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Economics Group, Defra

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Estimating the Cost-effectiveness of Biofuels

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Summary

- A range of carbon saving estimates for biofuels (from increased GHG emissions to savings of over 100%) exist in the literature and vary by feedstock, production process and assumptions about end use of co-products.

- Sugar-cane bioethanol is currently the most cost-effective biofuel produced.

- DfT, using Intergovernmental Analysis Group (IAG) methodology, estimate that currently biofuels have a higher cost for mitigating carbon relative to other measures.

- A review of the literature also found biofuels to be high cost, other than sugar-cane ethanol which is estimated to be cost-effective.

- As crude oil prices rise biofuels should become more cost-effective. A review of the literature found that the crude price at which biofuels become competitive varies by biofuel feedstock.

- Forward looking analysis suggests that sugar-cane and cellulosic bioethanol will be cost-effective means of mitigation and that these biofuels will need to be part of a low carbon technology mix if the UK is to achieve its medium and long-term CO2 targets at lowest cost. This suggests that policy in support of biofuels should be tailored to maximise cost-effective carbon savings.

- Stern argues for an additional case, other than the carbon externality, for Government intervention: when innovation market failure exists. That is, when obstacles that hinder the development of low carbon/renewable technologies exist. The extent to which this market failure applies to biofuels is unclear.

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1.0 Introduction

Liquid transport biofuels are supported by governments using a range of tax and regulation measures. For example, the EU has set a 10% biofuels target for 2020 (10% of transport fuels are to be biofuels). Support for biofuels aims to achieve a number of policy objectives including: increased security of supply, reduced greenhouse gas (GHG) emissions and support for the rural economy. However, reduced GHG emissions is considered to be the prime objective of UK and EU policy. This paper reviews the literature on, and analysis the extent to which biofuels are a cost-effective means of mitigating carbon. The paper also contextualise the Stern Report conclusions for biofuels.

Biofuels offer potentially significant carbon savings from the transport sector. However, the cost of biofuel production, at historic crude oil prices, has been higher than for conventional transport fuels. This implies that there is an economic cost of abatement. In assessing whether biofuels provide a cost-effective means of carbon abatement the cost of abatement should be compared to the shadow price of carbon (SPC) (the SPC is an estimate of the damage costs of one additional tonne of carbon emitted into the atmosphere and is time dependent). The SPC for 2007 is estimated to be £25.4/tCO2e.

Studies have shown that the cost of biofuel mitigation varies with feedstock used and production process employed. For example, a closed system which uses the co-products of biofuel production can have savings in excess of 100%.[2] In particular, the cost and benefits are said to be dependent on a number of factors including:

- the relative price of crude oil and agricultural commodities;
- the amount of energy used to cultivate, process and transport the biofuel;
- the biofuel feedstock used;
- whether and to what extent land displacement occurs.

2.0 Current Government Cost-effectiveness Estimates

DfT estimated, using Intergovernmental Analyst Group (IAG) and Green Book guidance, the cost-effectiveness figure for extending the Renewable Transport Fuel Obligation (RTFO) for the Energy White Paper (EWP) 2007[3]. This estimated biofuels to be relatively expensive compared to other policies and the social cost of carbon at a cost of between £15/tCO2-£85/tCO2 with a central estimate of £48/tCO2 (£175/tC). Figure 1 below sets out the cost-effectiveness for a range of technologies/policies assessed for the EWP. Extending the RTFO from 5% volume to 10% energy by 2020 (red bar) is around the middle of the estimates.

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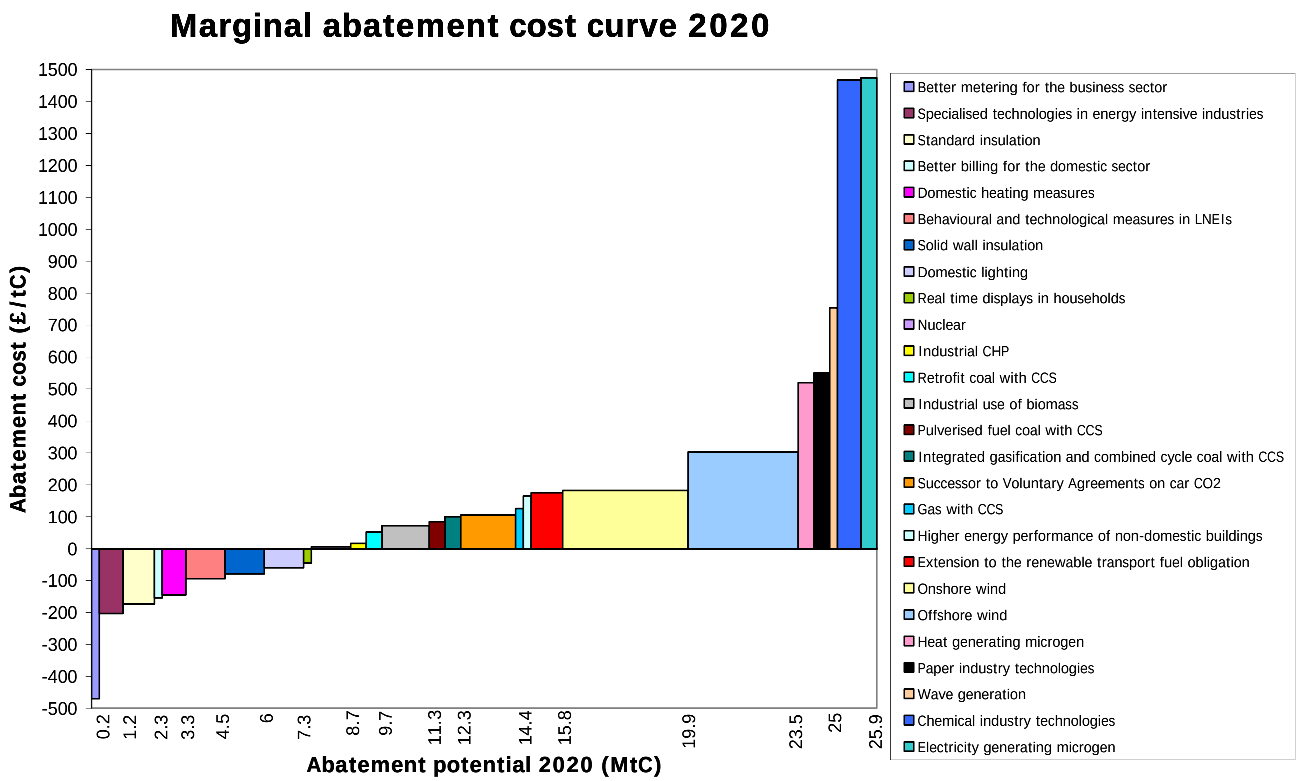
[2] Carbon Life Cycle Analysis: What is the Net Contribution of Bioenergy to CO2 Abatement?, North Energy

[3] The Renewable Transport Fuels Obligation is a regulatory instrument that obligates fuel suppliers to ensure that a percentage of their fuel is from a renewable source. The RTFO begins in 2008-09 at 2.5% and increases to 3.75% for 2009-10 and 5% by 2010-11.

However, since these figures were produced DfT have published an impact assessment of the RTFO with an improved modelling methodology[4]. The impact assessment estimated the cost of carbon abatement through biofuels to be between £67/tCO2-£146/tCO2 with a central estimate of £104/tCO2 (£380/tC). Although this estimate is based on a 5% by volume biofuel penetration we could use it as a proxy for the cost-effectiveness of a 10% biofuel penetration. This new estimate thus moves biofuels to the higher end of costs in figure 1. £104/tCO2 is significantly higher than the 2007 shadow price of carbon (SPC), £25.4/tCO2 in 2007 and £32.9/tCO2 in 2020.

Figure 1 Marginal abatement cost estimate in 2020 produced for the EWP 2007*



*marginal in this instance refers to the additional (abatement)

The above £104/tCO2 figure is an estimate of the cost of the RTFO policy which includes the cost of regulation and other impacts of the policy over its whole lifetime. It is not necessarily an estimate of the economic resource cost of biofuel production. The two may or may not be the same. An estimate of the additional resource cost of biofuels, excluding the wider policy costs listed above, can be obtained by taking the difference in litre production cost between biofuels and conventional fossil fuels. This is what is done in the following analysis. Forward

[4] http://www.opsi.gov.uk/si/si2007/draft/em/ukdsiem_9780110788180_en.pdf
The main methodological change was a change in the assumption of the impact of biofuels lower calorific value compared to fossil fuels. Bioethanol has around two-thirds of the energy of petrol and biodiesel around nine-tenths that of diesel. DfT in their previous analysis assumed that the quantity of bio- and fossil fuel needed to travel a given distance was the same, however based on recent evidence this assumption was adjusted so that additional fuel would be required to travel the same distance. This reduces total carbon saved and increases the cost of the policy.

looking resource cost estimates, and GHG emission, per unit of fuel for 2010[5] are set out in table 1 below, as is the cost-effectiveness estimate based on these figures.

Table 1 2010 biofuel cost-effectiveness estimates assuming life-cycle GHG savings of 54%

Fuel	Unit cost of production (ppl)	Emissions[6] (kgCO2/litre)	Cost-effectiveness (£/tC)	Cost-effectiveness (£/tCO2)
Diesel	32	2.87	n/a	n/a
Petrol	28	1.72	n/a	n/a
Biodiesel	52	1.32[7]	473	129
Bioethanol	38	0.79	355	97

The cost-effectiveness estimates obtained from this analysis, £129/tCO2 and £97/tCO2, are similar to the new DfT central figure of £104/tCO2. The GHG/carbon[8] savings figure is an average for all biodiesel and bioethanol coming from a range of feedstocks. The unit costs for all the fuels are DfT estimates in 2007 prices. The fossil fuel estimates use the BERR central crude oil price to 2020.

The carbon savings from biofuels used in this analysis are based on one scenario and in reality could be higher than 54%. Indeed the assumption that UK biofuel consumption will be made up of a weighted mix of all biofuels from around the world, independent of their cost and GHG savings, is unrealistic. One would expect that fuel suppliers would acquire biofuels at the lowest cost possible to meet any obligation and the government has since announced that it intends to adjust the structure the RTFO so that it specifically incentivises carbon saving from biofuels from 2010. The analysis in the remainder of this section flexes the GHG saving assumption to determine what impact this has on cost-effectiveness.

Average carbon savings from biofuels in 2010 are expected to be marginally higher than assumed above at 57% and with unit costs unchanged the cost-effectiveness estimate should improve marginally. Table 2 sets out cost-effectiveness estimates for 2010 assuming biofuels, on average, deliver life-cycle GHG savings of 57%.

Table 2 2010 biofuel cost-effectiveness estimates assuming life-cycle GHG savings of 57%

Fuel	Unit cost of production (ppl)	Emissions (kgCO2/litre)	Cost-effectiveness (£/tC)	Cost-effectiveness (£/tCO2)
Diesel	32	2.87	n/a	n/a
Petrol	28	1.72	n/a	n/a
Biodiesel	52	1.64[9]	448	122
Bioethanol	38	0.98	337	92

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[5] Production unit cost figures are from 'Explanatory Memorandum to the Renewable Transport Obligation Order 2007' and are available at: http://www.opsi.gov.uk/si/si2007/draft/em/ukdsiem_9780110788180_en.pdf

[6] Emissions are on a life-cycle basis and for all GHG. Figures are taken from the BEAT model produced by North Energy for Defra.

[7] Assumes GHG savings of 54% for both biodiesel and bioethanol. GHG saving estimates do not include the impact of lower calorific values of biofuels and will overstate cost-effectiveness.

[8] Carbon and GHG are used interchangeably in the paper

[9] Assumes GHG savings of 57% for both biodiesel and bioethanol

Assuming the slightly higher average carbon savings of 57% does improve the cost-effectiveness estimates marginally. However, the improvement, £7/tCO2 and £5/tCO2 respectivly, is very marginal and is still significantly higher than the 2007 and 2010 (£27/tCO2) SPC. Also, relative to other mitigation measures estimated for the EWP, even assuming saving of 57%, biofuels are still at the more expensive section of the MAC curve. It is very unlikely that in the near term biofuels will produce on average GHG savings of more than 57% unless all UK biofuel is sugar-cane ethanol.

In the longer term the potential carbon savings biofuel can generate is likely to increase. It should be possible in 2020 for biofuels to generate on average carbon savings significantly in excess of 57%. Table 3 below sets out cost-effectiveness estimates for 2020 assuming average carbon savings of 75%. The table also includes fuel production cost estimates for 2020 in 2007 prices[10]. With these cost and savings estimates biofuels become a cost-effective means of mitigating carbon with cost per tonne of CO2 (£33 and £31) below or equal to the 2020 SPC of £33/tCO2[11].

Table 3 2020 biofuel cost-effectiveness estimates assuming life-cycle GHG savings of 75%

Fuel	Unit cost of production (ppl)	Emissions (kgCO2/litre)	Cost-effectiveness (£/tC)	Cost-effectiveness (£/tCO2)
Diesel	30	2.87	n/a	n/a
Petrol	27	1.72	n/a	n/a
Biodiesel	37	0.72[12]	119	33
Bioethanol	31	0.43	114	31

The analysis in table 3 implies that by 2020 if biofuel production costs fall to the levels indicated, by 29% and 16% for bio-diesel and ethanol respectively, and assuming average carbon savings of 75% biofuel will be a cost-effective means of mitigating carbon. The analysis doses not indicate which biofuel will be cost-effective. However, it does illustrate that some biofuels have the potential to produce cost-effective carbon savings. It also suggests that policy should be tailored to incentivise the maximisation of carbon savings so as to increase the likelihood of the outcome indicated by the above analysis occurring. In the short-run (i.e. before planned and potential policy measures, including tariff reductions, and technological advances have resulted in falls in the cost of the biofuels used in the UK) it is very unlikely that biofuels will, on average, achieve average carbon savings of 75%. Thus, the figures in table 3 will, as indicated by the previous outputs, significantly over estimate the current position.

[10] Production cost estimates DfT estimates and taken from 'Explanatory Memorandum to the Renewable Transport Obligation Order 2007'
[11] Figures are in 2007 prices
[12] Assumes GHG savings of 75% for both biodiesel and bioethanol

2.1 Cost-effectiveness Estimates from the Literature

Numerous studies have estimated potential carbon savings for a range of biofuel feedstocks. However, studies estimating the economic cost of achieving mitigation by feedstock are less numerous. Outputs from a number of studies from a literature review are presented in table 4 below.

Table 4: Outputs of biofuel reports from the literature review

Study	GHG savings (%)	Cost per litre (ppl)	Cost-effectiveness (£/tCO2e)
World Bank (2007)			
Biodiesel	47-75%	33	33*
Bioethanol (maize)	10-20%	33	377*
Bioethanol (sugarcane)	60-90%	16	-35*
Greenergy (2007)			
Bioethanol (sugarcane)	77%	11	-95*
Concawe (2006)			
Biodiesel	40-70%	n/a	161
Bioethanol (sugar beet)	32-65%	n/a	185
Bioethanol (wheat)	30-70%	n/a	186
MEACAP (2006)			
Biodiesel (sunflower oil)	n/a	n/a	121
Biodiesel (OSR)	n/a	n/a	114
Bioethanol (sugar beet)	n/a	n/a	347
Bioethanol (wheat)	n/a	n/a	692
Bioethanol (maize)	n/a	n/a	289
CE (2006)			
Biodiesel (OSR)	40%	n/a	207
Bioethanol (wheat)	30%	n/a	448
Bioethanol (sugar beet)	30%	n/a	379
Bioethanol (sugarcane)	80%	n/a	n/a
UNSW (2006)			
Bioethanol (sugarcane)	90%	10	-113*
Imperial College (E4tech) (2005)			

Biodiesel	40-60%	n/a	n/a
Bioethanol	7-70%	n/a	n/a
Bioethanol (sugarcane)	70%	n/a	23
Sheffield Hallam (2003)			
Biodiesel (OSR)	57-80%	n/a	n/a
DfT (2002)			
Bioethanol (oil seeds)	54%	41.2	151*
Bioethanol (wheat)	54%	30	175*
Bioethanol (sugar beet)	54%	34	219*
Bioethanol (sugarcane)	70%	12.6	-9*
ABARE (2001)			
Bioethanol (sugarcane)	70%	n/a	51

These are calculated values based on outputs from the studies as no cost-effectiveness figures were given.

The cost-effectiveness estimates from the literature support the current DfT analysis and conclusions, i.e. other than sugarcane ethanol biofuels are not currently a cost-effective way of mitigating carbon. The highest cost per tonne of carbon saved, of the above studies, was in the MEACAP (2006) study which estimated the cost per tonne of CO2e (CO2 equivalent) for wheat bioethanol at £692. The lowest cost, other than sugar-cane ethanol, at £114/tCO2 was for biodiesel OSR. Of the two studies that calculated carbon abatement costs for sugar-cane ethanol, the more recent one (Imperial College (2005)) estimated it to be cost-effective (i.e. cost of mitigation is below the 2007 SPC). Estimates using outputs from studies (World Bank (2007), Greenergy (2007), UNSW (2006) and DfT (2002)) indicated that sugarcane ethanol, can be cost-effective. However, these figures were not produced by the studies themselves but calculated using outputs from the studies and need to be treated with caution, especially given some magnitudes (-£113/tCO2e), as the basis of the calculated estimates may not be consistent with the studies.

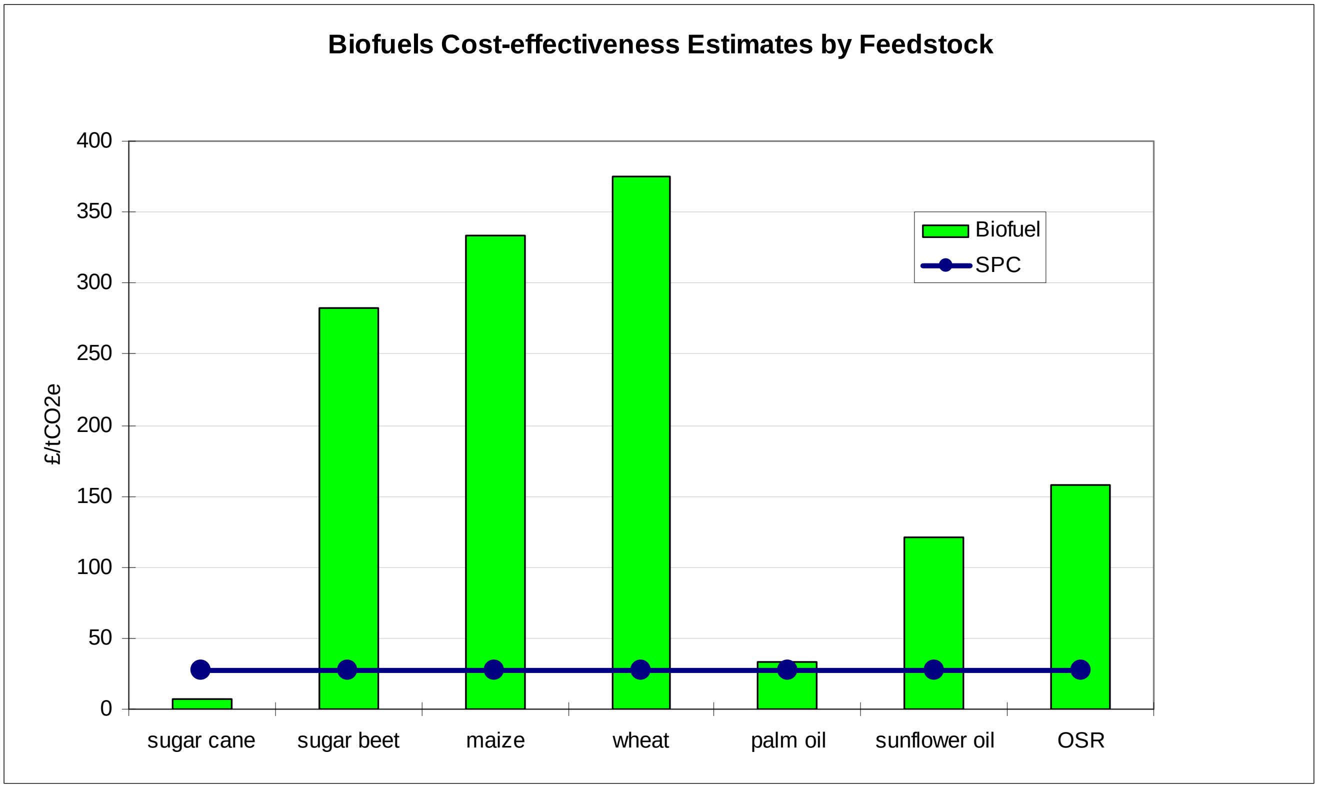
Sugarcane's estimated cost of production (and estimated carbon savings) make it cost-effective. Unit costs range from around 10-16ppl. This is less than half of the next best biofuel for which cost figures were obtained. Life-cycle carbon savings for sugarcane are estimated to be as high as 90%. However, these estimates do not take into account land displacement effects (as is the case with the other fuels). Recent studies suggest that this could be a significant omission and potentially reverse the results.

Taken together, the above analysis implies that given current technology and costs, unless the biofuel is sugarcane based it is not a cost-effective means of carbon mitigation. This position, as indicated by the analysis in section 2.0, may change with improvements in biofuel production.

Figure 2 below sets out in more detail the average cost-effectiveness estimates from the literature by biofuel feedstock. It reinforces the above conclusions, i.e., currently most biofuels, particularly grain bioethanols, are an expensive way to mitigate GHG emissions.

The analysis implies that feedstocks produced in the EU produce the most expensive biofuels, for both biodiesel and bioethanol. (Note that although figure 2 presents cost estimates for different biofuel as a single figures table 2 above shows the degree to which cost estimates even for the same feedstock vary). As stated above the GHG savings figures underpinning the analysis in figure 2 do not include the impact of land use change. This is could be a very significant issue for EU feedstocks as well as third country feedstocks such as sugarcane and palm oil, particularly if indirect land use change is taken into account. This is an area that requires further detailed analysis.

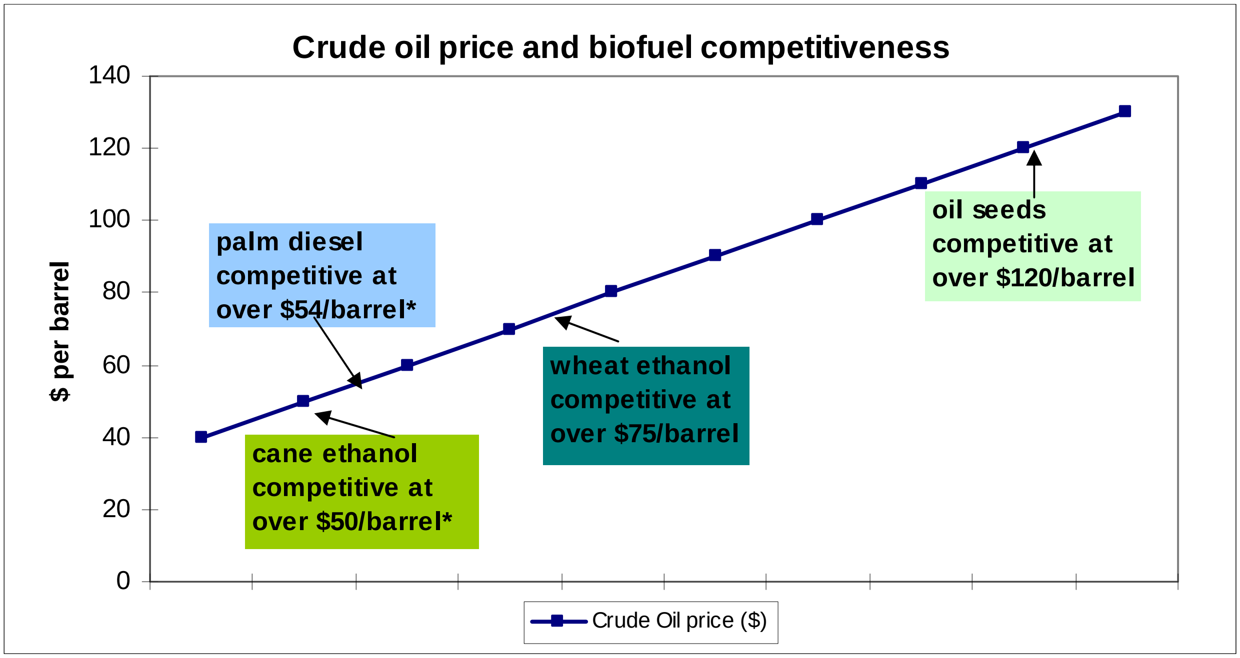
Figure 2 Biofuel cost-effectiveness estimates by feedstock



<u>At what crude oil price do biofuels become cost competitive?</u>

One key factor that determines whether a biofuel is a cost-effective means of mitigation is the crude oil price (crude oil accounts for the largest portion of petrol and diesel production costs). Higher oil prices imply higher fossil fuel prices and should improve the cost competitiveness of biofuels. At current oil prices (over $100/barrel) a review of the literature and Defra analysis suggests that most biofuels, other than oilseed biodiesels, should be cost competitive, i.e. the cost of production of biofuels become similar to fossil fuels. Figure 3 below sets out at what crude price studies suggest different biofuels <u>should</u> become cost competitive.

Figure 3 Illustrative crude oil price and biofuel cost competitiveness



*Bioenergy: An Assessment, World Bank (2007), Patrick Avato
**Why is palm oil placing tropical rainforests (2006)

The output in figure 3 should be treated with some caution as they are not based on fully specified models and the impact of higher oil prices on biofuel production energy costs are not necessarily taken into account. More significantly, the recent higher oil price has been coupled with higher commodity prices, including biofuel feedstocks. This impact is not accounted for in the above analysis. Recent analysis by Defra[13] projected that an increase in the crude price from $40 to $100/barrel increased oil seeds producer prices in the EU by between 20-30%. It is likely that the increase for more competitive crude oil substitutes like palm oil and sugar-cane ethanol is likely to increase by a bigger margin. Recent reports on crude palm oil suggest the price is likely to increase to £1000/tonne in 2008 with prices averaging around £900/tonne for the year. In 2006 the price was half this level. Thus, higher crude prices may not necessarily result in increased cost competitiveness of biofuels at the levels suggested by figure 3.

Wider environmental impacts

The increased use of biofuels could have wider perverse environmental impacts such as loss of biodiversity, adverse water use and air quality impacts. These impacts have not been considered in this paper.[14] This is an area of work that will be taken forward within Defra.

[13] Implications of $100pbb oil price for UK Agriculture (2008)

[14] A good discussion of the wider environmental impacts of increased biofuel use is included in the 2008 AEA paper 'Review of work on the environmental sustainability of international biofuels production and use'

2.2 Forward Looking Cost Estimates

A number of studies have considered the potential of carbon abatement opportunities in 2020 and 2030 and concluded that UK carbon targets can be achieved at relatively low costs. These studies assume that early action is taken to stimulates investment in low carbon technologies, including biofuels, and this brings down costs. For example, the McKinsey (2007) MAC (marginal abatement cost) curve for the UK in 2020 and 2030 estimates that UK abatement targets can be achieved at €90/tCO2e in 2020 and €40/tCO2e in 2030, that is the marginal abatement cost of achieving the target is €90 and €40 per tonne of CO2 in 2020 and 2030 respectively. Biofuels are included as a technology that will cost less than €90 and €40 in 2020 and 2030 respectively. Details of the assumptions undying the analysis assume well-to-wheel carbon savings for biodiesel of between 20-50% with costs falling from 0.47 to 0.41 €/litre, or 13%, by 2030. McKinsey state that biodiesel penetration will not pass 10% due to engine technology constraints such as filter capacity.

Bioethanol is perceived to have more potential but is also assumed to achieve 10% penetration to 2020 with further penetration only possible after this date with changes to the petrol vehicle fleet. Carbon savings estimates range from 70% (wheat grains) to 90% (sugarcane and cellulosic ethanol). Cost reductions for cellulosic ethanol are expected to be large, 53% by 2030. With its relative cost advantage McKinsey expect imported sugarcane ethanol to make-up 1/3 of the 2010 biofuel target (5%) and 2/3 of the 2020 target (10%). This level of import penetration is expected to be maintained to 2030. Given these assumptions, and the estimated costs of sugar-cane ethanol given above, it is not surprising that McKinsey assume that biofuels can be a cost-effective means of carbon abatement.

The McKinsey analysis suggests that going forward the cost of second generation biofuels will fall much more than first generation fuels. Two main factors explain this: (i) second generation technology is at an earlier stage of development and is therefore likely to benefit from greater learning curve cost reductions than first generation technology; (ii) feedstocks account for a significantly smaller share of total costs for second generation fuels (feedstock costs for fist generation fuels are estimated to be about 80% of costs) and therefore there is opportunity for processing costs to fall for second generation fuels. McKinsey estimate that the cost of cellulosic ethanol will fall by over 50% from 2002 to 2030. Cost falls for biodiesel are expected to be just 13%. Table 5 below sets out cost per litre in euros for different biofuels in 2002 and 2030 and the percentage reduction over this period.

Table 5 Biofuel production cost €/litre in 2002 and 2030

	Cost in 2002	Cost in 2030	% fall
Biodiesel	0.47	0.41	-13%
Grain ethanol	0.40	0.37	-8%
Sugar-cane ethanol	0.27	0.22	-19%
Cellulosic ethanol	0.47	0.22	-53%

Also of significance to this work stream is the McKinsey analysis conclusion that for the UK to achieve its CO2 targets (26-32% reduction in CO2 by 2020 and 60% by 2050 relative to 1990 levels) early action is critical. McKinsey conclude that technologies that can achieve cost-effective abatement over the next 20 years require the UK to act now. Included in this set of technologies is biofuels.

Analysis by Vattenfall (2007) on global abatement opportunities support the McKinsey conclusions: that sugar-cane ethanol and cellulosic ethanol are/will be cost-effective means of carbon abatement. Their 2030 MAC curve suggests that sugar-cane ethanol will have a negative abatement cost while cellulosic ethanol will be only marginally positive (<€10/t/CO2e). These estimates are below the SPC implying that abating carbon using biofuels is economically beneficial.

Biofuels have been given additional impetus in the EU with the proposals contained in the 2008 EU Renewable Energy Directive. The RED states that by 2020 20% of EU final energy demand should come from renewable sources and that biofuels account for 10% of transport fuels. In analysing the cost of meeting the RED the Department for Business Enterprise and Regulatory Reform (BERR) estimated the relative cost-effectiveness of different renewables. The analysis produced by Poyry[15] estimated the abatement cost of achieving the 20% target for both the EU and the UK. Their analysis suggests that within the EU as a whole the lifetime abatement cost per tonne of CO2 abated from biofuels is more than 20 times that achieved from renewable electricity and heat sources. The equivalent figure for the UK is 13 times more costly. Table 6 below sets out the Poyry outputs.

Table 6 Cost-effectiveness estimates for different EU & UK renewable energy sources

Lifetime abatement cost (€/tCO2)	**EU**	**UK**
Total Renewable Energy Sources (RES)	26	57
Electricity and Heat RES	12	18
Transport RES	215	236

The Poyry figures do not include second generation biofuels and this explains the much higher costs compared to the McKinsey figures. Moreover, these figures are for all biofuels whereas the McKinsey figures are most cost-effective and second generation biofuels.

3.0 Stern Review Conclusion on Biofuels

Stern identified a range of market failures, other than the carbon externality, that justify government intervention and suggests that to achieve least cost carbon abatement, policy should be designed to tackle each of these market failures. Broadly, Stern identifies three distinct sets of market failures:

- carbon externality
- innovation market failure
- other market failures (such as information asymmetries or capital constraints).

All three market failures could to some degree be applied to biofuel production and consumption. The carbon externality is well documented and is the main basis for government support (fuel duty incentive) and regulation (RTFO) for biofuels. However, there may be justification for government/EU support due to the other two market failures identified.

[15] 'Compliance Costs for Meeting the 20% Renewable Energy Target in 2020' Poyry 2008

Stern sets out that the first essential element of climate change policy is carbon pricing. By imposing a cost on carbon emissions, emitters, if they are rational and profit maximisers, will seek to minimise this cost and reduce emissions, if it is profitable to do so. If it is not, then emitters will continue to emit and pay the price of emissions. However, higher production costs are likely to imply higher product prices which should reduce demand, even if only marginally, and this should reduce emissions. Although not set as a carbon tax, a carbon price for fossil fuels could be said to exist in the form of fuel duty tax, with biofuels being taxed at 20ppl less than fossil fuels because of their carbon performance. And although the duty derogation has had some success in developing the UK biofuel market, it has not developed the market sufficiently to achieve the EU indicative biofuel targets. The RTFO, to come into force in April 2008, will establish a 15ppl buy-out price, thereby increasing the effective carbon price for fossil fuels as the duty derogation of 20ppl will still exist in 2008[16].

Stern suggests that if carbon mitigation is to be achieved on the scale and pace required and at lowest cost it is not sufficient to just have a carbon price (a carbon price is likely to reduce carbon emissions from road transport but it is unlikely to do so to the scale or pace required to prevent dangerous climate change). Additional policy measures are required to encourage technological innovation which could speed the development of low carbon technologies and reduce cost of abatement in the longer-term. That is, it is only by establishing a policy framework that encourages investment in low carbon and renewable technologies now that long-term cost mitigation can be minimised. This framework could be applied to biofuels as they appear to be part of a portfolio of cost-effective means of carbon mitigation from road transport in the medium term (importantly, alongside energy efficiency improvements) and as the McKinsey analysis suggests biofuels are/will be a cost-effective means of mitigation. The analysis for the UK assumes the current RTFO framework is in place.

In addition to a carbon price, Stern highlights the role of technological innovation in achieving low cost mitigation. By encouraging greater penetration of biofuels, it is argued that the cost of mitigation will be reduced more quickly because cost of production will fall more rapidly through learning effects. Historically as new technologies have expanded production their marginal costs have fallen because, one must assume, people learn to do things better the more they do them, the more individuals/organisations involved in the industry the greater the likelihood of innovation and the greater the degree of specialisation. Applying this to biofuels, it could be argued that by requiring 5% of transport fuel to be biofuel, the RTFO is enabling biofuel producers to move more quickly down their marginal cost curve. The RTFO should encourage greater investment in biofuels which should drive innovation and reduce costs. However, establishing a biofuels framework that rewards carbon savings is necessary to encourage additional investment in second generation biofuels. This should speed reduction in production, and therefore mitigation, costs.

[16] At Budget 08 it was announced that the biofuel duty derogation would be set to zero from 2010-11 but that there would be a 30ppl buy-out price.

4.0 Conclusions

This paper has shown that biofuels are not a homogeneous product in terms of life-cycle GHG/carbon savings. A range of savings are estimated even for a single feedstock. The paper has also shown that most current biofuels do not offer cost-effective carbon savings, with cost per tonne saved in some cases exceeding £300/tCO2. This represents poor value for money at the present time compared to other policy options. In the longer term the potential carbon savings biofuel can generate is likely to increase. While it is unlikely that all biofuels will offer cost-effective savings, some biofuels, including sugarcane ethanol and cellulosic ethanol, are or are expected to be cost-effective. **This suggests that policy in support of biofuels should be tailored to maximise carbon savings rather than providing blanket support for all biofuels**.