Liquid biofuels – industry support, cost of carbon savings and agricultural implications

Prepared for Defra Organic Farming and Industrial Crops Division

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INDEX

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SUMMARY

Background
As part of a wide range of measures drawn up by the EC in response to international agreements to reduce green house gas emissions, the European Commission proposes that EU member states should move towards development of transport biofuels and has set 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 vegetable or other plant oils) and bioethanol (derived from fermentation of starch or sugar crops) dominate as the most technically feasible and commercialised alternative renewable fuel sources. Biodiesel can also be derived from animal fats, grease and tallow that would otherwise be disposed of as waste (legislation preventing use of waste cooking oils in animal feed will become effective from October 2004).

Fuel offered for sale must meet European Standard BS EN 590. Blends of 5% biodiesel in ordinary mineral diesel should meet this standard, but pure biodiesel may not. Standards are in the process of being tightened to account for biodiesel use in blends. A European standard for biofuel (EN 14214) is being formalised. It is proposed that EN 590 should be modified to state that the biodiesel component of any blend must separately comply with EN14214.

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 on the forecourt. Current UK fuel duty rates provide for a 20p/l reduction in duty for biodiesel compared with conventional Ultra-Low Sulphur Diesel (ULSD). A similar duty cut for bioethanol will come into force from January 2005. The current duty rebate on biodiesel has incentivised commercial production of biodiesel from waste oil, but little UK production from fresh rapeseed oil. Approximately 100,000 tonnes is thought to be the limit for biodiesel production from these 'waste' materials. Current biodiesel production is running at just under 800 tonnes per month (May 2003). No bioethanol is currently being sold in the UK.

UK fuel demand is predicted to be 40.3 M tonnes by 2005 and 44.5 M tonnes by 2010. Based on the EC indicative targets, this gives a target for substitution of 0.8 million tonnes in 2005, rising to 2.56 million tonnes in 2010. It is anticipated that meeting these targets would result in carbon savings of around 0.5 M tonnes by 2005 and 1.5 to 2 million tonnes by 2010**.** However the scale of feedstock production required to meet these targets is challenging.

The technology to produce RME is proven and commercial production of significant quantities of RME from 'fresh' rapeseed oil could be achieved within 24 months. Production of bioethanol from wheat and sugar feedstocks could also be achieved within the same timescale. However, generation of bioethanol from wood, agricultural wastes (straw) and other biomass (including paper waste) will require further research and development before commercialisation.

Meeting the targets
In the short term it is likely that only biodiesel production will be sufficiently well developed commercially in the UK to contribute significantly to meeting the targets for 2005. Biodiesel production from waste oils and fats will only meet a fraction of the demand, limited to around 0.1 million tonnes. A further 0.2 million hectares of oilseed rape would be required to meet targets for substitution of road diesel alone and just under 0.5 million hectares to substitute for

2% of all transport fuel requirement in 2005. This would represent a significant increase in the oilseed rape area of between 45 and 108% (assuming the existing area is retained for current food outlets). Meeting the target for 5.75% substitution will require a much broader range of biofuel feedstocks.

For a number of reasons, it is unlikely that biodiesel derived from UK oilseed crops will be able to significantly exceed 2% of UK transport fuel demand. Other feedstocks will be required to meet the demand. The UK produces a significant exportable cereal surplus of around 2.9 million tonnes, but it is unlikely that all of this would be available for bioethanol production. In addition, forthcoming reform of the sugar regime and opening up of the sugar market to developing countries is likely to significantly affect profitability of UK sugar beet production and the industry is predicted to contract over the next 10 years. For illustrative purposes it is assumed that around half of the exportable wheat surplus could be made available for bioethanol production and that at least half of the current area of sugar beet is retained and used for bioethanol production in 2010. Even with this level of supply there would still be a requirement for around 1 million tonnes of bioethanol production to meet the 2010 substitution target. This demand would have to be met from novel sources such as lignocellulosics. A possible breakdown for supply from these sources is given in Table I, which indicates that up to 1.06 million hectares of land in the UK would need to be directed to biofuel production to meet the indicative targets for 2010 (The current UK arable area stands at 5.8 million hectares).

Table I. *Scenario to meet the 2010 targets for biofuel substitution (5.75% of all road transport fuels). (Assumes limited availability of starch and sugar feedstocks)*

Feedstock	Fuel required (million tonnes)	Feedstock area (thousand ha)	% of current crop area
Waste fats/oils	0.10		
Rape oil (RME)	0.70	459	102
Wheat grain	0.40	173	11
Sugar Beet	0.40	98	55
Wheat straw	0.25	*	-
Miscanthus	0.20	100	-
Short Rotation Coppice	0.50	229	-
Total:		**1,059**	

* sourced from wheat grain area

Impacts on the farmed environment

Between 0.56 and 0.80 million hectares have been in set-aside in recent years, growing biofuel crops on set-aside would reduce impacts on the rest of the farming operation and crop rotations etc. It is likely rape cropping will intensify in areas of current production but may result in a better balance of cereal to non-cereal crops in intensive wheat growing areas. There are likely to be some agronomic challenges but most UK arable farming businesses should be able to deal with these. Decoupling of support payments from crop to area-based payments under revision of the CAP should also remove the current restrictions on areas of UK oilseed rape production which was previously affected by the Blair House Agreement.

Biofuel production from a broad mix of arable crop feedstocks will have a neutral effect on the farmed environment. However, any replacement of spring sown break crops by an expanding winter oilseed rape or cereal area would be undesirable due to impacts on crop diversity and farmland birds. In the longer term, as technology improves, cereal straw and other arable crop wastes could provide raw material for ethanol production without significantly affecting the farmed environment. Growing biofuel crops on un-cropped land, or in predominantly grassland areas would have more significant impacts on the local environment. Replacement of natural-regeneration set-aside with biofuel crops 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. 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.

Costs of production and duty rebates

Current estimates of costs of production from conventional arable feedstocks mean that it is unlikely that the current biodiesel duty rate and the proposed duty cut of 20 p/litre for bioethanol will stimulate further production in the UK. However, the current Government position is that the proposed duty cut more than accounts for the environmental benefits associated with use of biofuels and that the duty reduction should support development of lignocellulose bioethanol production in the medium to long term. There are concerns that any further reduction in duty could lead to significant import of biofuels.

Biofuel production costs are significantly affected by volatility in price of feedstocks which represent a significant proportion of final fuel cost. Current industry figures indicate that duty cuts of 27 p/l are required to incentivise biodiesel production from ‘fresh’ rape oil (with conventional diesel @16p/l pre tax) and 26-29.9p/l to incentivise bioethanol production from wheat and 24 p/l to encourage production from sugar beet (with conventional petrol @15p/l pre tax). The price of feedstocks is likely to remain high with alternative feed, export and even soild biofuel markets available.

Value of carbon abatement

The Government currently accepts £70/t carbon (equivalent to £19/tonne CO_2), adjusted upwards by £1/tonne per year as the social cost of carbon emissions. It is acknowledged that this figure is subject to significant levels of uncertainty and is under review. Using this figure, the cost of green house gas abatement achieved by biofuels is calculated as the CO_2 saving achieved for the duty forgone (20p/l in this case). This gives CO_2 abatement costs of around £91-£143/tonne CO_2 saved for bioethanol derived from wheat and £110-£178/tonne CO_2 for biodiesel derived from rapeseed (£76/tonne from waste oil). This is worth between 2.9 and 5.0 p/litre of fuel at current costs (Table II), which is significantly less then the duty rebate on offer. The Department for Transport calculates that reductions in particulates associated with use of bioethanol would be worth between 0.08 and 1.18p/litre (for rural and urban areas respectively) at the proposed duty rate of 20p/litre. Improved sources of data are required to provide definitive figures for a range of tailpipe emissions.

Likely costs to the Exchequer

Given that it will take time to build biodiesel and bioethanol plants and that investment would have to be staged, biofuel production is likely to grow gradually in the UK. In addition, there could be limits in achieving the 5.75% substitution target for 2010 for the reasons highlighted earlier. Growth is therefore likely to be limited in the medium term. The impacts of a gradual increase in biofuel production on costs to the Exchequer for a range of duty incentives is given in Table III.

Table II. *Justified carbon credits for biofuels*

	Abatement cost range* £/t CO_2 (2003)	Justified carbon credit (pence/litre of biofuel)	
		2003	**2010**
Bioethanol	91	4.78	5.25
	143	2.92	3.21
Biodiesel	110	4.76	5.23
	178	2.94	3.24
Biodiesel (waste oil)	76	5.03	5.60

* *From Department For Transport scenarios*

Table III. *Impacts of various rates of biofuel duty incentives on costs to the Exchequer in term of income forgone based on a gradual uptake of biofuels*

		2004	**2006**	**2008**	**2010**
Diesel use (billion litres)		21.46	23.81	26.14	28.53
Petrol use (billion litres)		27.75	27.15	26.66	26.18
Total fuel(billion litres)		49.21	50.96	52.80	54.71
Uptake of biofuels		***0.8%***	***1.5%***	***2.3%***	***3.0%***
	Duty rebate				
Cost -£ Million	20 p/l	78.74	152.87	242.86	328.27
	22 p/l	86.61	168.16	267.14	361.09
	24 p/l	94.49	183.45	291.43	393.92
	28 p/l	110.23	214.02	340.00	459.58

A 20p/litre rebate on fuel duty, is likely to cost the Exchequer £78 Million in the sort term rising to £328 Million in the medium term for a relatively modest uptake of biofuels. Increasing the duty rebate will have little impact in the short term but would significantly add to costs in the medium term when levels of production increased. Rates of duty incentive currently being requested by industry (27-28 p/litre for biodiesel and 24 p/l for bioethanol) would cost the Government in the region of £394-460 million/annum by 2010 depending on the level of uptake. This has to be balanced against the benefits accruing from biofuels for the environment, fuel security, the risk of increasing imports and impacts in the rural economy.

Socio-economic impacts

Any reductions in duty applied to biofuels can be offset to some extent by revenue generated from increased employment in other sectors of the economy. Additional on-farm employment or revenue generation occurs where biofuel crops are grown on set-aside, as more labour is invested in crop production than in maintenance of set-aside. The direct levels of employment created are low. Around 2 jobs are likely to be created in agriculture per 1000 tonnes of biodiesel production. Recent studies suggest bioethanol production from wheat and sugar beet would generate around 5.5 jobs/1000 tonnes of bioethanol production. Few additional jobs are created in biofuel processing. A 100,000 tonne biodiesel plant would employ in the region of 62 staff in processing and blending industries. A similar sized bioethanol plant would employ 50-55 staff, plus a further 16-28 in fuel blending and transport.

Recently published work, indicates that compared to imported fossil fuel supplies, the production of biofuels has a net beneficial impact on the UK economy due to the incomes that are generated in the agricultural, manufacturing, engineering construction, retail distribution and transport haulage sectors. The share of costs which is retained in the UK economy increases from about 82% for gasoline and diesel to about 91% for bioethanol and 95% for biodiesel. The agricultural sector, together with manufacturing, wholesale, retail and transport haulage sectors are the main beneficiaries.

Taking account of savings in job seeker's allowance and returns accruing to other sectors of the economy which are themselves taxed, it has been calculated that the actual impact on the Exchequer of a 24 p/litre duty cut for bioethanol is around 18 p/litre in lost revenue and around 22.5 p/litre for a 29p/litre duty cut.

Other means of support

Lack of capital infrastructure limits biofuel production in the UK, particularly for bioethanol production. A typical 100,000 tonne bioethanol plant would cost around £50 million to build. The costs of capital depends on the asset life of the production plant and the rate of return required by investors. Industry estimates that the difference between depreciating over 5 and 10 years adds 6 pence/litre to capital costs for a typical bioethanol plant. Accounting for long term depreciation of capital assets is difficult given the uncertainty over the life expectancy of any duty cut, however it is unlikely that Government could give guarantees over a period greater than 5 years. Providing a capital grant of up to 40% of costs with payback over 6-8 years would save in the region of 2-4 p/litre in final fuel costs depending on the scale of production. This would reduce costs to the Exchequer in the medium to long term and would provide support to domestic production while minimising the need for further duty cuts which could increase imports of biofuels.

Capital funding up to a ceiling of £5 million could be available from Regional Development Agencies in support of biofuel production. For a typical 100,000 tonne plant, this could be worth between 0.5 and 1.0 p/l on a plant depreciated over 10 or 5 years respectively.

The way forward

The means by which stimulation of the industry and the development of a UK market could be pursued will depend on Government policies and on consideration of the public and private costs involved. Various implementation strategies are possible including:

Further reductions in excise duty in favour of bioethanol and biodiesel (with the possible exception of biodiesel derived from waste oils). The main problem with this approach alone is the ability to guarantee the duration of the rebate which will affect the period over which capital can be written off. Industry is looking for write-off periods of 8-10 years or more. Reducing duty alone risks sucking in more imports. A phased approach of lowered duty followed by an increase later could be an option.

Capital Grants alone, applied under state aid rules, are unlikely to provide sufficient incentive to start investment in new facilities. However, subsidies towards the cost of capital investment in production facilities, combined with fuel duty incentives appear to have significant potential.

UK legislation could be introduced to specify a minimum biofuel blend in gasoline and diesel. This has the advantage of shifting costs from the tax-payer to the consumer of the fuel and mandatory blending would ensure better monitoring of biofuel uptake. However it does not guarantee that production would be UK based. This approach may also fall foul of free-market legislation by favouring large over small and individual producers by adding an additional burden on fuel marketing.

Other fiscal incentives for users of biofuel could include rebates on the annual road fund licence, exemption from congestion charging in cities and reduced fees for parking – though these are unlikely to stimulate rapid uptake to the degree required.

In summary, the optimal implementation strategy for incentivisation of biofuels would appear to be a combination of fuel duty reductions in favour of biofuels and further Government subsidies in the form of grants for capital investment in feedstock conversion plants.

1. BACKGROUND

1.1. *EU biofuel substitution targets*

As part of a wide range of measures drawn up by the EC in response to international agreements to reduce green house gas emissions, the European Commission has proposed that EU member states should move towards development of transport biofuels and propose 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 vegetable or palm oils) and bioethanol (derived from fermentation of starch or sugar crops) dominate as the most technically feasible and commercialised alternative renewable fuel sources that perform at least as efficiently as their petrochemical counterparts. 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 on the forecourt. Current UK fuel duty rates provide for a 20p/l reduction in duty for biodiesel compared with conventional Ultra-Low Sulphur Diesel (ULSD). A similar duty cut for bioethanol will come into force from January 2005.

1.2. 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. Fuel offered for sale must meet European Standard BS EN 590. Blends of 5% biodiesel in ordinary diesel can meet this standard, but pure biodiesel or blends containing more than 5% biodiesel may not (according to fuel suppliers Greenenergy). The European standards body CEN is in the final stages of formalising a European Standard specifically for biodiesel - EN 14214. It is proposed that EN 590 should be modified to state that the biodiesel component of any blend must separately comply with EN14214. Reputable suppliers of biodiesel should already comply with this.

1.3. Current UK biodiesel production relies predominantly on use of waste vegetable oils as a low-cost feedstock as current costs prevent significant production from ‘fresh’ rapeseed oil. However, there are additional technical problems associated with use of waste oils and animal fats feedstocks that can affect achievement of the EU biofuel specifications, limiting their use to incorporation in blends with mineral diesel. Previous use of vegetable oils means they are of variable quality and they must be purified to reach the required standard. The oil or oil mix used will affect the efficiency of conversion and the properties of the final fuel. Derivation of biodiesel from animal fats produces a fuel with a high cold filter plugging point – which means that performance at low temperatures is likely to be adversely affected. The high level of free fatty acids in animal fats also means that a greater amount of processing is required with animal fats than vegetable derived oils. Animal fats represent a cheap waste product and an attractive source of raw material.

1.4. The current duty cut of 20p/l on biodiesel has incentivised commercial production of biodiesel from waste oil, but currently little UK production from fresh rapeseed oil (though some rape is be being grown in the UK for export contracts, and some biodiesel is being produced in the UK by Greenergy from oilseeds grown in France and Germany). The price of waste vegetable oil has risen dramatically in response, from £150/tonne in June 2002 to £223/tonne in February 2003 (compared to ‘virgin’ rapeseed oil costs of between £350 and 600/tonne). Somewhere in the region of

100,000 tonnes is thought by industry sources to be the limit for biodiesel production from these 'waste' materials (British Association for Biofuels and Oils). Customs and Excise figures indicate that current biodiesel production is running at just under 800 tonnes per month (May 2003), but only 26% of this is sold as a blend (95%:5% (mineral:biodiesel)). No bioethanol is currently being sold in the UK. Currently the largest producer of biodiesel in the UK is Rix Biodiesel who currently supply biodiesel blend (95:5) derived from waste vegetable oil to 61 forecourts in the north and North East. Greenergy currently supply 3 forecourts in the south and west of England with a 95:5 biodiesel blend, though in this case it is said to be derived from 'virgin' rapeseed oils (www.greenergy.com)

1.5. 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. It contains no sulphur and so does not contribute to SO_2 emissions.

1.6. There is a cost to the Exchequer (in terms of duty forgone) from stimulating the development and uptake of biofuels in the UK. This cost has to be balanced against the objectives of the UK Government to create a low carbon economy and in meeting target for reducing CO_2 emissions by a variety of means ranging from increased fuel efficiency to stimulation of low-carbon technologies. The current and planned duty rates for biofuels are calculated by the UK Government to reflect current thinking on the environmental value of such fuels in mitigating the effects of climate change and other beneficial effects on air quality etc. The current Government stance is that it would require evidence of additional benefit to the UK from an environmental, socio-economic or cost of carbon abatements basis to stimulate any further revision of duty rates.

1.7. Comparisons of costs between different carbon-saving technologies are equilibrated by calculation of the costs (including public subsidies) per tonne of carbon saved. Public-funded support for liquid biofuels has to compete with demands and cost savings achieved by other technologies to ensure the most cost-effective achievement of the UK Governments aims.

1.8. *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. 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 (Figure 1). The future wide commercialisation of lean-burn, direct fuel injection petrol engines could improve fuel efficiency (by up to 20% or more according to ESSO) as could the development of lighter vehicles using 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 report.

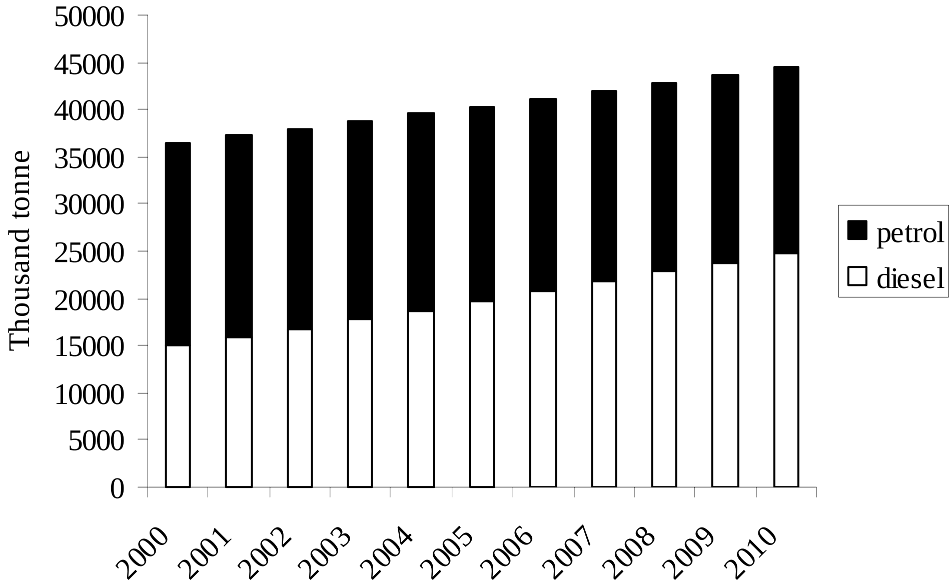

Figure 1. *Actual and predicted transport fuel use in the UK*

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

2. THE AGRICULTURAL IMPACTS OF BIOFUEL CROPPING IN THE UK

2.1 *Biofuel feedstocks*
Oilseed rape is the crop most likely to provide large volumes of home-grown competitively priced oil for biodiesel production in the UK for the foreseeable future. Average yields across the UK are typically around 3–3.5 tonne/ha, though the very best crops can achieve around 4 t/ha. Current UK rape oil production stands at around 1.15 million tonnes and UK crushing capacity exceeds UK crop potential. Discussions with industry reveal that with current best practice one tonne of rapeseed will yield 0.415 tonne (472 litres) of Rape Methyl Ester (RME) (Biodiesel). Based on a 'good' UK yield of 3.5 t/ha, this gives a potential RME production potential of up to 1.45 tonne per hectare of oilseed rape in the UK. The technology to produce RME is proven and commercial production of significant quantities of RME from 'fresh' rapeseed oil could be achieved within 24 months. Discussions with industry indicate that further improvements in efficiency are anticipated and RME yields could be increased to 1.525 tonnes/ha of oilseed rape in the longer term.

2.2 Bioethanol can be produced by fermentation of sugar, starch and cellulose feedstocks. The choice of feedstock depends on cost, technical and economic considerations. The technologies for derivation of ethanol from ligno-cellulose feedstocks (i.e. feedstocks such as straw, wood waste or paper waste etc) are immature and will probably take at least 5-10 years to reach commercial optimisation. Wheat will be the main UK starch bearing crop used for ethanol production in the UK (costs and risks incurred in producing and storing potatoes, the other main UK starch crop, negates its use compared to cereals). At a typical yield potential of 8 t/ha, it is possible to produce in the region of 2.5 –3.2 t ethanol/ha from wheat in the UK.

2.3 Ethanol production from sugar beet would rely on storage of extracted beet juices (these are currently stored for up to 48 weeks per year by British Sugar). UK sugar beet is capable of producing around 3.8-4.3 tonne/ha of ethanol. However, sugar beet production in the UK will be severely affected by reform of the EU Sugar Regime under WTO agreements (which will limit price supported quotas) and the aims of the 'Everything But Arms' concessions to less developed countries which will open up EU markets to overseas imports. EU prices are currently three times those of the world price for sugar. It is estimated that returns to growers could fall by around a third to around £18-20/tonne. Without an alternative market the sugar beet area could decline significantly. This improves prospects for bioethanol production by reducing costs of feedstock (which accounts for around 50% of final cost) which would bring cost of ethanol production into line with that for biodiesel. However, it is currently unclear what level of returns will be required to encourage continued production of sugar beet in the UK or what level of transitory compensation will be available to growers during the process of reform. Development of an alternative use for sugar beet through ethanol production could mitigate against the anticipated decline in crop area.

2.4 Facilities for commercial production of ethanol from wheat and sugar beet feedstocks could be built within an 18-24 month timeframe, producing ethanol at an estimated cost of 38-42 pence/litre, depending on feedstock and plant capacity. Industry estimates indicate that support equivalent to at least 24 pence/litre (guaranteed for 15 years) would be required to stimulate investment in a 100,000 t/year production facility.

2.5 The intimate mix of lignin and cellulose found in plant structural components is termed lignocellulose. In essence, for bioethanol production, the lignin is separated from the cellulose (and left as a by-product) the cellulose is then broken down (hydrolysed) into its constituent sugars which are then fermented to produce ethanol. This is a more complicated and costly approach than that applied to starch and sugar feedstocks. Cereal straw, Miscanthus (energy grass), wood (forestry waste and short rotation coppice (SRC)) and more recently waste paper are considered to be suitable potential commercial sources of lignocellulose. Estimates of bioethanol yields are given in Table 1 below. Currently costs of paper waste collection, sorting screening and shredding make this feedstock expensive and unattractive compared to other feedstocks. According to figures generated in the EEDA study, production costs for ethanol derived from waste paper are nearly four times those of production from wheat straw (27.68 p/litre v 7.26 p/litre for costs of collection, preparation and transport) where costs of collection are borne by the bioethanol producer. The potential for ligno-cellulosics requires further development and demonstration. Ethanol derived from such sources is unlikely to be competitive for several years. US estimates of the cost of producing ethanol from poplar 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. Currently, lignocellulosics technology requires more support than those for processing sugar and starch crops to stimulate investment in research and development.

Table 1. *Typical Ethanol yields from various lignocellulose feedstocks*

Feedstock	Ethanol yield (litres/tonne)
Wheat straw (@ 85% Dry Matter)	240-360[a c]
Miscanthus (@ 70% Dry Matter)	230 [b d]
SRC/Forest waste (@70% Dry Matter)	170 [c] -280 [b]
Waste paper	309 [b]

Date Sources [a] Woods and Bauen, 2003 (Imperial College) [b] Bullard et al. 2003 (EEDA) [c] Marrow and Coombs 1990 (ETSU) [d] Turley et al. (2002) (Defra OFIC study)

2.6 *Meeting Fuel replacement targets*

The scale of production required to meet the EU substitution targets is given in Table 2. The associated carbon savings estimated to arise from meeting the substitution targets are also presented. The latter is based on estimates of carbon savings generated from Department for Transport scenarios (Tables 7 & 8). Savings of around 0.5 M tonnes of carbon are anticipated for 2% substitution in 2005, rising to around 1.5 to 2 million tonnes of carbon by 2010 if the substitution targets are met, but this will be difficult.

Table 2. *Targets for transport biofuel replacement based on predicted fuel use and estimates of likely carbon saving arising from substitution*

	Predicted fuel use (million tonnes)	Target for substitution (million tonnes)	Estimated carbon saving (million tonnes per annum)†
2005 (2% substitution)			
All fuels	40.3	0.806	*0.453-0.653
Diesel only	19.8	0.395	0.222-0.320
2010 (5.75% substitution)			
All fuels	44.5	2.56	1.423-2.058
Petrol Only	19.6	1.13	0.619-0.899
Diesel Only	24.9	1.43	0.804-1.159

* Assuming all met from biodiesel (see paragraph 2.7)
† Based on extremes of range derived from Dept For Transport scenarios (Tables 7 & 8)

2.7 *Meeting the target for 2005*

In the short term it is likely that only biodiesel production will be sufficiently well developed commercially in the UK to contribute significantly to meeting the targets for 2005 and duty reductions for bioethanol will only have been in action since the beginning of the year. It is anticipated that bioethanol production may have started at one or two pilot plants but further refinement would be required to optimise the process. It is therefore assumed that bioethanol would make little contribution by 2005. Waste oil industry estimates indicate that around 0.1 million tones of Fatty Acid Methyl Ester (biodiesel) could be produced from waste vegetable oil and animal fat sources. This already takes into consideration the imminent (from October 2004) Animal By-Products Regulation ban on the feeding of catering waste (which includes cooking oil) to farm animals. This currently accounts for up to 80,000 tonnes of vegetable oil in the UK, where use for biofuel would provide a welcome route for what would otherwise be costly disposal. The remaining demand would have to be met from Rape Methyl Ester (biodiesel) derived from rape oil. Based on the efficiency of conversion presented earlier, 0.2 million hectares of oilseed rape would be required to meet targets for substitution of road diesel alone or just under 0.5 million hectares to substitute for 2% of all transport fuel requirement in 2005 (Table 3).

2.8 The 2% substitution target for all transport fuels could be met by growing 0.5 million hectares of oilseed rape on either set aside or by subsituting for other crops in the arable rotation. Between 0.56 and 0.80 million hectares were under set-aside in the UK between 2000 and 2002, according to the latest Defra statistics, the most recent assessment only covers up to 2002 where 0.61 million ha were set-aside). This increase would effectively double the current UK oilseed rape area. Growing biofuel crops on set-aside would reduce the impact of biofuel cropping on the rest of the farming operation and crop rotations etc. Overall this is likely to result in intensification of rape cropping in areas of current production but may result in a better balance of cereal to non-cereal crops in intensive wheat growing areas. There are likely to be some agronomic challenges in achieving this but most UK arable farming businesses should be able to accommodate and deal with these. Decoupling of support payments from crop to area-based payments under revision of the CAP should also remove the current restrictions on areas of UK oilseed rape production and limits on tonnages of rapemeal generated for use in the animal feed industry, which were previously affected by the Blair House Agreement. Meeting only 2% of the 2005 diesel demand would halve the amount of oilseed area required and ease pressures on the rest of the arable rotation.

Table 3 *Scenario to meet the 2005 targets for biofuel substitution - 2% of road diesel use alone, or 2% of all road transport fuel use*

	Feedstock	Fuel required (million tonnes)	Feedstock area (thousand ha)	% of current crop area
2% Diesel substitution only	Waste fats/oils	0.1		
	Rape oil (RME)	0.3	203	45
2% All transport fuel	Waste fats/oils	0.1	-	
	Rape oil (RME)	0.7	487	108

2.9 *Meeting the target for 2010*

Meeting the target for 5.75% substitution will require a much broader range of biofuel feedstocks. It is unlikely that the oilseed rape area could be expanded much beyond double the current area without having significant impacts on yield potential and farm logistics. However, some limited increase in efficiency of production could be expected. Soil type and climatic issues do limit the areas of the UK where oilseed rape can be successfully grown, so increased production is likely to come from increased intensification of rape cropping in areas of current production (where rape dominates as the main non-cereal break crop). Achieving this level of increase is likely to require a financial incentive to encourage farmers to substitute industrial for food crops and to switch from current rotations designed to optimise financial returns. It is not clear whether the security of long-term guaranteed payment contracts for industrial crops, which potential biofuel companies suggest will be the preferred purchasing option, will be sufficient to achieve this level of production. With such limits, it is unlikely that UK produced biodiesel generated from waste sources and rapeseed will exceed 2% of UK transport fuel demand (Table 4).

Table 4. *Scenario to meet the 2010 targets for biofuel substitution (5.75% of all transport fuels). I - Optimum availability of starch and sugar feedstocks*

Feedstock	Fuel required (million tonnes)	Feedstock area (thousand ha)	% of current crop area
Waste fats/oils	0.10		
Rape oil (RME)	0.70	459	102
Wheat grain	0.80	346	21
Sugar Beet	0.83	202	114
Total		1,007	

2.10 It is assumed that by 2010 the technology for production of ethanol from wheat and sugar beet is fully commercialised. The UK is a net exporter of wheat. In all but one of the last 10 years the UK has had an export surplus of between 19 and 28% of UK wheat production. The exception to this was in the 2001/02 season where this fell to 5%. Over the last five years the export surplus has averaged close to 20% representing 2.9 million tonnes of grain, capable of producing up to 0.8 million tonnes of ethanol.

2.11 The UK sugar beet area is regulated by quota and has reached 205,000 ha in previous years. This probably 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 in association with cash crops such as potatoes or root vegetables alternating with winter cereals. This limits the potential for further expansion within the rotation. Assuming this beet area is maintained and there is some uncertainty about this with regard to impacts of reform of the sugar regime this could potentially produce up to 0.83 million tonnes of ethanol.

2.12 With maximised production of biodiesel from all UK oil sources, use of all export wheat for biofuel production and diversion of the maximum UK sugar beet area into biofuel production, then close to the target for production of 2.56 million tonnes of biofuel by 2010 could theoretically be achieved (Table 4). However this scenario unlikely to be achieved in practice. Reform of the sugar regime will reduce future returns to sugar beet growers and crop area is therefore likely to decline, with growers of smaller acreages ceasing production in the long term. Levels of transitionary compensation payments (yet to be decided) will have an impact on the area of production that survives reform of the sugar regime. Cereal export markets demand premiums for meeting quality specifications and any deficit in supply from export surplus for bioethanol production would have to be met by imported grain, or by direct competition with grain markets for home consumption. Alternatively bioethanol would have to be derived from other sources.

2.13 If it is assumed that UK biodiesel production is optimised at around 0.8 million tonnes, around half of the exportable wheat surplus could be made available for bioethanol production and that at least half of the current area of sugar beet is retained in 2010, then there would still be a requirement for around 1 million tonnes of biofuel to meet the 2010 targets for replacement. This demand would have to be met from novel sources such as lignocellulosics. A possible breakdown for supply of bioethanol from these sources is given in Table 5.

2.14 It is assumed that the problems and costs associated with collection and separation of waste paper negate use of this as a competitive feedstock. Wheat straw could be used in the locality close to processing plants but transport costs will limit the radius of supply areas, so it has been assumed that only around 10% of the UK wheat area could supply this market, capable of producing 0.25 million tonnes of ethanol. Miscanthus and short rotation coppice (SRC) provide higher biomass and therefore higher ethanol yields/unit area than cereal straw which could ease the logistics of raw material supply. In terms of efficiency of bioethanol production (i.e. tonnes of feedstock required per tonne of ethanol) Miscanthus and SRC appear very similar as feedstocks. To meet the balance of biofuel demand just over 0.3 million ha of biomass crops would be required (Table 5). This is in addition to increased demand for such crops from the bio-energy sector for electricity generation from renewables. Some of the target could be met from forestry thinnings or waste wood, but it has been estimated that this would not account for more than 30,000 tonnes of ethanol production.

2.15 Meeting the target for biofuel production from bioenergy crops will prove difficult. Crops such as SRC and Miscanthus rely on long-term supply contracts to guarantee confidence to invest by farmers. Currently the returns on such crops are not favourable compared to conventional arable crops so there is little incentive to start the process of conversion. There is also a lag phase of at least 2-3 years before the crops mature. With appropriate incentives, and given the current downturn in extensive livestock production systems, biomass cropping could expand into areas currently under grass production in order to meet demands for energy production. Without access to such additional areas of production it will prove very difficult to meet the indicative target for biofuel substitution in 2010.

Table 5. *Scenario to meet the 2010 targets for biofuel substitution (5.75% of all road transport fuels). II - Limited availability of starch and sugar feedstocks*

Feedstock	Fuel required (million tonnes)	Feedstock area (thousand ha)	% of current crop area
Waste fats/oils	0.10		
Rape oil (RME)	0.70	459	102
Wheat grain	0.40	173	11
Sugar Beet	0.40	98	55
Wheat straw	0.25	*	-
Miscanthus	0.20	100	-
SRC	0.50	229	-
Total		1,059	

* sourced from wheat grain area

3 IMPACTS ON THE FARMED ENVIRONMENT

3.1 *Traffic impacts*

Traffic impacts will depend on what proportion of biofuel production occurs on set-aside land, where crop movements will increase the overall traffic impact. Biofuels derived from conventional crop feedstocks will have little impact on UK crop movements as in the majority of cases they would have been moving off farm anyway for conventional use. Growing biomass crops or retaining crop residues as lignocellulose feedstocks may reduce transport pressure during the peak harvest period as harvest of perennial lignocellulosic crops takes place during late winter and residues are generally retained on farm until required/collected. Traffic pressure is likely to be concentrated around large biofuel plants and these are most likely to be established alongside existing crushing or sugar refining plants to save on transport costs.

3.2 *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 in terms of impacts on crop diversity and for 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 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

3.3 *Replacement of set-aside - environmental impacts*

If the required additional biofuel crop production was met from production on set-aside land, the majority of naturally regenerated set-aside would disappear. Replacement of this 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.

3.4 *Expansion of perennial lignocellulosic crop production - environmental impacts*
The impacts of short rotation coppice and Miscanthus cropping on the farmed environment are likely to be relatively benign compared to those of other arable crops. 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.

3.5 *Landscape*
Most current commercially viable biofuel feedstocks (oilseed rape, cereals and sugar beet) will be grown in rotation as part of a mix of several crops on the farm. Introduction of perennial crops like SRC and Miscanthus for biofuel production would require more 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. More detailed information is available from a Defra commissioned review by Turley *et al*. (2002).

4 IMPACTS ON THE RURAL AND WIDER ECONOMY

4.1 *Impacts of cropping for biofuel production*
Any reductions in duty applied to biofuels can be offset to some extent by revenue generated from increased employment in other sectors of the economy. The impacts differ depending on whether crops are grown on set-aside or within the existing crop rotation. Significant additional on-farm employment or revenue generation occurs where biofuel crops are grown on set-aside rather than as a replacement for food crops as significantly more labour is invested in crop production than in maintenance of set-aside.

4.2 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. Impacts of farming enterprises on the rural economy are estimated by evaluating cash flows in the rural economy arising from cultivating a crop. After deduction of costs (cash which usually fails to enter the rural economy to any significant degree) the remaining cash 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. The value of any production/functions or 'rural multiplier' commonly used in such analyses will change over time.

4.3 Using input/output analysis and multiplier methodologies estimates of the extra employment generated by biofuel production plus estimates of the number of jobs created in processing has produced widely different employment estimates between European studies. A review of these for Defra (Turley *et al*., 2002) indicated employment generation figures ranging from 5 to 16 jobs/1000 tonnes of biodiesel production from crops grown on set-aside land. The authors calculated using rural multipliers that a figure of around 2 jobs created per 1000 tonnes of biodiesel production was a more likely estimate for the UK for feedstock production on set-aside land, the figure would be nominal where cropping occurred outside set-aside. The same could be said for on-farm revenue generation. Significant additional farm income will only flow where biofuel crops are grown on set-aside. At this stage it is difficult to estimate how development of lignocellulosics would affect farm incomes, so comments are restricted to impacts on current arable feedstocks – i.e. rape, wheat and sugar beet. The prices being discussed within the industry for oilseed rape for biofuel production are in the region of £8-12/tonne less than those likely to be available for conventional markets. As feedstock cost is such a large component of costs there is pressure to keep costs down to a minimum. Those wishing to procure stocks hope that the offer of long-term supply contracts will encourage farmers to produce biofuel crops in return for some security in future financial return. Growing cereals or oilseeds on set-aside could improve returns to growers by as much as £140-£300/ha, depending on the yield potential, though this would depend on whether additional contract labour or machinery was required to handle the extra crops area.

4.4 Following the mid term review of CAP, it has been agreed that an Energy Crop Payment of €45/ha/year would be made available to support biofuel energy crops up to a maximum guaranteed area (MGA) across the EU of 1.5 million hectares. Where this MGA is exceeded, payments will be scaled back proportionately. At current rates of exchange this is worth £32, however the scale of crop production required to meet the biofuel targets (as discussed earlier) means that the MGA will be rapidly overshot and the payment is likely to be scaled back. Assuming that oilseed rape growers could access the full payment rate, then at current yield levels this would provide some compensation (i.e. around £9/tonne for a 3.5 t/ha rape crop, and proportionately more for lower yielding crops) for the lower prices being indicated for biofuel contracts by those procuring rape for biodiesel production.

4.5 Estimates of job creation from bioethanol production have mainly focussed on US experiences which have produced very low employment estimates due to the large scale of production and the extensive low labour input of North American farming systems. Recent work for EEDA (Bullard *et al.* 2003) indicated employment creation figures of around 5.46 jobs/1000 tonnes of bioethanol production from a 50:50 feedstock of wheat and sugar beet (labour intensive) crops grown on set-aside.

4.6 It is more difficult to assess impacts outside agriculture. Very few additional jobs are created in biofuel processing. A 100,000 tonne biodiesel plant would employ in the region of 43 staff according to German studies. Data reviewed by CSL from the North East Biodiesel Partnership indicate that a 100,000 tonne biodiesel plant would create up to 62 jobs in the processing and blending industry. The EEDA study estimates that a similar sized bioethanol plant would employ 50-55 staff, plus 12-18 HGV haulage jobs and a further 4-10 jobs in fuel blending. This study indicated that additional regional employment in the region of 2.9 jobs/1000 tonnes of production would be generated.

4.7 The EEDA study and further work by the authors has attempted to assess the impacts of the additional employment created by bioethanol production on cash flow in the rural economy of East Anglia by detailed macro-economic analysis using the UK national Input-Output Table. The information presented below is drawn from the detailed input:output analysis on bioethanol, which has recently been undertaken by Ecofys and ADAS for EEDA. For the benefit of this brief, equivalent figures for biodiesel have been estimated but do not benefit from the same level of rigorous analysis in the time available.

4.8 The comparative gasoline and diesel costs are based on an oil price of $26/barrel using imported petroleum.

4.9 Figure 2 shows the distribution of production costs for bioethanol and biodiesel compared with diesel and gasoline produced from fossil fuels. The biofuels have credits for sales of by-products to other markets such as the animal feeds market.

4.10 Figure 3 shows the value added component which contributes to the UK economy (i.e. as a contribution to GDP) and a net imports component for the goods and services which need to be imported from outside the UK economy. At the macro-economic level, compared to imported fossil fuels, the production of biofuels has a net beneficial impact on the UK economy due to the incomes that are generated in the agricultural, manufacturing, engineering construction, retail distribution and transport haulage sectors.

4.11 Table 6 lists the share of overall costs (including fuel duty) by imports and total value added. The share of the costs which is retained in the UK economy increases from about 82% for gasoline and diesel to about 91% for bioethanol and 95% for biodiesel. Hence the production of UK based bioethanol and biodiesel increase the value added to the UK economy.

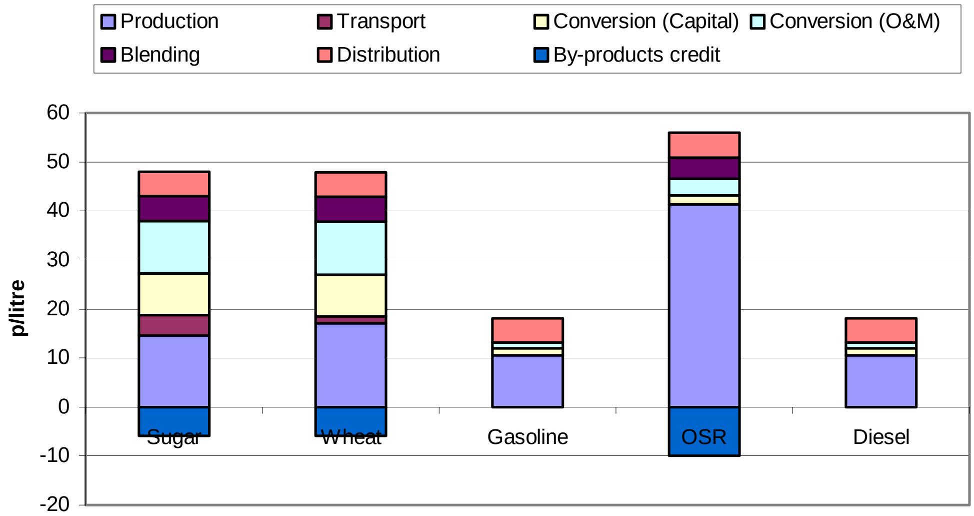

Figure 2. *Distribution of costs for bioethanol, biodiesel, diesel and gasoline (i.e. general running costs)) [The 'production' segment covers growing and harvesting costs. Processing and fermentation costs are covered by the capital cost segment and the O&M (operations and maintenance) segment]*

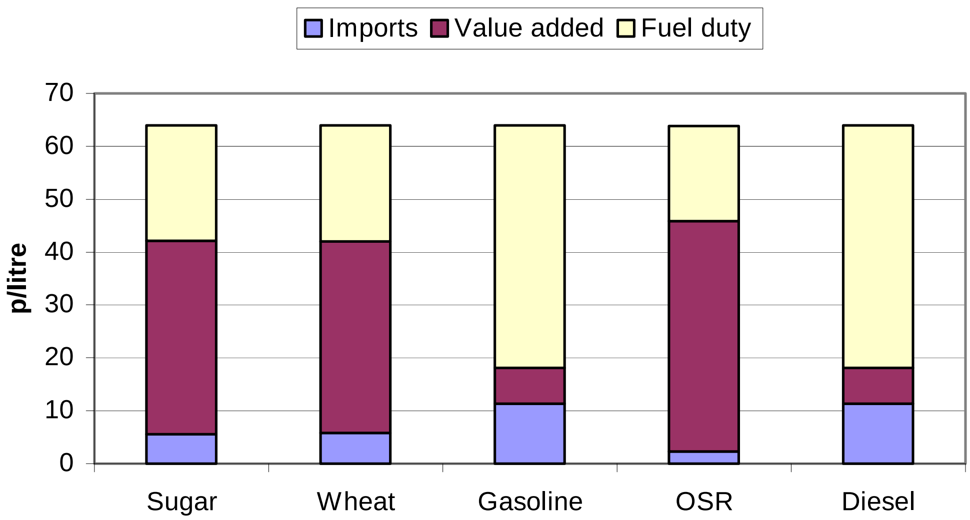

Figure 3. *Value added and net imports for biofuels and fossil fuels with fuel duty included at the level required to equalise the retail price of each fuel at the filling station. (Calculated using a duty of 45.82 p/litre for gasoline and diesel, but omitting the VAT component).*

Table 6. *Share of costs represented by imports and value added*

Feedstock	Imports as % of overall costs	Value added as % of overall costs
Wheat	9.1	90.9
Sugar	8.7	91.3
Gasoline import 100%	17.8	82.2
OSR	5 (estimated)	95 (estimated)
Diesel	17.8	82.2

4.12 Figure 4 shows the distribution of value added across the principal economic sectors for the case of bioethanol production from UK wheat. It can be seen that the agricultural sector, together with manufacturing, wholesale, retail and transport haulage sectors are the main beneficiaries. A similar breakdown would be expected for biodiesel.

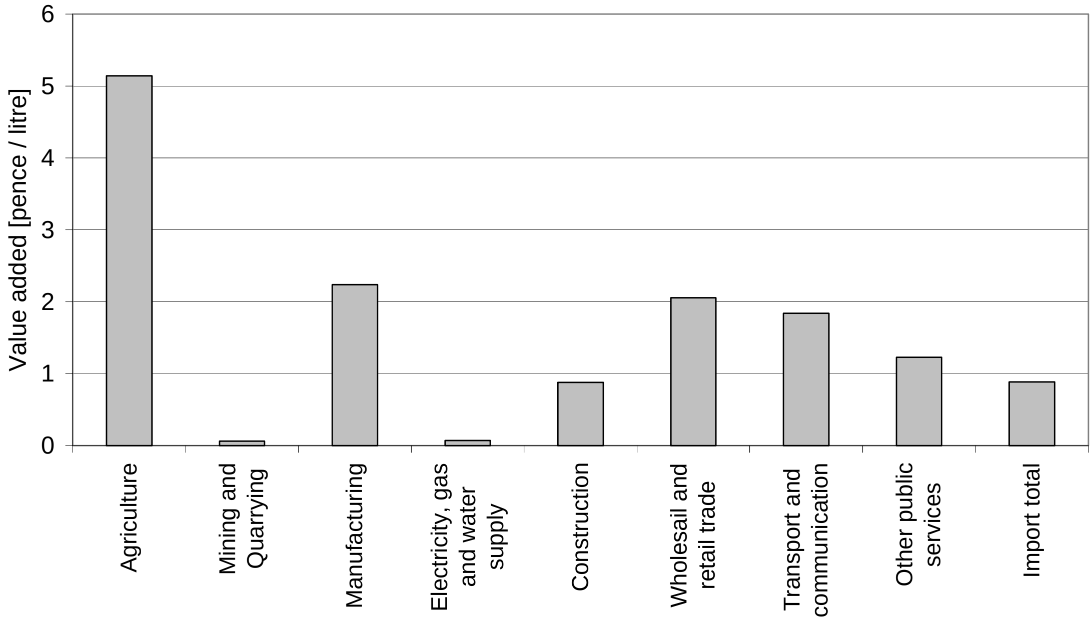

Figure 4. *Distribution of value added for bioethanol – main sectoral beneficiaries [the 'agriculture' sector is as defined in the UK national input/output tables as agriculture and related services. All other farm inputs are accounted for by other sectors – e,g, manufacturing (for machinery), utilities and transport etc.]*

4.13 Bioethanol production from UK grown wheat or sugar beet sources requires the equivalent of a duty cut of 24 p/litre to equilibrate the retail price with that of gasoline derived from fossil fuel. Due to the net benefits associated with offsetting job seeker's allowance (through the creation of additional jobs in the economy) and the distribution of costs to other sectors of the economy which are themselves taxed, calculations in the EEDA study estimate that the actual impact on the Exchequer of a 24 p/litre duty cut is around 18 p/litre in lost revenue. Biodiesel production from UK grown oil seed rape (OSR) requires the equivalent of a duty cut of around 27-29 p/litre based on the most recent data available from industry sources. Due to net benefits similar to those estimated for bioethanol production, it is estimated that the actual impact to the Exchequer of a 29p/litre duty cut is likely to be around 22.5 p/litre. Any government spending will generate some revenues by encouraging industry or spending etc, and this approach is is not unique to biofuels.

5 THE SOCIAL COSTS OF CARBON EMISSIONS –ESTABLISHING AN ESTIMATED COST

5.1 A figure of £70 per ton of carbon emitted (within a range from £35-140/tonne) has been used by Government Departments in recent months as an estimate of the cost of damage associated with carbon emissions to the environment. Calculation of such costs is integral to development of ameliorating fiscal measures. Different technologies and means of ameliorating polluting emissions may be subject to differing levels of direct or indirect public subsidy. The cost of emission reductions attributable to different technologies must also be compared against the costs of damage to ensure cost effective public spending.

5.2 This £70/tonne of carbon figure is derived from a review report by Defra’s Environment Protection Economics Division, produced for Defra and the Treasury by Clarkson and Deyes (2002). This reviewed existing studies which have attempted to place a value on the social costs of emitting Carbon. Given the uncertainty in this area and the ongoing research, periodic review of the costs is recommended to account for updating of models and increasing knowledge on the impacts of climate change. Moneterising the damages associated with carbon emissions in complex and there is little consensus on a specific figure, which is why an illustrative range is preferred, however a consistent figure is required to asses comparative impacts in different sectors to aid policy formation. Other authoritative sources (Prof. David Pearce) have suggested that a more appropriate social cost would be in the range of £4-£27 per tonne of carbon emitted. Such comments have led Defra to keep such costs under review. The £70/tonne figure is currently therefore used as an indicative figure and is classed as ‘under review’. It should also be noted that there is considerable uncertainty around the figure – as illustrated in the cost range indicated above.

5.3 The majority of existing studies are US focussed and extrapolate findings to other areas of the globe. The social cost is calculated by complex modelling techniques based on one of two broad approaches; Cost Benefit Analysis (CBA) or Marginal Cost (MC) approach.

5.4 Cost Benefit Analysis, involves calculation of the ‘optimum’ level of carbon emission levels at the point at which the marginal cost of reducing emissions is equivalent to the estimated marginal costs of damage caused. The social costs of carbon is then defined as the level of carbon tax required to achieve the optimum level of emissions.

5.5 The Marginal Cost approach attempts to calculate directly the difference in future damage levels caused by a marginal change from current levels of emissions, without any reference to optimality.

5.6 With both approaches there are a number of significant scientific and economic uncertainties in applying these approaches that include:

- **Estimation of current and future emissions levels**
- **Estimation of the social damages associated with the emissions:** a) estimation of impacts of emissions on changes in the carbon content of the atmosphere b) estimation of the climatic impacts associated with any increase in atmospheric carbon content and c) identification of the physical and monetary impacts resulting from climate change.
- **Choice of discount rate** (i.e. the rate at which future impacts should be discounted to todays values).

5.7 Different values for social costs of carbon in the reviewed studies relate to differences in approaches to identification and valuation of impacts – i.e. the range of impacts considered, values placed on non-market impacts and the way climate change is modelled, plus the means by which such effects are accounted for by economic mechanisms. In many cases there is a lack of clarity in the derivation of key parameters that causes difficulty in comparing results between models. In general, higher monetary values for damages per tonne of Carbon emissions are likely to be associated with studies that consider a greater range of impact categories and/or where higher levels of monetary value are associated with impact damage.

5.8 Most recent studies agree on assumptions of levels of present and future green house gas emissions and all employ the same basic carbon cycle model to predict the impact of carbon emissions on atmospheric carbon concentrations. Studies vary in their estimation of the effects on global temperatures of doubling atmospheric CO_2 concentration but most defer to data published by the Intergovernmental Panel on Climate Change (IPCC).

5.9 In most cases it is assumed that the social costs of emissions will increase linearly over time – as atmospheric carbon levels will not stabilise until the end of the next century despite any abatement strategy, in addition, economies will continue to grow.

5.10 The social cost figure of £70/tonne of carbon emitted (at 2000 prices) is derived from a single study (Eyre et al., 1999) which was seen to derive the most support from other sources of information in derivation of its parameter values.

5.11 The work of Eyre *at al*. (1999), uses a Global Climate model (MAGICC) run in association with information on temperature changes generated by a global model of CO_2 changes derived by the Goddard Institute of Space Sciences (GISS) to calculate the average global temperature change and seas level rise. The GISS data is then used to produce projections of climate change across the globe.

5.12 In the work of Eyre *at al*. (1999), marginal costs for damages associated with global warming are calculated by functions for individual categories (i.e. agriculture, human mortality and a range of other impacts etc), allowing damages to be calculated in terms of rate and level of change. These are calculated using two models - Framework for Uncertainty, Negotiation and Distribution (FUND) and the Open Framework for Climate Change Assessment (OF) model. FUND is used to derive the dynamic impacts of climate change while the OF model is used to produce spatial data. It is the combination of these models that makes the work of Eyre *at al*. (1999) the most sophisticated to date. FUND considers impacts over five main impact categories and nine major world regions.

5.13 The areas most commonly identified as being most susceptible to damage caused by climatic change are -

Sea level rise (coastal protection, dryland loss, wetland loss, agriculture, human migration)
Agriculture
Extreme weather (hurricanes, storms, floods, hot/cold spells)
Species loss/biodiversity
Malaria
Water resources
Health and welfare

5.14 Impacts are derived from literature or modelled and are expressed in terms of monetary values and/or numbers of people affected. It is acknowledged that there are weaknesses in calculation of non-market impacts (i.e. impacts on biodiversity). The changing value of carbon emissions over time is accounted for in the work of Eyre *at al*. (1999), which accounts for changing per capita incomes over time.

5.15 When accounting for costs/benefits occurring over different years it is necessary to discount future values to present values. This procedure reflects the fact that capital can be invested today and can yield interests over years. The crucial aspect concerns the choice of the discount rate used in environmental valuations. High discount rates reduce the present value of future/costs and benefits (effectively making any future impacts irrelevant to current political decisions). In all environmental studies, for ethical reasons, low discount rates are adopted (2-5%). However, within this range the choice of the discount rate remains discretional and the consequences on the value of the estimated social costs are larger the longer the time horizon considered.

5.16 On behalf of the Treasury and Defra, Clarkson and Deyes (2002) recommended that the work of Eyre *at al*. (1999) provides the best estimate of social costs of carbon emissions for the use in UK policy making as it is the most sophisticated of the studies published to date. Its wide range of impact categories means that its estimate is generally higher than that of earlier, simpler studies. The work also attempts to directly model on a global basis rather than extrapolate from US data. Clarkson and Deyes (2002) conclude that £70/t C (which includes equity weighting to take account of differences in per capita income) is a defensible illustrative value for carbon emissions in 2000, which should be raised by £1/t C for each subsequent year.

5.17 Acceptance of the value was facilitated by a DETR study of the financial impacts of implementation of measures to meet the 2010 Kyoto targets, which calculated that it would cost in the region of $79 (£48) per tonne of carbon to meet global emissions targets for a 5.2% reduction. More stringent reductions will increase such marginal abatement costs. Clarkson and Deyes concluded that £70/t C was likely to be more consistent with levels of effort required to meet international obligations than other non-equity weighted figures.

5.18 £70/t C lies at the upper end of estimates of costs produced to date. As discussed above, this estimate is based on assessment of a wider range of impacts than other recent studies and it looks at impacts outside the US in more detail. The regionalisation of damage impacts and equity weighting of impacts increases estimates of cost by a factor of around two (i.e. from £32 to £71/t C). Applying this methodology to other studies would increase estimates of cost from those studies.

5.19 There is very significant level of uncertainty surrounding any estimate of social costs of carbon emissions and this does not take account of any risk of climate catastrophe. Clarkson and Deyes (2002) advise use of a lower and upper limit of £35-£140/tonne for use in any sensitivity analysis, the disproportionately larger upper limit reflecting the increased risk of catastrophic events.

5.20 The social cost of carbon emissions is currently under review by Defra's Environmental Protection Economics Division. Current advice is that the value of £70/t C should be used with limits shown.

6 TREASURY AND DEPARTMENT OF TRANSPORT CALCULATIONS OF BIOFUEL DUTY INCENTIVES

6.1 *Costs of production*

Biofuel production costs are affected by volatility in price of feedstocks and the value attributable to by-products (e.g. animal feed from bioethanol and glycerol from biodiesel production). The Dept for Transport has reviewed a number of studies and has developed a range of scenarios for costs and green house gas emissions associated with bioethanol (Table 7) and biodiesel (Table 8) production and use. The figures used (derived from other recent studies) are in broad agreement with costs of production for bioethanol estimated by a study for the East of England Development Agency (EEDA) (Bullard et al., 2003) and for biodiesel cost estimates by Cargill in 2003 (Budget submission to the Treasury). These figures indicate that duty cuts of 27 p/l are required to incentivise biodiesel production from 'fresh' rape oil (with conventional diesel @16p/l pre tax) and 26-29.9p/l to incentivise bioethanol production from wheat and 24 p/l to encourage production from sugar beet (based on DFT interpretation of British Sugar figures) (with conventional petrol @15p/l pre tax). The EEDA analysis indicated that similar duty incentives would be necessary to stimulate ethanol production from wheat and sugar beet feedstocks. The current duty cut of 20p/l on biodiesel has incentivised commercial production of biodiesel from waste oil, but currently little UK production from fresh rapeseed oil. The Government recognises that current estimates of costs of production from conventional feedstocks (wheat and sugar beet) mean that it is unlikely that the proposed duty cut of 20 p/litre will stimulate conventional bioethanol production and biodiesel production from rape oil in the UK. However, the current Government position is that the proposed duty cut already more than account for the environmental benefits associated with use of biofuels and that this rate should support development of lignocellulose bioethanol production in the medium to long term. There are concerns that any further reduction in duty could lead to significant import of biofuels.

Table 7. *DFT figures for bioethanol productions costs updated with EEDA study figures and further assessment of carbon costs (all figures in pence per litre unless otherwise stated) for bioethanol derived from wheat feedstocks and biodiesel derived from 'waste' oil.*

Scenario (see below):	I -Straw residue not used as fuel in bioethanol plant	II-Straw used as fuel in bioethanol plant	III -Straw not used as fuel in bioethanol plant	IV -'Eco-ethanol' - straw used as fuel in bioethanol plant	EEDA Biomass used as fuel in bioethanol plant	Petrol (ULSP)
Raw materials & labour	20.23	20.23	20.23	22.00	18.54	
Operating and marketing	9.81	9.81	9.00	9.81	10.80	
By-product credit	-5.86	-5.86	-6.00	-5.86	-5.90	
Capital repayment [a]	8.29	8.29	5.00	8.29	8.50	
Producer margin	4.00	4.00	4.00	4.00	5.00	
Blending costs	Included	Included	Included	Included	5.00	
Cost pre tax	43.88	43.88	41.00	43.88	41.98	15.00
Cost + conv. Fuel duty (ex VAT)	89.70	89.70	86.82	89.70	87.80	60.82
Cost incl.VAT (17.5%)	105.40	105.40	102.01	105.40	103.17	71.46
Duty cut required (before VAT)	28.88	28.88	26.00	28.88	26.98	
GHG emissions (kg/l)[c]	1.293	0.628	1.293	0.331	0.612	2.799
GHG Saving (kg/l)	1.506	2.171	1.506	2.371	2.186	
GHG Saving (%)	54%	78%	53%	85%	78%	
Carbon saving (kg/l)	0.411	0.593	0.411	0.674	0.597	
Cost of CO_2 saving (duty forgone)	£143/t CO_2	£99/t CO_2	£126/t CO_2	£91/t CO_2	£123/t CO_2	
Social value of saving [b] 2003	2.92	4.21	2.92	4.78	4.24	
2005	3.00	4.33	3.00	4.92	4.36	
2010	3.21	4.62	3.21	5.26	4.66	

[a] 15 years @ 12% for all but EEDA data @ 15%
[b] Value of social costs of carbon emissions 2003 = £71/t, 2005 = £73/t, 2010 = £78/t
[c] based on 100 Kt bioethanol plant, except for EEDA figures which are based on figures in the Hallam report for a 40Kt plant
I = British Sugar data for prices, Concawe data for carbon life cycle analysis (LCA) – (most realistic scenario)
II = British Sugar data for prices, Concawe data for carbon life cycle analysis (LCA)
III = Department for Transport data for prices, Concawe data for carbon life cycle analysis (LCA)
IV = British Sugar data for prices, General Motors/LBST 2002 data for carbon life cycle analysis (LCA)

Table 8. *DFT figures for costs and emissions associated with biodiesel production from 'fresh' and 'waste' oil. (all figures in pence per litre unless otherwise stated)*

Scenario:	I straw not used for fuel in biodiesel plant	II straw used for fuel in biodiesel plant	III straw not used for fuel in biodiesel plant	Waste oil	Diesel (ULSD)
Producer margin	4.00	4.00	4.00	4.00	
Cost pre tax	43.00	43.00	43.00	35.00	16.00
Cost + conv. Fuel duty (ex VAT)	88.82	88.82	88.82	80.82	61.82
Cost incl.VAT (17.5%)	104.36	104.36	104.36	94.96	72.64
Duty cut required (before VAT)	27.00	27.00	27.00	19.00	
GHG emissions (kg/l)	1.402	0.652	1.451	0.619	3.106
GHG Saving (kg/l)	1.704	2.454	1.520	2.487	
GHG Saving (%)	55%	79%	51%	80%	
Carbon saving (kg/l)	0.465	0.670	0.415	0.679	
Cost of CO_2 saving (duty forgone)	£158/t CO_2	£110/t CO_2	£178/t CO_2	£76/t CO_2	
Social value of saving [a] 2003	3.303	4.757	2.946	4.82	
2005	3.396	4.891	3.029	4.96	
2010	3.628	5.226	3.237	5.30	

[a] Value of social costs of carbon emissions 2003 = £71/t, 2005 = £73/t, 2010 = £78/t

I = ECOTEC (2001) data for prices, Mortimer (2002) (Hallam)) data for carbon life cycle analysis (LCA)
II = ECOTEC (2001) data for prices, Mortimer (2002) (Hallam)) data for carbon life cycle analysis (LCA)
III = ECOTEC (2001) data for prices, General Motors/LBST (2002) data for carbon life cycle analysis (LCA)

6.2 In terms of future prospects for conventional ethanol and biodiesel production, there is limited scope for reducing production costs in the medium term by increasing efficiency of bioethanol production from wheat or sugar beet feedstocks or biodiedsel from rape. The price of feedstocks is also likely to remain high with alternative feed or export markets available. Though costs for sugar beet will fall, duty rebates in excess of 20 p/l are still anticipated to be required even after reform of the sugar sector when prices are expected to decline to £18-£20/tonne.

6.3 *Risk of imports with further duty cuts*
Ethanol can be procured cheaply on international markets (for as little as 12 p/l for Brazilian ethanol). However taxation and distribution costs mean that it is unlikely that the UK would be flooded with biofuel imports. It has been estimated (Bullard *et al*., 2003) that Brazillian Ethanol landed in the UK, after accounting for blending and retail margins, would be in the region of 10p/l cheaper than UK produced bioethanol from wheat and sugar beet. However application of import duty for denatured alcohol (of 6-7 p/l) would bring costs closer in line with that of UK produced bioethanol. Other EU member states with lower duty rates for biofuels than the UK are likely to be higher priority targets for imported supplies. It is anticipated that there will be limited international trade in refined liquid biofuels in the medium term due to scarcity of supply and domestic European demands.

6.4 *Green House Gas (GHG) savings*
The value of biofuels in reducing GHG emissions depends on the feedstock and method of production, i.e. whether by-products (from crop production or processing waste) are used to fuel the plant or add credit to the Life Cycle Analysis of GHG emissions by preventing loss to the atmosphere. For example, in Tables 7 and 8, GHG emissions are significantly reduced in cases where straw is used as a fuel in the processing plant. (Note that in life cycle analysis for biofuels, the emission of carbon during fuel combustion is assumed to equate with that fixed during growth of crop biomass, i.e. there is a zero balance, all other emissions relate to energy invested in crop production, transport and fuel processing etc.)

6.5 Past US research examined by the Dept for Transport indicated that the carbon savings from bioethanol were poor compared to alternatives such as biodiesel from waste vegetable oil. However more recent European research, working with EU-based farming systems and updated production methods, has indicated significant improvements in life cycle carbon savings. There has been considerable debate and disagreement over the carbon savings associated with biofuel production. Latest figures suggest greenhouse gas savings of between 51 and 65% for bioethanol (v Ultra Low Sulphur Petrol (ULSP)), 56-80% for Rape Methyl Ester and 84% for biodiesel derived from waste oil (v Ultra Low Sulphur Diesel (ULSD)) Mortimer *et al*. 2002, Woods and Bauden, 2003). There are also now updated figures on costs of production supplied by the industry which show relative agreement between studies which allows more confident costing of any carbon savings.

6.6 *Costs of carbon savings*
The Treasury currently accounts for the value of the carbon credit retrospectively in its duty incentive calculation, as the credit allowance is calculated as a proportion of the duty incentive offered (i.e. the cost to the Treasury in duty forgone).

6.7 The Treasury accepts £70/t carbon, adjusted upwards by £1/tonne per year (see section 5) (equivalent to £19/tonne CO_2) as the social cost of carbon emissions. The cost of green house gas abatement achieved by biofuels is calculated as the CO_2 saving achieved for the duty forgone (20p/l in this case). This gives CO_2 abatement costs ranging from £91-£143/tonne CO_2 saved for bioethanol (depending on the production method) (Table 7) and £110-£178/tonne CO_2 for biodiesel (£76/tonne from waste oil) (Table 8). The Treasury then expresses the standard social carbon cost/actual carbon abatement cost as a proportion of the duty incentive to derive what is termed the "proportion of costs justified by carbon benefit".

e.g. Social cost of carbon = £70/tonne
Cost of abatement = £522/t carbon (=£143/ tonne CO_2)
Fuel duty reduction (cost) = 20p/l

Proportion of cost justified by carbon abatement = (70/522) x 20p/l = 2.68p/litre

6.8 The cost of carbon abatement is therefore calculated on a proportion of costs basis, which is a circuitous method of allocating a carbon abatement credit element to the duty incentive offered. A more direct approach would be to directly calculate the value of abatement using the social value of carbon cost adjusted by years to calculate the actual costs saved based on actual values for reduction in GHG emissions (social cost method). Comparing these two methods the Treasury method in the majority of cases underestimates the value of biofuels in reducing GHG emissions (Table 9). However these differences are small and would be outweighed by the wide range of costs and uncertainty associated with calculation of the social costs of carbon highlighted in the previous section.

Table 9. *Comparison of justified carbon credits calculated by Treasury and actual social costs method (using upper and lower limits fromDepartment for Transport scenarios presented in Tables 7 and 8)*

	Abatement cost (2003) Range* £/t CO_2	Justified carbon credit (pence/litre)			
		Treasury method		Social cost method	
		2003	**2010**	**2003**	**2010**
Bioethanol	91	4.19	4.67	4.78	5.25
	143	2.67	2.98	2.92	3.21
Biodiesel	110	3.47	3.87	4.76	5.23
	178	2.15	2.39	2.94	3.24
Biodiesel (waste oil)	76	4.82	5.30	5.03	5.60

* *From DFT scenarios (Tables 7 and 8)*

6.9 The actual duty rebate for biodiesel and the proposed 20p/l duty rebate for bioethanol were introduced on the basis of the lowest rate at which it was anticipated that biofuel production could or would be stimulated at costs similar to those of ULSD and ULSP. Environmental benefits have not been incorporated directly into duty rebate calculations on a pence/l cost:benefit basis. Much of the current debate focuses on what level of duty could be supported if environmental benefits are taken into account. Part of the difficulty in making such calculations is the lack of environmental or economic data required to assess the impacts of pollutants.

6.10 The Dept for Transport estimates that a 5% bioethanol blend would reduce particulate emissions (PM10) by between 1.6 and 2.6% (equivalent to between 0.475 and 0.793 killotonnes per annum at current levels of petrol use). It is estimated that abatement costs for particulates are in the order of £1.5 million/tonne, while impact costs are estimated at £6000/tonne in a rural environment and £90,000/tonne in an urban environment. Using the Treasury method, the Dept for Transport calculates that this is worth between 0.08 (rural) and 1.18p/litre (Urban) for bioethanol based on current duty incentives. Without data on actual emissions for such fuels it is not possible to calculate what the cost would be based on the social cost method.

6.11 Although most studies show reductions in emission of particulates and sulphur dioxide, there is wide variation in results between studies. Figures collated by Ecotec (2002) suggest that a 5% biodiesel mix would reduce particulates by as much as 37% and the savings for Bioethanol would be much greater. There is a need to derive more definitive data on tailpipe emissions to enable more informed assessment of emissions in comparable situations and to ensure common expression of results. Currently it is very difficult to compare results between studies and in some cases between fuels where ultra low sulphur fuels are not included as control treatments.

6.12 Some work has been done to estimate the damages arising from polluting emissions. The EC's ExternE projects estimates monetary damages (converted from euros) of £4992/tonne for SO_2, £5705/tonne for Nitrous Oxides (NO_x) and £10,698/tonne for particulates. Again the value for particulates differs significantly from that used by the Dept for Transport in its calculations.

6.13 Without such data it will not be possible to make much progress on allocating benefits to fuels on a cost:benefit basis. Biofuels are seen as a costly way of saving emissions and the current Government position is that there is little incentive to increase the duty reduction which already outweighs the value of carbon and other savings that would be achieved. Though it is recognised that lignocellulosic technologies offer significant improvements in GHG reductions there is currently little interest in increasing the duty differential in the short-medium term to stimulate lignocellulose technologies because of the difficulty in reversing this differential in future years when technology matures and costs of production decline.

6.14 Past experience shows that the cost of mitigation of transport related pollution is always significantly higher than measures adopted in other areas of the economy. Work to reduce CO_2 emissions, where transport accounts for around 20% of emissions, means that there is likely to be little focus on the transport sector until benefits from cheaper mitigation measures are exhausted which will sideline a key problem area. There is therefore a strong argument for doing more in this area to improve the local air quality and carbon performance of the sector.

7 COSTS TO THE EXCHEQUER

7.1 Given that it will take time to build biodiesel and bioethanol plants and that investment would have to be staged, biofuel production is likely to grow gradually in the UK. In addition, there could be limits in achieving the 5.75% substitution target for 2010 from UK sourced feedstocks for the reasons highlighted in earlier sections. The Dept for Transport has looked at a number of options for uptake of biofuels and at the high end of their estimates for realistic levels of uptake it envisaged that substitution levels could reach 0.8% in 2004, rising to 3% by 2005 (current production is only 0.05% (May 2003).

7.2 Given that bioethanol and biodiesel will effectively be subject to the same level of duty reduction, it can be assumed that estimates for substitution levels can be applied to total fuel consumption, irrespective of the balance of supply of biodiesel and bioethanol. On this basis estimates of costs to the Exchequer (in terms of income forgone) were calculated for a range of duty reduction rates (Table 10).

Table 10. *Impacts of various rates of biofuel duty incentives on costs to the Exchequer in term of income forgone based on a gradual uptake of biofuels*

		2004	**2006**	**2008**	**2010**
Diesel use (billion litres)		21.46	23.81	26.14	28.53
Petrol use (billion litres)		27.75	27.15	26.66	26.18
Total fuel(billion litres)		49.21	50.96	52.80	54.71
Uptake of biofuels		***0.8%***	***1.5%***	***2.3%***	***3.0%***
	Duty rebate				
Cost -£ Million	20 p/l	78.74	152.87	242.86	328.27
	22 p/l	86.61	168.16	267.14	361.09
	24 p/l	94.49	183.45	291.43	393.92
	28 p/l	110.23	214.02	340.00	459.58

7.3 At current (biodiesel) and proposed (bioethanol) levels of fuel duty, the gradual increase in adoption of biofuels will cost the Exchequer £78 Million in the sort term rising to £328 Million in the medium term for a relatively modest uptake of biofuels in the UK. Increasing the duty cut has little impact in the short term when uptake is low but would significantly add to costs in the medium term when levels of production increased. At rates of duty currently being requested by industry (incentives of 27-28 p/litre for biodiesel and 24 p/l for bioethanol) this is likely to cost the Government in the region of £394-450 million by 2010 depending on the level of uptake. This has to be balanced against the benefits accruing from biofuels for the environment, fuel security, risk of increasing EU import and impacts in the rural economy.

7.4 Estimates from the EEDA study indicate that returns to the Exchequer accruing from the added value stimulated from UK biofuel production could reduce costs to the Exchequer by around 6 p/l. This would reduce costs to the Exchequer by between 21% (at a 28p/l duty rate) and 30% (at a 20p/l duty rate). Based on the above figures this would reduce costs to the Exchequer in 2010 to between £229 million for 3% uptake at a 20p/l duty rate and £361 million for 3% uptake at a 28p/l duty rate.

7.5 If the social costs of carbon abatement are also taken into consideration based on an average credit (derived from Table 9) of 3.85p/l for 2004 and 4.23 p/l for 2010 then costs to the Exchequer are effectively reduced by between 35 and 50%, the highest reductions being associated with the lowest duty rates.

7.6 Costs to the Exchequer could be reduced over the medium to long term by providing capital support payments to reduce the burden on investors at start up. This would mean that lower duty cuts would be required to ensure parity with fossil fuels. However, this would depend on the Governments resource to provide up front support and its opinions on the length of pay back period which is likely to run to at least 6 or more years before costs of investment could be covered by producers who could then withstand lower returns on sales.

8 ALTERNATIVE MEANS OF SUPPORT

8.1 *Capital costs*

Lack of capital infrastructure limits biofuel production in the UK, particularly for bioethanol production. Efficiency is related to scale of production and a typical production plant would be capable of producing 100,000 tonne per annum. A bioethanol plant would cost around £50 million or more to build (Table 11). Increasing the scale of production up to 300,000 tonne per annum would reduce running costs by around 10%. The costs of capital depends on the asset life of the production plant and the rate of return required by investors (Table 12). A rate of return of 15% on capital is slightly higher than would be used in a normal energy investment analysis but reflects the additional financial and technical risks associated with the development of a new product in a well-established market. This rate compares favourably with the 12% rate used by British Sugar in their (publicly presented) calculations of investment costs[1] for a 100,000 tone bioethanol plant, which anticipated a payback over a 5 year period. In the case of British Sugar, it was calculated that the difference between amortising over 5 and 10 years added 6 pence/litre to all capital costs (which equates to 15.7 p/litre v 9.96 p/litre for a 5 and 10 year payback period respectively). Accounting for long term depreciation of capital assets is difficult given the uncertainty over the life expectancy of any duty cut, however it is unlikely that Government could give guarantees over a period of greater than 5 years which industry is looking for.

8.2 Figure 5 shows the impact on the requirement for fuel duty exemption of using a capital grant mechanism to support bioethanol production, assuming that the subsidy or fuel duty incentive is used to reduce the retail price of bioethanol to that of gasoline. In practice, subsidies of more than 40% would not be allowed by the EC. According to the scenario in Figure 5, providing a capital grant of up to 40% of costs would save in the region of 2-4 p/litre in final costs depending on the scale of production (though in practice this will be influenced by rate of return required by investors and period of investment as discussed earlier). Based on the figures and estimates for biofuel uptake in Table 10, this would reduce costs to the Exchequer (in

[1] Although it is understood that British Sugar might be in a position to fund the investment in a bioethanol production plant from their balance sheet.

terms of income forgone) by between £66 and 98 million per annum by 2010, assuming a duty reduction of 28p/litre was required to ensure parity with fossil diesel.

Table 11. *Estimated capital costs for a generic bioethanol plant of 100,000 t/year capacity using wheat or sugar beet feedstock.*

Item	**Costs (£M)**	**Comments**
Main process plant	18.5	Includes feedstock preparation, fermentation, distillation, drying and associated process equipment
Ancillary plant	14.0	Includes feedstock handling, effluent treatment, chemical handling and storage, cooling towers, on-site utilities (CHP plant), and warehousing
Design/planning	7.5	Includes engineering design, plant specification, procurement and QA
Construction services	16.5	Includes site labour costs, head office costs, insurance during construction, temporary buildings, small tools, consumables and field construction supervision
Roads and infrastructure	1.5 to 4.0	Includes land clearance, site services, fencing, parking, roads, workshops and laboratories
Land	1.0 to 7.0	Acquisition costs for green field site area approximately 6 ha, dependent on alternative uses.
Total	59.0 to 67.5	

Source Bullard et al 2003 (EEDA)

Table 12. *Effects of payback period and rate of return on investment capital on cost per litre of production (capital cost only - pence/litre) for a 100,000 tonne plant requiring £50 million capital investment at a 15% rate of return (assuming plant is running at full production - costs will increase at lower throughput))*

	Return on investment		
Payback period (years)	10%	12%	15%
5	8.25	8.40	8.62
10	4.13	4.20	4.31
15	2.75	2.80	2.88

8.3 Commercial scale biofuel plants would appear to be eligible for capital grants under current state aid rules which allow support for technologies which promote the development of renewable energy. Grants of up to 40% would be permissible in all areas and further support could be made available in objective 1 areas (i.e. those with assisted area status). This is an area where further discussions will take place between Defra and DTI in relation to the impacts of state aid issues.

8.4 Capital funding up to a ceiling of £5 million could be available from Regional Development Agencies in support of biofuel production. On a 100,000 tonne plant costing 50 million, this could be worth between 0.5 and 1.0 p/l on a plant depreciated over 10 or 5 years respectively.

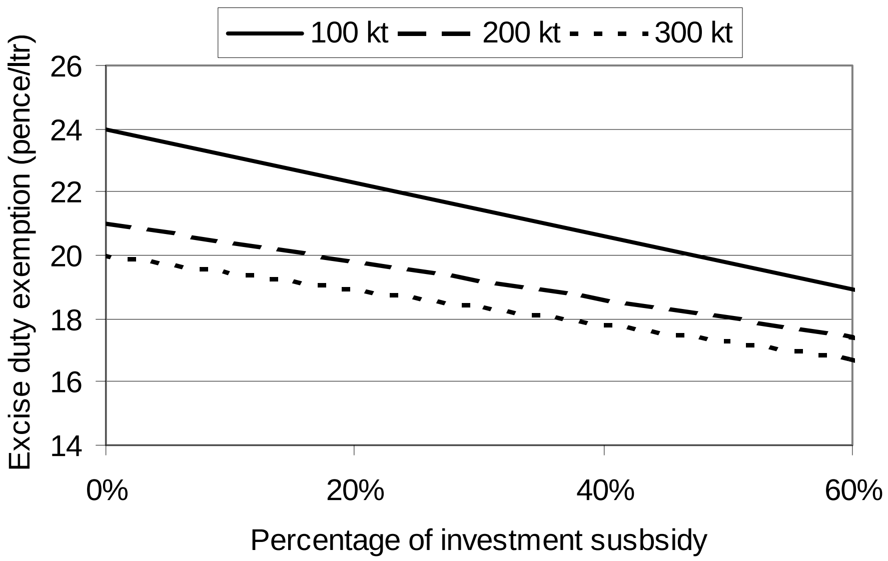

Figure 5. *Impact of using a capital grant mechanism to support bioethanol production from wheat or sugar beet for varying plant size (100 to 300 kilotonnes) on duty exemption required (based on payback over 15 years on a £50 million investment in capital) (Derived from Bullard et al. 2003(EEDA))*

8.5 For spending on plant and machinery, the Inland Revenue would anticipate a write off period of 8 to 9 years (based on the general write-off rate of 25% a year on a reducing balance basis). Equipment with a commercial life of 25 years or more can be written off at 6% depreciation, while spending on industrial buildings can be written off at 4% a year over 25 years

8.6 *Capital Grants Scheme*
DTI's Capital Grants' Scheme funds a number of demonstration projects to help reduce both the costs and risks involved in new developments, primarily to maximise the contribution to the Government's targets for renewable electricity supply within the UK. The New Opportunities Fund is also contributing £50 million to renewable energy projects as a part of its Transforming Communities Programme. This programme is currently fully subscribed.

8.7 *Enhanced Capital Allowances*
Enhanced Capital Allowances (ECA's) allow a greater proportion of the capital spend to qualify for tax relief against profits made during the period of investment. This can provide a modest cash-flow boost to profitable businesses. ECA's in this context are a business tax relief for spending on designated technologies. The same State Aid Rules apply as to any other Government support scheme. The Enhanced Capital Allowance Scheme (ECAS) enables business to claim 100% first year capital allowances on investments in energy saving technologies and products. This means that the whole cost of the investment can be written off against future taxable profits. However, the scheme currently only applies to energy saving technologies listed on the Energy

Technology List (ETL)[2], which satisfy the eligibility criteria. ECA's really only apply to individual pieces of plant equipment and biofuel production plants would currently not attract such funding, though aspects of the plants equipment could be eligible if built with energy saving components on the ETL list. Currently, ECA's are likely to have little impact on the economics of biofuel production.

9. SUPPORT FOR INDUSTRY DEVELOPMENT

9.1 A UK liquid biofuel industry using currently available technology and arable crops as feedstocks can offer economic development benefits for the agricultural sector and rural communities. However, the transport biofuels industry requires active stimulation and encouragement from the public purse, through a variety of fiscal or industrial support measures if any significant commercial production is to be stimulated as a means of contributing to Government aims for carbon abatement and fuel security in this sector. The means by which stimulation of the industry and the development of a UK market could be pursued will depend on government policies and on consideration of the public and private costs involved. Various implementation strategies are possible such as:

- **Further reductions in excise duty** in favour of bioethanol and biodiesel (with the possible exception of biodiesel derived from waste oils) – the main problem with this approach alone is the ability to guarantee the duration of the rebate which will affect the duration over which capital can be written off. Industry is looking for write-off periods of 8-10 years or more. Reducing duty alone also risks sucking in more imports. A phased approach of lowered duty followed by an increase later could be an option.
- **Subsidies towards the cost of capital investment** in production facilities, possibly combined with fuel duty incentives. Capital Grants applied alone, under state aid rules, are unlikely to provide sufficient incentive to start investment in new facilities.
- **UK legislation specifying a minimum biofuel blend** in gasoline and diesel. This has the advantage of shifting costs from the tax-payer to the consumer of the fuel. Mandatory blending would also allow better monitoring of biofuel uptake. However is does not guarantee that production would be UK based. This may also fall foul of free-market legislation by favouring large over small and individual producers by adding an additional burden on fuel marketing.
- **Other fiscal incentives for users of biofuel** could be considered including rebates on the annual road fund licence, exemption from congestion charging in cities and reduced fees for parking – though these are unlikely to stimulate rapid uptake to the degree required by current indicative targets.

9.2 The optimal implementation strategy for biofuels appears to be a combination of fuel duty reductions in favour of biofuels and further Government subsidies in the form of grants for the capital investment required for the feedstock conversion plant.

[2] The technologies in the ETL are: boilers, refrigeration equipment, motors, variable speed drives, thermal screens, CHP, lighting, pipework insulation, heat pumps for space heating, radiant and warm air heaters, solar thermal systems and compressed air equipment.

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