Most energy crops will be grown in rotation as part of a mix of several crops on the farm. Introduction of perennial crops like SRC and Miscanthus requires more careful planning, with stands lasting from 5 to 20 years (Graham, Liu and English, 1995). Most biofuel feedstock crops would not add to the variation in structure of the landscape, being present already on large areas. The exception to this is willow coppice and Miscanthus, though these crops do not give much variation in colour to existing arable crops (European Commission, 2000).

Landscape design is important to introduce variety into the vegetation/crop mosaic, and to maximise the "edge-effect" to increase visual interest. Landscape buffers can also be used to help to protect watercourses from soil or water runoff. Sloping landscapes are also more visible so impacts can be exaggerated

Oilseed Rape

The yellow flowers of oilseed rape are accepted in the countryside, but would be seen as a disruption in areas without these crops. The plants are not attractive outside the flowering month and block cropping is likely, which could lead to large areas dominated by oilseed rape. It is unlikely that there would be an expansion in OSR cropping outside of the traditional areas of production.

Sugar Beet

Sugar beet is best grown in regions where arable crops are already established. It is unlikely that the crop will expand significantly, if at all, outside of the current production areas. Sugar beet fields are relatively bare until late spring, and sparsely vegetated until after mid-May. It is considered not to be a very aesthetically pleasing crop.

Cereals

Wheat dominates the local landscape in many regional. It is not anticipated that there would be any increase in the cereal acreage in the landscape, and in some cases it could decline if economics favour more intensive rape cropping for biofuel production.

Short rotation coppice

It is anticipated that there could be an increase in perennial biomass crops grown for biofuel. SRC adds structural diversity to agricultural landscapes, which should enhance biodiversity on a regional scale (Graham, Liu and English, 1995). The impact of SRC on the landscape can be minimised by designing plantation to fit into existing landscape. For high density planting, parallel rows are needed, but these do not necessarily have to be straight rows. With different blocks being cut every year structural diversity can be maintained with graduated heights. However, willow and is taller than most arable crops and could obscure views. SRC crops can be marginally more intrusive than arable crops, but they are unlikely to have any significant negative visual impact in lowland areas. However, the Council for British Archaeology (2000) believes extensive SRC plantations could be unsympathetic to the wider historic landscape character.

Miscanthus

Most lowland sites in England would be suitable for Miscanthus cropping (DEFRA, 2001). Miscanthus is a non-native with an unfamiliar growth habit in the UK countryside. It is not dissimilar in character to that of forage maize, though it is taller. It is likely to have a significant visual impact in the countryside.

Noise Impact

Noise from farming SRC and other biomass crops would be comparable to noise from arable farming and therefore would be acceptable in arable areas but perhaps less so in areas less used to such noise.

Traffic Impact

Both the RDA and the Food and Drink Federation consider than an increase in renewable energy crops would lead to an increase in rural traffic (Sustainable Development Commission, 2001). For example, road access will be needed to transport large quantities of coppice wood during the harvest season (Scottish Agricultural College, 2000) and planning permission may restrict delivery timings, size and type of vehicles. However, where conventional arable crops are used as feedstocks then there is likely to be little impact on the movement of crops, which would have been moving off farm anyway. Growing of crops specifically for lignocellulose on arable farms may actually reduce transport pressure at the peak crop harvest time as harvest of lignocellulosic crops takes place during late winter. Harvested material may then be stored on farm (where practical) to ease pressure on central storage and allow co-ordination of transport from several sites etc. Transport is only likely to be increased noticeably with expansion of lignocellulosic feedstocks onto non arable land, where additional journeys are being made. Remote areas where conventional farming may be marginal tend to have the most under developed transport facilities. This often works against a centrally placed processor or production facility collecting feedstock crops from a wide area, which would be the type of development favoured for biofuel production where economies of scale could be realised.

7.2 Production Plant

Visual Impact

The physical appearance of biofuel production plants may raise public objections. Designs of any rural plants would need to be sympathetic with the landscape character and/or screening with trees would need to be considered. (British Biogen, 2001). In reality most biofuel production plants are likely to be associated with existing sugar refining and oilseed crushing plants, or industrial refining plants in a more urban context as this will reduce logistical problems of transport etc.

Traffic Impact

Overall, increases in vehicle movements may be minimal, but traffic is likely to be more concentrated around large biofuel plants.

8.0 POTENTIAL ENVIRONMENTAL IMPACTS ARISING FROM BIOFUEL PRODUCTION SCENARIOS

The impacts of arable crops and potential biomass biofuel feedstocks on resource use (agrochemicals and fertiliser), resource protection (soil resource and risk of nutrient leaching) and biodiversity are reviewed in Appendix I.

As discussed previously, targets for biodiesel production would be met either from either a) growing rape on set-aside land, predominantly replacing naturally regenerated set-aside or b) displacement of some wheat by oilseed rape and/or c) diversion of crop from food use into the biofuel market (driven by market advantage), with little change in impact on the environment.

In the longer term, biofuel production is likely to be met from a broader mix of feedstocks, primarily from diversion of feedstocks from food or sugar by-products into bioethanol production. In these cases there is a neutral effect on the farmed environment, though there could be a move towards reducing agrochemical inputs where quality of product rather than quantity is less of an issue. In the longer term, the technology for producing bioethanol from lignocellulose is likely to improve significantly, and costs of production will decrease. While cereal straw and other arable crop wastes could provide some of the raw material, without affecting the farmed environment significantly, SRC and biomass crops like Miscanthus are much more effective sources in terms of ethanol yield/unit area.

8.1 Replacement of set-aside by oilseed rape

If all of the required production was met by additional oilseed rape production on set-aside, the majority of such set-aside would disappear. This would result in an increase in intensification, in terms of cultivations, pesticide and fertiliser use, with potential implications for resource protection and biodiversity. However, oilseed rape has less negative environmental impact than some other crops in many respects (see Appendix I).

Although use of nitrogen fertiliser is relatively high, nitrate leaching from oilseed rape crops is lower than with many other crops. However, nitrate leaching after rape can be higher than that after cereals due to the higher nitrogen residues left in the field. In comparison, a flush of nitrogen can also be released after ploughing of rotational set-aside in preparation for the following crop. Oilseed rape is unlikely to contribute substantially to problems of soil erosion or compaction. However, pesticide use is a concern, particularly the amount of insecticide use in the summer and its potential impact on non-target invertebrates, including pollinators, natural enemies of crop pests, and invertebrate food items of farmland birds. There is no indication that pesticide use on industrial rape is lower than on conventional rape crops. If the area of oilseed rape increased substantially, there could be an impact on abundance of some groups of invertebrates in arable areas, with knock-on effects on other species through the food chain. In particular, there is a need for more research on potential impact on wild bees foraging in rape crops.

Crop and habitat diversity are generally accepted as being beneficial, both for biodiversity and landscape. The replacement of naturally regenerated set-aside by oilseed rape would lead to a decrease in habitat diversity, and in combination with rape grown for food use could lead to large blocks of rape fields in some areas, with detrimental consequences for biodiversity and landscape. Where alternative forage was unavailable, excessive feeding on rape by deer could lead to poisoning of roe deer, which has been observed in Austria and Germany, though not so far in the UK.

Naturally regenerated set-aside generally has higher biodiversity than crops. However, rotational set-aside is generally sprayed with broad-spectrum herbicide in spring or early summer, so plant diversity in late summer may be higher in some rape crops, depending on the level of weed control achieved. In such cases, more weed seeds will be produced in rape crops, providing potential food for seed-eating birds. As rape stubbles are usually ploughed soon after harvest, this food source is unlikely to remain available for long. In contrast, naturally regenerated set-aside can provide a source of food throughout the winter, which has been identified as important for declining birds such as yellowhammer, cirl bunting, corn bunting and skylark (Evans *et al*., 1997).

Not all species would be adversely affected by the replacement of naturally regenerated set-aside with oilseed rape. Oilseed rape is particularly important for woodpigeons, being the major source of winter food in most years for this species. Woodpigeons have increased substantially in recent years, and were the most frequently recorded species in the Breeding Bird Survey in both 2000 and 2001 (Raven *et al.,* 2002). As they are widely regarded as a pest species, any further increase in their numbers would be regarded by most farmers as undesirable. Oilseed rape is also an important food source for nestlings of linnet, and there is evidence that the increased rape area during the 1970s and 80s may have helped to stem the decline in linnet numbers (Moorcroft *et al*. 1997). A further increase in rape area could therefore be beneficial for this species.

In conclusion, the replacement of current forms of set-aside with oilseed rape would on balance be environmentally detrimental, due to the resulting increase in intensification and reduction in habitat diversity, though a few species would probably benefit. However, oilseed rape has a less negative environmental profile than some other crops, and imaginative mitigation measures could help to minimise environmental damage from an increase in rape area. These could include measures to avoid large-scale block–cropping, introduction of a percentage of non-crop habitat and increased awareness of, and incentives for, the need to minimise pesticide use and follow the principles of integrated crop management.

8.2. Replacement of other crops by oilseed rape

As the growing of additional rape would be most likely to occur where oilseed rape is already widely grown, the replacement of other break crops such as winter beans or spring-sown peas or barley would result in a reduction in crop diversity in the rotation, the impacts of which could be environmentally detrimental depending on the crop replaced. For example replacing spring-sown crops with winter sown crops removes overwinter stubbles which are beneficial to farm land birds etc. Spring crops also have a more open canopy structure, preferred by ground nesting birds e.g. Skylark. Spring crops also support more spring germinating weeds such as *Polygonums* and Chenopodium album (fat hen) which have a high value as bird food sources.

On heavier land, oilseed rape is likely to replace second wheats, resulting in increased crop diversity, as wheat is currently the dominant crop. The balance of environmental impact in this situation is difficult to predict, with gains and losses in different areas.

Wheat and rape are relatively similar in terms of fertiliser and pesticide use, though insecticide use is higher on oilseed rape, and insecticides are generally applied in the summer when they are likely to have greater effects on non-target species. In contrast, a large proportion of insecticide application to wheat is made in the autumn. Fungicide use is higher on wheat, but fungicides have a lower environmental impact than insecticides. Herbicide use is also greater on wheat, and oilseed rape crops may carry a higher level of broad-leaved weeds, especially where crop density is low, which could support a higher level of invertebrates and provide more feeding opportunities for birds.

Rape crops are less prone to soil erosion and compaction than wheat, but more prone to nitrate leaching after harvest. In terms of biodiversity, species using the two crops differ, so some would benefit from increased rape while others would lose. Overall, the environmental impact of replacing second wheats with oilseed rape is likely to be broadly neutral.

8.3. Increased area of perennial crops.

The UK area suitable for growing arable crops is well utilised, though there may be some scope for replacement of food crops with energy crops with appropriate financial incentives. However, in the longer term, if a significant proportion of fuel needs are to be met from biological sources, it is likely that there will be a need to look beyond the constraints of current arable crops (for which there will still be a demand from the food sector both at home or abroad) to perennial crops such as short rotation coppice and Miscanthus which could be cluster-planted near processing plants.

SRC and Miscanthus require less inputs and sequester more carbon than arable crops, e.g. SRC can produce a 91% reduction in fossil fuel depletion, an 84% net saving in carbon dioxide emissions and a 78% net saving in greenhouse gas emissions, compared to figures of 60%, 68% and 53% respectively for oilseed rape (Mortimer *et al.*, 2002).

Livestock farming is now only marginally profitable or is unprofitable in parts of the west of England and Wales, and is only viable at all because of CAP subsidies. Perennial crops could represent an alternative or additional form of income for livestock farmers (Randerson et *al.*, 1997; Heaton *et al.*, 1999), thus potentially making available a large area of land for biofuel production. For example, there are over 900,000 ha of upland agricultural land in Wales that could be used for growing SRC (Heaton *et al.*, 1999).

Perennial crops would be seen as a longer-term investment, with plantations of both SRC and Miscanthus lasting 20-30 years. Economic viability would depend on the nearby location of a biomass plant. Short rotation coppice may be used to extend wooded areas near such plants, to add to present forest waste products and feedstocks.

In terms of resource use and protection, SRC and Miscanthus are relatively benign. Fertiliser use is modest, and pesticide requirements are also likely to be low, especially if integrated crop production guidelines are followed. Risks of soil erosion, phosphate losses and nitrate leaching are all low after the establishment year, and soil organic carbon content will increase over time. However, care is needed in siting crops to avoid problems with soil rutting and compaction during harvest.

The impact of perennial crops on biodiversity and landscape will depend on the species and scale of planting. Provided expansive areas are not planted, they would increase the structural diversity of the landscape. SRC may be of use in AONB's (if carefully sited to avoid obstruction of views), bio-remediation sites or alongside watercourses, where farming of cereals and oilseed rape may be limited. There is however some concern that the deeper roots of SRC and Miscanthus may be more harmful to archaeological remains than shallow rooted annual crops and such sites should not be selected for planting. It takes some effort to return SRC plantation land to former agricultural use, and rhizomes of Miscanthus are particularly difficult to remove completely, as plants can regenerate from small amounts of plant material.

SRC is likely to be more valuable for biodiversity than Miscanthus, especially if willow is planted rather than poplar. Miscanthus is a non-native, and the shade and litter produced by established plants are likely to exclude most other flora. Willows are native and support a wide variety of birds, mammals, invertebrates and other plants, especially if managed sympathetically. The varied structure created by the harvesting rotation of SRC provides habitat for species occupying a range of ecological niches, from open ground to woodland.

In conclusion, the planting of SRC has the potential to enhance biodiversity and the landscape, provided that planting is sensitively carried out and management is sympathetic. There is potential (with appropriate financial support) to utilise grassland areas in the west of the UK for SRC production as an alternative source of income and land use to complement the existing livestock and forestry industries in these regions. The regional potential for bioenergy cropping is summarised in Appendix II.

9.0 HEALTH ISSUES

9.1 Oilseed rape

The bulk of reported crop-related allergies by the general public in recent years have related to oilseed rape production. Following anecdotal evidence of complaints attributed to the increase in oilseed rape production, studies of the impacts of rape production on human health were started in the late 1980's, most of these in the UK were undertaken in Scotland. By 1989 the topic was receiving a significant amount of press coverage. Few similar reports have been made in France, Germany or Canada where there are large acreages of rape production.

There is a lot of conflicting research, in part due to failures in methodology, from which confusion arises. The British Medical Council's Institute of Environment and Health convened an experts meeting on the subject in 1996, which concluded that there is evidence of effects on human health associated with the cultivation of oilseed rape, but no convincing evidence that rape is the cause of widespread ill health in the general population. A significant amount of research has been done in Scotland. For example MacFarlane Smith (unpublished) reported that in a random sample of people in the Forfar area of Scotland, 46% of the test population recorded allergic symptoms (hay-fever like) during the flowering period, which also included changes in skin test reactivity to oilseed rape in 36% of patients, though it was concluded that a substantial study was required to identify the causal agents.

The claimed adverse effects of oilseed rape cultivation on human health was reviewed in the British Medical Journal in 1998 (Hemmer, 1998). Oilseed rape pollen is allergenic, but data on the incidence of sensitisation is conflicting. Generally allergy to rape pollen is uncommon, even in intensive areas of production, and is more commonly associated with individuals with multiple sensitivities. Sensitive individuals show a broad cross sensitivity to birch and grass pollen allergens and allergy to oilseed rape probably represents a sub-set of grass-pollen allergic patients. Oilseed rape pollen may augment or protract symptoms arising from tree or grass pollen in sensitive individuals. During the flowering period it is difficult and rare to achieve pollen loading levels sufficient to cause allergic reactions close to dwellings (Hemmer, 1998). Sensitivity therefore is most acute during peak flowering periods or in close proximity to fields.

Other potential causes of sensitisation have been highlighted, for example pesticides. However, the range of agrochemicals used is not significantly different from that of other crops. There is also no data to support high air loads of fungal spores being responsible for symptoms. Volatile chemicals associated with oilseed rape (terpenes, aldehydes and organic disulphides) may theoretically have an impact on sensitive individuals, by affecting mucous membranes, but there is little evidence that such compounds reach sufficient concentrations in air to cause such reactions.

Clearly flowering oilseed rape may be suffering from guilt by association. Pollen from other species could equally be responsible for effects attributed to the very visible flowering rape crop. Where populations with a contrasting incidence of rape production in the locality have been compared, then both populations reported an increase in hay-fever like symptoms, wheezing and itchy skin from May to August (work of Soutar *et al.* 1994, cited by Marquard and Walker, 1995) the early part of which coincides with flowering of oilseed rape. Asthmatics appear to be particularly affected during this critical time frame, and in the very limited studies to date, asthmatics report an increased recourse to use of medicines during this period. As the incidence of asthma sufferers, for whatever reason, appears to be on the increase in the UK, focus on oilseed rape as a source of irritants is likely to continue.

9.2 Other crops

Outside of the general problems experienced by hay fever sufferers with cereal-derived pollen, few crops other than rape have attracted attention as a source of allergies. However, storage of grains and seed crops is a source of potential problems. Storage moulds and mites are a source of allergens and serious lung infections (Farmers Lung). Incorrect storage of seed or grains is the culprit. As seed or straw quality may be less of an issue with crops grown for non-food uses, there could be an increased incidence of mould and insect infestation in storage if pesticide use is reduced or if less attention is paid to proper storage, as required by Assurance Schemes etc for certification for food and animal feed use.

10.0 SOCIO ECONOMIC ASPECTS OF BIOFUEL PRODUCTION

Reductions in duty applied to biofuels can be offset to some extent by revenue generated from increased employment. The following sections attempt to indicate the added value that could flow from biofuel production in terms of job and wealth creation. The greatest effects are realised where cropping takes place on otherwise unproductive land, effects are relatively neutral where one crop substitutes for another. Expansion of oilseed rape onto set-aside for biofuel production is taken as one example, and expansion of SRC onto grassland is used as a second example.

10.1 Introduction - A cautionary note

In assessing the socio-economic impact of biofuels, attention is commonly focused on the economic output (gross or net) of the feedstock production system or biofuel processing plant and/or on resulting employment in the wider economy. Changes in feedstock prices or costs of processing have a significant impact on output and employment. Such changes are difficult to predict as they arise from a complex interaction of many variables. Changes in output and employment are assumed to be the result of a well-defined relationship. However this assumption is questionable and the value of any production/functions or 'rural multiplier' commonly used in such analyses will change over time. Following the approach of previous studies (Mortimer *et al*, 2002, Forestry Commission, 2000), the following sections will briefly illustrate the impact of biofuel production on potential financial output and employment for a range of scenarios and typical biofuel production plant sizes.

10.2 Direct, indirect and induced effects

Impacts of farming enterprises on the rural economy are estimated by evaluating cash flows in the rural economy arising from cultivating a crop. This generates a direct income and attracts subsidies. After deduction of costs of production and fixed costs (cash which usually fails to enter the rural economy to any significant degree), the remaining cash (net income which represents farmer and labourer income) can be spent locally and has a *direct effect* on the rural economy. At the same time, the growth in any particular sector of the rural economy is likely to have positive effects on related sectors. This is because of the interconnection in the production system. Such effects occur in terms of additional income and employment. These effects are assigned '*multipliers*' which provide an approximation of the total effects applicable to the primary production.

In the simple case of farm management costing, gross margins are used to indicate the economic impact of a crop. Such gross margins do not include elements for fixed costs (since such costs are not specific to a single crop but to the business as a whole) and therefore they overestimate farm income. Despite this, they can be used to provide an approximation of income flow into the local community for a particular crop enterprise.

'*Induced effects'* concern the effects associated with spending of the additional income generated (known as a 'Keynesian' multiplier).

Multipliers can be derived to assess the production relationship between different parts of the economy (induced effects). For example, an increase in the production of a commodity (for example oilseed rape) will have an impact on related industries (fertilisers, pesticides, oilseed processing industries) boosting both output and employment in these related industries. The magnitude of these indirect effects depends on the level of interconnection and is reflected in the scale of the applied multiplier (known as a 'Type I' multiplier). Adding the effects of the Keynesian multiplier (induced effects) (representing subsequent expenditure) to that of the Type I multiplier produces a 'Type II' multiplier. The limitations of these approaches are discussed elsewhere (Mortimer *et al.* 2002).

Multipliers have not been developed specifically for many crops, and SRC is a relatively new crop in the UK and so has not been studied in detail regarding its knock-on effects in the local or wider economy. However, it is possible to estimate multipliers for the above crops based on multipliers generated for cereal cropping or closely related enterprises, such as forestry for example. Table 10-1 illustrates the Type I and Type II multipliers applicable to cereal crops (which would include oilseed rape) and forestry enterprises (which is probably the closest currently to an estimate for SRC production).

Both OSR and SRC have the potential to stimulate significant additional employment and income generation. The potential for additional revenue generation would appear to be greater for arable crop than for SRC production. Multipliers derived for cash crops other than potatoes are calculated to be lower than those for cereal crops (Leat *et al.*, 1989).

Table 10-1 'Multipliers' for biofuel crop production

	SRC (forestry derived)		OSR (cereal crop derived)	
	Income	Employment	Income	Employment
Type I	1.66[3]	1.31[3]	2.22[1]	1.56[1]
Type II	1.78[2]	1.43[2]	2.67[1]	1.75[1]

[1] Data from from Leat *et al.*, 1989 ('cereal crops' multiplier).

[2] From Forestry Commission, 2000 – (local and rural multiplier (forestry enterprise)).

[3] Derived from data source in note 2 above, using ratios calculated from direct and indirect costs and jobs data presented, and adjusted to remove allowance for additional urban effects.

Spatial and social effects

The spatial dimension concerns the occurrence of effects at the local or national level, while the social dimension is concerned with the distinction between rural and urban communities. In the present context local and rural communities will be considered together, as detailed analysis is required to separate these, which is beyond the scope of this study. As biofuel production plants are more likely to be based in urban environments (see section 7.2), the direct effects of biofuel feedstock production are likely to be realised in the rural community but effects related to biofuel production are only likely to affect the urban community, as the likely scale of plant involved in processing and logistics considerations will lead to production facilities being sited near existing crushing or refining plants etc.

10.3 Biodiesel and bioethanol production- impacts on jobs and the local economy.

Biodiesel production

A plant producing 125,000 tonne per annum of biodiesel would employ around 43 staff (extrapolating from data presented by Walker and Korbitz, 1994**)**. This will also affect employment outside the processing industry. To produce 125,000 t of diesel 329,000 tonne of rapeseed would be required. Assuming improved yields (4t/ha) this would require 82,000 ha.

Assuming either

- A) The rape is grown on set-aside land, or
- B) The rape is grown on conventional arable land (substituting for 2nd wheat);

then

A) If the rape is grown on set-aside land it will have a direct effect on employment, as set-aside management is less labour intensive than that of rape cultivation. Managing 82,000 ha of set-aside requires cutting, spraying and ploughing. This equates to a labour requirement of 1.2 hours/ha, which equates to 98,400 man hours for 82,000 ha. Assuming a 40 hour working week for 45 weeks per year (1800 hours per year) management of this area of set-aside would employ 55 people.

The cultivation of oilseed rape requires ploughing, drilling, fertiliser and agrochemical application and harvesting. This equates to around 3 man hours/ha, 246,000 man hours for 82,000 ha which equates to 137 man years.

Cultivation of rape on set-aside land, to supply a 125,000t plant, would create an extra 82 jobs on the farm (one for every 1000 hectare of crop grown on set-aside, equivalent to 0.65 jobs/1000 tonnes of biodiesel). When the oilseed rape multiplier effect associated with the added-value of this farm activity is considered (1.75 (Table 10-1, type II multiplier)) the total number of jobs created raises to 144 (equivalent to 1.15 jobs/1000 tonnes). These figures are lower than those presented in other studies. Walker and Korbitz, 1994, using the input/output method of Lea *et al*, 1989, calculated that 12 additional man years were required per 1000 hectares to manage rape rather than set-aside (which appears excessive), which generated a further 7 jobs/1000 tonnes of RME produced. These studies used an input-output model to obtain an employment coefficient, based on estimates of employment created by each £ of extra output. This means that the employment associated with set-aside was calculated to be very low (given its low economic value). The figures we calculate are based on actual labour input (Nix, 2001) required to manage set-aside/cultivated land, and are in agreement with those cited by producers involved in the NE Biodiesel Working Group (John Seymour note to DEFRA OFIC Division).

Walker and Korbitz, 1994, also calculated a value for additional employment using standard mandays, and concluded that oilseed rape production for biodiesel on set-aside generated 5 additional jobs/1000 ha (3.2 on farm and 1.8 off farm). Clearly there is a significant amount of variation in the estimates of number of jobs created on farm by biofuel feedstock production, and these increases will not be realised where other crops are replaced by biofuel crops rather than non-productive land, as labour will just be diverted from one enterprise to the other (see 'B' below).

Examining the wider impacts, German studies (Schöpe M 1996 (cited by Körbitz W. 1998)) estimated (based on a 300,000 tonne/annum RME plant) that RME production stimulated 16.1 jobs/1000 litres of RME production, in rural areas in the biodiesel industry and related trades, mostly in small and medium sized enterprises. Figures for Ireland suggest a 30,000 tonne RME plant would generate 324 jobs (Körbitz W.

1998), which suggests an employment ratio of around 10 jobs created per 1000 tonne of RME production. Figures for the UK (John Seymour note to DEFRA OFIC Division) suggest 7 jobs/1000 litres of RME production would be created. Again there is obviously wide variation in estimates of the employment opportunities generated by biodiesel production.

With respect to effects on gross margins, oilseed rape margins are typically around £385/ha. When the multiplier effect is considered (2.67 (type II multiplier)), the figure for the impacts arising increases to £1028/ha (a total of £ 84 millions from 82,000 ha of oilseed rape, equivalent to 0.7 million/1000 tonne of RME produced).

B) Growing oilseed rape outside of set-aside would have a much smaller effect in terms of employment generation as there would be swapping of crop enterprises. Oilseed rape would either be sold into the market for fuel or food use depending on current market demand, or alternatively with suitable inducements, oilseed rape grown specifically for biofuel would displace other crops in the rotation (most probably second wheat crops). The net effect of this is very difficult to quantify and would depend on the relative magnitude of the multipliers associated with the rural economy for each crop and on the relative ability of the new (biodiesel) and old (food industry associated with wheat) industry to create and sustain jobs.

Bioethanol production

4.4 billion litres of Bioethanol production in the US is estimated to have created 200 thousand jobs in the agricultural and rural sector (Terry de Winne, Biofuels Northern Ireland), equivalent to 0.045 man years per 1000 litres of production. This low level compared to above figures for biodiesel probably reflects efficiency of scale and the low labour input associated with extensive US crop production systems. More information is needed on bioethanol production in the European context to enable appropriate estimates of added value to the rural economy.

One way in which bioethanol production could significantly influence rural communities is if biofuel feedstocks expand from conventional crop sources to lignocellulose production in areas with currently little or no arable production, which would be a significant shift. The example used in this report is a possible expansion in the area of SRC.

A plant producing 135,000 tonne of ethanol would require around 750,000 tonne of hardwood lignocellulosic material. This could be supplied by SRC supplemented by small quantities of forest and wood processing waste. For illustration around 2% of bioethanol production is assumed to be derived from waste wood (equivalent to 18,000 t)). Such a plant would require 71,500 ha of SRC (assuming a ethanol yield of 2t/ha). Given that perennial energy crops have high set up costs and rotational harvests, equivalent annual values for revenue have been estimated (Nix, 2001, SAC, 2002, Mortimer *et al.*, 2002) and range between £203-400/ha for SRC (including grants and support provided under the Energy Grant Scheme and AAPS)[†].

It is possible that SRC could be grown on rotational grassland eligible for payments under the Arable Area Payment Scheme, replacing extensive sheep or beef production

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[†] SRC would currently need be grown on grassland eligible for AAPS payments to be viable.

Table 10-2 Sensitivity analysis of SRC and Grassland output based on 71,500 ha (required to produce 135,000 tonne of ethanol from SRC)

	SRC						*Sheep production*			
GM (£/ha)	203[a]		287[b]		400[c]		315[d]		325[e]	
Multiplier	1.8	2.6	1.8	2.6	1.8	2.6	2	2.5	2	2.5
Tot (£ million)	26	37	36	53	51	74	45	56	46	58
£'000/1000 tonnes of bioethanol production	194	280	274	395	381	551				

[a] SAC, 2002
[b] Mortimer *et al.*, 2002
[c] Nix, 2001
[d] Nix, 2001 (upland sheep)
[e] Nix, 2001 (lowland sheep)

systems. SRC is a very labour intensive crop to establish and harvest, but requires little attention in the 2-3 year intervals between harvesting to the extent that SRC is less labour intensive than management of sheep/livestock enterprises. Therefore it is possible that moving to cropping with SRC would reduce direct employment on the farm. The total effect would depend on the values of the employment multiplier for SRC and grassland. Even though estimates of the multiplier for SRC have been estimated (1.31-1.43), a detailed study would be required to assess the impact of substituting crops such as SRC for grassland. The multiplier associated with the forestry sector net output has been estimated at 1.8 (local and rural effects) to 2.6 (all activities) (English Forestry, 2000). This estimates that the total benefits to the rural community arising from the cultivation of 71,500 ha of SRC to supply a 135,000t ethanol plant, would be £26-74 million[‡].

Using a gross margin for sheep (average lowland and upland) of £315-325/ha and a multiplier of 2-2.5[§]., this would equate to generation of £45-58 million for the same area of grassland. Table 10-2 illustrates the sensitivity analysis associated with different estimates of output for SRC and sheep enterprises. While the generation of biofuels would appear at face value to add greater value to the rural economy, this is based on the assumption that SRC will receive AAPS support payments. Without access to such payments SRC production is much less profitable than extensive livestock enterprises. A recent comparison of SRC and sheep enterprises (Heaton *et al*., 1999) concluded that in the absence of subsidy payments, SRC would be the more profitable of the two enterprises, provided at least 8 tonnes of dry matter could be produced at a chip price of £35/tonne. This yield level should be achievable in the UK uplands with appropriate inputs. The study also concluded that SRC production could be supported with lower subsidy payments than those currently paid to sheep producers. Access to such subsidy payments will be necessary if the government wishes to stimulate production of SRC outside of the current arable area for either biofuel or bioenergy production.

[‡] Calculated using a multiplier of 1.8-2 on the gross margins for SRC production.

[§] Leat *et al*., 1989, estimated an income multiplier of 2.57 for sheep production in the Grampian region.

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Appendix I Environmental issues associated with liquid biofuels crop feedstock production

I.1 Introduction

This section summarises the evidence for differential effects in terms of resource use, resource protection, biodiversity and landscape for the crops with potential for biofuel production. The economic, technical and logistical factors governing the likelihood and extent of use for each crop are dealt with in previous sections of the report.

I.2 Resource use

I.2.1 Fertiliser

Figure I-1 shows the average use of fertiliser on arable crops grown for food in the UK.

Wheat and oilseed rape require high nitrogen applications, whilst p*otatoes* need large amount of phosphate and potassium to achieve optimum yield.

Short rotation coppice (SRC) and *Miscanthus* should establish a balance over time in which fertiliser supplements are only necessary to balance offtakes, which should be low. However, inputs of nitrogen may be required aid establishment while the soil nutrient and organic matter cycles adjust. (Murphy & Helal, 1996)

Fertiliser recommendations from the Swedish University of Agricultural Sciences for willow coppice are given in Table I-1 (Larsson, 1996), which are lower than those currently applied to most UK non-leguminous arable crops. In the ARBRE project, SRC is used as a means of disposing of composted sewage, applied at the equivalent of 250 kgN/ha/year (the maximum recommended rate in the Code of Good Agricultural Practice for the Protection of Water). Applications are made only at planting and/or harvest (i.e. after three years) (Pitcher & Everard, 2001).

Fertiliser requirements for Miscanthus are around 130 kg/ha N, 20 kg/ha P and 100 kg/ha K, some of which can come from recycling of harvest residues if these are not removed (Nix, 2001). In relative terms these are low compared to most arable crops. The relatively high K requirement compared to common combinable crops is not seen to be of any environmental concern.

I.2.2 Pesticides

Wheat, oilseed rape, sugar beet and potatoes: All, to a greater or lesser degree, require pesticide inputs to achieve maximum saleable yield (Table I-2). In terms of ranking, potatoes are sprayed most often closely followed by sugar beet and wheat crops. Oilseed rape and pea crops are treated similarly but break crops such as beans or spring barley are treated less often.

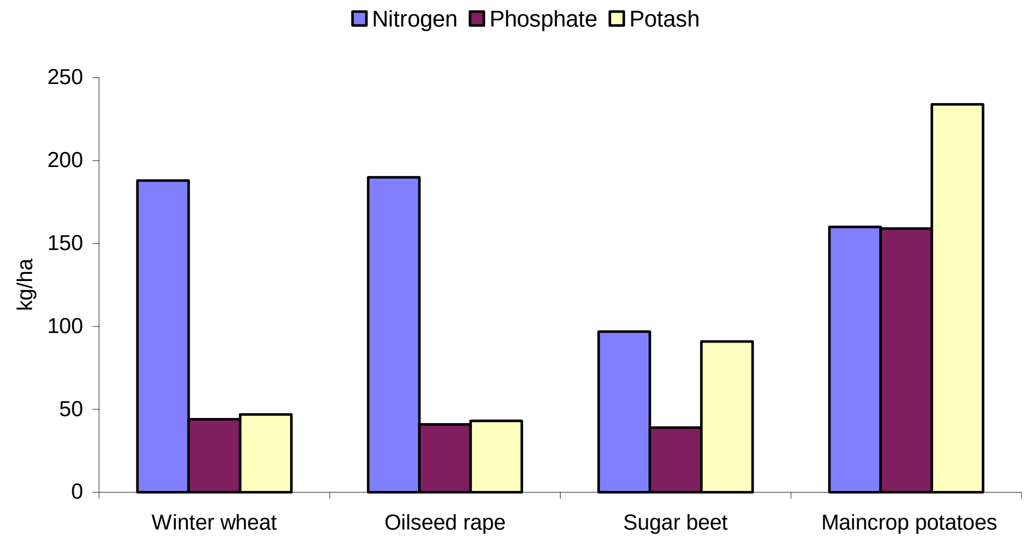

Fig I-1. Average fertiliser use on arable crops, 2000.
Source: British Survey of fertiliser practice

Table I-1 Fertiliser recommendations for willow coppice in Sweden

	Nutrient	Mineral soil kg/ha	Organic soil kg/ha
First year after planting	N	45	0
	P	15	15
	K	40	40
Second year (and each fourth year)	N	100-160	0
	P	35	40
	K	110	130
Other years	N	90-120	60

Fungicide use is high in potatoes to control blight and herbicide input is high in sugar beet because of its uncompetitive nature. Insecticides are used in all crops, but in sugar beet a large proportion of insecticide use is in the form of seed dressings, which have less impact on non-target species. Insecticide use is particularly high on oilseed rape to control major pests such as cabbage stem flea beetle, pollen beetle and aphids. Molluscicide use is highest in potatoes and oilseed rape which requires protection during crop establishment. In wheat, most of the insecticide use is directed against aphids, the majority being applied in the autumn for control of Barley Yellow Dwarf Virus (BYDV), of which aphids are the vectors.

Set-aside: In 1998, 69% of set-aside had naturally regenerated cover, 13% was sown to grass, and 13% grew industrial oilseed rape. The remainder comprised wild bird cover (2.5%), linseed (1.3%), woodland (0.7%) and miscellaneous other types of cover (0.6%) (Pesticides Usage survey; unpublished data). Most pesticide use on

Table I-2. Comparison of food crop area treated with different pesticide groups in Britain in 1998. (% of area grown), for crops which could form feedstocks for biofuel production and crops which they may replace in the rotation.

	Wheat	Oilseed rape	Industrial oilseed rape	Sugar beet	Potatoes	Field beans	Peas	Spring barley
Insecticides:								
Carbamates	*4*	*4*		*16*	*48*	*12*	*51*	*0*
Organochlorines	*<1*	*1*		*<1*		*0*	*<1*	*<1*
Organophosphates	*18*	*<1*		*<1*	*9*	*5*	*28*	*7*
Pyrethroids	*84*	*133*		*13*	*41*	*65*	*81*	*1*
Other Insecticides	*1*	*1*		*13*	*28*	*<1*	*18*	*<1*
Total Insecticides	107	140	165	43	127	81	178	9
Fungicides	418	223	248	87	982	283	175	117
Growth Regulators	132	8	16	0	6	0	<1	12
Herbicides[1]	336	231	296	727	310	175	309	162
Molluscicides	13	27	10	2	68	2	<1	<1
Nematicides	0	0	0	15	23	0	0	0
Seed Treatments	103	105	110	269	81	13	92	100
All Pesticides	1111	734	845	1142	1516	554	754	401

1 Including desiccants

Source: Pesticide Usage Survey Report 159: Arable Farm Crops in Great Britain 1998 (Garthwaite & Thomas, 1998) *naturally regenerated set-aside* consisted of glyphosate, applied to kill the vegetation in late spring or early summer prior to cultivations for a following crop. Pesticide use on *industrial oilseed rape* grown on set-aside was similar to that used on conventional oilseed rape crops (Table I-2).

Short rotation coppice, Miscanthus: Weed control is necessary for both crops in the first year to ensure establishment, and also in the second year for Miscanthus. After this, little or no weed control is necessary. Several pests and diseases have been identified for both crops, but at present there is little benefit from fungicide and insecticide use. However, as these crops become more widespread, pest and disease problems are becoming more severe, resulting in an increased use of crop protection chemicals.

I.3 Resource protection

This section covers the impact of potential energy crops and set-aside on soil and water. Emissions to air are not considered.

I.3.1 Soil erosion

Cereals: Winter cereals mainly only affects late sown, poorly established crops on susceptible soils, or those sown into an over-fine or compacted seedbed.

Oilseed rape: Normally less susceptible to erosion than cereals due to early establishment. Also not commonly grown on light soils susceptible to erosion. Spring oilseed rape usually follows cereals and provided a stubble is left over winter the erosion risk will be low.

Sugar beet: In part due to requirement for medium and light textured soils, there is a high risk of erosion, especially between April and June before the canopy has closed, and after harvest, when rutted and compacted bare ground can create ideal conditions for erosion. Cultivation soon after harvest can reduce this risk.

Potatoes: High risk of erosion, similar to sugar beet. Can be exacerbated by runoff along furrows.

Set-aside: Crop stubble and regenerating green cover will help reduce erosion risk, though it will be higher than for continuous vegetation cover. Long-term set-aside sown to grass or other continuous cover will have a low erosion risk.

Short rotation coppice, Miscanthus: There is a high risk of erosion on susceptible soils in the first year because cuttings are planted at wide row spacing and crop establishment is slow. Once established, erosion risk is likely to be low (Murphy & Helal, 1996).

I.3.2 Soil compaction

Cereals: Most likely to occur if cultivations take place under wet conditions. A "plough pan" can develop at plough depth if ploughing takes place when the soil is wet.

Oilseed rape: Because winter rape is sown early (generally in August), conditions for cultivations are generally favourable, and compaction is less likely.

Sugar beet: Harvest is carried out in autumn and winter when the risk of compaction by harvesting machinery is high.

Potatoes: Compaction by harvesting machinery is a risk particularly for the later harvested maincrop potatoes. Compaction of the furrows can also occur due to repeated passes by machinery.

Set-aside: Naturally regenerated set-aside can offer an opportunity to relieve compaction by appropriate subsoil cultivations (only after 1 July) or mole ploughing provided that these do not interfere with the requirement to maintain a green cover over winter.

Short rotation coppice, Miscanthus: The major risk of soil compaction is at harvest, when heavy harvesting and transporting machinery must operate on the land during winter. Both crops require adequate moisture for good yields and SRC thrives on wet soils, but a balance needs to be found between good growing conditions and ability to harvest the product. Miscanthus in particular has a requirement for well-aerated soils and does not grow well on wet, compacted soils; harvesting under wet conditions can also damage the rhizomes (Schwarz & Greef, 1996). Harvesting in summer is a possibility where soil conditions preclude winter harvest.

I.3.3 Soil organic matter

Organic matter in soil improves soil structure and nutrient cycling, makes soil easier to work, less susceptible to damage and reduces vulnerability to erosion. Any increase in organic matter represents sequestration of carbon. Changes in cropping can lead to a change in soil organic matter (SOM) towards a new equilibrium, but the process is slow and it can take several decades for the new steady state to be reached (Jenkinson, 1990).

Where grain, seed or roots only are removed from the field, significant amounts of crop biomass can be returned to the soil (Table I-3), but if these residues are removed (for example to be used as fuel in a biomass plant), then a decline in soil carbon can occur over the long term. Short rotation coppice and Miscanthus return large amounts of organic matter to the soil and breakdown rates are slow, leading to accumulation of organic matter over time (Table I-3). King & Bullard (2001) estimated carbon sequestration of 8.75 t/ha under Miscanthus, four years after planting in Norfolk and Matthews & Grogan (2001) predict increases in soil organic carbon of 0.31, 0.41 and 0.93 t C/ha/yr as the crop establishes. Carbon accumulation is affected by time of harvesting, e.g. mean C sequestration rate under Miscanthus was 1.17 t C/ha/yr if harvested in February, but only 0.62 t/ha/yr if harvested in September.

Table I-3. Annual return of biomass to the soil under various cropping systems (reproduced from Murphy & Helal, 1996).

Cropping system	Harvested biomass	Shoot biomass returned to the soil	Total biomass returned to the soil
Wheat – grain only	6.83	7.58	9.02
Wheat – grain + straw (commercially harvested)	12.06	2.35	3.79
Whole crop wheat	14.11	0.30	1.74
Oilseed rape	2.97	5.05	5.85
Oilseed rape + straw	6.47	1.55	2.35
Miscanthus	17.00	4.00	6.3
Short rotation coppice	12.00	3.72	5.29
Sugar beet	11.00	3.75	5.22
Sugar beet + tops	14.75	0	1.48

I.3.4 Nitrate leaching

Among conventional cropping systems, greatest risk of nitrate leaching is associated with pea, potato and oilseed rape crops, with cereals and sugar beet being less susceptible (MAFF, 1993; Goulding, 2000).

Wheat: Most nitrate leaching occurs in autumn, when nitrogen availability exceeds uptake.

Oilseed rape: Rape grows rapidly in the autumn and will ‘mop-up’ residual nitrogen. However, the crop leaves relatively high residues of nitrogen in the soil post-harvest, in part due to the high nitrogen content of the straw, increasing the risk of nitrate leaching during the following autumn and winter.

Sugar beet: Nitrogen fertiliser use on sugar beet is relatively low. However, nitrogen leaching can occur in spring when the ground cover is low, and after harvest in late autumn.

Potatoes: Potatoes leave large nitrogen residues in the soil because they are relatively inefficient at nutrient capture.

Set-aside: Nitrate leaching from set-aside is generally low provided an adequate green cover is established, but can be relatively high after ploughing out of rotational set-aside, as the residues of the green cover break down (Goulding, 2000).

Short rotation coppice: Although application rates of fertiliser are generally low, offtakes are also low, leading to a positive nitrogen balance of 40-90kg N/ha (Murphy & Helal, 1996). The crop is deep rooted and has high water uptake rates, so the potential for nitrate leaching is relatively low.

Miscanthus: Rates of fertiliser use are similar to SRC, but offtake rates are high (100-150kg/ha/yr, cf. 36 kg/ha/yr from SRC; Murphy & Helal, 1996). Leaching losses are low, apart from the first year after planting when uptake does not balance availability (TableI-4).

Table I-4. Nitrate leached (kg/ha) from Miscanthus during winter (from Christian & Riche, 1998) (cf typical values from arable crops of 30-100 kg/ha)

	Fertiliser applied kg N/ha		
	0	60	120
1993-4 (first year after planting)	154	187	228
1994-5	8	24	87
1995-6	3	11	30

I.3.5 Phosphate

Raised phosphate levels in inland water bodies cause eutrophication, damaging the ecology and causing excessive algal growth which can block filters, increasing the cost of supplying drinking water. Phosphate is not readily leached from soil as is nitrate, due to its relative insolubility in water. Most phosphate losses are in the form of phosphate bound to suspended soil material. Phosphate pollution of water is therefore related to erosion risk, and crops such as potatoes and sugar beet with high phosphate requirements and high erosion risk are likely to increase phosphate losses, whilst cereals, oilseed rape, SRC and Miscanthus, which have lower P requirements and are less susceptible to erosion, are less likely to cause problems.

I.4 Biodiversity

The biodiversity assessment focuses particularly on birds, because:

- more information is available
- they form the subject of a Public Service Agreement and are used by Government as an indicator of agricultural sustainability and Quality of life.
- they are more likely than other groups to be significantly affected.

Table I.5 summarises preferences or avoidance of relevant crop types by bird species included in the Governments Farmland Bird Index, red and amber lists and the Biodiversity Action Plan.

Evidence for other groups is also summarised.

I.4.1 Birds

Preferences of birds for certain habitats or crops are related to vegetation structure and diversity, food availability, accessibility, management practices, and the surrounding landscape features (e.g. hedges, ponds). Much recent research into habitat use on farmland has been prompted by the widespread declines of many farmland bird species (Baillie *et al.*, 1997). This research has been aimed at identifying the factors behind the declines, which have been found to be related to changes in farmland practices and agricultural intensification (Fuller *et al.*, 1995; Chamberlain & Fuller, 2000; Benton *et al.*, 2002). Relatively little information is available on comparative habitat and crop preferences for farmland birds, except for recent work on set-aside (Buckingham *et al.* 1999; Henderson *et al.*, 2000; Henderson & Evans, 2000). The available information for habitat preferences for farmland birds of conservation concern is summarised in Table I-5. The absence of a rating for preference or avoidance indicates that no relevant information was found for the species or habitat.

Set-aside

Most species showed a preference for set-aside in summer and winter compared to other crop types (Table I-5; Buckingham *et al.*, 1999; Henderson *et al.*, 2000; Henderson & Evans, 2000). This was especially so for Skylark *Alauda arvensis* (Donald *et al.*, 2001, Evans *et al.*, 1997; Vickery & Buckingham, 2001). In general, numbers of birds are higher on rotational or first year set-aside than longer term or non-rotational set-aside (Buckingham *et al.*, 1999; Donald *et al.*, 2001a; Henderson *et al.*, 2000; Watson & Rae, 1997). The open vegetation structure and botanical diversity in set-aside provide increased foraging opportunities and food availability compared to other crops. Set-aside is of particular value as a feeding habitat for seed-eating birds in winter. The switch to autumn drilling for most crops has meant that fewer stubbles are available than previously, and the autumn crops themselves contain few seeds (Draycott, 1997, Jones, 1992). Management practices affect the value of set-aside for many species (e.g. herbicide usage, mowing (Watson & Rae, 1997; Robinson & Sutherland, 1999)). Where wild bird cover is grown on set-aside, increased benefits for birds in terms of seed and invertebrate food supply and nesting opportunities have been recorded (Murray, 2001).

Oilseed rape

Green *et al.* (1994) studied the distribution of passerines in hedgerows in relation to adjacent crop type. Crop types in order of preference were: oilseed rape>potatoes>autumn-sown cereal>peas>beans>sugar beet>spring cereal. Lack (1992) also found preferences by farmland birds for oilseed rape over all other arable crops. Food availability (invertebrates) may be an important factor in this preference (Green *et al.* 1994, Holland *et al.* 2002). Oilseed rape is an important food source for young linnets *Carduelis cannabina* (Moorcroft *et al.* 1997) and nesting habitat for reed buntings *Emberiza schoeniclus* (Lack 1992). There may be differences in attractiveness between spring-sown and autumn-sown varieties (Mason & MacDonald 2000). Oilseed rape stubbles may also be an important food source for some species in the winter (Brickle & Harper 2000). Woodpigeons (*Columba palumbus*) in particular depend on oilseed rape to prevent starvation during the winter (Inglis *et al*, 1997)

Wheat

Cereal crops (predominantly wheat) comprise 70% of arable crops in Britain (Potts 1997). Some species, including yellowhammer *Emberiza citrinella*, skylark, quail *Coturnix coturnix* and grey partridge *Perdix perdix* are found in high numbers in wheat, but this may be a reflection of the amount of habitat available, rather than crop preference (Wilson 2001; Holland *et al.* 2002). Many species appear to avoid wheat during the winter (Table I-5). Wheat commonly has high numbers of invertebrates, but these may be adversely affected by pesticide treatments (Moreby *et al*. 1994), and the timing of sowing (Reddersen 1994). Insect availability and suitability for nesting may also decrease as the crop matures during the summer (Lack 1992). Conversely, grain availability may increase (Stoate *et al*. 1998).

Potatoes

Green *et al*. (1994) found potatoes to be the second most preferred crop type for hedgerow-dwelling birds, but little information is otherwise available for specific species preferences. Slight preferences for potato crops were found for breeding skylark, whitethroat *Sylvia communis* and yellowhammer *Emberiza citrinella*, and a stronger preference by yellow wagtail *Motacilla flava* (Mason & MacDonald 2000). Potatoes had the fewest invertebrates compared to other crops, due to intensive cultivation, poor spring ground cover and high pesticide regimes (Holland *et al*. 2002), which makes its attractiveness to a broad suite of farmland birds (Green *et al*. 1994) unexpected.

Sugar beet

Sugar beet does not appear an especially attractive crop for farmland birds, perhaps due to the low abundance of invertebrates compared to other crops (Holland *et al*. 2002). Little work has been done on bird usage of sugar beet in Britain, but Vogrin & Vogrin (1998) studied usage in Slovenia. Lapwing *Vanellus vanellus*, skylark, yellow wagtail and whitethroat were found breeding in sugar beet, with lapwing and skylark having higher densities here than on wheat. Dunnock *Prunella modularis*, linnet and woodpigeon all used sugar beet fields in autumn and winter (Crocker *et al*. 2002; Lack 1992).

Short-rotation coppice

Little comparative work has been carried out on bird preferences for short-rotation coppice (SRC) in Britain. Berg (2002) in Sweden found some species (eg. grey partridge, song thrush *Turdus philomelos* and whitethroat) favoured SRC in comparison to cereal, set-aside and grassland (Table I-5). Others, such as skylark, dunnock and tree sparrow *Passer montanus* did not. Adjacent habitats and SRC height appeared to be important determinants of preference. Sage & Robertson (1996) compared willow and poplar SRC. Willow SRC contained more bird species than poplar. Increased structural complexity of SRC was found to increase the number of passerine species and individuals. Overall, large plantations with different age classes may increase songbird diversity and abundance on farmland (Sage & Robertson 1996), although some species may be adversely affected. In winter, SRC can provide cover for birds in otherwise open areas of farmland (J. Allcock, unpublished data).

Miscanthus

No research appears to have been carried out on bird usage of *Miscanthus* crops. There is unlikely to be further information on this until significant areas of plantation are realised.

Table I-5. Preference or avoidance of crop types by farmland birds of conservation concern.
(B = breeding period, W = winter, ++ = strong preference, + = preference, - = avoidance, 0 = neutral, s = stubbles; h = harvested; ns= newly-sown).

Species	Farmland Bird index	Red list	Amber list	BAP	Habitats											
					Set-aside		Rape		Wheat		Potatoes		Sugar beet		SRC	
					B	W	B	W	B	W	B	W	B	W	B	W
Kestrel	*		*		+?	+?	-	-	+?	+?						0
Grey partridge	*	*		*	+/-	+	+	+	+	-/+			-		+	+
Quail		*							+				-		-	
Stone-curlew		*		*	+				-				+?			
Lapwing	*		*		+		-	-	-	+/-	+h	-?		-?	-	-
Woodpigeon	*				+		+	++	-	-/+ns				+	-	-
Stock dove	*		*		+		0		0	+?			+		-	-
Turtle dove	*	*			+		-		-		-		-			
Barn owl	*				+	+										
Skylark	*	*		*	++	++	+/-	-/+	-/+/0	--	+?	+s	+?	-/+	-	-
Yellow wagtail	*		*		-/+		-		-		+		+		-	
Dunnock			*		+	0	+		-	-				+	-	+
Mistle Thrush			*		+				-							0
Song Thrush		*		*	+	0/-	+	+	-/+?	-					+	+
Whitethroat	*				+/-		+/-		-		+		+		+	
Starling	*	*						-	-	-					-	0
Jackdaw	*				+			-		-		+		-		0
Rook	*				+	+?	-	+?	-	-	+	+		-		-
House sparrow		*					+		+?							
Tree sparrow	*	*		*	+	0	+	0	+	0				+	-	+?
Greenfinch	*				+	+	+	0	+?/-	-/+s					+	+
Goldfinch	*				+	+	+	+s	-	-			0	-	-	-
Linnet	*	*		*	+	+	++	+	-	-	-		-	+	+	-
Bullfinch		*		*	0		+		0				0			+
Yellowhammer	*	*			+	+	+/-	-/+s	-/+	-	+		0	-/+	+	+
Cirl bunting		*		*	+	+		0		-						
Reed bunting	*	*		*		+	++	0	-	-	-			+	+	+
Corn bunting	*	*		*	+	+	-/+	+s	-/+				-		-	

I.4.2 Mammals

Farm crops are unimportant as habitats for most mammals. Among small mammals, only wood mice (*Apodemus sylvaticus*) regularly use crops (Tew et al., 1994), and bats generally prefer to forage over unimproved grassland, woodland or water (Walsh & Harris, 1996). Bats will forage over short rotation coppice (J. Aegerter, pers comm.).

One mammal of conservation interest which does use farm crops is the brown hare (*Lepus capensis*). Brown hares have declined in recent decades and have a Biodiversity Action Plan. They feed on different crops as the year progresses. Depending on stage of growth, and are most abundant on mixed farms with a high diversity landscape (Tapper & Barnes, 1986; Tapper, 1989). Thus, any change in cropping patterns leading to greater uniformity of cropping is likely to be detrimental to hares.

When double-zero (00) varieties of oilseed rape were first introduced, there was some concern that poisoning of mammals was occurring due to excessive consumption of rape. This was stimulated by observations of mortality of roe deer (*Capreolus capreolus*) and hares in Austria and Germany in 1986. Subsequent research showed no mortality among hares from feeding on 00 rape, and it was concluded that the observed hare mortality was due to other factors (Askew, 1990; Marquard & Walker, 1995). Although hares do eat some rape, they prefer cereals and grasses, however where fields are large they may be forced to feed on rape against their preference (Petrak & Uhl, 1990). In contrast, researchers concluded that roe deer deaths were caused by ingestion of oilseed rape (Askew, 1990) but since the initial mortality, deaths associated with rape ingestion have only been rarely reported, and the problem has not increased as the area of 00 rape has grown (Marquard & Walker, 1990). Research in the UK concluded that 00 rape was unlikely to pose a threat to roe deer when other food is plentiful and weather conditions not severe (Sibbald, 1992). It is possible however that further increases in rape area could force deer in some regions to eat larger amounts of the crop, giving rise to further problems.

I.4.3 Invertebrates

Relatively few studies have compared the value of different crops for invertebrates. Holland et al. (2002) found that oilseed rape, peas and beans tended to have higher densities of invertebrates compared to cereals, and potatoes and sugar beet had lower densities. Moreby and Southway (2002) found few consistent differences between crops, however, most insect groups were significantly more abundant in wild bird cover grown on set-aside than in commercial crops. Wild bird cover is also attractive to butterflies (Boatman & Bence, 2000). Moreby & Aebischer (1992) also found that numbers of invertebrates important in the diet of grey partridge chicks were three times as high in set-aside as in wheat.

Carabid beetles and linyphiid spiders, which are useful biocontrol agents, tend to be present at higher levels in cereals and oilseed rape than in potatoes, peas and other non-cereal spring crops (Booij & Noorlander, 1992; Holland et al., 1998)

Insect pollinated broad-leaved crops and weeds are used by foraging bees, both honey bees and bumble bees. An increase in the area of crops such as oilseed rape could be beneficial for honey bees and some species of bumble bees, but could also be detrimental if they were encouraged to forage in the crop when insecticides were being sprayed. Pyrethroid insecticides can be applied to oilseed rape crops in flower, but recommendations are to spray in the early morning or late evening, when honey bees are less active. Unfortunately, these are peak foraging times for bumble bees, which may be particularly vulnerable to direct spraying (Thompson & Hunt, 1999). Current risk assessment procedures consider only honey bees and do not take account of bumble bees, despite their importance as pollinators for a wide range of plant species.

Willows provide a habitat for more insect species than most other trees (Kennedy & Southwood, 1984). Sage & Tucker (1997) found over 50 invertebrate species or groups in short rotation coppice. Willows supported more groups than poplars. In addition to pest species, predators and parasitoids were commonly collected, plus other non-pest species. The authors suggest an integrated pest management strategy, designed to enhance the impact of natural enemies, as the best approach to pest control in SRC.

I.4.4 Plants

Most crop species have low densities of weeds because herbicides are used to minimise crop competition. Oilseed rape crops often have higher levels of broad-leaved weeds than cereals because the herbicides available for use in oilseed rape to control broad-leaved weeds are not as effective as those used in cereals, and the presence of weeds late in the season has little effect on rape yield (Lutman, 1993). This situation may be reversed however if the growing of herbicide tolerant varieties of genetically modified (GM) oilseed rape is permitted.

In sugar beet, great attention is paid to weed control because of the uncompetitive nature of the young beet plant. Counter-intuitively, the availability of herbicide tolerant GM varieties may allow higher levels of weeds to be permitted in sugar beet crops, at least for part of the growing period (Pidgeon *et al.*, 2001)

Sage (1995) found wide variation in the ground flora of short rotation coppice, ranging from areas devoid of other plants to those with complete ground cover. Plant communities differed between ex-arable and ex-grassland plots, and age of the stand was also important. In older stands, a more stable and diverse plant community had developed with fewer annuals and invasive perennials and more slower growing perennials. A well developed ground flora improves the habitat for nesting birds and small mammals (Sage, 1998). Much of the floral diversity of coppice plantations is found in the rides and margins and sympathetic management of these areas could enhance their overall biodiversity.

Miscanthus stands are likely to have little floral diversity once established owing to the dense layer of litter which is produced, combined with shading by the dense leaf canopy. However, disturbance caused by harvesting may open up the sward in places, allowing a ground flora to persist (Bullard *et al.*, 1995), but this would only be for short period of time.

Appendix II - ***UK Regions – potential for cellulosic biomass cropping***

North East

Over 1/3 of the landscape has national designations. The North East only has small areas of high quality agricultural land. Large areas are designated "tranquil areas" by the Countryside Agency and CPRE. Yorkshire has been the site of the ARBRE project, incorporating the first electricity generating plant to be run on wood chips, from forest residues and SRC. Mitigating measures have included incorporating broad headlands to keep views open and staggered row endings to prevent a "wall of coppice" effect for overlooking properties.

East Anglia

Agriculture in Cambridgeshire is mainly comprised of combinable crops, but East Anglia also produces 55% of the national sugar beet crop (The Agricultural Committee, 2000). There are currently initiatives to develop Miscanthus in the area around Ely as a bioenergy crop.

North West

The North West regional renewable energy study suggests that Cumbria could provides 36% of the regions renewable energy capacity by 2010. The Solway Plane, Eden Valley and South Cumbria are identified as potential areas for planting SRC. This could mean major changes in landscape as pasture and arable crops are replaced with bioenergy crops (Cumbria County Council, 2001).

London and surrounding suburbs

Wood can be provided from existing (and prospective) forestry sources for biomass energy production. It has been predicted that within the 40 km radius around London, there is a potential for producing 35Mwe by SRC (Mayor of London *et al.*, 2001).

Midlands

Land in the East Midlands is intensively farmed, with 78% of land in agricultural land use. There is a regional woodland planting target of an additional 65,000 ha by 2021. SRC could form part of this (Leicestershire County Council, 2001).

The Midlands have the potential for biomass plant development and new forestry opportunities are high, and would be in keeping with the local landscape.

South East

There is a large amount of unmanaged woodland in the region with potential for bioenergy use (Hams, Evans and Taylor, 2001). The South East is the most heavily wooded region in England.

South West

Potential sources of biomass are available from existing coppice woodland and from the productive local agricultural industry (Cornwall County Council, 1997).

Wales

There is potential to grow SRC on marginal land in upland mid-Wales (Randerson, Heaton, Slater and Wildig, 1997). Over 900,000ha of upland agricultural land in

Wales is capable of growing short rotation willow coppice. Current land use is primarily sheep production. The future of SRC in the uplands is dependent on future sheep subsidy levels. SRC would increase the structure of a predominantly agricultural landscape (Heaton, Randerson and Slater, 1999). However, large areas of Wales are protected because of their sensitive ecosystems and landscapes.