Evaluating the opportunities for high blend liquid and gaseous biofuel penetration in the UK

Prepared for

Low CVP

by

Transport & Travel Research Ltd

in association with

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Sustainable Transport and Fleet Efficiency Specialists

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Version 1.1 Final
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CONTENTS

EXECUTIVE SUMMARY

Background and purpose of the report

This study has been conducted by Transport & Travel Research Ltd (TTR), in association with Fleetsolve and commissioned by the Low Carbon Vehicle Partnership (LowCVP).

The purpose was to investigate: the opportunities for liquid and gaseous biofuels with blends greater than 10% by volume; their potential for penetration into the UK fuel mix; the associated commercial and environmental benefits as well as barriers, and; recommend the most appropriate mechanisms to stimulate take-up.

LowCVP had identified that the use of these biofuels in high blend form could make a positive contribution to reducing emissions in the transport sector. However the potential and viability of this contribution or potential obstacles to the development of a high blend and gaseous biofuels market were not well understood. To better understand market deployment opportunities and barriers this study considers a wide range of factors including: vehicle duty cycles within major vehicle classes, blend limits and refuelling strategies and additional capital and operational costs.

Policy context

The Renewable Energy Directive (RED) sets a target for 10% renewable transport fuels use by 2020. Most of this target is expected to be met through supply of liquid biofuels of low blends of petrol and diesel. The development of EU regulations incorporated into CEN fuel standards provides a mechanism to support progress towards these targets.

As road transport fuels contain steadily increasing proportions of biofuel, new vehicles will be designed to use these latest EN standard fuels.

The UK is legally obliged to achieve the RED 2020 10% target. Current vehicle specifications only enable around 6.5% of the RED target to be achieved using low blends. High blend liquid and gaseous biofuels create potential pathways to achieving the 10% target as do other mechanisms such as hydrogenated vegetable oils.

Encouraging and supporting the implementation of high-blend biofuel may offer a suitable, effective option to deliver the RED targets and further decarbonise transport fuels. This study has sought to identify near term options, the contribution which high blend biofuels could make to the required carbon reductions and mechanisms to stimulate market expansion.

Study scope

The study has assessed the status of current and near-market fuels including availability and practicability of use and compatibly with vehicles. It has estimated the potential for GHG emissions reductions through assessing the use of various fuel types in different vehicle classes. Well to wheel lifecycle GHG emissions for different biofuels have been derived from RED default values. The current legislative, policy and fuel taxation environment has also been reviewed and summarised.

The information used in the study has been obtained from a limited number of trials in the UK and experience from overseas plus various literature and other resources. Existing models for specific fuels and vehicles have also been used and further modelling conducted to meet the purpose of this study.

The study has reviewed the costs, performance and impacts of 13 different fuels:

- Euro V diesel
- Euro V petrol
- biodiesel B5
- biodiesel B30
- biodiesel B50
- biodiesel B100
- Bioethanol E5
- bioethanol ED85
- Biomethane (compressed)
- Biomethane (liquefied)
- Pure Plant Oil (PPO)
- Biomass To Liquids (BTL)
- Hydrogenated Vegetable Oil (HVO)

Suitable fuels have been assessed for use in vehicles in 8 classes:

- Car
- Light Good Vehicle (LGV)
- Bus
- Medium Goods Vehicle (MGV)
- Heavy Goods Vehicles (HGV) rigid small
- HGV rigid large
- HGV articulated small
- HGV articulated large

In total 72, vehicle-fuel combinations have been assessed. For each type of vehicle considered the impact of different vehicle/fuel options is based on estimated numbers of vehicles in each class for which switching to high-blend biofuel operation is possible in the medium term. This takes into account the practicality of supplying high-blend biofuels to different parts of the UK vehicle parc, based on existing fuelling infrastructure and vehicle re-fuelling practices. For example, with HGV the proportion of vehicle in each target fleet are based on the number of vehicles registered to owners with HGV fleets of over 50 vehicles, because these are very likely to practice own-tank fuelling. An assumption has been made that the same proportion will apply for MGV fleets. For local buses about half of all vehicles operating services in Passenger Transport Executive (PTE) areas have been assumed. Less ambitious targets are used for the LGV and car sectors (5% of total vehicles), due to the reported difficulties of fuel supply industry to service public forecourts. The actual market proportions used in the analysis are shown in the table below.

Vehicle parc proportions used in the analysis

Vehicle sector	No of vehicles (2007/2008)	% considered for biofuels use	No of biofuelled vehicles
HGV artic. large	1,12,255	21%	23,541
HGV artic. small	9,699	21%	2,034
HGV rigid large	72,662	21%	15,238
HGV rigid small	100,443	23%	23,140
MGV	151,164	20%	30,233
Bus (local services)	31,184	20%	6,237
LGV	3,187,000	10%	318,700
Car	27,000,000	5%	1,350,000
Total	30,664,407	5.8%	1,769,123

Each combination of vehicle and biofuel has been compared to the baseline cost to an operator of a vehicle using conventional fuels. The study has assessed fuel costs excluding duty and VAT in order to compare options on a neutral basis. Spring 2009 spot prices forms the basis for the fuel price estimate. The levels of duty derogation necessary to compensate for additional capital and operation costs have also been estimated as a measure of how effective such a mechanism might be in supporting the implementation of high blend biofuels.

There are appreciable sustainability concerns of biofuels, including their indirect effects. The GHG saving calculations used in this study do not account for land use change effects, which can be significant. The RED now includes some mandatory sustainability criteria and the EU is presently considering how to account for and manage indirect effects. Ensuring that biofuels used in high blends are sustainable remains a challenge, and would need to be addressed for a significant high blend market to deliver benefits. However this is not the specific focus of this study.

Potential benefits

Present estimates for all UK road transport emissions in 2007 was 123 $MtCO_2e$ p.a[1]. Current UK use of biofuels contributes c.2.6% of UK fuel mix for road transport[2], a saving of about 1.5 Mt CO_2e. By 2013/14 on current projections this saving is expected to have risen to 3Mt CO_2e. The majority of biofuel will have been supplied in low blends B5 and some E5, with carbon cost effectiveness' of £224/tonne and £182/tonne respectively.

The study has identified that single vehicle-fuel combinations which alone could save over 2.4 million tonnes of CO_2 equivalent per annum, almost 2% of total UK domestic road transport emissions. Savings from single fuels range applied across vehicle classes range from 1.5 to 5.5 $MtCO_2$, up 4% of total domestic emissions.

[1] http://www.defra.gov.uk/evidence/statistics/environment/globatmos/download/xls/gatb05.xls
[2] RFA Monthly Report 14: 15 April 2009 - 14 June 2009

The supply of high blend biofuels into one market sector will also stimulate opportunities for use in others and a larger cumulative impact is likely to be realised.

The table below summarises key results from the study. It shows estimated potential for GHG reduction with different biofuels for the classes of vehicles assessed as well as estimates of additional cost to the operator, per tonne of CO_2e saved, from the appropriate baseline (standard diesel or petrol).

GHG emission reductions and cost effectiveness

		Baseline GHG (CO_2e)	Biodiesel (B5)	Biodiesel (B30)	Biodiesel (B100)	PPO	Biomethane (bi-fuel)	Biomethane (dedicated)	Biomethane (dual fuel)	Ethanol (E5)	Ethanol (E85)	Ethanol (ED 95)
HGV large artic (20% total fleet)	GHG reduction Mt p.a.[1]	14.86	0.38	0.47	1.58	1.61		2.41	2.05			
	% of baseline[2]	100.0	2.5	3.2	10.6	10.9		16.2	13.8			
	Cost £/t [3]		224	479	283	236		143	137			
HGV small artic (20% total fleet)	GHG reduction Mt p.a.	0.46	0.05	0.07	0.23	0.24		0.36	0.30			
	% of baseline	100.0	2.5	3.4	11.3	11.6		17.3	14.7			
	Cost £/t		224	461	275	248		98	121			
HGV large rigid (20% total fleet)	GHG reduction Mt p.a.	0.78	0.09	0.12	0.39	0.40		0.59	0.41			
	% of baseline	100.0	2.5	3.2	10.6	10.9		15.9	11.2			
	Cost £/t		224	488	293	270		239	266			
HGV small rigid (20% total fleet)	GHG reduction Mt p.a.	0.61	0.07	0.09	0.31	0.31		0.39	0.25			
	% of baseline	100.0	2.5	3.5	11.7	11.9		14.9	12.1			
	Cost £/t		224	684	365	334		481	599			
MGV (20% total fleet)	GHG reduction Mt p.a.	0.42	0.05	0.06	0.21	0.22		0.27	0.19			
	% of baseline	100.0	2.5	3.0	10.1	10.4		12.7	8.9			
	Cost £/t		224	1097	505	480		488	576			
Bus (20% local bus fleet)	GHG reduction Mt p.a.	3.43	0.09	0.10	0.35	0.35		0.53				0.47
	% of baseline	100.0	2.5	3.0	10.1	10.4		15.4				13.7
	Cost £/t		224	476	282	255		186				448
Light Goods Vehicles (10% fleet)	GHG reduction Mt p.a.	14.12	0.41	0.21	0.71	0.80	0.98				0.87	
	% of baseline	100.0	2.9	1.5	5.1	5.7	6.9				5.6	
	Cost £/t		185	951	517	482	516				269	
Car (5% total fleet)	GHG reduction Mt p.a.	65.02	0.80	0.49	1.64	1.84	2.23			1.18	1.76	
	% of baseline	100.0	1.2	0.8	2.5	2.8	3.4			1.8	2.8	
	Cost £/t		185	797	554	556	857			194	339	

Notes:

1: Tonne of CO_2e reduced from baseline

2: % of total baseline vehicle sector emissions

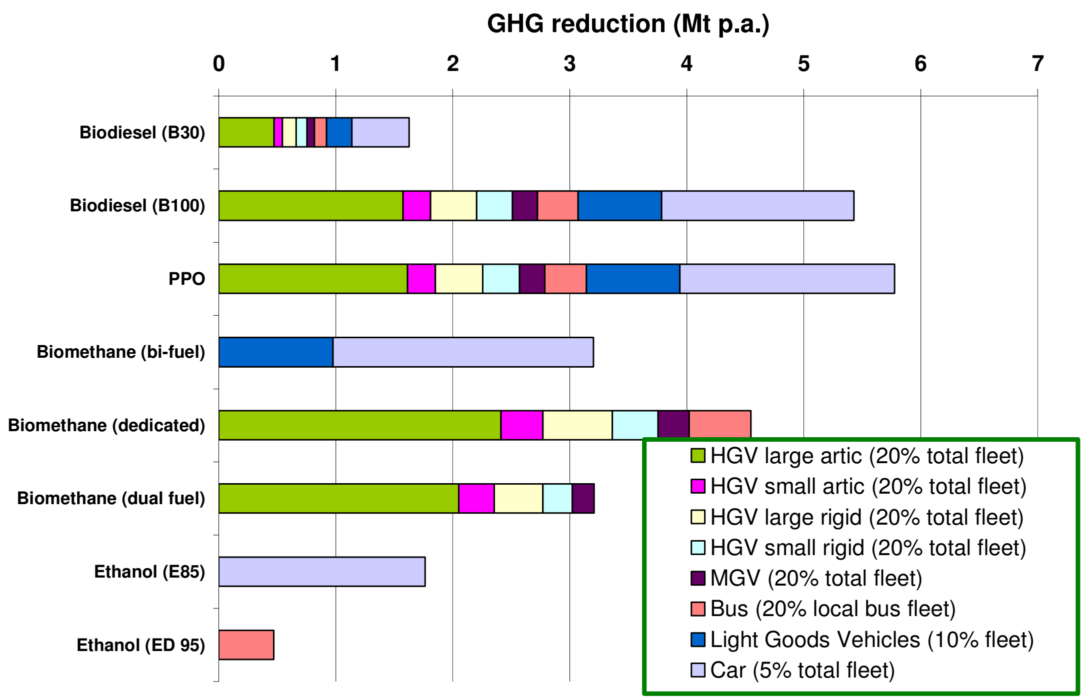
3: £ per tonne CO_2e reduced, over baseline (CO_2e and costs of Euro V diesel or petrol vehicle)

[hatched box] : Fuel not considered applicable.

Key observations are:

- GHG savings of up to 2.4 $MtCO_2e$ p.a. may be realised from the HGV (large artic) fleet if biomethane were deployed successfully in 20% of vehicles. Lower, but significant, GHG savings may alternatively be realised from B100 or PPO (1.58 or 1.61 $MtCO_2e$ p.a.) This is before any additional GHG savings from using high-blend biofuels in other types of HGV.
- Biomethane use in dedicated vehicles could offer a significant saving of 4.5 $MtCO_2e$, and total potential use of biomethane in dedicated, dual and bi-fuel vehicles could realise savings totalling over 10 $MtCO_2e$ with 80% of this saving coming from goods and service vehicles where refuelling infrastructure may be easier to facilitate than for passenger cars, given sufficient biomethane fuel.
- Savings of 0.5 Mt CO_2 could be achieved from use biomethane in local bus fleets and the same from large rigid HGV. Notably, the number of buses that could generate this saving (18,000) is around half that of large rigid HGVs (34,000).
- A high impact combination for light duty vehicles, usually fuelled from forecourts is bioethanol (E85) in 5% of the car fleet and 10% in LGV. This is estimated to generate GHG savings totalling 2.6 $MtCO_2e$ p.a with use of E85 solely in 5% of passenger cars alone saving 1.76 $MtCO_2e$ p.a.;
- B30 used in LGV (van) and cars produces lower GHG reductions of 0.7 Mt $MtCO_2e$ due to a relatively high fossil fuel component. However this route offers advantages in that some manufacturers' diesel engines currently in use are already technically compatible with B30.

The figure below shows the cumulative potential CO_2 savings that could be achieved for each fuel type by through use in the stated proportion of each vehicle class if market forces permitted.



High blend liquid and gaseous biofuels also have some air quality benefits. Evidence from a range of studies points towards a reduction in particulate matter (PM) across the full range of biofuels. For NO_x emissions the picture is more mixed, with some trials indicating a slight increase in emissions from biodiesel. The relative performance of biofuels compared to standard fuels will change in the future as petrol and diesel vehicles become cleaner. However biofuel specific technologies and additives will also develop (e.g. dual-fuel retrofit for PPO or biomethane), as has been seen with fossil fuels, reducing NOx emissions.

Costs

To assess the economics of different combinations of vehicles with biofuels, the capital and operation costs have been evaluated compared against use of conventional fuels. These evaluations have reviewed data on additional vehicle hardware, differing energy content of biofuels and thus fuel consumption, fuel price, amended maintenance or additional re-fuelling infrastructure.

To remove possible bias from duty levels, with the exception of duty derogations estimates, fuel prices used in the study exclude duty as well as VAT. It should be noted that spot fuel prices from Spring 2009 have been to perform calculations in this analysis of options comparative benefits, however since fuel price is subject to change, consequently comparative benefits of option will also change.

The current policy of encouraging low blend biofuels in many cases does provide the lowest cost route for users to adopt biofuels, and the lowest cost of carbon saving. However the study suggests that biomethane used with buses and HGVs specifically associated with long distance duties and own-tank filling is more cost effective than current biofuels and fossil fuels. This is validated by the current use of gas fuel by some HGV operators, and verified in the duty derogation estimations within the study.

The study also shows that targeting high-blend biofuels on the heaviest vehicles is likely to produce a better return for additional costs incurred. Light duty vehicles are generally less cost effective candidates for investment in clean technologies/fuels, primarily because they have lower emissions per km and cover a shorter distances each year. This reduces the 'pay-back' of investing in extra technology.

The range of OEM vehicles that can use high-blend biofuels is increasing and technical, cost and availability barriers for using B30 and E85 in vehicles reducing. It is also anticipated that additional costs from using some high-blend biofuels, servicing in particular, will reduce thereby improving cost-effectiveness.

Effect of Discounting Fuel Duty

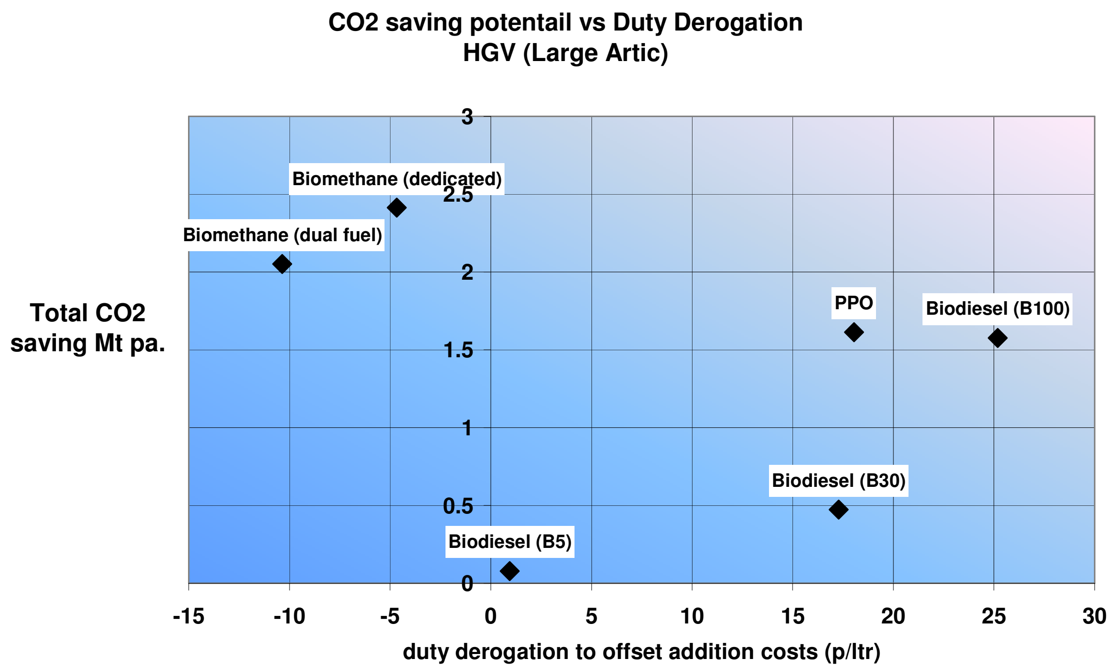
Fuel duty differentials are needed to grow the market and encourage operators to adopt high blend liquid and gaseous biofuels, providing a fiscal incentive to taking commercial risk as early adopters.

To determine the viability of duty derogation as an option for incentivising high blend biofuel adoption, the levels of duty derogation necessary to compensate for additional capital and operation costs with various biofuels have been estimated. The duty differential required to equalise overall lifetime costs, varies for each vehicle-fuel combination

For this part of the study only, the analysis has considered fuel duties, as at Spring 2009 and duty derogations has been estimated with respect to these values. VAT has still been excluded.

For HGVs where the study suggests a major opportunity for economic CO2 reduction, it is estimated that all high blend biofuels could be incentivised through a mechanism of 27 pence per litre derogation in fuel duty, with some fuels requiring much less. Large articulated HGVs present a major opportunity for carbon saving using biomethane. This gaseous fuel can also be a cost-competitive fuel option, with current duty rates, as savings in fuel costs can compensate additional capital costs given a sufficient amortisation period.

The potential impact of incentivising a fuel can also be evaluated by comparing the estimated total CO_2 saving per annum with the duty derogation is shown in the figure below for HGV (large artic).



Duty derogations in the study have been calculated on a break-even basis, considering amortised costs of vehicle ownership and operation. However it is worth noting that operators are likely to seek shorter payback periods and financial advantage before adopting such fuels and higher derogations than those estimated may be necessary in order to encourage market adoption and expansion.

Effective vehicles and fuel combinations

There are a range of factors and influences on the suitability of biofuels for each of the main vehicle types.

For HGVs and MGVs operated on the basis of depot fuelling, significant GHG reduction may be realised though adoption of, (in order of GHG saving potential),:

- B100;
- PPO; and
- biomethane (dual-fuel then dedicated).

The initial investment needed to operate with biomethane is comparatively high, however in the medium-term (over 5-7 years) biomethane is by far the most cost-effective way of reducing carbon in HGV, followed by PPO and B100. Operators will experience new technical requirements for operating with biomethane compared to liquid fuels and PPO operation is not currently warranted for use by any major OEM although some vehicles may be retrofitted by a specialist third party, with some also providing warranties.

For operators with large fleets of HGVs, there is the potential for also operating LGV's on the same fuel, whether it be biomethane, biodiesel or PPO. Alternatively, a continued or expanded supply of B30 and E85 at selected forecourts could form a basis for incentivising take-up by individuals and owners of small van fleets, since some major OEMs now offer models of vehicles warranted to use these fuels. Servicing requirements of these vehicles can be increased, although this is not mandated for some vehicles and here B30 offers a highly cost effective option.

Based on a mixture of practicality, potential for GHG reduction and cost effectiveness, a strategy to encourage high-blend biofuel use in cars in the UK should strongly consider bioethanol (E85), followed by biodiesel (B30). However, it should be noted that the expansion of the high-blend biofuels at forecourts faces a number of barriers, primarily the constraint on capacity to hold stocks, and to supply a greater number of different fuels at many locations, particularly smaller sites. It is recommended that a select number of high blend biofuels are prioritised.

Barriers and Recommendations

There are a number of barriers to high blend biofuels which are outlined below together with specific recommendations.

1) Political commitment and support

A major proportion of consultees cited the lack of clear government policy and direction and an absence of long term planning as barrier to the take up of high blend biofuels.

For high blend liquid biofuels, the removal of the duty differential for biofuels in 2010 is the most serious barrier and will totally undermine the viability and adoption of high-blend biofuels. Early adopters of high blend biofuels, whilst contributing to CO_2 savings, are commercially penalised by the higher capital and operating costs associated with fuels. Without direct incentive or support, costs reductions and economies of scale will be delayed and may represent a long term barrier for market expansion.

Recommendations

- ***Duty Derogation for biofuels should be introduced based on carbon saving potential and cost, maturity of supply chains, the associated additional capital and operational costs;***
- ***Issue of Renewable Transport Fuel Obligation (RTFO) certificates under the RED should be linked to the GHG intensity of fuels;***
- ***Use the company car taxation framework should be used to further incentivise low-carbon fuels and fuel-efficient vehicles;***
- ***Long term policy and direction in biofuels and clear strategy for meeting GHG targets from road transport should be developed to provide confidence to the market;***
- ***The Bus Service Operators Grant (BSOG) and the £30 million Low Carbon Emission Bus (LCEB) fund should be widened to include more types of low-carbon fuels.***

2) Fuel production, distribution and supply

Constraints in the fuel distribution network means that different grades of low-blend biofuel will already have to be accommodated i.e. EN 590 / EN 228 with increasing biofuel content, and a lower blend 'protection grade'. For high-blends to be realistic for the mass-market (i.e. retail/forecourt) fuel distributors will seek to prioritise and focus available distribution capacity on agreed high blend fuels which may require Government guidance.

Distribution of UK produced biomethane as a low-carbon transport fuel will require a coordinated and supported approaches to certify injection of biomethane into the existing gas supply network.

Recommendations

- ***Government, working with stakeholders, should explore options available to agree one high blend of bioethanol and one high blend of biodiesel to roll-out at selected, strategic forecourts;***
- ***The Alternative Fuels Framework should be used to support more types of high-blend biofuels, while targeting available fuels where there are most carbon reduction benefits.***
- ***Government, working with regulators and the utilities industry should develop a green certification system for grid injection of biomethane to incentivise production and facilitate low-cost distribution of this fuel through an existing network.***

3) Sustainability and Standardisation

Presently there are large variations in quality of blended biofuel fuels produced by different sources, particularly in biodiesel blends. Quality can vary considerably due to advanced blending techniques, additive packs or selecting most appropriate feedstock source, for example rape seed for UK conditions. Degradation of fuels such as B5 during storage and distribution further contribute to the variance.

Recommendations

- ***A minimum specification for biofuel use in vehicles, i.e. an EC Regulation or Directive for beyond B10 should be set;***
- ***EU sustainability standards and reporting should continue to be progressed as required.***

4) Availability of vehicles

Vehicle operators consulted reported that warranty terms for their vehicle if used with biofuels were difficult to obtain, understand and were possibly inconsistent. This lack of clarity has affected vehicle purchasing decisions and confused carbon reduction objectives.

There is no forum through which major vehicle purchasers can collectively develop and communicate their vehicle requirements to OEMs. Such purchasers are seeking vehicles that can operate on fuels at higher blends than the 7% currently covered by the Fuel Quality Directive (FQC), and resulting specifications developed CEN that are planned to extend to 10% biofuel. (included in EN590 and EN 228)

Recommendations

- ***A forum of major vehicle purchasers and suppliers of target vehicles should be created to understand long-term requirements and align supply and demand strategies, supporting early adoption;***
- ***Warranty requirements for additional servicing for biofuelled vehicles should be clarified on a Europe-wide basis and access to accurate information on warranty/approvals, including for older vehicles still in use should be improved***
- ***An EU-wide programme to support manufacturers to test their vehicles for standard ranges of high-blend biofuels should be funded, with the objective of increasing the proportion of vehicles offered with warranty;***
- ***Vehicle taxation should be more tightly linked to the carbon saving potential of high-blend biofuels. E.g. VED for cars and vans and Reduced Pollution Certificates for Heavy Duty Vehicles.***

5) Sustainability and public/media perception

Negative public image as well as genuine uncertainty over the sustainability of biofuel production and use remain strong concerns to potential adopters and supporters of biofuels, motivated by sustainability and CSR goals.

Recommendations

- ***Indirect land use change effects should be considered once understood and when a standardised methodology is agreed (end 2010);***
- ***Fuel support policy should be linked to the air quality strategy refresh, which will need to address evidence that bus and HGV emissions are significant sources of air pollution.***

The authors wish to recognise the contributions of members of LowCVP, notably the project Advisory Group.

1 INTRODUCTION

1.1 Background and purpose

Transport & Travel Research Ltd (TTR), in association with Fleetsolve, were commissioned by the Low Carbon Vehicle Partnership (LowCVP) to investigate the opportunities for high blend (>10% by volume) liquid and gaseous biofuel penetration in the UK and recommend the most appropriate mechanisms to stimulate take-up.

LowCVP's previous work illustrates that some biofuels may be able to make a significant contribution to greenhouse gas savings and therefore the use of these biofuels in high blends would make a positive contribution to reducing emissions in the transport sector. A number of obstacles to the development of a high blend and gaseous biofuels market for sustainable biofuels must be addressed in order to realise the potential benefits; these include, for example, blend limits, fuel costs etc.

The study investigates issues of a technical, fiscal and regulatory nature, and draws on practicable experience, including that from outside the UK. Sustainability is an important issue when considering production and use of biofuels. Sustainability of biofuels is a topic being examined and progressed through various other studies and initiatives of the LowCVP. Therefore, the assessment biofuels sustainability is outside the scope of this particular study.

This study has benefited greatly from LowCVP member contributions of information, and the involvement and advice of an Advisory Group at key stages in the study.

1.2 Fuels included in the study

Following the scoping phase of this study LowCVP FWG members recommended the following fuels be taken into the full assessment stage of the study, because they are relevant to current commercial operations or close-to-market:

- Biodiesel (first generation, i.e. FAME);
- Bioethanol;
- Biomethane; and
- Pure Plant Oil.

The study benefited from particularly active provision of information on these fuels from a number of organisations both inside and outside the LowCVP membership including Cenex (biomethane), Matrix Biofuels (PPO) the BEST project and Greenergy (bioethanol), Joule Vert (biodiesel and others) and UKPIA (fuel standards).

It was also recommended that the study examine second generation biodiesel (Biomass to Liquid process) and Hydrogenated Vegetable Oils and compare where useful. It was agreed that given the lack of availability of high-blend versions of these fuels the analysis would be less detailed than for other high-blend biofuels.

LowCVP FWG members recommended that the following fuels were not taken forward to the options assessment.

- Hydrogen (liquid and gaseous);
- E-diesel (15% bioethanol, 85% diesel); and
- Biobutanol.

Hydrogen and biobutanol did not fulfil the study scope for examining current or near to market fuels and E-diesel was excluded on ground of safety due to its low flash point.

1.3 Contents of this report

This report presents the findings from the study, covering all fuels and vehicles agreed as in scope.

Chapter 2 sets out the sector assessment analysis, examining a number of factors that are relevant to using high-blend biofuels in UK vehicle fleets, differentiated by vehicle type.

Chapter 3 examines barriers, drivers and potential support mechanisms and sets out feedback received from various stakeholders in the study. It also includes an overview of the policy context formed by the relevant Directives, regulations, reviews and strategies.

Chapter 4 presents the option assessment of vehicles and fuels, where the relative performance (on emissions and cost) is set out and absolute figures for GHG reductions are presented. An analysis of fuel duty as an option to stimulate uptake of biofuels is also presented.

Chapter 5 presents the study conclusions and recommendations about which combinations of vehicle type and fuel have emerged as the most promising for market expansion from the analysis done in this study.

Annex A1 includes the details of methodologies and data sources. Annex A2 to A10 provides more detail on each of the fuels considered by the study. Annex A11 sets out the study questions included in the brief as a checklist of the work undertaken.

2 SECTOR ANALYSIS

2.1 Introduction

This chapter examines a number of factors that are relevant to using high-blend biofuels in UK vehicle fleets, differentiated by vehicle type.

Section 2.2 outlines issues surrounding the fuelling of different types of vehicle with high-blend biofuels, including fuelling profile, size of fleet and the decision making process.

An analysis of different sectors of the UK vehicle parc and their characteristics, in terms of vehicle numbers, ownership and age profiles is provided in section 2.3. This section also includes information about what vehicles (by manufacturer/model) are currently suitable to operate with various high-blend biofuels.

Section 2.4 examines existing and forthcoming influences on the vehicle parc and use of fuels, including legislation, regulations and consultations arising from the European Commission and UK Government.

Section 2.5 and 2.6 cover the rationale and possible focus for using high-blend biofuels in the UK transport market: the likely requirement to meet Renewable Energy Directive targets; and the significant contribution to GHG emissions from certain sectors of the parc (and therefore the opportunities to reduce). In addition, section 2.6 confirms the fuels that are considered in the study, based on early findings and supported by Advisory Group recommendations, that were taken through to the more detailed Option Assessment described later in Chapter 4 of this report.

2.2 Factors affecting suitability for high-blend biofuels

A number of factors related to vehicle type and their range of typical operations can affect suitability for uptake of high-blend liquid and gaseous biofuels.

2.2.1 Type of ownership and size of fleet

The ownership of road transport vehicles takes a variety of forms. The range includes many private individuals owning one or two vehicles for personal or work-related use, small businesses owning one or more vehicles for their own transport and companies and organisations that operate fleets with many vehicles, either to support their own business activities or directly to provide a transport or haulage service for their customers.

Fleet size is an important characteristic, and can be considered as having four main categories:

- extra large fleets (100+);
- large (51 - 100 vehicles);
- medium (11 - 50 vehicles); and

- small fleets (0 - 10 vehicles).

The size of fleet is relevant to the amount of fuel used and whether it is economical to operate own-tank fuel storage and dispensing, or use forecourts (for commercial or privately owned vehicles.

A key factor in whether or not to have own-tank fuelling is the amount of fuel used. Small operators, with fewer than 10 vehicles, can very rarely justify own-tank fuelling facilities due to low volume fuel purchasing. In this case, they are dependent on public forecourts, or possibly bunkered fuel services if they can negotiate access and their duties include a return to base for fuelling. Operators of medium and large fleets are more likely to find own-tank fuelling cost-effective. Own-tank storage and dispensing enables some choices to be made over type of fuel.

In addition the operators of particularly large fleets will be able to negotiate over vehicle warranties. Larger fleet operators are more likely to be able to influence the support for alternative choices of fuel.

2.2.2 Fuelling profile and availability of fuels

As discussed in section 2.2.1 there are various fuelling options (to suit the 'profiles' of vehicle operators). We have considered the three main fuelling options as follows, with providing particular opportunities for the use of biofuel:

- Own tanks, providing the most flexibility (at a cost);
- Bunkered fuel service which pools costs, which requires the owner to support biofuel provision, as well as sufficient other customers; and
- On-road filling at public forecourts and HGV filling stations, which depends on the owner/operator supporting biofuels and the demand of other customers.

Advice given by project partner Fleetsolve to its clients is that they generally need to be using around 800,000 litres of diesel p.a. before it becomes cost-effective to operate their own fuelling facilities. For the purposes of this study we have assumed that fleets with over 50 vehicles are very likely to use over these volumes and therefore practice an own-tank fuelling profile (by using multiple depot locations if necessary).

Obtaining high-blend biofuels at the preferred grade is not as straightforward as purchasing standard diesel. Most major oil distribution terminals are able to store and distribute a limited number of grades, but their current preference will be B5 or E5. Biodiesel plants will produce B100 for onward sale to refineries (much of it destined for B5) and are generally not set up to offer a range of biodiesel blends.

Large UK fleet operators buy fuel that is transported by road tanker to their depot, bought at bulk price and delivered in quantities up to 30,000 litres per load. This is the norm for conventional diesel, and also by users of liquid biofuels such as biodiesel, PPO and bioethanol. Compressed tanks of biomethane are transported by truck in the UK at present (but across the EU availability and method of transport will vary).

Some biofuels are imported, some produced in large plants in the UK and some in smaller plants and operations operating in a smaller catchments area. Fleetsolve have observed a geographical bias in the location of users of biodiesel, clustered nearer the large refineries or plants producing biodiesel use for example, where these fuels are either more heavily promoted to local customers or more easily supplied. The potential of many biofuels for a distributed production model provides an opportunity to reduce the transport costs in financial and GHG emission terms, if they can compete on cost grounds with imported versions.

Bunkered fuel services exist where a distributor stores and dispenses fuel to a range of customers with accounts. They are aimed primarily at the HGV sector and have the potential to provide more customised fuelling options to the benefit the supply of high-blend biofuels. Bunkered fuel services generally restrict themselves to diesel rather than petrol due to flammability and HSE requirements) so technically are suitable distribution channels for biodiesel and/or PPO.

A small number of natural gas stations operate by way of agreement to supply a limited number of third-party operators (thereby using a bunkered filling site model). These could provide a small part of the necessary infrastructure to supply biomethane. UK biomethane is currently available direct by tanker (from a land-fill based production site) to customer or from one filling station in Somerset.

High-blend biofuel is currently available on some public forecourts. The largest forecourt supplier of biofuel is Morrison's with B30 at 130 filling stations (given a sparse but national coverage) and E85 at 21 forecourts, out of 350 forecourts in total. B30 is currently priced the same as standard diesel and E85 at 2ppl lower than standard petrol. This needs to be put in context of over 9000 filling stations nationwide in the UK, however the top 5 retailers make 60% of fuel sales and control in excess of 3,000 sites. A 10% coverage of retail sites, focussed on the larger forecourts, would provide a significant improved national network for high-blend biofuels.

Large forecourts are generally restricted to sell up to 3-4 different grades of fuel due to tank configuration, and most currently elect to sell one or two high performance fuels alongside standard petrol and diesel. Small sites are limited to two grades. The current EN fuel standards allow for E5 and B7 (as from July 2009 BS EN 590 came into force giving max of B7). A new E10 standard will be available by 2011-2012. At the same time the Renewable Energy Directive (RED) requires an E5 'protection grade' to be made available for older cars until 2013, and this could be extended. This requirement further restricts forecourt availability for any additional grades or blends.

On a local scale there are a number of small scale biodiesel producers across the UK with on-site pumps offering public access, supplying a limited number of local filling stations. The same will supply small volumes by the container, which is also a method of purchasing PPO.

Finally, there are the home-producers of biodiesel and those obtaining PPO for personal or small business use, taking advantage of the Treasury concession that allows 2,500 litres of biofuel to be produced before payment of duty.

Sweden and Germany undertook quite rapid fuelling infrastructure development in response to clear policy levers for different biofuels (including biomethane, bioethanol, PPO and bioethanol). See Chapter 3, Box 3.2 for more information on mechanisms used in Sweden. It is suggested that many current barriers of availability and difficulties of distribution would be overcome if there was a market demand.

2.2.3 Vehicle warranty

A concern of many vehicle purchasers will be the warranty offered by the OEM to the original purchaser. Most purchases will wish to operate their vehicle under the conditions of the warranty. Feedback from stakeholders has been that information on warranties (for use with high-blend biofuels) has not always been easy to obtain. A range of warranty information has been obtained for a range of vehicles from this study, however, with clear indications about models and conditions of service.

In some cases there is a gap between what is technically feasible and the warranty position of the OEM. One reason is that OEM will have take a view about whether their advice on maintenance and operational regimes (required for some biofuels) will be carried out, or whether they wish to support vehicles that are potentially being used with a greater range of fuels (some without European-wide standards of quality defined). The outcome is in fact a range of positions warranty, which may depend on the type of customer. This means some vehicle operators who would like to operate with high-blend biofuels are discouraged for doing so.

In some cases engine retrofit specialists offer warranties for vehicles they modify, or where the OEM partners with and then approves the modification provided by a specialist supplier. In other cases, because users adopt high blends voluntarily they will take a commercial view of the warranty and proceed without it. Both these positions seem to be about filling a gap left by OEMs in the face of low market demand. Overall, in the interpretation and discussion of options for expanding the market for high-blend biofuels we have tended to consider fully warranted vehicles as a stronger basis for development, given vehicle and fuel company support is necessary for a robust long-term approach.

2.2.4 Vehicle duties and range

If a vehicle operator is going to use a high-blend biofuel and invest time and resources in setting up its operation they will want to use the fuel for the maximum amount of miles possible, and not re-fill with conventional fuel if at all possible.

It is possible to specify the size of fuel tank of many Heavy Goods Vehicles (HGV) which means an ability to customise a vehicles' range from each tank of fuel. For Medium Goods Vehicles (MGV) and lighter commercial vehicles fuel tank size and specification is fixed by the Original Equipment Manufacturer (OEM), meaning much less ability to customise the fuelling range.

If the fuel has a lower energy density than the normal petrol/diesel equivalent, then vehicle range will be reduced if tank size remains the same. This is a particular issue with bioethanol, as information from Swedish bus fleets is that the volume of fuel used is around 1.6 times that of a diesel bus. This means that bioethanol vehicles need to be able to store more fuel on-board or re-fuel more frequently than the diesel or petrol equivalents. Some operators have found a small mpg penalty from switching to high blends of biodiesel, so this may be an issue for this fuel. Increasing tank size is an option to increase vehicle range available to many types of HGV.

Payload size can influence the ability of an operator to use some biofuels. Low-weight/high volume goods mean the vehicle is below maximum payload, enabling fitting of larger tanks, for greater range, or heavier / additional tanks necessary for dual-fuel storage and / or the heavier tanks required for gaseous fuels. Where payloads approach the limit, the addition of extra weight for carrying a fuel can constrain operations. A tilt test must also be passed, which is influenced by adding additional fuel tanks onto the roof, as is common with gas fuelled buses. This has been a factor for some bus manufacturers who have reduced capacity by 2-3 passengers when configuring vehicles with gas storage tanks. For this reason, when considering biomethane, liquefied gas has some advantages over compressed gas because of its higher energy density, enabling smaller tanks to be fitted or a greater range to be achieved with the same weight/size of fuel tanks.

2.2.5 Vehicle operator decision-making

A range of motivations have been found for fleet operators to consider using biofuels. In some cases, the motivation is economic: the duties, mileages and types of vehicle used by the operator suit a particular biofuel and they will reduce costs if they choose this over petrol or diesel. This has occurred with some types/blend of biodiesel and for high-mileage HGV operating with natural gas or biomethane. In other cases, the motivation is corporate social responsibility, which can be sufficient to choose biofuel even if it is same cost or the biofuel costs slightly more. These two positions represent either end of the spectrum of motivations, and sometimes are combined. There are also cases where a hire/reward operator will use a biofuel because their ultimate customer requires it, or the operator is able to charge more for their service because they are using a biofuel.

A relevant factor for freight vehicles could be whether they are used for ‘own-account’ operation or purely for ‘hire and reward’. Own account operators carry goods on their own behalf (i.e. a supermarket running own vehicle fleet carrying own goods). Hire/reward operators are transporting other people’s goods for payment. Own account operators are operating vehicles as just one part of their overall activity. Therefore, they may be able to consider a small change in transport costs (due to high-blend biofuel) as a small element in their overall cost base. In contrast hire/reward operators are only in the business of moving goods and are therefore very sensitive to cost changes. They will tend to take up innovations in fuelling and vehicle operations because it can offer a cost-saving. However, even in this sub-sector there are examples of operators taking up high-blend biofuel when it meant cost increases, because their ultimate clients were interested to specify this option and pay an additional charge for the added value of environmental benefits.

These factors, and other drivers, are covered further in Chapter 3 of this report.

2.2.6 Geography

From Fleetsolve's analysis of their customer base for support and services for biofuel there seems to be a geographical factor involved in take-up of high-blend biodiesel. There are more customers based near large cities (London, Birmingham etc) than in the countryside. This may be motivated by environmental concerns over air quality or a wish to promote the use of cleaner fuels as part of Corporate Social Responsibility (CSR). There is also a cluster of customers in Cornwall and it is thought this is linked to the area receiving significant EU Objective 1 funding, some of which was channelled into green innovation and ethically based businesses. Finally, there are clusters of biofuel users near Merseyside, Humberside, Bristol and the Thames Estuary. These are areas with significant biofuel refining facilities, which appear to be increasing the availability and/or promotion of the fuel in their hinterlands.

2.3 Current status of the UK vehicle parc

2.3.1 Vehicle type

As a first step to consider the relevance of high-blend biofuels to different types of road transport vehicle we break down the entire vehicle parc into sub-sectors according to nine vehicle types:

1. HGV, articulated, large (28 - 44 tonnes);
2. HGV articulated, small (<28 tonnes);
3. HGV, rigid, large (> 24 tonnes);
4. HGV, rigid small (7.5 to 24 tonnes);
5. Medium Goods Vehicles (MGV) (3.5 - 7.5 tonnes);
6. Light Goods Vehicle (1.3 - 3.5 tonnes);
7. Passenger Cars, private use or commercial use (e.g. taxi/police/utilities);
8. Motorcycles, private use or commercial use (police, couriers etc);
9. Public Service Vehicles (PSV), bus (local commercial services/ contracted service), express coach, community transport;

The division of HGV has been done on the following basis:

- HGV artic large – these are the largest road transport vehicles, used for trunking movements of goods across the country between depots and into mainland Europe;
- HGV artic small – these are more specialist vehicles often used for moving liquids, or other goods into city and urban areas where greater manoeuvrability is required;
- HGV rigid large – the heaviest largest rigid goods vehicles, often used for short distance movement of aggregates and waste materials or as Refuse Collection Vehicles;
- HGV rigid small – lighter rigid vehicles, often used for onward movement of goods to and from depots across a city or regional basis.

In reality HGV (including large artics) will deliver large consignments in a range of sectors including in urban areas (e.g. to supermarkets), and the description above is simply to indicate that the majority of their mileage is done on trunk roads.

Table 2.1 shows the number of vehicles of each type currently licenced to UK based owners and organisations.

Table 2.1 – Number of vehicles by sector and type

Vehicle sector	No of vehicles (2007/2008)	Source
HGV artic. large	112,255	TSGB[3]
HGV artic. small	9,699	TSGB
HGV rigid large	72,662	TSGB
HGV rigid small	100,443	TSGB
MGV	151,337	TSGB
LGV	3,187,000	TSGB
Car	27,000,000	Vehicle licensing stats[4]
Motorcycle	1,200,000	Vehicle licensing stats
PSV	90,317	Traffic Commissioners Report 07/08[5]

Each of these sectors of the parc is now considered in more detail.

2.3.2 Car fleet

2.3.2.1 Vehicle numbers and operations

In 2007/2008 a total of 27 million cars were registered[6], and a total of 402 billion car vehicle kilometres were travelled during 2007[7].

The car population comprises vehicles registered as private vehicles by individuals, cars owned by companies in fleets or provided to their employees as a benefit, vehicles in car-hire fleets, as well vehicles used in businesses such as taxi operations etc. The majority of these, whether private or company owned, will refuel via the forecourt. Some vehicles will have access to own-tank fuelling at depots generally maintained primarily for heavier, commercial goods vehicles.

In terms of large passenger car fleets, then UK government and public sector fleets include a minimum of 75,000 light duty vehicles, the three largest fleets being the NHS (over 30,000), the Police (over 16,000) and the MOD (over 7,000). Other significant fleets include those in the Environment Agency and HMRC at around 4,000 light duty vehicles each. Biodiesel trials have been taking place with B22[8] at the Environment Agency.

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[3] Transport Statistics Great Britain: TSGB 2008
[4] Vehicles licenced - data tables; Transport Statistics Bulletin Vehicle Licensing Statistics 2007
[5] Traffic Commissioners' Annual Reports 2007–08, DfT, October 2008
[6] Transport Statistics Bulletin Vehicle licensing Statistics 2007
[7] Transport Statistics Great Britain, 2007
[8] B*x* = standard method for referring to diesel fuel with a biodiesel component. See Annex B for more details on biodiesel.

Table 2.2 shows the age profile of the current UK car vehicle parc. [9]

Table 2.2 – Age profile of UK car vehicle parc

Age of fleet (years)	Number	%
12 plus	2,401,242	9
6 to 12	11,673,491	41
4 to 6	4,947,246	18
3 to 4	2,429,878	9
2 to 3	2,323,494	8
1 to 2	2,216,206	8
0 to 1	2,236,019	8

Table 2.2 shows that 50% of all cars are over 6 years old, with 41% of the total being in the range 6 to 12 years old. In recent years the fleet replacement rate has been around 8% per annum, or some 2.2 million new vehicle registrations per year. The current economic climate means that new car sales have reduced markedly, so it may be a few years until this rate is reached again. However, historic data do still indicate the size of the new vehicle market, and the potential scope of policy decisions on influencing purchasers to make decisions that reduce carbon emissions. Two current examples are the Vehicle Excise Duty (VED) and the Benefit in Kind (BIK) company car tax systems.

2.3.2.2 Current incentives for GHG reduction

From April 2009 the VED system was reformed to incentivise lower emitting cars. The key points are:

- For cars in Band B (up to 120 g/km CO_2) for petrol and diesel are frozen at £35, with rates for vehicles using 'alternative' fuels also frozen at £15;
- From April 2009, a new graduated VED system applied, with a new top band – Band M – for cars emitting over 255g/km of CO_2; and
- In 2010/11, a new first year rate for all cars will be applied, which further incentivise lower emitting vehicles (i.e. the zero VED rate will extend to all new cars emitting 130g/km of CO_2 or less in the first year of ownership).

In addition discounts are applied to Benefit In Kind (BIK) company car tax on alternative fuelled vehicles (discount applicable to scale charge 2007/08), as follows:

- Electric - 6%;
- Hybrid petrol/electric (registered on or after 01/01/98) - 3%;
- Liquid Petroleum Gas (LPG)/ Compressed Natural Gas (CNG) gas only engines (registered on or after 01/01/98) - 2%;
- Bi-fuel (gas/liquid fuel, type-approved) (registered on or after 01/01/00) - 2%;
- E85 Bioethanol fuel - 2% (applicable from 2008/09).

[9] Transport Statistics Bulletin Vehicle licensing Statistics 2007

Indications are that BIK has an impact on company car purchasing decisions and this has improved that sub-sectors average CO_2 emissions compared to the private motorist fleet.[10]

2.3.2.3 Availability of biofuels and vehicles

As noted already, some high-blend biofuels are available on some public forecourts, thereby accessible to private individuals for use in suitable vehicles.

By far the largest forecourt supplier of biofuel is Morrison's with biodiesel (B30) at 130 filling stations. Biodiesel is also available from individual producers on a local basis, and via some small scale (local) distribution networks. Hence, it could be said that a sparse but national network exists for high-blend biodiesel.

High-blend ethanol (E85[11]) is available at 21 Morrison's forecourts, providing a limited coverage.

One public filling station for biomethane is operating in Somerset, which can fuel gas vehicles designed to run on natural gas. Compressed natural gas (CNG) is available from a small number of locations (under 20), many operating as bunkered services under agreement to supply specified users. Hence there is no current national fuelling network to back-up CNG or biomethane fuelled vehicles, which in most locations would have to rely on home-fill systems.

Despite a rather sparse fuelling network an increasing range of vehicles are being made available in UK specification that can operate with high-blend biofuels, generally on the back of demand from mainland European markets.

Flexi Fuel Vehicles (FFVs) can run on E85 (85% ethanol/15% petrol) or petrol only, or a mix of both fuels using just one fuel tank. A number of manufacturers produce FFVs, with the widest ranges being offered in Brazil, however in the UK a range of models are available.[12] For example, several Ford vehicles are available with FFV engines, these include the Ford Focus Flexi-Fuel, Ford Focus C-Max Flexi-Fuel and Ford Mondeo models. FFV models available from Saab include the Saab 9-5 BioPower 2.0t (180bhp), Saab 9-5 BioPower 2.3t (210 bhp) and Saab 9-3 BioPower, specifically designed to operate on bioethanol. Volvo now offers its flexifuel models S80, S40, C30, V50 and V70 in the UK. Renault (Clio) and Peugeot (407 Bioflex) have offered a few model in the UK market from 2009. Renault have been producing FFV for the Brazilian market and they have committed that by 2009 50% of petrol-engine Renaults offered for sale in Europe will be able to run on fuels containing up to 85% of ethanol. By 2009, 50% of petrol-engine Renaults offered for sale in Europe will be able to run on fuels containing up to 85% of ethanol, and a few are starting to be made available in the UK.

[10] Personal communication from ARVAL.
[11] Ex = standard method of referring to fuel with an ethanol component (in this case 85% bioethanol, 15% petrol).
[12] http://www.comcar.co.uk/newcar/companycar/poolresults/e85tax.cfm

For vehicle owners or operators that wish to use biomethane, Volkswagen Audi Group (VAG) are currently producing CNG versions of left-hand drive Caddy LDV/MPV and Passat passenger car models for sale in Germany and Sweden, with the promise of UK specification Caddy Panel Van and 7 seat mini-MPV version in summer 2009[13]. A number of vehicle models are produced for mainland European markets in left-hand drive form.

In addition, a number of diesel vehicles can be operated biodiesel blends above B5, bolstered by the PSA group policy on biodiesel use (Peugeot Citroën).

All Peugeot and Citroen cars, people carriers vans since 1998 with HDi engines can be operated with B30. It is estimated, based on vehicle sales by manufacturer and the typical diesel/petrol split over the last 10 years that some 700,000 plus PSA group diesel vehicles are owned by UK motorists. PSA group have confirmed that the B30 fuel sold by Morrison's (manufactured for them by Harvest Energy) was submitted for analysis by their laboratories in France. This fuel meets the PSA quality criteria and is compatible with their diesel engines. No alterations are needed to the engines to run on this fuel, although specific engine oil and a more frequent maintenance schedule must be observed for vehicles using B30.

There are many manufacturers (Ford, Jaguar, Land Rover, Mini etc) who use the PSA Group engines but have not adopted the PSA Group policy on compatibility with B30.

It is planned that all Renault diesel cars will be able to run on fuel containing up to 30% of bio-diesel from 2009.[14]

VAG has produced past models approved for RME EN14214 (not FAME in general) recognised by their use of rotary pump engines (identifiable as having a "PR Code"). None of the Pumpe Düse (PD) engines which started to be introduced in some models from 2000 are approved to use more than 5% biofuel. Vehicles fitted with a DPF must not use 100 per cent biodiesel or B30 biodiesel.[15 16]

There are no known cars designed or warranted to use PPO from new. However, conversion kits are available for a selected range of diesel vehicles and have been fitted by long-standing suppliers (to the German market for example).

2.3.3 MGV and LGV fleets

2.3.3.1 Vehicles, numbers and operations

Vehicles between 3.5 and 7.5 tonnes are used for a range of duties, and normally comprise large panel vans, Luton vans, drop-sided vans and vehicles based on these chassis (including mini-buses). Light goods vehicles (up to 3.5 tonnes) can be car derived vans or 'transit' sized vans.

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[13] http://www.just-auto.com/article.aspx?id=98230

[14] Renault UK website, viewed May 2009

[15] Communication from VW during course of study.

[16] Audi website: http://www.audi.co.uk/audi/uk/en2/owners_area/biodiesel/RME-biodiesel.html

Table 2.3 – Number of vehicles by sector

Vehicle sector	No of vehicles (2007/2008)	Source
MGV	151,337	TSGB
LGV	3,187,000	TSGB

The type of detailed ownership information readily available for HGV is not available for these types of vehicles. For example, for LGVs we only know that 50% are company owned, with the remaining 50% owned by private individuals[17]. It seems likely that a good number of the 50% in private ownership are used for business purposes.

The table below shows the age profile of the current UK LGV vehicle parc. [18]

Table 2.4 – Age profile of UK vehicle parc

Age of fleet (years)	LGV	
	Number	%
12 plus	302,741	9
6 to 12	1,096,762	34
4 to 6	526,434	17
3 to 4	306,810	10
2 to 3	307,964	10
1 to 2	314,286	10
0 to 1	332,238	10

Table 2.4 shows that 43% of LGVs are over 6 years old, with 34% in the range 6 to 12 years old. Around 300,000 new vehicles have been registered each year for the last few years, showing a quicker proportional fleet renewal than for cars. In fact LGV total mileage rates have been increasing faster than other types of vehicle and this is predicted to continue into the future.[19]

In terms of large goods vehicle fleets, the UK government and public sector fleets operate a minimum of 35,000 commercial vehicles (over 3.5 tonnes). The three largest fleets being the NHS (approximately 14,000), the Police (over 6,000) and the MOD (over 4,000). Other significant fleets include those in the Environment Agency at around 2,000 MGV/HGV and the Forestry Commission with 1,200 vehicles.

MGV tend to be owned by a range of organisations and individuals, and some of the former will use return to base patterns of fuelling and overnight storage at depots. LGV will be distributed in a similar way.

Many of the operators of large van fleets (BT, Royal Mail, British Gas, plus many of the courier companies) operate return to base fuelling and overnight parking at depot. The national courier companies (DHL, City Link, TNT, UPS etc) tend to operate a 'hub-and-spoke' network to that van fleets will return to the same depot

[17] Transport Statistics Bulletin Vehicle licensing Statistics 2007
[18] Transport Statistics Bulletin Vehicle licensing Statistics 2007
[19] Transport Statistics Great Britain, Traffic Data Tables (s7), 2008

serving their HGVs used for trunking networks. City Link and DHL both operate around 3,000 vans and UPS 700. Royal Mail operates over 30,000 vehicles (so we might estimate well in excess of 5,000 vans) and their subsidiary GLS operate 17,000 vehicles, some of which will also be vans. The opportunities and benefits for own-tank fuelling are much greater in such an arrangement where the whole fleet uses the same fuel supplies. Depot based operation can be contrasted with a number of national organisations where vans are parked overnight at the home of the driver (e.g. BSB Sky) and some Council fleets moving away from own-tank/depot fuelling to using forecourt fuel cards to reduce overhead costs.

2.3.3.2 Availability of biofuels and vehicles

Iveco have warranted a number of their Cursor engines to operate up to B30 FAME since 2000, an engine range used in larger vans and LGV such as the Iveco Daily.

PSA group warranty a range of vans to operate with up to B30:

- All Peugeot Vans designated 'HDi' from 1998 onwards including 207, Bipper, Partner, Expert and Boxer; and
- All Citroen Vans designated 'Hdi' from 1998 onwards including C2, Nemo, Berlingo, Dispatch and Relay.

In both 2007 and 2008 there were over 21,000 Citroen and 16,000 Peugeot commercial vehicles (van) registered in the UK,[20] the majority being diesel, which suggests that at least 200,000 of such vehicles have been registered since 1998.

B30 can be used under warranty in Vauxhall Vivaro and Movano vans, plus the Renault Traffic and Master range of vehicles. Six month figures for the start of 2009 suggest the number of registered Vauxhall Vivaro's in the UK is 3192 and Vauxhall Movano's is 807[21], so likely to total some 8,000 vehicles registered per year.

For biomethane use the UK buyer of large vans has a choice of the Iveco Daily (with many combinations of body size on combinations of chassis and engine), including van, chassis cab and minibus versions of models at 3.5t, 4.0t, 5.0t and the chassis cab version only at 6.5t using a 3.0 litre gas engine. The Mercedes Benz Sprinter is likely to be on sale in 2009 which provides for many combinations of body including mini-bus vehicles. Right hand models of CNG trucks are produced in Japan for their national market (stimulated by environmental zone regulations across the Greater Tokyo are that apply to diesel vehicles).

Small (car derived) vans are available to the UK market, based on the Ford FFV (ethanol) and the VW Caddy CNG/petrol bi-fuel.

No OEM supplying into the UK and European markets warranty their vehicles to run on PPO, however a range of conversion kits are available from long-standing developers and suppliers. In some cases insured warranties are available to cover the fuel and engine components.

[20] SMMT, email communication, 2009.
[21] Vauxhall Customer Assistance, 15 June 2009.

2.3.4 HGV fleet

2.3.4.1 Vehicles, numbers and operations

The division of HGV into the four sub-categories used for this study and the corresponding number of registered vehicles is shown in Table 2.5 below.

Table 2.5 – Number of vehicles by sector

Vehicle sector	No of vehicles (2007/2008)	Source
HGV artic. large	112,255	TSGB
HGV artic. small	9,699	TSGB
HGV rigid large	72,662	TSGB
HGV rigid small	100,443	TSGB

Further division of the freight vehicle parc can be seen in Table 2.6 below, where fleet size data for the total HGV fleet is given.

Table 2.6 – Fleet size for HGV fleets

Fleet size (no of veh)	Number of vehicles[22]		Number of fleets[23]	
	Vehicles	% of total	Fleets	% of total
0 to 10	139,148	44	96,000	95
11 to 50	97,436	31	4,500	4
51 to 100	31,456	10	750	1
over 100	45,679	15	300	0.3

The table shows that the majority of HGV fleets (95%) have less than 10 vehicles. In fact, approximately 50% of operators (45,000) licence only 1 vehicle. At the other end of the spectrum, 300 operators (0.3%) have fleets of over 100 vehicles, and because of the large fleet size these operators account for 15% of all HGV numbers. These vehicles are very likely to practice own-tank filling from return to base or via a depot network. This points to a relatively small number of operators which, if they all adopted high-blend biofuels, would still comprise a significant number of vehicles and fuel usage.

The table below shows the age profile of the current UK HGV vehicle parc. [24]

Table 2.7 – Age profile of UK HGV vehicle parc

Age of fleet (years)	HGV	
	Number	%
12 plus	66,684	13
6 to 12	172,746	33
4 to 6	84,442	16
3 to 4	49,815	9

[22] VOSA Effectiveness Report 2007/08
[23] Focus on Freight, DfT, 2006
[24] Transport Statistics Bulletin Vehicle licensing Statistics 2007

2 to 3	54,369	10
1 to 2	52,691	10
0 to 1	46,993	9

Table 2.7 shows that for all HGV types 46% are over 6 years old with 33% in the range 6 to 12 years old. The number of new registrations per year has been around 9-10% of the total, or 40-50,000 vehicles per annum. However, new truck sales have dropped markedly in 2008/9 financial year as the UK economy has gone into recession.

Some information about vehicles' duty cycles can be inferred from the type of licence that the operator holds. Table 2.8 gives licensing details for HGV fleets licenced in 2007/2008.[25]

Table 2.8 – Licensing details for UK HGV fleet

HGVs	**explanation**	Number of licences	Total specified vehicles on licence	Average fleet size
Restricted licence	own goods everywhere	48382	103973	2.1
Standard National licence	own + hire and reward GB	38924	188853	4.9
Standard International licence	own + hire and reward everywhere	11010	88283	8.0
Total		98316	381109	3.9

Table 2.8 also gives information on the average fleet size for each type of licence. It should be noted that for a Standard International PSV licence, in particular, there are some very large companies that hold a significantly higher number than the average.

2.3.4.2 Availability of biofuels and vehicles

The vast majority of HGVs are powered using diesel fuel, with a small number of specialist vehicles operating on petrol or gas.[26] Higher blends of biodiesel are warranted for use in a selected number of manufacturers' engines. Some engine manufacturers specify a particular type of biodiesel (e.g. RME) possibly to ensure RME is not interchanged with SME for example.

Renault Trucks gives a manufacturer's guarantee of two years for the use of biodiesel (FAME) mixed with diesel up to 30% for all engines in its trucks (Euro 3, 4 and 5). The warranty is subject to two conditions: the intervals for the change of oil should be increased to twice normal rate; and if RME (rape seed biodiesel) is used, it should comply with the European norm EN 14214.[27] Advice is also given about fitment of fuel heaters and filter change.

[25] Traffic Commissioners' Annual Reports 2007–08, DfT, October 2008
[26] TSGB 2008: Vehicles licenced - data tables
[27] Alternative Fuel Trucks, The Association of European Vehicle Logistics (ECG), 2008

Scania vehicles can be used under warranty with 100% biodiesel (RME) if equipped with unitary injectors, without any supplementary modifications to the engine being needed. More frequent oil changes are required.

A number of MAN engines are warranted for 100% biodiesel operation[28] if the fuel is RME and conforms to DIN EN 14214, together with a number of conditions and restrictions.

MAN common rail engines may be run on RME only if a guarantee is purchased for the injection system components. The chassis of all trucks with engines cleared for RME operation are equipped with RME-compatible components (fuel system, fuel level transmitter).

Daf trucks will warranty a number of engines used in their trucks for B100 operation, and will warrant B30 provided a fuel line heater is fitted.

A wide range of Daimler-Chrysler trucks and buses can be operated on biodiesel (specified only as FAME), and past marketing has emphasised that all their engines can operate on 100% biodiesel, given a range of precautions and increased service intervals.

Iveco have warranted a number of their Cursor engines to operate up to B30 FAME since 2000. Iveco withdrew warranty support for B100 biodiesel due to concerns over engine durability with the higher blend.

Gas engines suitable for use with biomethane are available in two forms for HGV: dedicated (gas only) or dual-fuel (gas-diesel mix). Daimler-Chrysler market the Econic range of vehicles to the UK, as is a semi-trailer truck that can operated in a range of configurations including curtain sides, box/refrigerated and Refuse Collection Vehicle. Gas engines as supplied by Cummins are also available in various HDV chassis. Iveco are likely to bring medium rigid CNG 12t/16t Eurocargo later in 2009 and have on sale the larger Iveco Stralis CNG 18t artic. Currently the choice of gas Refuse Collection Vehicles would be limited to the Mercedes Econic, but it is likely that other vehicles will be available in 2009/10 from Dennis Eagle and Iveco (based on the Stralis engine/chassis combinations).

An alternative to purchasing a new dedicated gas engine vehicle is to retrofit dual-fuel equipment to a diesel vehicle and fuel with natural gas or biomethane. Dual fuel systems are bee developed and supplied in the UK market by two companies, Hardstaff Group and Clean Air Power. Both companies have developed equipment in co-operation with engine manufacturers, and between them can convert popular engines from Volvo (e.g. FH12), vehicles with the Caterpillar C12 engine, DAF (55, 65, 85) and Mercedes Benz Axor. In early 2009 Clean Air Power signed a Letter of Intent with Volvo Powertrain (Volvo) to incorporate Clean Air Power's Dual-Fuel technology into Volvo Truck engines (development and commercialisation of products), which will intended to lead to marketing and support by Volvo Trucks.

[28] D08 engines - RME operation permissible from eng. no. xxx8953591xxxx; D20 engines; and D26 engines; D28 engines - RME operation permissible from eng. no. xxx8953001xxxx.

Sainsbury's are operating HGV fitted with CAP dual-fuel system, fuelled by biomethane.

Scania has recently been testing bioethanol fuelled trucks in Sweden using modified compression ignition engines (using lesson learned from bus markets). These were not market ready at the time of this study.

There are no known major truck engine manufacturers supporting PPO use with warranties. A key factor is the need for retrofit conversion of the basic diesel engine design. Key developers/suppliers of PPO retrofit equipment offer various levels of guarantee or insured warranties for HGV they convert. A number of UK HGV operators are using their vehicles with pure plant oil (PPO), after suitable modifications, some on a trial basis and others on an ongoing basis.

2.3.5 Public Service Vehicle

2.3.5.1 Vehicles, numbers and operations

The Public Service Vehicle (PSV) fleet is made up of buses running local services (both commercial and supported services), coaches, and community transport vehicles. In 2007/2008 a total of 90,317 PSVs were registered[29], and a total of 2.3 billion PSV vehicle kilometres were travelled during 2007[30].

Information about vehicles' size and duties can be inferred from the type of licence that the operator holds. Table 2.9 below gives licensing details for PSV fleets licenced in 2007/2008.[31]

Table 2.9 – Licensing details for UK PSV fleet

PSVs	Details – restrictions, size vehicle, use	Number of licences	Total specified vehicles on each licence	Average fleet size
Restricted licence	Up to 2 vehicles, less than 8 passengers	3,596	5,005	1.4
Standard National licence	Any size, GB only	3,087	31,184	10.1
Standard International licence	Any size, everywhere	2,392	54,128	22.6
Total		**9,075**	**90,317**	**10.0**

Fleets operating under a restricted licence are most likely to be community transport vehicles, Standard National licences used for the local bus service fleet and Standard International for coaches. It should be noted that for Standard International PSV licence, in particular, there are a few very large companies that hold a significantly higher number of licence than this average. The most promising fleets are likely to be those operated for local bus services, given their return to base fuelling patters and maintenance at own depots.

29 Traffic Commissioners' Annual Reports 2007–08, DfT, October 2008
30 Transport Statistics Great Britain, 2007
31 Traffic Commissioners' Annual Reports 2007–08, DfT, October 2008

Table 2.10 shows the age profile of the current UK vehicle parc. [32] Table 2.10 shows that 58% of PSVs are over 6 years old, with 40% in the range 6 to 12 years old. A comparison with other vehicle types shows that the bus fleet has the lowest replacement rate and therefore the highest average age.

Table 2.10 – Age profile of UK vehicle parc

Age of fleet (years)	**PSVs**	
	Number	%
12 plus	33,282	18
6 to 12	72,808	40
4 to 6	25,148	14
3 to 4	13,043	7
2 to 3	12,650	7
1 to 2	12,006	7
0 to 1	12,055	7

A typical local bus service vehicle can be assumed to have an average life of 12 years, based on full-sized buses (single and double deck) having a 16 year life, midi-buses a 12 year life and super-minis a 8-10 year life. Detailed research into a selected number of bus operators[33] showed that the average age varies across the fleet by type of vehicle:

- Minibus – 4.7 years;
- Midibus – 7.7 years;
- Single Deck – 7.5 years;
- Double Deck – 8.0 years;
- Coach – 7.7 years.

The same research, based on a selected number of major operators, suggests that the national fleet replacement rate for local bus services was only around 5.4% in 2006, confirming the slow rate of fleet renewal.

For operators who wish to run buses or coaches on high-blend biofuels there are a small range of options.

2.3.5.2 Availability of biofuels and vehicles

Currently, the arrangements for Bus Service Operators Grant (BSOG) negate to a large degree any benefit from reduced duty on biofuels (through duty rebate as subsidy) which means it is more expensive per litre for bus operators to use high-blend liquid and gaseous biofuels (compared to a HGV operator for examples). Changes to BSOG have been announced, and a premium payment will in future be paid to low emission carbon buses, which includes hybrid and other innovative drive-trains and biomethane from among the range of possible low-carbon fuels.

[32] Transport Statistics Bulletin Vehicle licensing Statistics 2007
[33] Bus Industry Monitor 2007 Volume 4, TAS Publications and Events Ltd, 2007

For a UK specification gas bus for use with biomethane the current options are Optare, who offer a range of buses with either dedicated Cummins gas engine or Hardstaff Dual Fuel technology in volumes of 10 or more.[34]

Gas powered buses are produced by major manufacturers for mainland European markets (Renault, Iveco, Man and Mercedes-Benz) but not sold into the UK at present. Volvo have signed a letter of intent with Clean Air Power to develop dual fuel technology on their HGV range and are also major supplier of chassis and engines to the bus industry in the UK.

Some of the major UK suppliers of bus chassis and engines have been warranted for use with high-blend biodiesel now and in the past.

The widely used Cummins range of heavy diesel engines is available for the range of bus types. B20 is certified for On-Highway: ISX, ISM, ISL, ISC and ISB engines certified to EPA '02 and later emissions standards, ISL, ISC and ISB engines certified to Euro 3. Changes to the service frequency, filter changes and in some cases oil quality monitoring is recommended.[35]

Mercedes/EVOBUS offers some current models able to use B100:

- EVOBUS standard buses: O 405/O 407/O 408/ O405 G/O 550 with OM 447 hLA
- EVOBUS low floor: O 405 N/O 405 GN with OM 447 hLA/O 530/O530 GN with OM 906 hLA and OM 457 hLA
- Mercedes OM 457HLA/LA, OM 501/502 LA and OM 906 LA may be run with biodiesel after individual consultation of Mercedes.[36]

Provided that the need for special service intervals is observed, Scania permits the use of up to 100% FAME biodiesel (meeting EN14214) in some of its engines.

PPO conversions are available on Optare buses from new running with a range of engines. Trials of PPO in bus fleets have been carried out by Optare and Alexander Dennis Limited using retrofit technology developed by Regenatec. Most other road vehicle manufacturers do not warrant their vehicles for Pure Plant Oil (PPO). Some developers of PPO retrofit equipment will offer insured warranties for certain vehicles in their product's range.

Scania produce a version of their compression ignition engine modified to run on ED-95, which is widely used in Sweden and has been purchased in UK specification for trials by Nottingham City Transport and Reading Buses.

2.3.6 Motorcycle fleet

The motorcycle fleet makes up a significant number of vehicles, with sales of such vehicles growing in recent years.

[34] Biomethane Toolkit, Cenex, 2008
[35] http://www.everytime.cummins.com/every/customer/biodiesel_faq.page? (viewed March 2009)
[36] http://www.sugre.info/tools_history.phtml?id=660&internal=&link=&field_id=7778&h_id=1434

Table 2.11 – Number of vehicles by sector

Vehicle sector	No of vehicles (2007/2008)	Source
Motorcycle	1,200,000	Vehicle licensing stats

Table 2.12 shows the age profile of the current UK vehicle parc. [37]

Table 2.12 – Age profile of UK vehicle parc

Age of fleet (years)	Motorcycles	
	Number	%
12 plus	249,662	20
6 to 12	393,069	31
4 to 6	179,586	14
3 to 4	88,827	7
2 to 3	99,274	8
1 to 2	109,244	9
0 to 1	143,256	11

Table 2.12 shows that 51% of motorcycles are more than 6 years old, with 31% in the range 6 to 12 years old.

Motorcycles are generally fuelled by petrol, and therefore are operating currently in the UK on E0-E5 as standard. The Honda Flex Fuel (Titan) motorcycle was planned for launch in spring 2009 in Brazil[38] and Yamaha is developing something similar [39] to run on higher blends of bioethanol and take advantage of the high availability of bioethanol blended fuel in Brazil and the US.

There has been some interest from UK motorbike fleet operators in modifying existing vehicles to operate with bioethanol. The most likely take up would be from the larger public sector fleets, such as NHS and Police services.

While this provides an interesting option for low carbon fuelling of this sector, more information is required on whether this provides a realistic or significant opportunity.

2.4 Rationale for high-blend biofuels

The Renewable Energy Directive states that all Member States need to have a 10 % share of the energy consumption in transport consisting of renewable energy by 2020. The following analysis (developed by the BEST project) illustrates a potential shortfall from relying on low-blend biofuels for use in petrol and diesel vehicles.

[37] Transport Statistics Bulletin Vehicle licensing Statistics 2007

[38] Honda to sell biomethane bike, March 2009 (http://www.biofuels-news.com/industry_news.php?item_id=621

[39] Yamaha dual fuel motorcycle revealed, October 2008 (http://www.motorcyclenews.com/MCN/News/newsresults/mcn/2008/October/27-31/oct2808-Yamaha-dual-fuel-motorcycle-revealed/?&R=EPI-103851)

Based on RED values, ethanol contains 21 MJ/l, petrol typically contains 32MJ/l, and therefore ethanol contains 65.6 % of the energy of a litre of petrol. As 10 % blend by volume is the maximum allowed according to the fuel quality directive this 10 % corresponds to 6.56 % by energy.

Biodiesel typically contains 33 MJ/l, and diesel typically contains 36 MJ/l. Biodiesel therefore contains 92% of the diesel energy per litre. As 7 % blend by volume is the maximum allowed according to the fuel quality directive this corresponds to 6.4% by energy.

In addition, the analysis above that leads to a 3.5% shortfall assumes that all petrol cars will be running on E10, which is unlikely given the number of older vehicles still in use (that will have a maximum tolerance of E5). With current government policy to remove duty differential for biofuels (with exception of biomethane) the selling price of E10 might be higher than for E5, which would further depress the actual demand for this product.

The conclusion that can be reached is that with the allowances in the FQD the maximum renewable substitution that can be reached using low-blends is 6.5%. The shortfall of 3.5% would actually decrease the more diesel being used in the fleet (due to lower allowable blend volume).

In terms of initiatives to close the gap then work is progressing. EN 590 and BS EN 590 both allow B7 now. B7 should be a precursor to higher blends such as B10, which is potentially allowed under RED with additional consumer information for blends above 10%. CEN are (only) working on B10 and E10 at this time but car industry still making cars that are limited to B7 and some existing cars are limited to E5. B10 and E10 could help close some of the gap if CEN reaches agreement on fuel standards that the manufacturers can match to vehicles for the mass markets of passenger cars and light vans. The European Commission's Joint Research Centre (JRC), EUCAR (European car industry research group and Concawe (European oil industry research group) are studying future options now in a three year study to be used (hopefully) by the European Commission's 2012 review of the Fuels Quality Directive.

An alternative route to increasing volumes of biofuel might be blending in proportions of HVO to increase the biofuel content and stay within the EN590 specification.

However, mass market second generation biofuels are not anticipated to be competitive until at least 2020. Relying on electric vehicles appears ambitious. Hence, something else is needed to make up the 3.5%. This suggests a need for some form of high-blend biofuel in one or more sectors of the vehicle parc to cover the deficit.

Looking wider than the question of just high-blend vs. low-blend considered above, the rationale for high blends in general can be extended and considered under a number of policy objectives: greater GHG savings; more effective use of biomass resources; achievement of targets with lower indirect effects; encouragement of localised production; and a degree of self-sufficiency and diversification of supply and distribution channels are all potential benefits that could arise from some of the high blend options included in this report

2.5 Potential for GHG savings

2.5.1 Vehicles

It is possible to consider a broad analysis of the potential for GHG savings. The following analysis of the UK road transport fleet by sector illustrates a number of key points about where effort on GHG savings could be focussed (see Table 2.13).

Table 2.13 UK vehicle parc profile

	$MtCO_2$ p.a.[1]	UK parc[2]	Av CO_2 per vehicle (t/v p.a.)[3]	Typical CO_2 per vkm (WTW)[4]	Ownership fragmentation
Cars	68.7	27 m	2.54	162 to 180	High
Vans (LGV)	19.9	3.4 m	5.9	220 to 300	Medium
Trucks (HGV)	25.8	0.7 m	36.9	600 to 1200	Low
Bus	4.9	0.1 m	49	700 to 1475	Very Low

Notes:
1) TSGB 2008: Chapter 3 Energy and the Environment data tables (2006 data);
2) Vehicles licensing statistics (data tables) from Transport Statistics Bulletin Vehicle Licensing Statistics 2007
3) Derived from sources 1) and 2);
4) Derived from analysis in this study of typical WTW values. Note, Car range is for petrol/diesel values, whereas LGV/HGV/Bus are for diesel but allow for a wide range of vehicle weight.

Table 2.13 clearly shows that cars produce the greatest contribution to road transport GHG emissions and make up the largest proportion of the vehicle parc. Based on the same DfT/Defra report used for $MtCO_2$ p.a. (DfT TSGB, 2008) the division between volumes of petrol and diesel fuel consumed by cars and taxis is at a ratio of 78:22. If adjusted for the higher CO_2 content of diesel the ratio is 75:25 (based on RED values of 32 MJ/litre for petrol and 36 MJ/litre for diesel). This suggests, based on these data sources, that for the existing parc petrol cars contribute some 51.5 Mt CO_2 p.a. and diesel cars contribute some 17.2 Mt CO_2 p.a. of the 68.7 Mt CO_2 p.a. figure shown in Table 2.13. However, sales of new passenger cars are more recently showing 40% for diesel vehicles. This is steadily reducing the share of emissions from petrol cars and is pertinent when considering the proportion of petrol/diesel engines used in the future car market and the potential for relevant high-blend fuels penetration levels (e.g. E85 vs. B30).

Further analysis of GHG emissions per vehicle km or by vehicle weight (tonnes/vehicle) show, however, that individual passenger cars have the lowest impact of all vehicle types. This, combined with a high degree of ownership fragmentation, means that if investment and effort are required to increase use of high-blend biofuels, it will tend to be less cost-effective (per tonne of CO_2 reduced) compared to targeting fleets with fewer owners/operators and with higher average GHG emissions per vehicle. This supports the current strategy of providing low-blend biofuels for the majority of passenger cars (at low/no cost to the owner). However, the technology development of some major manufacturers of passenger car and car-derived is pointing towards increasing flexibility to use higher blends (e.g. B30 and E85). If high-blend fuels could be made available (at a reasonable infrastructure cost) alongside low-blend fuels there is an opportunity to reduce a significant overall source of GHG emissions.

In the long term, it will be more economically efficient to concentrate on comparative advantage of technologies in each sector than blanket approaches across all sectors. High blend approaches offer the possibility to focus extra effort in particular sectors.

Given the relatively low number of HGVs and their comparatively high contribution to CO_2 emissions, this sector presents the greatest potential to reduce GHG emissions and should be the priority for using low carbon (bio) fuels at high-blend levels.

The significant CO_2 emissions per bus, low overall number of owners and depot-based nature of bus operations means this sector still provides a very worthwhile 'fast-track' option for GHG reductions. Reforms to the Bus Service Operators' Grant announced in the Budget 2009 confirmed that "operators will receive per-kilometre payments for the low-carbon buses that they operate to incentivise their introduction", which will include biomethane powered vehicles.

Examining the van fleet, the overall contribution of 19.9 $MtCO_2$ p.a. is considerably greater than for buses, but the much greater number of vehicles (3.4 m) means a lower overall contribution on a tonnes per annum basis. They are, however, contributing more per vehicle than cars, due to relatively higher mileage and engine capacities. Light/Medium Goods Vehicles registrations have been experiencing the fastest growth sector in vehicles/mileage (20% growth in 5 years) and these vehicles tend to have high individual average mileages. As a result, it could be argued that van fleets provide a good opportunity for GHG reductions.

In terms of future growth, then DfT's Road Transport Forecasts from 2007 provide an indication of likely trends. It can be seen from Table 2.14 that the greatest growth is forecast in the LGV sector, followed by cars and taxis. Heavier goods vehicles are predicted to grow marginally and bus/coach not at all.

Table 2.14 Forecasts of road traffic in England (v/km): 2010-2025

Veh km (England)	2003	2010	2015	2025
Cars & taxis	100	111	120	127
Goods vehicles	100	104	106	112
LGV	100	117	134	167
Bus and coach	100	100	100	100
All motor traffic	100	111	121	131

Index: 2000 = 100
Goods vehicles: above 3.5 tonnes

2.5.2 Fuels

LowCVP FWG members recommended that the following fuels were not taken forward to the options assessment.

- Hydrogen (liquid and gaseous);
- E-diesel (15% bioethanol, 85% diesel); and
- Biobutanol.

Hydrogen did not fulfil the study scope for examining current or near to market fuels, biobutanol for the same reason and E-diesel due concerns over safety and availability.

LowCVP FWG members recommended the following fuels be taken into the option assessment stage of the study, because they are relevant to current commercial operations or close-to-market:

- Biodiesel (first generation, i.e. FAME);
- Bioethanol;
- Biomethane; and
- Pure Plant Oil.

It was also recommended that the study examine second generation biodiesel (Biomass To Liquid process) and Hydrogenated Vegetable Oils and compare where useful. It was agreed that because high-blend versions of these fuels are not currently available to vehicle operators the evidence and data on practical use is lacking and thereby the analysis should be less detailed than for other high-blend biofuels.

3 DRIVERS, BARRIERS AND SUPPORT MECHANISMS

3.1 Introduction

This chapter considers the motivations for current levels of interest from various types of organisation in high blend biofuel. Examples of high-blend biofuels in use with UK fleets are to be found in the Annexes corresponding to each fuel type.

The chapter also identifies and then, examines the barriers encountered by those wishing to expand the market for such fuels and highlights the types of action that might be needed to overcome the barriers on the way to market expansion.

Much of the information on which this chapter is based was collected directly from a range of stakeholders, via a three stage process. Firstly, stakeholders from a range of organisations were invited to complete an on-line response form with a series of questions designed to collect their views (on barriers, drivers and support mechanisms). Where further information was offered, this was followed-up by interviews with a number of representatives from such organisations. The third stage of the process was a workshop to review the key barriers and to look in more detail at the support mechanisms that might be used to overcome these.

The chapter also includes a section on current and forthcoming policy, legislation and government reviews, as these are important influences on the development of markets for high-blend biofuels.

3.2 Drivers

A range of motivations lie behind an interest in high blend biofuels, as identified during the consultation process. Some of these ‘drivers’ apply to many different types of organisation, whereas others apply to a specific sector, for example fuel producers or vehicle manufacturers.

An issue raised frequently during the consultation process was the environmental concerns of the organisation and their wish to take steps towards carbon reduction. A consultation question asked organisations to identify the main motivations for running vehicles on biofuels and, of the 14 organisations that chose to answer this question, 12 identified environmental image or environmental benefits such as carbon reduction for their interest in high-blend biofuels. Examples of why organisations are choosing to use biofuels included a *“commitment to environmental management”*, *“implementing sustainable biofuels as part of a Carbon Reduction Programme that aims to reduce company emissions by 75%”* and to gain *“greater knowledge of operating with these fuels and be seen to be active in this area”*.

For vehicle operators, environmental image and credentials are an important consideration, whereas for the fuel producers and suppliers it is the environmental concerns of their customers (i.e. the vehicle operators) that is the driver (or pull factor) that provides the motivation to develop supply chains. Organisations involved in supplying and distributing fuels are in a key position in providing the link between fuel producers and fuel users, and as such are keenly aware of the drivers and motivations operating within the supply chain. One fuel supplier reported that the main driver for their business was *"Customers interested in reducing GHG emissions from fleets on a well to wheel basis",* and another that *"Our customers understand the benefits and have a positive approach to CSR".*

Other motivations identified across the range of organisations responding to the consultation included the RTFO financial considerations, the role of financial support mechanisms and subsidies (for example fuel duty incentives) and the potential for cost savings and increased profits from direct use of high-blend biofuels.

A small number of organisations also mentioned the need for energy diversification and reduced dependence on fossil fuels, although it is likely these are not short-term issues affecting their day to day operation.

Organisations involved in the supply of feedstocks identified the following drivers and motivations:

- Opening of new market opportunities, and the potential for this market to grow in future;
- Diversification of the customer base;
- Less stringent requirements for profitable biofuels compared to processing of food-stuffs;
- Finding new or alternative use for a product – e.g. waste, biomass;
- Benefits/attraction of local procurement channels and stability of demand.

In particular, the use of what would otherwise be a waste product was identified as a key driver for those involved in biomethane production. In contrast, for oil-seed based fuels the fuel vs. food decision was illustrated thus: *"One of our PPO suppliers…, can't afford the investment in food grade crushing equipment, and so presses for the biofuel industry."*

Organisations involved in operating vehicles are mainly motivated to use high-blend biofuels because of their environmental credentials, with some also attracted by the potential for improved vehicle performance and reduced wear.

Organisations involved in vehicle and component manufacture identified the following motivations for their interest in high-blend biofuels:

- Opportunity to learn ahead of second generation biofuel availability;
- Opportunity to demonstrate alternative vehicles;
- Potential future growth market; and
- Customer demand.

Such motivations are encapsulated by one vehicle manufacturer as follows "*Consumer demand for cleaner less expensive fuel sources is growing. This is an under-developed market in which huge growth is possible, particularly for smaller innovative companies able to react more rapidly to market futures. Benefits are commercial, environmental and will impact on company sustainability.*"

3.3 Relevant policies

Existing and forthcoming policy drivers affecting the vehicle parc and use of fuels include legislation, regulations and reviews arising from the European Commission and at national level from UK Government.

3.3.1 Legislation

EU Biofuels Directive and supporting legislation

The European Union has developed a number of policy instruments importance to the increased supply of biofuels.

The European Union "Biofuels Directive" (Directive 2003/30/EC) requires Member States to set and achieve targets for increased use of biofuel. Indicative targets were set at 2 percent for December 2005 and 5.75 percent for December 2010 (on an energy basis).

Amendments in 2003 to the Energy Taxation Directive (Directive 2003/96/EC) allow Member States to provide financial support for biofuels in the form of reduced fuel excise duty (subject to State Aid control) which the majority do. In addition, the European Common Agricultural Policy provides subsides for energy crops (including wheat but excluding sugar beet) grown on set-aside land.

In response to the EU Biofuels Directive the UK developed the Renewable Transport Fuel Obligation (RTFO).

Carbon emission standards for cars

The European Union has agreed demanding, mandatory carbon emission standards for new cars, with a specific target of 130g CO_2/km from vehicle technology averaged across the new vehicle fleet to be achieved by 2012 and 95 g CO_2/km in 2020. In 2007 the average UK passenger car was 164.9 g CO_2/km and the 2008 average was 158.0 g CO_2/km.[40]

EU Renewable Energy Directive

Both the Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD) were adopted in December 2008 as part of a package of six laws on energy and climate. The Renewable Energy Directive centres on a legally-binding European target for 20% of all energy types - electricity, heat and transport fuels - to come from renewable sources from 2020. The major cornerstones of the RED are the reduction of GHG emissions and the security of supply.

The RED is a comprehensive framework bringing together all sectors, which have so far been covered by different directives. As the most important piece of legislation to promote renewables, the RED replaces the Biofuels Directive (2003), which set an

[40] SMMT, 2009.

indicative target for the use of biofuels of 5.75% by energy in 2010. The RED target is 10% by energy by 2020, approximately 12% by volume (depending on the mix of Petrol/Diesel).

This target seeks to turn around slow growth in European biofuel use in petrol and diesel, since the targets in the existing Biofuels Directive (2003) - to expand the 0.5% proportion of biofuels in road transport fuel to 2% by 2005 and 5.75% by 2010 were unlikely to be met. In the first year of the UK's RTFO (2008/9) the volume of biofuel supplied accounted for 2.6% of the fuel supplied for road transport in the UK.[41]

The Commission has suggested certification schemes to promote the use of bioethanol and biodiesel from agricultural crops. It believes that biofuels could contribute 14% of the European transport fuels market by 2020 - the equivalent of 43 million tonnes of oil a year.

Reflecting the controversy of some biofuel production methods, the Renewable Energy Directive requires greenhouse gas savings of at least 35% in using biofuels towards the transport fuel target. This rises to 50% GHG savings in 2017. It also states that land with a high biodiversity or carbon stock should not be used to produce biofuels.

Member States are expected to communicate their National Action Plans on renewable energy by June 2010.

EU Fuels Quality Directive

Adopted in late 2008 at the same time as the RED, the Fuels Quality Directive (FQD) substantially amended a 10-year old Directive (98/70/EC) that sets technical specifications based on health and the environment for fossil fuels. Directive 98/70/EC was first changed in 2003 and then had to be reviewed two years later partly due to consideration of biofuels.

The amendment to Directive 98/70/EC on environmental quality standards for fuel aims at:

- further tightening environmental quality standards for a number of fuel parameters;
- enabling more widespread use of ethanol in petrol; and
- introducing a mechanism for reporting and reduction of the life cycle greenhouse gas emissions from fuel.[42]

Contrary to the existing provisions of Directive 98/70, in which biofuels are merely mentioned as one of several fossil fuel components, the amended text gives the strong impression that the Directive is now a law on biofuel quality standards. This is mainly due to the fact that the new directive introduces a mechanism to monitor and reduce GHG emissions, the so-called decarbonisation mechanism.

[41] RFA website (http://www.renewablefuelsagency.org/rfa/news&pressreleases) viewed August 2009
[42] Europa Press Release, http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/08/800

Annex II of the FQD allows up to 7% biodiesel blend and Member States are permitted to market higher biofuel blends[43]. Specifications to enable 7% biofuels to be used in all new vehicles have been developed by CEN, with representation from vehicle manufacturers.

The EU committed itself under the Kyoto Protocol to reduce GHG emissions by at least 20% unilaterally by 2020 and by 30% if a global agreement can be reached. All sectors will need to contribute to these goals. The combustion of road transport fuel is responsible for around 20% of community GHG emissions. Therefore the new FQD requires fuel suppliers to reduce life cycle GHG emissions of the fuel they put on the market. By 2020 they need to achieve a (mandatory) reduction of at least 6% compared to the EU-average level of GHG emissions in 2010 with possible interim targets of 2% by 31 December 2014 and 4% by 31 December 2017. The fuel suppliers are free to choose how to achieve these targets. They can either decrease their emissions by reducing flaring and venting at production sites (upstream) or by using more biofuels or alternative fuels (downstream).

Biofuels used for compliance with the GHG reduction target need to comply with the sustainability criteria, which are defined by the Renewable Energy Sources Directive (RED) and have been entirely copied into the FQD. An additional (indicative) 4% reduction may be obtained through the use of carbon capture and storage technologies and electric vehicles (2%) and the purchase of credits under the Clean Development Mechanism of the Kyoto Protocol (2%). The total required reduction by 2020 could therefore be increased to up to 10%. The strong link between the RES-D and the FQD is not only demonstrated by having the sustainability criteria in common but also through the fact that a review of this decarbonisation mechanism needs to take place in 2014.[44]

Climate Change Act

UK Government is also significantly expanding the scope of its policies in this area. The Climate Change Act 2008 (CCA) aims to create a new approach to managing and responding to climate change in the UK through: setting ambitious targets, taking powers to help achieve them, strengthening the institutional framework, enhancing the UK's ability to adapt to the impact of climate change and establishing clear and regular accountability to the UK, Parliament and devolved legislatures. The CCA sets binding legal commitments to reduce UK CO_2 emissions, which aim to reduce emissions in 2050 by 80%.

3.3.2 Regulations

Renewable Transport Fuel Obligation

The UK's Renewable Transport Fuel Obligation (RTFO) Programme forms one of the Government's main policies for reducing greenhouse gas emissions from road

[43] FQD 2009/30/EC published in OJ L140 of 5 June 2009
[44] Biofuels International - The new EU directive on fuel quality standards and its implications, http://www.biofuels-news.com/content_item_details.php?item_id=143

transport, and places an obligation on fuel suppliers to ensure that a certain percentage of their aggregate sales are made up of biofuels. The RTFO commenced on 15 April 2008, and can be met by supplying biodiesel and bioethanol in a variety of blends and also with biomethane.[45]

The targets for the RTFO for the first three years are set out below. The targets for biofuel as a percentage by volume of road transport fuel are mandatory with a buy-out permitted, while the targets for sustainability are indicative of expected performance. RTFO targets are 2.5% volume 2008/9, 3.25% 2009/10, 3.5% 2010/11, 4.0% 2011/12, 4.5% 2012/13, 5.0% 2013/14. In the first year around 2.6% was achieved by obligated suppliers, in excess of the target.

Table 3.1 RTFO targets by year

Year:	**2008/09**	**2009/10**	**2010/11**
Biofuel use by volume	2.5%	3.25%	3.5%
Environmental sustainability standard	30%	50%	80%
Greenhouse gas emissions reduction	40%	45%	50%

It should be noted that the target of 2.5% biofuel in the total road transport fuel supply has been compromised by the identification of a drafting error in the RTFO Order. As a result fossil fuel supplied as a blend with biofuel in 2008/09 did not incur an obligation. The provisional total for legally obligated fuel in 2008/09 is 21 billion litres (less than half of the total road transport fossil fuel supply of 46 billion litres), putting a total obligation on all fuel suppliers of about 500 million litres. As about 1.3 billion litres of biofuel were supplied, this means that nearly two and a half times the number of certificates needed to meet the 2008/09 obligation have been issued.[46]

It can be noted that 5% by volume target represents the maximum biofuel content allowed by European Specifications to be sold on the forecourts as standard petrol or diesel at the time the legislation was drafted. Therefore, the main influence of the RTFO is to encourage provision of a large volume of low-blend liquid biofuel, taking into account the composition of the existing road transport fleet. European specifications (EN standards) are being revised to enable higher blends of biofuel to be used as a component part, for example B7 is now allowed and E10 by 2011-2012. These are still relatively low blends however, compared to the proportions some vehicle manufacturers will warranty their vehicles to use.

By encouraging the supply of renewable fuels, the RTFO was intended to deliver reductions in carbon dioxide emissions from the road transport sector of 2.6 - 3.0 million tonnes per annum (equivalent to carbon savings of 700,000 - 800,000 tonnes).

[45] DfT (2008) - Carbon and Sustainability Reporting Within the Renewable Transport Fuel Obligation
[46] RFA (http://www.renewablefuelsagency.org/rfa/news&pressreleases) viewed August 2009

The RTFO targets for mixing a proportion of biofuel into traditional fuels follow the EU's 2003 Biofuels' Directive. This directive suggested that countries should set targets of 5.75 per cent of road fuels as biofuel by energy content. The UK target of 5% by volume is around 4% by energy. .

Since the Gallagher Review of biofuel sustainability the Government has delayed the introduction of the requirement for biofuels to comprise 5% of road transport fuel, from 2010/11 to 2013/14. It has kept the EU target of 10 per cent by energy by 2020 and is now working on the legislation to implement the Renewable Energy Directive which was published in the Official Journal in June 2009 (see section 2.4).

The EC are to report on sustainability in December 2009, and make proposal for a methodology for taking into account Indirect Land Use Changes (ILUC) in December 2010. One view is that incorporation of ILUC may restrict the supply of sustainable biofuels and/or reduce the GHG savings which may be achieved. An EC review will take place in 2014.

Alternative Fuels Framework

The establishment of an Alternative Fuels Framework (AFF) by the UK Treasury was set out in the 2003 Pre-Budget Report to guide the duty regime for alternative fuels.[47]

The framework sets out principles which can be applied to all types of fuel. The purpose of the framework is to ensure that policy continues to reflect the environmental benefits that alternative fuels can deliver and to establish a clear rationale for decisions on Government support. Key aspects of the framework have been described by Government under the headings shown in Box 3.1 below.

Box 3.1 – Alternative Fuels Framework guidelines

Statement of principles:

- Policy must be environmentally sustainable. Levels of support should reflect the full environmental impact of the fuel.
- Policy must be economically sustainable. The Government should not support an industry whose long-term survival is dependent on excessive levels of subsidy unjustified by environmental benefit.
- Policy must be socially sustainable. Support should reflect broader considerations of social impact and fairness.
- Policy must be affordable and provide value for money. Where fuels fulfil the criteria set, support will be given where it is both cost effective and affordable.

The Importance of Certainty:

- the Government recognises the importance of providing as much certainty as it can on duty differentials, to help provide the necessary stability, confidence and market conditions for investors. The Government will therefore commit to a rolling three-year period of certainty on the differentials in duty rates for alternative fuels.

The Environmental Case:

- the central priority will continue to be on environmental gains, with the emphasis being on quantified benefits that are based on the life-cycle carbon performance of the fuel. Recognising the comparatively high cost of carbon reduction in the transport

[47] Pre-Budget Report, HM Treasury, 2003

sector, the Government will nevertheless seek to meet key environmental objectives in a cost-effective way; and
- the Government will take account of fuels that have additional environmental benefits by, for example, improving air quality and reducing waste.

The Economic and Social Case:
- the Government will only offer support beyond that justified by environmental benefit if there is clear evidence that this support will result in enhanced future benefit;
- in assessing the level and types of support available, the Government may also take into account other benefits to the economy arising from the use of alternative fuels; and
- where there is a direct link to Government priorities, and clear and well established evidence of benefit.

The guidance notes that, in the Government's view, duty incentives alone can be a very blunt instrument, so where there are clear reasons for incentives to be more focused on specific objectives, the Government will also consider other means of support, such as capital incentives, grants or regulatory solutions which may be more suitable, better targeted and better value for money.

The AFF is sufficiently broad in scope to be used for reaching a decision to either support or withdraw support for (high-blend) biofuels. Fuels currently listed under the Alternative Fuels Framework are LPG and Natural Gas (including biomethane). It was recently announced that under the AFF mechanism biomethane will continue to enjoy a duty differential against fossil fuels beyond April 2010.

3.3.3 Policy setting reviews and funding initiatives

The Stern Review

The Stern Review [48] on the Economics of Climate Change for the UK Treasury, released on October 30, 2006, by economist Lord Stern of Brentford, discusses the effect of climate change and global warming on the world economy. Its main conclusions are that one percent of global gross domestic product (GDP) per annum is required to be invested in order to avoid the worst effects of climate change, and that failure to do so could risk global GDP being up to twenty percent lower than it otherwise might be. Stern's report suggests that climate change threatens to be the greatest and widest-ranging market failure ever seen, and it provides prescriptions including environmental taxes to minimise the economic and social disruptions. In June 2008 Stern increased the estimate of investment required to offset climate change to 2% of GNP to account for faster than expected climate change.

UK Climate Change Programme

As context to reductions that might be possible via high-blend biofuels, the UK Climate Change Programme (Defra, 2006) predicted base case emissions for 2010 transport emissions at 46.5 MtCe. This is equivalent to 170.66 $MtCO_2e$, which is the

[48] Nicholas Stern (2006) - The Economics of Climate Change - The Stern Review

standard way of presenting GHG emissions in this study. From the programme, planned initiatives to reduce emissions by 2010 were as follows:

- Measures included as part of the 2000 Climate Change Programme - 5.1 MtCe (equivalent to 18.7 $MtCO_2e$);
- The voluntary agreement package including reform of company car taxation and graduated vehicle excise duty (2.3 MtCe), wider transport policies (0.8 MtCe) and the planned fuel duty escalator (1.9 MtCe) being the main contributors (equivalent to 18.3 $MtCO_2e$); and
- RTFO and improving the efficiency of new vehicles - 1.7 MtCe by 2010 (equivalent to 6.24 $MtCO_2e$).

It should be noted that latest 2007 Defra figures for transport emissions by end-user in fact lower, at 156 $MtCO_2e$ (including the small contribution from domestic aviation), and it is this figure that estimated GHG savings from biofuels will be compared against in this study.[49]

UK Biomass strategy

It has been acknowledged in the UK's Biomass Strategy[50] that using biomass in heat and power applications is generally more cost effective than biofuels. However, the same strategy notes that biofuels offer one of the few routes in the short term to reduce carbon emissions from transport, where total emissions are rising. In contrast, the power generation sector has a number of possible sources, including wind, tidal and solar. Finally, improvements in production processes are anticipated to improve biofuel cost-effectiveness, but clearly this requires investment and demand in order to bring these effects into play.

The King Review

The Chancellor commissioned Professor Julia King to undertake an independent review to examine the vehicle and fuel technologies which over the next 25 years could help to decarbonise road transport, particularly cars. Part I of the Review, published on 9th October 2007, set out the potential for reducing CO_2 emissions from road transport.[51] The report had a positive message: that there is significant potential to reduce CO_2 from cars, both in the next few years and in the medium and longer term, and that this could bring considerable benefits for the UK. It set out the role that more efficient vehicles, cleaner fuels and smarter consumer choices need to play in reducing emissions. The key findings on the potential for CO_2 reduction were that:

- almost complete de-carbonisation of road transport is a realistic long-term objective, through electric or hydrogen-powered vehicles. This will require major technological breakthroughs as well as substantial progress towards de-carbonising the power sector.
- at low cost and by 2030, per kilometre emissions could be reduced by 50 per cent - equivalent to a 30 per cent reduction in the absolute level of emissions, assuming continued travel demand growth.

[49] http://www.defra.gov.uk/environment/statistics/globatmos/download/xls/gatb05.xls
[50] Defra, UK Biomass Strategy, 2007.
[51] HM Treasury (2007) – The King Review of Low Carbon Cars (Part 1).

- fuels must be considered on the basis of their life-cycle CO_2 emissions. Biofuels can occupy a segment of the UK fuel market but care must be taken not to expand demand too quickly, before crop breakthroughs and robust environmental safeguards are in place.

These significant reductions in CO_2 from road transport are achievable in the short term through progress on bringing new technologies to market and smart consumer choices such as buying a low-carbon vehicle, as well as some contribution from biofuels.

The King Review Part II, published on 12th March 2008, picked up on these challenges and made a series of recommendations aimed at ensuring that government, industry, the research community and consumers all contribute to realising this potential for reducing CO_2 emissions.[52] A key recommendation was for Government to set a long-term direction for policy that has CO_2 reduction at its heart, rather than any one method of achieving it. Different technologies are likely to offer the most potential to reduce CO_2 emissions in the short, medium and long term. Good policy should target CO_2 reduction in recognition that the most efficient methods are likely to change over time.

The King Review concluded that in the short term, while the internal combustion engine remains dominant, the scope for decarbonising fuels (rather than making vehicles more efficient) may be largely determined by the scope to expand biofuels sustainably as other possible low-carbon fuels cannot be widely used in the current vehicle stock.

However, in the longer term it is likely that there will be significant scope to decarbonise fuels through using electricity and hydrogen (where low CO_2 production routes are available) as well as through new biofuels that have very low productive land requirements. By 2050, a carbon free fuel mix is a possibility – although this is likely to be largely dependent on the degree to which electricity generation can be decarbonised and will also require developments in vehicle technology.

Low Carbon Transport Innovation Strategy and Platform

The Low Carbon Transport Innovation Strategy[53] (2007) sets out a wide range of measures that the Government is taking to transform the market for lower carbon vehicles. These include:

- adjusting the Vehicle Excise Duty (VED) and company car tax regimes to further encourage the purchase of lower carbon vehicles and support for the move to demanding and mandatory CO_2 standards for new cars at a European level; and a

- low carbon vehicle procurement programme that has an initial £20m of funding, to support the public procurement and demonstration of innovative lower carbon vehicles in fleets of public organisation. Initially targeted at

[52] HM Treasury (2007) – The King Review of Low Carbon Cars (Part 2).
[53] DfT (2007) - Low Carbon Transport Innovation Strategy.

vans, a second potential phase will target a different sector of the vehicle parc.

In parallel the Low Carbon Vehicle Innovation Platform (LCVIP) launched by the Technology Strategy Board and the Department for Transport (DfT), is allocating up to £20m of funding to support low carbon vehicle research, development and demonstration projects.[54] This is the first competition under the Low Carbon Vehicles Innovation Platform, which seeks to position the UK's automotive sector to benefit from growing public and private sector demand for lower carbon vehicles.

The competition is focussed on bringing forward relatively near market low carbon vehicle technologies, whether for private or public service vehicles, that could be viable candidates for commercialisation or fleet procurement initiatives over the next five to seven years.

3.4 Barriers

A range of barriers have been identified through the stakeholder consultation process and an overview of these is given below:

Table 3.2 Barriers to use and market expansion of high-blend biofuels

General: • Fuel quality control • Lack of fuel standards • Access to infrastructure / limit on infrastructure in existing fuel networks • Lack/uncertainty of long term regulatory/fiscal policy • Lack of clear government signal regarding technology / fuel roadmap • Lack of long term incentives • Negative press / public image • Cost concerns (vehicles, infrastructure) • Fuel prices relative to fossil fuels; duty derogation issue • Warranty issues/Restrictions by motor manufacturers on the use of high blends in existing vehicles • Lack of knowledge/clear information • Sustainability concerns, and lack of sustainability standards for feedstocks • Uncertainty in the long term market limits investment • Customer confusion about fuels, options and other issues
Feedstock supply: • Weak supply chain structure • Limited acceptance by fuel providers • Changes in fuel manufacturers requirements • Cost of inputs • Fluctuation of fuel prices, making margin management difficult
Production and distribution:

[54] Technology Strategy Board (2007) - Low Carbon Vehicles Innovation Platform First Technology Competition.

• Availability of feedstock • Poor RTFO implementation • Costs of raw materials • Competition from subsidised producers in the US • Difference in approaches across the EU has fragmented the market • Requirements for small-batch fuel blends
Vehicle operators: • Sourcing quality fuel/ availability of fuel • Availability of suitable vehicles • Fuelling infrastructure • Fuel economy and range • Servicing • Whole life cost (inc residual value) • Training for different vehicle driver/maintenance requirements • Possibility of unintended impacts on toxic emissions from vehicles
Vehicle manufacturers: • Transition period with legacy vehicle stock • Changes to operating practice • Unsuitability of current engine management systems • Customer reluctance • Image of biofuels compared to electric and hybrid technology

A number of key issues were identified from the full list of barriers above during a workshop with LowCVP FWG and PCWG members for more detailed consideration.

The key issues identified during the workshop were as follows, each which is reported on in sections below:

1. Constraints in the existing fuel distribution network, including forecourt capacity;
2. Lack of guidance on high-blend fuel quality control;
3. The availability of vehicles;
4. Additional capital and operational costs;
5. Uncertainty on the sustainability of some biofuels and related policy;
6. The present public perception/ media image of biofuels;
7. Lack of long term policy and government direction for high blend biofuels;
8. Lack of long term incentives (financial support mechanisms).

3.4.1 Constraints in the existing fuel distribution network

Organisations within each stage of the supply chain and fuel distribution networks report issues related to supply and demand of biofuels.

Feedstock providers need to be sure of a market for their product in the long term, in order to plan ahead. Uncertainty in long term policy also means that the future for supplying feedstock to the biofuel industry is uncertain; farmers need to have a good idea of the future demand and future market in order to make sure they are producing crops that will sell. A long term view is required for planning perennial crops, and for new crops that require any significant investment. Due to the fluctuation in oil prices, both the biofuel pump price and the demand for biofuel feedstocks fluctuate, and this makes it difficult for feedstock suppliers to calculate and predict the margins they will earn on supplying to the biofuel industry.

Because of these issues, biofuel producers can have difficulty in obtaining the feedstock, as farmers choose to produce other crops, or supply to other industries.

High-blend biofuels are currently distributed by a range of UK based companies, purchasing fuels for blending to own-specification products or for holding locally for onward distribution to key customers. Feedback from stakeholders / LowCVP members involved in distribution of high-blend biofuels has included information on expansion plans for current distribution networks, but which also require clear policy signals to encourage a sustained market on which to base the business plan.

These supply side constraints in turn cause supply issues for vehicle operators. When choosing to operate a fleet on a particular high blend biofuel the fleet operator needs to know that the required fuel will be available not just in the immediate term but also in the longer term, particularly if the decision involves investing in specific vehicles. Supply issues can be either in obtaining the fuel directly, for on-site or depot based operations, or in the limited availability of fuel at the forecourt.

For vehicle manufacturers the supply of fuel is also an issue, with the limited availability of fuels on the forecourt representing a significant barrier to the market for vehicles operating on these fuels. For users to invest in alternatively fuelled vehicles they need to know that the fuel is available and will continue to be available in the future.

The issues of supply, demand and availability are closely linked with those of sustainability and fuel quality control: vehicle operators and vehicle manufacturers want fuels to be of a consistent quality and to fulfil sustainability requirements. More details about these issues are given below.

3.4.2 Fuel quality, standards and proliferation of blends

There have been problems with customer acceptance of high blend biofuels due to the variable quality of the fuels available. Poor quality fuels can lead to problems in the vehicle, for example by having an effect on vehicle performance, or by causing technical problems requiring additional maintenance and repair. Fleet operators need to know exactly what the fuel they are using is, and that it will perform as expected.

A related issue is that of vehicle warranties. Many vehicle manufacturers will invalidate the warranty for vehicles if high blend biofuels are used. This discourages customers from using these fuels, and causes customers to feel uneasy about using these fuels even in vehicles that are no longer within their warranty period. A key issue to overcome is that of obtaining approval for biofuel use within the existing vehicle fleet, and this is addressed in more detail in section 3.5

Many consultees expressed the opinion that clearly defined standards for specific blends of biofuels would create a common reference point and give customers greater confidence and peace of mind in using high blend biofuels. Fuel standards could also give vehicle manufacturers greater confidence to test fuels, set guidelines on, for example, different maintenance requirements and then allow specific fuels to be used within the vehicle warranty period. If a number different specifications exist, it is difficult for manufacturers to know to which they should design their vehicles. Agreed specifications for each fuel are required by technology providers; without a specification it is very difficult for them to understand what it is that needs to be provided. Fuel standards would also give fuel producers and distributors a common set of standards to work to.

It is clear from the consultation that there is quite a lot of confusion around fuel quality standards. Three key standards are relevant to this study, which are those establishing specifications for fuels in the European Union:

- EN 14214 includes specifications for fatty acid methyl ester (FAME) fuel for diesel engines, up to B100. FAME biodiesel that meets this standard can be used in a diesel engine (if the engine has been approved to operate on biodiesel) or blended with petroleum diesel fuel;
- EN 590, the European diesel fuel specification, is also applicable to biodiesel blends currently up to 5% of FAME;
- EN228, the current European specification petrol, covers fuels that can contain up to 5% ethanol; and
- EN15376 specifies ethanol for use in EN 228.

The current EN fuel standards enable E5 and B7 blends of biofuel. B7 could be available now, with pump labelling. A new EN228 standard allowing E10 will be available by 2011-2012. Fuel industry representatives assert that E10 and B7 will produce around 6% by energy in all transport fuels (see section 2.4) and therefore if it could be deployed across the whole fleet meets RED and FQD requirement to around 2015/16. The benefit of this timescale to conventional fuel suppliers and vehicle manufacturers is that it provides time to make further changes to fuels and their standards in line with technology developments and progress towards 2020 targets of 10% by energy. Pushing ahead of this development plan naturally meets with resistance due to the investment and participation in the currently mandated process. However, from section 2.4 of this report we see a justification for greater use of high-blend biofuels because of the risk that this pace of progress may in fact not be sufficient to keep the UK on track with RED targets.

Fuel quality issues and the variability of biodiesel from different feedstock is a significant concern to the vehicle manufacturers, and a number of vehicle operators consulted during this study. This signals a clear demand for standardised definitions of fuel quality criteria. A key question seems to be whether these should be defined and for which fuels and blends. In answer, CEN standardisation for blended fuels (covered by EN590 and EN228) is progressing to higher biofuel blends. It is very likely to progress sequentially in line with the minimum RED/FQD requirements for future years and there will be a significant gap between these standards and that which can be reached by high-blend biofuels. However, EN 14214 for biodiesel and standards for pure ethanol EN 15376 do exist and so can be used to define the biofuel element blended into the EN 590 or EN228 product.

It seems unrealistic to expect engine manufacturers to produce all their engine range with an ability to operate at all blends of biofuel, which is a potentially costly capability that could also be largely redundant if the fuel is not then made available or consumers can choose not to use it. However, current inconsistencies in approach and difficulty in obtaining information undermine the confidence of some vehicle operators to use biofuel with the range of vehicles currently available and compatible.

A very relevant issue is how well fuel is stored and handled during the distribution process. There are reported problems with conventional diesel that can contain up to 5% biofuel. These should be addressed by adherence to fuel specification standards, but it is likely that poor handling after production and through the distribution chain that is the source of degradation of the fuel.[55] It will important that this is addressed as EN 590 specification raises the limit of biofuel to 7%. If there are lessons to be learned this may help improve the distribution and storage practices for higher-blend biofuels as well.

A number of consultees expressed the opinion that a proliferation of different fuels and blends are confusing for the end-user. Critically, for fuel producers, supplying a larger number of blends is more expensive and therefore less commercially viable. There is a limit to the number of fuels that can be made available at forecourts. Each filling station has a set number of storage tanks (which the number of pumps feed from) and are therefore must make a choice about what they supply. There are also concerns that too much choice on the forecourt will lead to confusion for consumers. This suggests that, for fuels targeted for forecourts in particular, a limited set of fuel types and blend should be promoted. There is, clearly, greater scope to use custom blends in specialist fleets with their own refuelling facilities – for example for bus fleets and other depot based fleets – but even in these cases setting up some robust biofuel pathways for some core types/blends of fuel should bring benefits and economies of scale.

3.4.3 Sustainability issues

The need to reduce carbon emissions is a key driver for the development of higher blend biofuels. One of the main conclusions of the Stern report was that there "is still time to avoid the worst impacts of climate change, if we take strong action now. The benefits of strong and early action far outweigh the economic costs of not acting."

All organizations are under pressure to reduce carbon emissions and a number of targets are in place to work towards these reductions. For example, the motor industry has been set targets for new cars of a fleet average emission of 120g/km CO_2 by 2012.

Carbon emissions from the transport sector are expected to increase in future years, as a result of increased travel demand. To combat this, the development of and investment in low carbon technologies and fuels is needed.

[55] Commercial Motor magazine, Derv in the detail, 19 March 2009

A large proportion of consultees identified environmental concerns as a key driver for the use of biofuel; this includes those supplying feedstocks, producing and distributing biofuels, operating vehicles and manufacturing vehicles. The nature of the motivation did vary depending on the type of business: for some the main driver was the customer demand and interest in fuels which reduce greenhouse gas emissions, and for others the driver was the environmental image of the organization. The main feedback from the consultation was on reducing carbon emissions; only one consultee mentioned the impacts of biofuel use on emissions of toxic pollutants. However, it is known that for UK local authorities with a twin responsibility to tackle local air pollution and climate change emissions any reduction or increase from use of biofuels on toxic pollutants (such as NO_x or PM) is an important attribute.

Because a key driver for the use of biofuels is the potential for reduced carbon emissions it is important to ensure that the appropriate biofuels are used. The consultation process identified a number of concerns over the sustainability of biofuel production and use, including negative publicity about biofuels and concerns about standards to ensure and certify their sustainability.

The Renewable Fuels Agency has built mechanisms to address sustainability issues into the RTFO reporting procedures, which are being progressively applied as the scheme rolls forward. When biofuel suppliers apply for Renewable Transport Fuel Certificates they are required to submit reports on the net greenhouse gas emissions reductions provided by the biofuels they supply, and the sustainability of the biofuels they supply.

3.4.4 Long term policy and government direction

A large proportion of consultees identified a lack of clear government policy direction and an absence of long term planning as barrier to the take up of high blend biofuels. Another way of looking at this is to say that this is a support mechanism that is currently missing, or not being implemented to its full potential. Examples from other countries in Europe, such as Sweden and Germany, with more robust markets for high-blend biofuel use in vehicles were frequently cited. This issue was raised by all sectors of biofuel supply chain, vehicle manufacturers and consumers. The feeling of consultees is that without a clearer policy for the future it is difficult to plan ahead and to make investments, for example in new or alternative technologies.

As an example, the recent decision from the Department of Transport to consult on amendments to the future path of the RTFO obligations has caused disruption to all sectors of the industry, as it represents uncertainty in the future role of biofuels.

How to set long-term policy levers and what they should be based upon is a key issue to address and is discussed in more detail in section 3.3.2.1.

3.4.5 Long term incentives: financial support mechanisms, subsidies and costs

These aspects are closely related to government policy.

Incentives

The report “Biofuels - At What Cost?”[56] reviews historic and existing support for biofuels across OECD countries including those in the EU which has often taken the form of government subsidies. A common policy used to support biofuels is an exemption from fuel-excise taxes, a support mechanism employed at some point in most OECD countries in which biofuels are consumed. In some areas of the US and Canada biofuels also benefit from exemptions from sales taxes. More recently the focus internationally has instead shifted to subsidising production directly or indirectly instead, for example through income tax credits or payments based on the volumes blended or produced. The overall conclusion from the review is that across the EU many current subsidy and support systems are incoherent, not well thought out and may not be appropriate. The report recommends that, rather than increasing or adding further subsidies, the current systems be revised.

However, for markets where subsidies on fuel exist any removal can have serious consequences. For example, a major issue facing biofuel producers and users in the UK are imminent changes to financial support to biofuels. In the UK biofuel production is supported directly and indirectly through the fuel duty derogation and through the energy aid programme. Energy aid payments amount to €45 per hectare, but are not available to all feedstocks. The fuel duty derogation has been 20ppl since 2002. From 2008 to 2010 biofuels have a combined duty derogation and buy-out price of 35ppl. The duty derogation of 20ppl ceases in April 2010 to be replaced by a penalty of 30ppl related to only the RTFO. This will effectively reduce the price competitiveness of high blend biofuels, resulting in existing high blends being sold between 7 ppl and 15ppl more expensive that their diesel and petrol counterparts, and increasing the price of B5/B7/E5.

The lack of long term incentives for high blend biofuels in the UK is a key issue to overcome and is addressed in more detail in section 3.5.

Obligations: The Renewable Transport Fuels Obligation (RTFO)

The RTFO, which came into effect in April 2008, requires fuel suppliers to include a specified percentage of renewable fuel in the fuel they supply. The percentage varies from year to year: for 2008-9 it is 2.5% by volume. The initial intention was that this would rise to 5% by 2010. However following the Gallagher review on the indirect effects of biofuels production the DfT announced a consultation on the RTFO which has led to a slowdown in the introduction of biofuels so that the 5% by volume target has now to be reached in 2013/14 instead of 2010/11.

The uncertainty in the future path of the RTFO was identified by a significant number of consultees as a barrier to the take-up of biofuels. The uncertainty in regulation and the lack of a clear direction or leadership in government policy were cited as disincentives to invest in the biofuels industry, particularly for feedstock suppliers and biofuel producers.

[56] Biofuels — At What Cost? Government support for ethanol and biodiesel in selected OECD countries, September 2007 - Global Subsidies Initiative (GSI) of the International Institute for Sustainable Development (IISD).

The RTFO acts as a driver for the use of biofuels, and therefore delivers a reduction in the overall carbon emissions from transport, but it gives little incentive to use high blends as in general compliance is being delivered through low blends. A common view is that the RTFO mechanism will not work as an incentive to the use high blend fuels because it is generally easier to meet the obligation using low blend fuels that can be used in existing vehicles. This is compounded by the decision to remove the duty differential for biofuels and allow the RTFO mechanism to be the main stimulant for UK biofuel production and use (as discussed above). High blend fuels require some upfront investment by the user (in time, money or both) and this generally requires some predictability about costs (ideally payback) over a period of time. This leads to a natural bias in favour of technologies that do not require upfront investment.

Fuel price: vegetable oils, biofuels and oil

A significant barrier to increased use of high blend biofuels is the relatively low cost of conventional fuels in comparison (before duty or VAT). Bulk purchasers have sometimes obtained biofuels at lower price than standard fuel in the recent past (due to expensive oil and cheap SME on the market) but generally biofuels cost more without subsidy or support.

A report by the Renewable Energy Association[57] notes that "the net income to the Exchequer from biofuels is made up of a combination of sources, including: Duty on fuels sold; VAT on fuels sold; Company car tax; VED tax; Corporation Tax from the growing biofuels sector; and income tax from employment created in biofuels. The Treasury loses money (in theory) with a duty derogation on biofuels. However, in the case of E85 it gains revenue over diesel vehicles due to the greater volume required to travel the same distance as a diesel car."

There is a strong link between the price paid to biofuel producers and oil prices, given the dominance of conventional refineries in the market for biofuels since the introduction of the RTFO and other similar mechanisms and their wish to manage their costs based on the oil price. Fuel producers report that when the price of fossil fuels falls this makes price matching the biofuel equivalents more difficult, because the costs of biofuel feedstocks are high by comparison. For feedstock providers the fluctuation of fuel prices makes margin management difficult. Until recently EU based biodiesel producers were also reporting strong competition from the US, due to the level of subsidised soy production in the US.

The price of biofuel is a key concern. The current 20ppl duty derogation seeks to reduce the price paid for biofuels to one closer to conventional fuels. When the duty differential is removed the price of most biofuels is normally always higher. The outcome of removing the 20ppl duty differential and relying on the RTFO buy-out price will be a strong disincentive for even existing levels of high-blend biofuel use in

[57] Policy Proposal: REA Submission for consideration of High Blend Biofuels duty rates and Company Car Tax for March 2007 budget

the UK. The exception will be for biomethane, which has been retained within the AFF and will enjoy a duty differential for a further 3 years minimum.

3.4.6 Availability of vehicles

Without vehicles being available no-one will supply alternative fuels and without the fuels being available no one will buy compatible vehicles. This is the quandary that has faced promoters of various fuels.

One approach to widening availability is to produce vehicles which can operate on both standard fuels and high-blend fuels. For example, the on-cost for B30 or E85 over standard fuelled vehicles is a few hundred pounds, and some HGV require few or no modification. For fuels such as biomethane or PPO an approach to market expansion has been for vehicle suppliers to link up with specialist companies experienced at adapting existing vehicle designs to work well with a particular high-blend biofuel (e.g. Volvo with CAP for dual-fuel diesel/methane and Optare for PPO-ready buses).

A related issue to whether a vehicle can be operated with a particular fuel concerns the warranty position of the OEM. In some cases there is a gap between what is technically feasible and the warranty position of the OEM. One explanation is that OEM will have taken a view about whether their advice on maintenance and operational regimes (required for some biofuels) will be carried out. Another barrier is that warranties are country specific as opposed to Europe-wide, which needs challenging. The outcome is a range of warranty positions, depending on the customer, and some customers who would like to operate with high-blend biofuels are discouraged. Overcoming this has been possible in cases where engine retrofit specialists offer warranties for vehicles they modify. In other cases, because users adopt high blends voluntarily they will take a commercial view of the warranty position.

The current availability of vehicles has been reviewed and presented in Chapter 3 of this report. There are a number of vehicles that can be used with high-blend biofuels (B30, B100 and E85) as standard and also operate with conventional fuels for added flexibility. The number of vans and cars with this capability is anticipated to grow in the short term as a result of a major manufacturer's commitment to supply vehicles with capability for B30 and FFV for E85 (Renault).

UK Government has supported the take-up of alternative fuelled vehicles in the past through the EST managed grant programmes, recognising that there are additional costs to vehicle operators from committing to low-carbon technologies. Generally, if policy creates the conditions for a market the market will provide its own solutions.

3.4.7 Public perception/ media image

The public perception of biofuels is currently one of great confusion. The average consumer is generally unlikely to be aware of the range of biofuels available, how they differ from one another, or the benefits and drawbacks of using any of these fuels.

Coverage of biofuels in the press has focussed on two main issues:

- Sustainability: little distinction between different fuels has been drawn, and the media image presented is that biofuels are bad for the environment, and furthermore are in direct competition with food crops and probably the cause of price hikes in basic foodstuffs;
- Fuel use: stories of engine failure related to homemade biodiesel have bred mistrust amongst general consumers.

So, where consumers are aware of biofuels they are, due to adverse media publicity, generally thought to be bad for the environment and damaging to vehicles.

Related issues, such as the changes in fuel economy and change in service requirements, are likely to be of great interest to consumers as a result of the financial implications.

3.5 Support mechanisms

The six key issues discussed above are summarised in Table 3.3, together with a description of the types of support mechanisms that could be used to address them. Consultation during the study asked respondents to consider what support mechanisms could address the barriers they perceived. These are considered in this section.

Table 3.3 Key issues and need for support mechanisms

Issue	Feedstock	Production/distribution	Use in vehicles	Vehicle manufacture	General/other	Support mechanisms
Development of the supply chain / availability issues	Need to be sure of a market for the feedstock. Investment is limited due to concerns over long term supply needs to this industry There is no national supply system for feedstocks	Availability of feedstock can be an issue, in particular feedstock with sustainability assurance.	Fuel supply can be an issue, particularly to the right quality standard and sustainability. Assuring consistent/reliable supply into the future. Links to issues around fuel quality control and sustainability. Refuelling infrastructure requirements limit choice.	Limited availability of suitable vehicles because manufacturers need to be sure of a market. Availability of refuelling infrastructure impacts on the willingness of the public to buy alternatively fuelled vehicles. Availability of fuel impacts on the willingness of fleets to invest in		Need to increase supply and demand throughout the chain. This could include: • Incentives to grow feedstocks • Price guarantees for raw materials • Increasing consumer interest and confidence via the introduction of sustainabilit y standards or reporting • Establishing fuel quality

Issue	Feedstock	Production/distribution	Use in vehicles	Vehicle manufacture	General/other	Support mechanisms
				alternatively fuelled vehicles.		standards • Encourage manufacturers to develop suitable vehicles • Make fuel available at neutral cost
Fuel quality control (high blends)		Problems with customer acceptance due to variable quality of fuels.	Poor quality fuels can lead to problems in the vehicle (performance, maintenance, repair) Customers need to know exactly what is being used. Biofuel use can lead to warranty problems.	Variable fuel quality impacts performance, maintenance Warranty issue Different requirements for different fuels		Improve fuel quality control by establishing standard definitions and fuel quality standards. Encourage manufacturers to approve biofuels for use in existing vehicles.
Sustainability	No differentiation between different feedstocks		Differentiation between biofuels, treatment of 1st and 2nd generation fuels		A key driver for biofuels is the reduced carbon emissions and therefore it is important to	Establishing sustainability standards or reporting Link GHG

Issue	Feedstock	Production/distribution	Use in vehicles	Vehicle manufacture	General/other	Support mechanisms
					ensure that the appropriate biofuels are used. This is tied into the concerns over public image	savings to the number of RTFO certificates issued, or introduced RTFC (Carbon) to run in parallel. Lower GHG emissions = lower duty costs Restrict availability of fuels at forecourt until fuel quality and sustainability issues have been addressed
Long term policy and government direction	No long term policy means that feedstock suppliers		While there are benefits to remaining technology neutral this has not been done consistently.		A large proportion of consultees identified a lack of clear	Clear government direction is needed: develop

Issue	Feedstock	Production/distribution	Use in vehicles	Vehicle manufacture	General/other	Support mechanisms
	cannot guarantee a continuation of a market for their product in the longer term		Support for new vehicle technology is required to overcome initial cost differential and this is expensive to maintain at sufficient levels across myriad technology options. Favoured vehicles changes and consumers cannot rely on support.		government policy direction and an absence of long term planning as barrier to the take up of high blend biofuels.	consistent long term legislation to lend confidence to the market. (legislation, long term policy targets)
Long term incentives (financial support mechanisms)	Fluctuation of fuel prices makes margin management difficult	Competition due to subsidised production in the US	Fuel economy can be a problem More regular maintenance needed			Further duty derogation beyond 2010, guarantee on future duty levels Subsidy to allow competition with fossil fuels Lower GHG emissions = lower duty costs

Issue	Feedstock	Production/distribution	Use in vehicles	Vehicle manufacture	General/other	Support mechanisms
						Reduced calorific value duty
Vehicle availability		Matching investment in supply chain difficult without greater certainty over demand. Competition for space from existing fuels and blends at refineries, supply chain and on forecourts.	Lack of consistent/centralised information for users. Concerns about user-comprehension and ability to re-fuel correctly if a wider range of fuels are offered.	Highly varied compatibility with high-blends across manufacturer and model ranges.		
Public perception/ media image			For many organisations using biofuels is a contributing to their environmental credentials and/or actively to reduce their carbon footprint. Bad press has provided a disincentive to using biofuels (as one reason – credentials	Consumer reluctance to pay higher than normal price for new technologies puts pressure on manufacturer. Manufacturer reluctance to allow biofuel	Few / no high profile incentives or support to purchase of alternative/biofuel compatible vehicles since demise of EST grant programme.	Publicise and promote work done in UK on sustainability standards for biofuels. Information campaigns to distinguish between types of biofuel, and potential for

Issue	Feedstock	Production/distribution	Use in vehicles	Vehicle manufacture	General/other	Support mechanisms
			– is undermined).	use within warranty sends a negative message to consumers		GHG savings. Encourage exemptions in any LEZ schemes and Parking schemes (link with Defra AQS refresh). Encourage warranties from more vehicle manufacturers, particular where they share same (compatible) engines.

In addition, the study workshop with LowCVP members identified the three most important barriers to the take-up of high blend biofuels to be:

- the lack of long term government clarity and support;
- the lack of long term incentives; and
- and the limited approval for using these fuels in vehicles.

The following section looks in details at the support mechanisms that might be employed to help overcome each of these barriers.

3.5.1 Long term government clarity and support

The potential support mechanism identified to address the lack of long term government support and clarity include:

- Package of long term incentives;
- Joined up thinking on CO_2, and clarity on what is required to meet targets and whether existing legislation is sufficient;
- Financial incentives to choose energy saving/ low carbon equipment;
- Link fuel duty to CO_2;
- Waste legislation (that encourages energy recovery); and
- Mandating that vehicles sold in the UK must be able to run on certain fuels.

Table 3.4 considers each of these support mechanisms and discusses how each might be achieved in practice and considers their attractiveness. An example of long-term government support is illustrated by the case study of Sweden in Box 3.2.

Box 3.2 - Government support and its role in developing the high-blend biofuels markets in Sweden

Political support and influence has played a key role in the development of the biofuels industry across Sweden. The National Government has offered a number of incentives that support increased use of biofuels, in particular incentives to encourage the use of clean vehicles.

- 2002- An agreement between the Social Democratic Party and the Green Party led to a 'green taxation' policy for renewable fuels, crucial for the Social Democrats to get the necessary support from the Green Party in Parliament. This meant that the energy tax and the CO_2-tax were removed from renewable fuels until 2013 making renewable fuels cheaper to use than fossil fuels. The impact of this policy cannot be underestimated!
- 2003- The Climate Investment Program, KLIMP, was established. Municipalities could apply for funding, for example of biomethane plants. However, the grants were quite randomly distributed between the different regions in Sweden.
- 2005- A congestion charging system begun operation in Stockholm, controlled by the National Road Administration. Clean vehicles were exempted from the charge as a way to strengthen the environmental profile of the system.
- 2006- A new law that all major filling stations must provide a renewable fuel. This was criticised because it favoured ethanol fuel because it is cheaper to install. A strengthened effort targeting biogas filling stations was then launched allowing gas companies to apply for funding.
- 2007- A grant equivalent to €1000 was offered to consumers buying a green car.

Table 3.4: Support mechanism - long term government clarity and support

Support mechanism	Would this support mechanism help and how?	How should it be implemented?	What would need to be done?	Rank
Package of long term incentives	Long term incentives give industry the opportunity to develop technologies, benefit from the economics of incentive schemes and prepare how their strategy will develop as incentives are reduced or removed.	Based on GHG emission savings, and tailored to each vehicle sector.	A feasibility study could be carried out to identify, evaluate and report on the options for this approach. This would provide answers to how this should be implemented.	
Joined up thinking on CO_2/ carbon reduction	Joined up thinking on CO_2 will ensure that technologies are fully researched before political decisions are taken that promote a certain technology without consideration of another; for example biofuels and the interaction with other vehicle components. The EU has set out clear targets for transport fuels in the Fuels Quality Directive & Renewable Energy directives. The FQD target is for a 6% reduction in GHG by 2020.	The newly established Department of Energy and Climate Change should have an overview of all proposed and existing CO_2 legislation. Expert groups (like LowCVP) should be consulted with regard to transport issues. EU legislation should be used to inform UK legislation	Proposed and existing legislation should be outlined and EU thinking incorporated. Subsequently a longer term group should be developed to investigate the implications of legislation and policy decisions.	1st

Financial incentives to choose energy saving/ low carbon equipment	Financial incentives could be used but care must be taken to ensure that sound science supports the choice of technologies.	Any type of incentive scheme must be carefully managed with appropriate demonstration of technologies, proof of performance, compliance criteria and measurement.	Government would need to identify a suitable administrator for such a scheme. Associated criteria and measurement would need to be set.	
Link fuel duty to CO_2	This approach would treat each fuel equally on its carbon merits and allow the market to determine the preferred fuels and therefore deliver best value to the customer while still meeting government targets. This has a consistency and provides the producer with a clear incentive to improve the fuel carbon quality. If established as a long term policy this would provide a rationale for future investment programme both for bio and non bio-fuel producers. A policy of this type would provide economic difficulties to some sectors (e.g. haulage) which the government would have to address.	Government would need to set out 'long term' policy and adjust duty rates.	A feasibility study would be required to demonstrate that this type of duty can be applied across a range of vehicles, including electric, and that it is a fair charge for road use.	2nd

Waste legislation (that encourages energy recovery)	The Waste framework Directive adopted in late 2008 contains a waste hierarchy, requirements for prevention schemes etc.	The Directive is now in the transposition process and this should be complete across Member States by 2010.	Harmonisation of prevention schemes is required to ensure the market operates competitively. In addition these schemes need to take a view on viable solutions to waste recovery. A feasibility study or assessment of the schemes will be required but the timeframe extends out to 2018.	
Mandating that vehicles sold in the UK must be able to run on certain fuels	This type of mandate could restrict development of new fuels/technologies.	It would need to be agreed with OEM, so voluntary approach is probably more likely to be achieved.	This would only be a workable option if it were established as an EU-wide program.	

3.5.2 Lack of long term incentives

The potential support mechanism identified to address the lack of long term incentives include:

- Duty incentives
- Demand management techniques (Road pricing, parking charges, priority, LEZ etc)
- Mandating public bodies to operate vehicles with high-blend fuels
- Mandating filling stations to provide high-blend fuel(s)
- Focus on own-tank or depot filling
- Increase value for Infrastructure Grant Fund[58]
- Create sector specific packages of support

Some further suggestions for creating incentives have been put forward in the past by the REA, show in Box 3.3.

Box 3.3 - Renewable Energy Association incentive proposals

The REA produced a document "Policy Proposal: REA Submission for consideration of High Blend Biofuels duty rates and Company Car Tax for March 2007 budget" in which they identified a number of potential mechanisms to drive the take-up of high blend biofuels.

Fuel duty

The REA proposed that High Blend Biofuels be moved within the Alternative Fuels Framework. This framework allows specific non-mainstream fuels to be incentivised by setting duty rates on a rolling three-year basis. This makes it possible to track the take-up and control the costs of each fuel. The REA proposed that E85, B30, and B100/Pure Plant Oils are moved into this framework and given specific fuel duty rates.

Proposed initial 3 year duty rates (p/l) for these fuels:

Fuel	2007/8	2008/9	2009/10
E85	15.0	16.0	17.0
B30	40.0	41.0	42.0
B100/PPO	5.0	6.0	7.0

At the proposed rates, a company running an E85 car would have an annual fuel cost increase of around £520 over the equivalent diesel car based on an annual mileage of 25,000 business miles.

Company car taxation

The REA proposed that Company Car tax for vehicles running on either E85 or B30 be given an incentive in a similar way to hybrid vehicles.

The proposed rate reductions were:

- E85 vehicles to receive a 5% reduction
- B30 vehicles to receive a 2% reduction

Vehicle excise duty

The REA proposed that for a three-year period, cars designed to run on E85 would receive a 2-band reduction on their VED category and those running on B30 a one-band reduction. For instance the Ford Focus 1.8 FFV would reduce from a Band E vehicle to a Band C one.

[58] Currently £1.5 million across all fuels (for fuelling equipment)

For Commercial Vehicles/Buses running on B100/PPO REA proposed that they are classified as 'Reduced Pollution' vehicles and automatically qualify for the lower VED rates applicable.

It was hoped that reductions in the VED would help to promote behavioural change amongst private individuals and encourage the purchase and use of low carbon vehicles.

Table 3.5 considers each of these support mechanisms, discusses how each might be achieved in practice and considers the level of support likely for each.

Table 3.5: Support mechanisms - long term incentives

Support mechanism	Would this support mechanism help and how?	How should it be implemented?	What would need to be done?	Rank
Duty incentives	Duty incentives can help to support capital investment in vehicle fleets and infrastructure by stimulate the market for emerging fuels.	Link fuel duty to CO_2 (as per REA proposals).	A feasibility study to demonstrate how duty incentives should applied.	2nd
Demand management techniques (Road pricing, parking charges, priority, LEZ etc)	These incentives could provide additional benefits both financially and in terms of convenience and time saving.	Identifying vehicles, fuels and associated technologies that reach minimum standards, and registered via a certification or permitting scheme. Core of scheme would ideally be via DVLA/VCA record process.	The wide range of fuels and technologies available makes this option difficult in practice at this point. However, if there was a clear message about what fuels and blends are supported and what is the minimum standard, then a permitting/certification scheme could build on this.	
Mandating public bodies to operate vehicles with high-blend fuels	This does not allow flexibility and there is a risk that it might preclude the use of appropriate vehicles.	High blend biofuels are not geographically widely available and therefore a mandatory requirement could be very restrictive and would incur extra cost and probably running miles to comply – this would lead to increased emissions and thereby negate any benefit.	A feasibility study could identify the regions in which a voluntary scheme might operate, and could identify the organisation that would be interested join the scheme over time, and whether there is potential such a scheme to become mandatory in the future.	

Support mechanism	**Would this support mechanism help and how?**	**How should it be implemented?**	**What would need to be done?**	**Rank**
		A scheme would have to be on a voluntary basis focussed on locations where fuels are, or become, available.		
Mandating filling stations to provide high-blend fuel(s)	This measure could stimulate consumer interest, but the infrastructure investment would be large.	There are concerns that this is not realistically practicable. Only large retail sites have the pump and tank configurations to dispense normally not more than two grades of each fuel. Smaller stations may be limited to fewer grades and therefore such a mandate could lead to sites closing. This has been observed in Sweden where such a mandate is in place.	Mandating is not required, this should be voluntary, but encouraged by incentives/grants (i.e. an expanded IGP). If mandating is done, it should be aimed at largest sites (with highest volumes of fuel sold) and following same lessons as for 'protection grades' of E5.	
Focus on own-tank or depot filling	In this approach the end user would have their own tank dedicated to the fuel and blend that organisation wishes to use.	This could potentially be less useful for large hauliers where vehicles will require bunkering at remote locations where that particular fuel may not be available.	Biofuels from different feedstocks, at different blend volumes require appropriate vehicle technology and servicing regimes to exist. This option would give suppliers an opportunity to forge better relations with the consumer in terms of all aspects of vehicle management. This approach will need a joined approach	1st

Support mechanism	Would this support mechanism help and how?	How should it be implemented?	What would need to be done?	Rank
			between fuel supplier, vehicle operator, OEM and lubricant manufacturer.	
Increase value for Infrastructure Grant Fund[59]	If Government mandated filling stations to provide high blend biofuels then this grant fund would have to increase significantly.	As per the existing programme, but on an expanded scale.	Additional funding to be found and review of funding criteria to enable both short and longer terms objectives to be met.	2
Create sector specific packages of support	Sector specific support packages would allow efforts to be focussed on the particular needs of individual sectors.		This would be required if fuels duty were to be charged on a CO_2 basis e.g. hauliers etc.	7

[59] Currently £1.5 million across all fuels (for fuelling equipment)

3.5.3 Availability of suitable and approved vehicles

The potential support mechanisms identified to address the issue of approval for use in vehicles include:

- Supporting a limited number of fuels and blends (e.g. E85, B10, B30);
- Set a minimum specification for biofuel use in vehicles (i.e. an EC Regulation or Directive for beyond B10);
- Improve access to accurate information on warranty/approvals; and
- Fund grant programme to support OEM testing of fuels in key vehicle categories.

Table 3.6 considers each of these support mechanisms, discusses how each might be achieved in practice and considers the level of support for each.

Table 3.6: Support mechanisms – increase approval of biofuel(s) for use in vehicles

Support mechanism	Would this support mechanism help and how?	How should it be implemented?	What would need to be done?	Rank
Supporting a limited number of fuels and blends (e.g. E85, B30)	For the mass market this could be a suitable approach, given probable confusion over different blends. It would enable OEMs and technology providers to focus effort on a limited number of fuel blends. Allows for limited storage in current filling station network, and storage/blending limits current at plants and refineries. More flexibility would be appropriate for HGV/Van fleet operation.	Could be implemented quite quickly but would need Government support.	OEM and retrofit providers to focus on a few blend levels; investment in filling stations to increase capacity for more blends (where feasible); investment at plants/refineries to handle more blends. Would require consumer education in terms of suitability of fuels and associated vehicle servicing requirements. Harmonisation of this approach across Europe would be appropriate.	2nd
Set a minimum specification for biofuel use in vehicles (i.e. a EC regulation or directive for beyond B10)	CEN would provide a mechanism for consistent and agreed fuels levels based on EU standards.	This requires agreements from fuels suppliers and motor vehicle manufacturers.	EC to adopt this as a strategy with regard to high bio fuels	
Improve access to accurate information on warranty/approvals	This mechanism will help but must be supported with appropriate cost of operation information and consider a life		Consumer education is key to the success of biofuel and high blend biofuel promotion across Europe. Many biofuels	

Support mechanism	Would this support mechanism help and how?	How should it be implemented?	What would need to be done?	Rank
	cycle approach to product performance. This is a matter for the vehicle manufacturer. It seems in the interest of each supplier to provide a vehicle which may operate on higher level blends since these may appeal to a wider audience		require that oil change service intervals are increased, i.e. if biofuel is used in a vehicle then oil change intervals are reduced therefore an increase in servicing costs. This should be examined from a life cycle approach to determine the cost to an owner/operator.	
Fund grant programme to support OEM testing of fuels (for their vehicles) EC or UK funded	A range of fuels and blends exist with different characteristics and different environmental credentials. The impacts of each fuel on the vehicle engine and associated technologies needs to be considered, as do the fuel storage requirements. Research must be undertaken by OEMs and associated vehicle technology suppliers to ensure that the durability, in use compliance and performance of vehicles is maintained with the use of biofuels at different blend	LowCVP PC and Fuels working groups could be consulted to draw up a list of suitable projects that could then be submitted to TSB and funded through the normal project call mechanism. Alternatively, due to the possible speed of introduction of these fuels a separate fund could be ring fenced to be used by RFA, for example, to be allocated to research and demonstration projects.	This may have to be a European rather than UK programme.	1st

Support mechanism	Would this support mechanism help and how?	How should it be implemented?	What would need to be done?	Rank
	volumes and from different feedstocks. Funding programmes to assess the performance of high blend biofuels would enable manufacturers to approve warranties and would give confidence to biofuel users.			

3.6 Conclusions

A range of barriers to use exist that are particular to high-blend biofuels, due to their inherent characteristics, variability and wide variety. They present a much more complex picture than conventional petrol and diesel and do not fit easily within the homogenised approach that makes supply of conventional fuels in the UK very efficient and cost-effective, to the benefit of the majority of vehicle operators. In addition, there are a number of barriers that exist because the market is relatively small. By choosing policies that encourage a market expansion some of the uncertainty and lack of availability of vehicles and infrastructure to fuel them would dissipate in the face of demand.

There are currently a considerable number of organisations that choose to operate vehicles with high-blend biofuels. Under the current duty regime and aided by market conditions for mineral and vegetable oils some users have been motivated by cost savings over conventional fuels. However, the strong impression from stakeholder feedback and from those working in the field is a larger number of users are motivated by sustainability concerns and the wish to reduce their carbon footprint. This is a valuable platform from which to implement policies that encourage further reductions in GHG emissions from the UK road transport sector.

The purpose of biofuels is predominantly to reduce carbon. Therefore policy must reflect this objective and allow the market to find the most economic measure(s) to achieve this.

Key area of support can be considered under the following topic areas:

- Development of the fuel supply chain and availability issues;
- Fuel quality control;
- Sustainability, and public perception/ media image;
- Availability of vehicles;
- Long term policy and government direction; and
- Long term incentives (i.e. financial support mechanisms).

Specific support mechanisms have been considered under each of these headings, many generated through stakeholder feedback, and considered for their degree of merit. Some support mechanisms will only work in tandem with others (i.e. there are clear dependencies).

4 OPTIONS ASSESSMENT

4.1 Introduction

The purpose of the options assessment is to address the question of what are the potential GHG savings from high blend liquid and gaseous biofuels, and at what cost.

4.2 Method

In this analysis GHG emissions are presented for each vehicle type using the range of biofuels agreed with the LowCVP. Emissions are estimated for each fuel using CO_2 equivalent (CO_2e) figures on a well to wheel basis (WTW), with GHG values from the Renewable Energy Directive.[60]

There are broadly speaking two ways to account for carbon emissions. One method is to credit all the emissions that would have resulted from burning petrol or diesel, considering biofuels to be carbon free as their combustion only releases carbon trapped during the growing process. This method gives the gross carbon saving, but does not capture the whole picture. The second method, and the one used in this study, is to include the carbon released during the production/extraction and transport of fuels, giving us the net emissions reduction for the well to wheel lifecycle of the fuel.

Each vehicle type has an illustrative GHG emission rate estimated (g/km CO_2e). The results are presented with low, mid and high values to account for the range of WTW GHG data. These vary by fuel, depending on the feedstocks and production processes. Current RED data (g CO_2/MJ) are based on values for cultivation, processing, transport and distribution activity. The study has not attempted to account for the indirect land-use change (ILUC) values.

The best and worst case values for each fuel are taken from RED for qualifying feedstocks/ processes. The mid-range GHG values were estimated by combining RED values for feedstock with an estimation about the UK-mix of biofuels. This draws together an estimate of the likely UK feedstock mix with the current Renewable Fuel Agency guidance[61] and the latest reported in-use data.[62] Annex A contains further details of the estimation process used. The mid-range values are then used in the remainder of the option assessment (total emissions and cost-effectiveness analysis).

[60] Directive 2009/…/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources

[61] Carbon and Sustainability Reporting Within the Renewable Transport Fuel Obligation Technical Guidance Part One V1.2, August 2008

[62] RFA quarterly report, April – October 2008.

Individual vehicle emissions are estimated by combining the carbon intensity of a given fuel with the fuel consumption of the vehicle using that particular fuel. The fuel consumption for a baseline vehicle (diesel, or petrol) is used and the remaining values estimated based solely on energy content of the fuel, adjusted for cases of dual-fuel vehicles). This provides fuel consumption values that broadly agree with much real-life experience of different high-blend biofuels, but does not take into account all the available experience of fuel consumption. Some operating experiences are reported as having better (or worse) fuel consumption that the energy content of the fuel would suggest.

Vehicle performance has been based on information found on current practice and experiences, including data provided by LowCVP members and their contacts. For the purposes of making a comparison the data set is static, and future predictions of vehicle performance have not been made. Work is underway to improve yields, engines and economics relating to most fuels (conventional, and biofuel) and the market is in a transitional phase. Therefore it has not been possible to predict relative costs reduction or performance improvement that might be achieved or commercial strategies to do so across all fuel types.

In order to estimate potential GHG reductions from each sub-sector of the vehicle parc vehicle emissions per km are combined with total vehicle km to estimate total GHG emissions (for each fuel). This was done by combining the illustrative vehicle's GHG emissions with the total vehicle kilometre travelled by the entire sub-sector of those types of vehicles on a national basis.[63] This provides a maximum GHG reduction should all vehicles of that type be used with a high-blend biofuel.

In addition a target sub-fleet is identified with a smaller number of vehicles that is more realistic. The proportion chosen for the target fleet varies by type of vehicle, based on what might be possible with an ambitious expansion programme. It should be noted, that while B5 and E5 are included in this analysis, the operation of the RTFO will mean these are the de facto standard in 100% of vehicles (rather than simply the target proportion chosen to illustrate the range of impacts from high-blend biofuels).

Clearly, the date at which the target fleet expansion of various biofuel could realistically be achieved will differ and could require different amounts of effort or supporting mechanisms to achieve. For example, widespread uptake of one fuel may be feasible much sooner (if it can be used in many existing vehicles compared to a fuel that requires new engine technology (which be dependant on the fleet replacement rate). Therefore, comparison between the various biofuels needs to be done carefully to avoid misinterpretation.

Cost information has been gathered from a number of sources to produce a price per km operation. This includes the up-front vehicle purchase price, the maintenance costs (per vehicle km) and the fuel price per vehicle km (based on fuel price and fuel consumption). Cost information is provided showing the components of a cost per vehicle km (as described briefly here) in Annex 1.

[63] Transport Statistics Great Britain, 2008, DfT.

The cost of fuel is based on selling prices from April/May 2009. Spot prices will continue to vary and the relationship between them keeps changing. The variability of fuel costs will effect the outcome of the analysis at any given time.

In practice a vehicle operator can sometime pay for new fuelling infrastructure via a small increment per litre/kg on the fuel. However, the basis of the fuel cost data obtained for this study does not to include infrastructure costs, and these are identified separately.

It was decided, following advice of the Advisory Group, that fuel prices should be without duty, in order to make a more transparent comparison of relative costs prior to any policy intervention. This will also more accurately reflect the relative price of biofuels from March 2010 when the duty differential is removed for all except for biomethane, which is inside the AFF, and will continue to benefit from a lower duty than other road transport fuels.

If a choice to use high-blend biofuels is to be made it then makes sense to consider which of the vehicle/fuel combinations are most cost-effective. Using cost effectiveness analysis (CEA) is a term for a range of methods to compare similar scenarios using input values estimated on a similar basis. As long as the assumptions about input values are similar, there can be some room for error: it is the relative performance of one option against another that is most important (generally against a baseline option) and it does not assess the value of benefits. This is not the same as cost benefit assessment (CBA), which aims to provide an absolute value of an option based on the balance (and value) of costs and benefits.

Each combination of vehicle and biofuel has been compared to the baseline cost of operating that same vehicle with conventional fuels. This provides a method to compare the relative costs of options against one another in two directions; by type or blend level of biofuel (within one sector of the vehicle parc) or by type of vehicles (comparing one against another when operating with the same fuel). It is also possible to pick out the most cost-effective vehicle/fuel options and the least cost-effective, which is done in the final section of this Chapter.

Practicability issues are addressed by summarising a mixture of qualitative and quantitative information. This type of information is presented in a table with summary text and a rating, based on a number of relevant criteria.

4.3 Bus

4.3.1 Background

The public service vehicle fleet (buses) comprise vehicles covered by Standard National, Standard International and Restricted licence, under which are operated local bus services, long-distance international services (coaches) and those services operating on restricted licence (up to 2 vehicles and less than 8 passengers per vehicle).

There are some specific characteristics of local bus fleets to be borne in mind:

- Ownership – 5 large national groups owning the majority of vehicles organised as area-based business units, plus many smaller local/regional operations;
- Depots tend to be located within urban areas near to where routes converge, with a more dispersed pattern in rural counties;
- Fuelling takes place at depot, with diesel being the main fuel; pilot fleets have operated on CNG in the West Midlands (until 2008) and bioethanol in Nottingham, and Reading (now ceased);
- Maintenance is generally done in-house by fitters and engineers, often on a rolling 3,300 mile / 28 day programme (spreading replacement items across a longer rota period);
- Vehicles are on a low replacement rate with a high average age: the national fleet replacement rate in 2006/7 was only 5.5%, and therefore vehicles tend to be of a high average age (8-9 years and lifetime of 14-16 years for single and double deck vehicles).

In terms of vehicle availability for use with high-blend biofuels the following options currently exist:

- Approval by some vehicle manufacturers for use of biodiesel (varying blends);
- Scania produce a version of their compression ignition engine modified to run on ED-95, which is available in UK specification;
- Optare offer a range of buses with either dedicated Cummins gas engine or Hardstaff Dual Fuel technology in volumes of 10 or more[64] for use with natural gas or biomethane. Gas engine buses are produced for mainland European markets (Renault, Iveco etc) but not sold into the UK;
- PPO ready engines are available in a range of Optare buses, Alexander Dennis Ltd has trialled PPO retrofit technology;
- High-blend biodiesel (in some cases up to B100) is approved for use in a number of models from manufacturers Mercedes/Evobus and Scania and a range of manufacturers fit Cummins engines which are approved for B20.

There are a total of 90,317 PSV registered in the UK and of these 31,184 are operated under standard national licences. Long-distance coaches are operated as part of the 54,128 vehicles with Standard International licence, and the remainder 5,005 vehicles are minibuses (fewer than 8 passengers) operated on restricted licence[65] we have focussed in this study on local bus services.

To estimate vehicle mileages we have used the same method as for HGV. TSGB statistics for total veh km for that vehicle type are divided by the number of registered vehicles of that type. This provides a liner average for each individual vehicle. The use of DfT/VCA stats ensures headline figures of total emissions are respected. For local bus services this produces a figure of some 74,600 km p.a. This is on the high-end of estimates, which may be because it is based on national data that will include rural bus routes. For many regions (e.g. South West, Norfolk, Suffolk etc) rural services will contribute significantly to overall bus mileage, but in most cases rural services pass through the major urban areas that exist in the region or district. For

[64] Cenex Biomethane Toolkit, 2008

[65] Figures from Traffic Commissioners' Annual Reports 2007–08, DfT, October 2008

comparison work done by TTR for pteg showed a more common Metropolitan vehicle milage to be some 59,000 km p.a., and work done for TfL used 55,000 as the default value for London Buses. The study has therefore generated some additional sensitivity analysis based on a lower annual bus milage, shown at the end of this sub-section.

Passenger Transport Executives (PTE) provide, plan, procure and promote local public transport in six of England's largest conurbations with Strathclyde Partnership for Transport fulfilling the same function in the Glasgow area of Scotland. PTEs produce the strategies for the development of local public transport networks; manage and plan local rail services (in partnership with the DfT); plan and fund socially necessary bus routes; work in partnership with private operators to improve bus services - for example through bus priority schemes; run concessionary travel schemes - including those for older, disabled and young people. As such they are a major force in UK public transport provision and are likely to be the front-runners empowering themselves under the Local Transport Act 2008, which will reform the way in which bus services are provided outside London. There are approximately 13,290 local buses operated in the PTE/SPT areas, which is around 40% of the total local bus fleet.

The most recent changes to regulations of the local bus service has been the April 2009 announcement on adjustment to BSOG. This will be changed to partially incentivise the operation of low carbon buses (primarily realised through hybridisation or other power-train efficiency modifications) and offset some of the cost differential between these vehicles and standard diesel fuelled buses. A bus will not be able to quality as a low emission carbon bus (LECB) simply from using biofuels however, unless it is using biomethane. A more comprehensive overall of BSOG is not ruled out for the future. In addition, a £30m fund has been announced up to support the purchase of LECB, targeted at the difference in cost between these and standard buses.[66]

The hypothesis for a market expansion scenario is:

- 26%% of PTE area local bus services use high-blend biofuel; and
- All UK local bus services use high-blend biofuels.

The target fleet of 6,266 vehicles comprises 20% of national local bus fleet and about 46% of PTE/SPT area fleet of 13,290 vehicles.

4.3.2 Benefits and Greenhouse gas reduction

This section illustrates savings of GHG emissions (W2W estimates) against a baseline (Euro V vehicle). Reductions are estimated for an individual vehicle (g/km C02e) and for the entire fleet and market expansion scenario outlined above.

4.3.2.1 Reductions per vehicle

GHG values for each fuel are combined with the fuel consumption values to determine the gCO_2e per vehicle kilometre travelled (veh km). The result of this

[66] DfT Press Release, 1 July 2009.

assessment is a range of figures for best-case, worst-case and a mid-range value for each fuel.

Figure 4.1: Relative GHG emissions per vehicle km – local bus

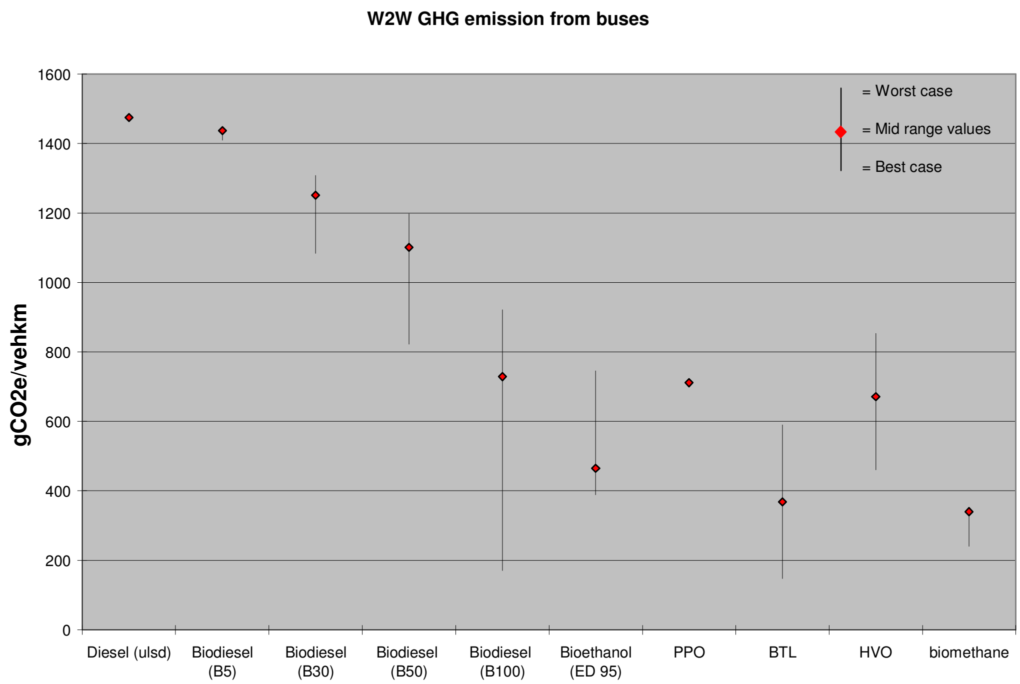


Figure 4.1 shows mid-range value (with a red diamond symbol) and the best and worst case range represented by the top and bottom of the vertical line dissecting each red diamond. As noted in the methodology section, the best and worst case values are included to show the range of values from the variety of possible feedstock (i.e. type of biomass). For example, in the case of biomethane the best performing feedstock is animal slurries. However, UK biomethane production reported to the RFA is currently derived from municipal solid waste and therefore the 'mid-range' value shown is not in the middle of the theoretical range.

A relatively large range in emissions could be produced from most biofuels, based on variations in their carbon emissions on a WTW basis. However, a pattern of GHG emissions is clear when looking across the fuels (based on the mid-range value).

The mid-range value for a Euro V bus operating with diesel (B0) is estimated as 1474 gCO_2e/km. A more realistic baseline for diesel may be 5% FAME (B5), which provides a slightly lower figure of 1437 gCO_{2e}/km. B30 and B50 are shown to have a reduced GHG value compared to the baseline (B0) of around 85% and 75% (or 1251 1101 gCO_2e /km).

Significantly lower GHG emissions are estimated from B100 and PPO, with 729 and 711 gCO_2e /km respectively (which are 48-49% of the B0 baseline).

The lowest GHG values for currently available high-blend biofuels are estimated for bioethanol (ED95) and biomethane, with 465 and 340 gCO_2e /km respectively (which are only 31.6 and 23.1 % of the B0 baseline).

100% HVO and BTL fuels are included for comparison purposes, acknowledging these are not supplied commercially at present in such a specification and the source information on GHG values has relied on a small number of (non-independent) sources. GHG emissions are estimated for BTL and HVO as 368 and 671 gCO_2e /km respectively, which are just 25% and 45% of the B0 baseline estimate.

From a GHG reduction perspective alone it can be seen that a range of high-blend biofuels offer significant and savings in gCO_2e/km on an individual vehicle basis.

4.3.2.2 Potential reductions across the fleet.

The study has developed estimates based on the use of different high-blend biofuels in the entire local bus sector of the UK vehicle parc and within a target sub-sector of the local bus parc.

The proposed market expansion scenarios illustrated are:

- All local bus services (standard national licences) use a form of high-blend biofuel (31,184 vehicles); and
- Almost one-half of PTE area local bus services use a form of high-blend biofuel fleets (47 % of the 13,290 PTE/SPT area fleet, which is 6,236 vehicles or 20% of total UK local bus fleet).

These scenarios provide an illustration of the maximum impact of high-blend biofuels (use in the total local bus fleet) and a lower impact assessment, based on a target sub-sector of half the vehicles in just PTE areas. The estimation is based on the RED values of CO_2e content per litre of fuel is combined with fuel consumption per km and then the total km travelled by local buses in the UK to arrive at tCO_2e /year. Mid-range GHG values are used for this estimation.

The benefits, shown in Figure 4.2 are compared to the baseline of diesel/B0 producing some 3,429,291 tCO_2e/year (noting that B5 used throughout the bus fleet would produce some 3,342,566 tCO_2e/year.

The same data on potential savings on tCO_2e/year under various fuels and scenarios can be seen in Table 4.1, quantifying the reduction against baseline in terms of % and also in tCO_2e/year.

Figure 4.2: Potential GHG emissions by fuel by fleet – local bus

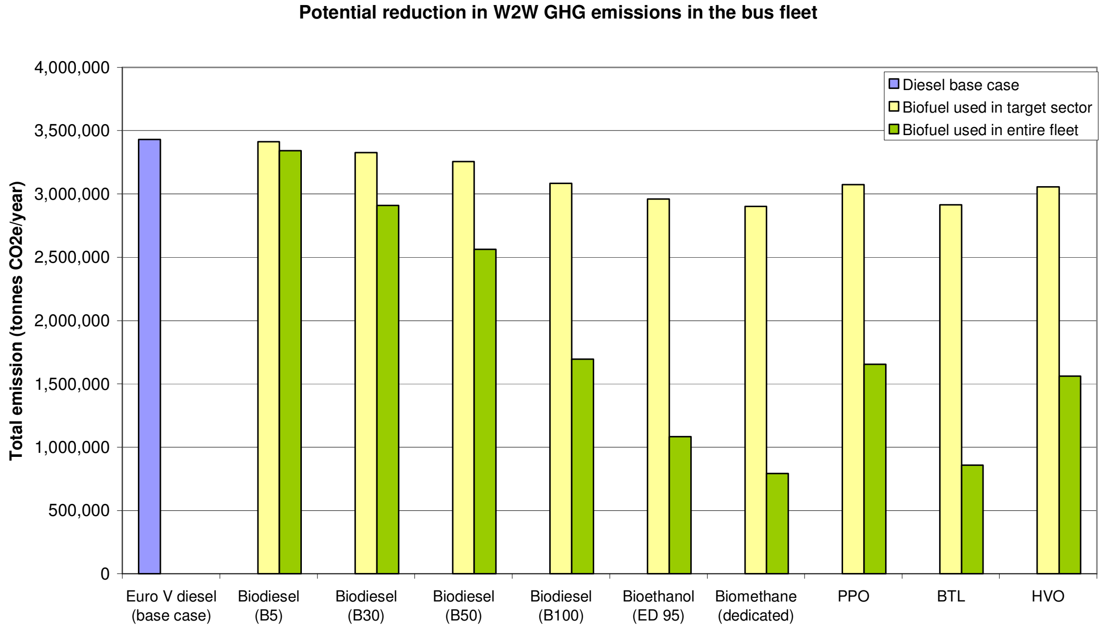


Table 4.1: Potential reduction in fleet GHG emissions – local bus

Bus & fuel	Total fleet		Target fleet (20%) @ 74.6K vkm p.a.	
	GHG W2W	CO2e (t/yr)	GHG W2W	CO2e (t/yr)
Euro V diesel (base case)	100.0	3,429,291	100.0	685,858
Reduction from base case	% reduction	Reduction	% reduction vs. total fleet	Reduction (t/yr)
biodiesel (B5)	0.0	86,725	0.5	17,345
biodiesel (B30)	0.2	520,347	3.0	104,069
biodiesel (B50)	0.3	867,245	5.1	173,449
biodiesel (B100)	0.5	1,734,491	10.1	346,898
bioethanol (ED 95)	0.7	2,347,119	13.7	469,424
biomethane (dedicated)	0.8	2,638,451	15.4	527,690
PPO	0.5	1,774,896	10.4	354,979
BTL	0.8	2,571,968	15.0	514,394
HVO	0.5	1,868,249	10.9	373,650

We can see from Table 4.1 that operating the entire local bus fleet with B100 or PPO could save around 1.7 million tCO_2e/year, and for even greater reductions bioethanol and biomethane could save between 2.3 and 2.6 million tCO_2e/year. This would take the GHG WTW output of the local bus fleet to only 32% or even 23% of the current baseline diesel (B0) operations.

4.3.3 Cost and practicality

4.3.3.1 Costs

This section considers the cost per vehicle of achieving the GHG reductions shown in the section above, based on the range of high-blend biofuels.

A cost estimate has been made based on vehicle purchase cost, fuelling infrastructure costs (if applicable), maintenance costs and fuel consumption/costs over the defined amortisation period at the annual vehicle mileage (vkm p.a.). The key output is the Overall Cost column showing £/veh km. Fuel costs are presented without duty or VAT in order to show the cost without any policy intervention. All other costs are excluding VAT. Costs are based on a fleet of 30-50 vehicles which return to base for refuelling, and smaller fleets may affect the overall cost (due to fuelling infrastructure cost differences).

Table 4.2: Vehicle cost estimates – local bus

	Capital outlay		Overall cost		Fuel				Annual costs		
Fuel	**New vehicle cost (£)**	**Fuelling infrastructure £/vehicle**	**Total cost £/veh km**	**Mainten-ance Costs**	**£ per litre / kg**	**Efficiency (l or kg / 100km)**	**amortisation (years)**	**Km pa**	**Fuel cost £p.a.**	**Maintenance £p.a.**	**Capital cost £p.a.**
Euro V diesel (base case)	120000	0	£0.57	0.22	0.31	0.474	8	75,000	£11,021	£16,500	£15,000
Biodiesel (B5)	120000	0	£0.58	0.22	0.33	0.476	8	75,000	£11,648	£16,500	£15,000
Biodiesel (B30)	120000	300	£0.67	0.27	0.42	0.484	8	75,000	£15,216	£20,250	£15,038
Biodiesel (B50)	122500	300	£0.71	0.27	0.47	0.491	8	75,000	£17,378	£20,250	£15,350
Biodiesel (B100)	122500	300	£0.78	0.27	0.59	0.509	8	75,000	£22,681	£20,250	£15,350
Bioethanol (ED95)	140000	1700	£1.02	0.27	0.60	0.855	8	75,000	£38,490	£20,250	£17,713
Biomethane (dedicated)	150000	14500	£0.78	0.3	0.51	0.400	8	75,000	£15,252	£22,500	£20,563
PPO	123450	300	£0.76	0.27	0.57	0.502	8	75,000	£21,383	£20,250	£15,469
BTL	120000	0	£0.88	0.22	0.96	0.474	8	75,000	£34,215	£16,500	£15,000
HVO	120000	0	£0.82	0.22	0.79	0.502	8	75,000	£29,681	£16,500	£15,000

Further cost information is provided in Annex A1.

The recommendation from most manufacturers is to halve the service intervals when running on biodiesel blends that are higher than B5. The elements of the service that require more attention when using biodiesel are the engine lubrication system and oil filter. The air filter and fuel filter (after the initial biodiesel changes) will only require changing at the normal intervals. However, an extra oil change during a year's service regime will increase service costs by 50% as this is the most expensive element of the process. In addition, at the current time, there are different qualities of biodiesel available across the country, which may be due to production factors or problems introduced through the transportation and storage of the fuel. Experience to date from Fleetsolve's support to vehicles fuelled with high blend biodiesel has been they are more likely to suffer from more instances of filter blockage, fuel line waxing during winter months, injector failures and DPF damage than a vehicle operating on normal diesel. In summary, taking into account true whole life costs for a fleet operated on high blend biodiesel, a realistic service cost up lift it estimated to be 80% above normal service costs.

From the study team's experience, PPO vehicles will also have a higher service cost uplift due to the fact that the system requires twin fuel tanks and filters in order to operate. Suppliers of PPO have confirmed the halving of service intervals for such vehicles. CFPP and filter blockage does improve with higher quality fuel, but for comparison with biodiesel a servicing uplift of 80% has been applied.

It should be noted that for local bus service the fuel costs to the operator are influenced by Bus Service Operators Grant (BSOG), which means a proportion of the duty paid can be claimed back by operators of local stopping bus services registered with the Traffic Commissioner. The table above shows costs without duty or BSOG rebate. More detail on fuel costs is available in Annex A.

The overall cost per vehicle kilometre (£ / vkm) varies depending on the fuel used as a result of vehicle cost, fuelling infrastructure and the cost of the fuel.

B0 and B5 provide the baseline cost as all other fuels are more expensive to use on a per vkm basis. Base costs of standard diesel have dropped back from their peak in 2008, which were making biofuels more competitive. In January 2009 some supplies of B100 cost less than B0. However, this is no longer the case as US soy based FAME products are discouraged from sale in the EU.

PPO, B100 and biomethane are estimated to have similar costs on a per vkm basis of around £0.76 – 0.78 / vkm. While biomethane has considerably higher capital costs (for vehicle and fuelling) lower fuel costs achieve a good degree of payback over the lengthy amortisation period.

Overall, bioethanol fuelled vehicles are estimated to have the highest costs, due to additional capital costs and considerable fuel costs. This is largely a factor of increased fuel consumption combined with the estimate of ED95 cost (currently around £0.6 /litre). This results in a cost per km of £1.02. In contrast the price of E100 (fuel grade) is based on £0.45 /litre, so 25% less. If the bus could be run on E100 then the lower cost of the fuel translates into an overall cost per vehicle km of £0.89. This is still the highest cost of the currently available fuels due to infrastructure, vehicle and fuel consumption factors, but closer to B100/PPO/Biomethane.

Prices for 100% BTL and HVO fuels are not being quoted by producers and there are no known UK commercial users of 100% at this time. Therefore, estimates are included for illustration only and the results should be viewed with due caution. Using figures of £0.79 pl for HVO and £0.96 pl for BTL (excluding duty or VAT) produces a £/vkm cost of £0.88 and £0.82 respectively. No additional infrastructure or vehicle on-costs are expected for using these fuels, so the costs will depend solely on the finished price of the fuel. This is likely to reduce over time, but at this stage no reliable estimates about the price of initial supplies at 10%-100% blends have been possible.

The cost (£/vkm) output is clearly sensitive to the input figures. This is particularly the case in this analysis where staff costs are excluded. As a result fuel costs make up the largest proportion of the variable costs, so small changes in fuel price can strongly influence the overall £/vkm.

Variations in fuel efficiency can also feed through via the fuel element, which is largely why bioethanol vehicles with relatively high fuel consumption have a relatively high £/vkm.

4.3.3.2 Practicality

The practicability of using high-blend biofuels in the UK local service bus fleet is considered in Table 4.3 below. This draws on the information contained in Annex A2 to A10 and from other studies. This information has been interpreted by the study team to provide a guide to the practicability considerations that will be of most concern to a bus fleet operator.

Table 4.3: Practicability considerations – local bus

	B0	B5	B30	B50	B100	ED 95	Bio-methane	PPO	BTL	HVO
PRACTICABILITY										
Availability of vehicles in UK	High	High	Medium	Low	Low	Low	Low	Medium	High	High
Availability of fuel in UK	High	High	Medium	Medium	Medium	Low	Low	Low-Medium	Very Low	Very Low
Fuelling infrastructure changes	None	None	Low	Medium	Medium	High	High	Medium	None	None
Maintenance	Normal	Normal	Raised	Raised	Raised	Raised	Norm to raised	Raised	Normal	Normal
ENVIRONMENT										
GHGe WTW (vs. baseline)	100%	97.5%	85%	75%	50%	32%	23%	48%	25%	46%
Air-quality: NO_x / PM vs. baseline	1.0 / 1.0	1.004 / 0.981	1.024 / 0.886	1.04 / 0.81	1.08 / 0.62	0.8 / 0.36	0.21 / 0.17	1.0 / 0.6	0.85 / 0.82	0.9 / 0.7
Noise	Norm	Norm	Norm	Norm	Norm	Lower	Lower	Norm	Norm	Norm
VEHICLE COSTS										
Capital	Norm	Norm	Raised	Raised	Raised	V.raised	V.raised	Raised	Norm	Norm
Operating	Norm	Norm	Norm to raised	Norm to raised	Norm to raised	V.raised	Lower to raised.	Raised	Dependant on fuel price.	Dependant on fuel price.
Overall	Norm	Norm	Norm to raised	Norm to raised	Norm to raised	V.raised	Varies with opex: Lower to raised.	Raised	Likely to be raised	Likely to be raised

The estimation of fuel availability is based on the ability of a bulk purchaser securing regular and reliable supplies. There are no constraints for B0/B5, but it becomes more difficult and time-consuming to obtain higher blends of biodiesel. There are infrastructure constraints at the present time to expansion of high-volume biodiesel at all blends due to the specification at which large UK refineries and plants store their fuel (in B100 or B50 forms, with less storage of B30). PPO is generally supplied by smaller scale producers/suppliers in the UK or large shipments can be organised for delivery to ports for onward transport. For these reasons B30, B50, B100 and PPO are classed as having only Medium availability in the UK. They are available, but not without some additional effort and cost, and the reliability of consistent quality supplies is not assured to anything like the same level as standard diesel. Looking to other fuels, biomethane is supplied by one or two producers currently in the UK and therefore the ability to serve expanded markets is yet to be proven and is not assured. Therefore it has been rated as low availability. BTL and HVO in high-blend form are not being supplied commercially in the UK (to the study teams knowledge) and may not be for some time. It is understood that suppliers would be interested to supply these fuels in high-blends, acknowledging it would be a niche/premium product. Overall, these have been rated as having very low availability of supply.

4.3.4 Cost effectiveness

Cost-effectiveness is the ratio of the total costs of the option to the emission benefit obtained (e.g. £ per tonne abated). In this study we have estimated a cost-effectiveness figure for each fuel and vehicle combination, based on additional costs and benefits over a baseline vehicle (in this case a Euro IV conventional diesel/petrol). In affect, we combine the emissions performance data in the section above with cost data, to examine another factor important to selecting technology/fuel options.

Cost-effectiveness is a parameter by which comparable options can be prioritised (for example from most to least cost-effective). This is important as most Government guidance suggests that options should be implemented cost-effectively. It should be noted that cost-effectiveness does not indicate how far an option will contribute in progress towards achieving a particular set of objectives. That is, an option may be very cost-effective but only have a very small potential to reduce total emissions. Finally, cost-effectiveness does not take into account all the potential benefits or dis-benefits of the options under consideration, which would require a more complex cost-benefit analysis approach (CBA). Instead, cost effectiveness analysis (or CEA) uses a more limited number of inputs selected on a similar basis for each of the options under consideration. In this way it is a like for like comparison, acknowledging it is not the full comparison that a CBA approach brings. For example, in the study analysis not all dis-benefits of biofuels are accounted for (e.g. ILUC) and neither are the benefits (e.g. a value on security of supply). The CEA analysis is done on the basis that if a choice is going to be made from a range of options it is good to know which are the better in cost terms and which the least favourable.

For cost effectiveness, two methods of presenting the combined cost/emission data are used:

- kgCO_2e reduced per £ spent over the baseline (i.e. standard diesel); and
- Cost (£ spent over the baseline) per tonne gCO_2e reduced.

Figure 4.3 shows the kgCO_2e reduced per £ spent over the baseline fuel (B0) for each of the fuels analysed. A high value in this analysis indicates a greater GHG reduction compared to fuels with a lower value.

Figure 4.3 shows results based on £0.45 pl for E100. In fact, the selling price (ex duty and VAT) of ED95 fuel was around £0.60 pl in late Spring 2009, some 25% higher, and the results of this input data is shown in Figure 4.4. Therefore the current cost-effectiveness is quite low at 3 kg per £ spent (for ED95 current price) compared to the theoretical 2 kg per £ spent over baseline for E100.

Figure 4.3: Cost effectiveness of reducing GHG – local bus #1

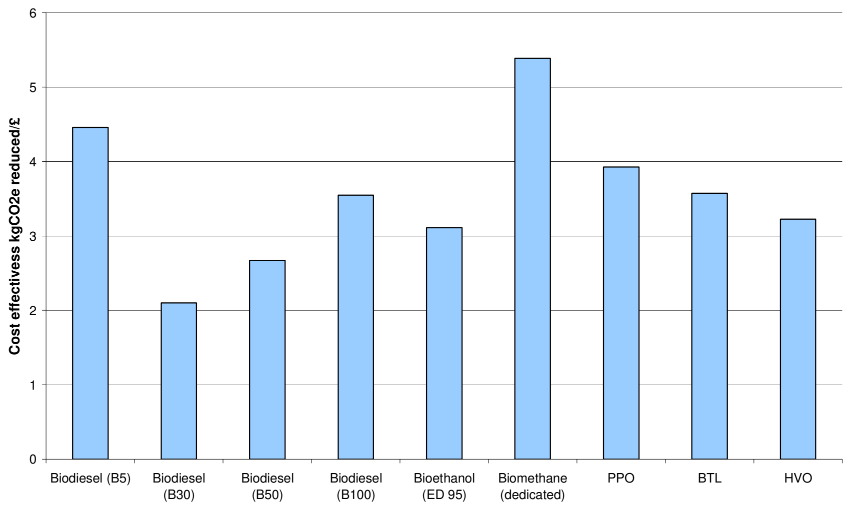
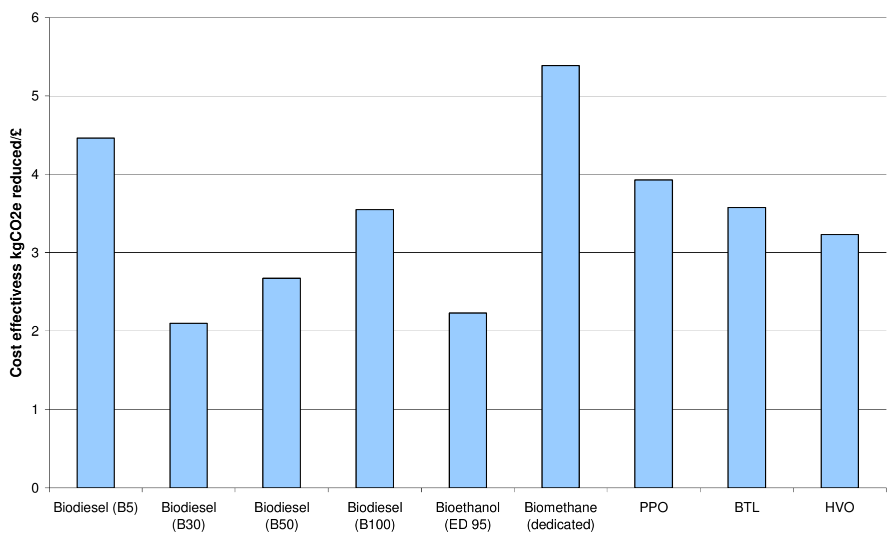


Figure 4.4: Cost effectiveness of reducing GHG – local bus #2



The first point to note is that B5 is one of the most cost effective fuels for GHG reduction. It is estimated to have very low additional costs (due to high cost of bio-element over diesel and blending costs) and a very small increase fuel consumption but brings with it a 2.5% CO_2e saving. However, the total GHG reduction is limited at this blend proportion, and given B5 is now the *de facto* standard diesel fuel it is now the baseline rather than an option to choose from when looking to the future.

Comparing currently available high-blend options this analysis places biomethane as the most cost effective. This reflects an estimated £/vkm that is comparable with B100 or PPO, combined with considerably lower WTG GHG emissions.

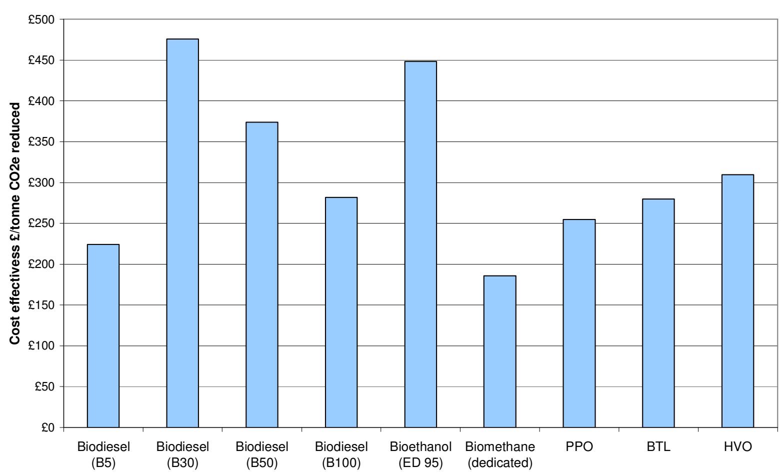
PPO performs better than B100 in this analysis due to marginally lower GHG emissions, slightly lower fuel costs and marginally lower fuel consumption (the first two attributable to lower processing requirements).

For the range of biodiesel blends examined in the study B100 performs better than lower blends B50 and B30 because the servicing costs are estimated as the same, but the GHG emission savings are proportionately greater for higher blend products.

The previous caveats over the BTL and HVO cost estimates should be noted. If the estimate of fuel price is at all realistic then this can still be offset by low / no change in maintenance or vehicle investment costs, so generating a cost effectiveness rating potentially rivalling lower cost fuels (viewed solely on a £ pl basis).

Another view is possible, based on much the same data. Cost per tonne of carbon abated is a common approach to comparing options and this is possible with the study data, as shown in Figure 4.5. A similar pattern to the previous analysis is seen, but displayed in reverse with lower values an indication of more cost effective carbon reduction that fuels with high values. Therefore, of the high blend options currently available to bus operators biomethane at £186 per tonne, PPO at £255 per tonne and B100 at £282 tonne appear most attractive (solely on cost grounds). A potentially more practicable blend of B30 costs the equivalent of £476 per tonne due to the assumed increase in servicing costs and the higher cost of fuel.

Figure 4.5: Cost effectiveness of reducing GHG – local bus £ per tonne



4.3.5 Sensitivity analysis

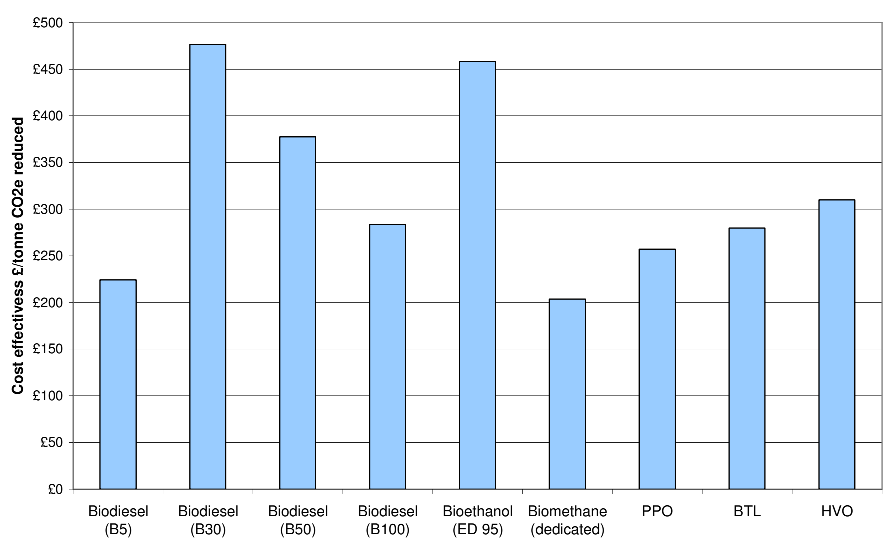
Many urban local bus services operate a lower annual mileage of around 59,000 km p.a. than the estimated national average of 74,600 km p..a. (method of calculation discussed in section 4.3.1). Therefore, a sensitivity analysis has been carried out with an annual mileage that is common on Metropolitan area bus services. The impact on GHG reductions and cost-effectiveness is shown in Table 4.4 and Figure 4.6. below.

Table 4.4: Comparison of national average and common urban area annual bus mileages for target fleet

Bus & fuel	Total fleet		Target fleet (20%) @ 74.6K vkm p.a.		Target fleet (20%) @ 59K vkm p.a.	
	GHG W2W	CO2e (t/yr)	GHG W2W	CO2e (t/yr)	GHG W2W	CO2e (t/yr)
Euro V diesel (base case)	100.0	3,429,291	100.0	685,858	100	685,858
Reduction from base case	% reduction	Reduction	% reduction vs. total fleet	Reduction (t/yr)	% reduction vs. total fleet emissions	Reduction
biodiesel (B5)	0.0	86,725	0.5	17,345	0.4	13,720
biodiesel (B30)	0.2	520,347	3.0	104,069	2.4	82,318
biodiesel (B50)	0.3	867,245	5.1	173,449	4.0	137,197
biodiesel (B100)	0.5	1,734,491	10.1	346,898	8.0	274,395
bioethanol (ED 95)	0.7	2,347,119	13.7	469,424	10.8	371,312
biomethane (dedicated)	0.8	2,638,451	15.4	527,690	12.2	417,401
PPO	0.5	1,774,896	10.4	354,979	8.2	280,787
BTL	0.8	2,571,968	15.0	514,394	11.9	406,883
HVO	0.5	1,868,249	10.9	373,650	8.6	295,555

Table 4.4 shows that a lower bus mileage results in a smaller reduction in GHG emissions. Given the same capital costs for vehicle and fuelling infrastructure this affects the cost-effectiveness estimates, with biofuels shower a high cost per tonne of carbon abated over the baseline (see Figure 4.6). For example, it is estimated that travelling 74,600 km p.a. a biomethane bus (dedicated) reduces GHG emission at a cost of £186 a tonne over the baseline diesel vehicle, but this increases to £203 a tonne if the vehicle travels a lower 59,000 km p.a.

Figure 4.6: Cost effectiveness of reducing GHG – local bus £ per tonne (based on a 59,000 km p.a. mileage)



4.3.6 Conclusions

Bus operators with an interest in high-blend biofuels are attracted by the environmental credentials, but also the possibility of improved vehicle performance and reduced wear. Cost considerations are always present and these will tend to dominate all operators view, even those with considerable motivation to implement changes that reduce their operations impact on the environment.

Reform of bus (fuel) subsidy (BSOG), announcement of a fund to support purchases of low carbon buses and bus service organisation (following the Transport Act 2008) could be viewed as support mechanisms with a positive impact on the potential for market expansion of high-blend biofuels in the UK.

The longer-term stability that could result from application of regulations from the LTA means that bus operators should be able to invest with greater certainty in their operations and make commitments to meeting public authority's objectives. When this happens it is possible to be more innovative with services and vehicles and fuels. Some of these characteristics are seen in London, although the capital also benefits from considerably higher subsidy per passenger than elsewhere in England.

The reform of BSOG announced in April 2009 will provide an enhanced payment of 6 ppkm for a low carbon emission bus, and there will be further support from a fund to help meet the additional purchase price of such vehicles. Biomethane vehicles will fall within the definition of a low carbon emission bus. Biomethane cost effectiveness appears good, but needs to be balanced by the high investment cost and longer payback period. This requires long term stability and certainty for private sector investment to be forthcoming. In addition, vehicle availability issues need to be overcome. Past experience of CNG means UK bus operators will be reluctant to spend their fleet replacement budget on new gas buses. Dual-fuel conversion of existing vehicles would mean lower capital costs compared to new dedicated vehicles, however dual-fuel works better (i.e. higher gas utilisation) when under steady running compared to stop-start conditions typical of urban bus routes. Therefore, Norfolk County Council help is converting existing buses to dual-fuel and this technology is of interest.[67]

4.4 HGV

4.4.1 Background (to sector)

Large articulated HGV are the largest road transport vehicles (28 - 44 tonnes) generally used for long distance movements of goods across the country, between depots and to/from mainland Europe. Tractor units can pull different types of trailer, depending on the good to be transported. HGV (large artics) complete the highest

67 http://www.ngvglobal.com/uk-first-bus-modified-for-dual-fuel-biomethane-diesel-0908

annual mileage of all commercial vehicles, with 110,000 to 170,000 km p.a not uncommon. We have used the TSGB figure of 11.99 billion km, which gives an average annual mileage of 113,455 (which is on the low end of estimates). There are around 112,255 such vehicles registered in Great Britain, with 10% operated by organisations with 51-100 vehicles (around 31,000 vehicles, 750 operators) and 15% operated by organisations with over 100 vehicles in their fleet (around 45,000 vehicles, 300 operators.)

Smaller articulated HGV (under 28 tonnes) are used for towing trailers/tanks where access or particular manoeuvrability is needed, for instance accessing city centres. They number some 9,098 vehicles and will tend to operate from a depot as they are used for more local distribution. We have assumed the same split between large and smaller fleets as for large artics, which provides a sufficient pool for vehicles that could be suitable for high-blend biofuels. TSGB figures for total distance travelled of 2.52 billion km pa are used to derive a best estimate of annual mileage, of 195,107 vkm pa (which is rather high), 100,000 vkm pa being closer to the norm.

Rigid chassis vehicles have a cab and loading area fixed to the same chassis. The largest, heaviest such vehicles are used in the construction and waste industries with low gearing and sometimes with tipper bodies. Refuse collection vehicles (RCVs) fall into this category too. It is estimated there are 73,662 rigid chassis vehicles in the over 24t class. TSGB records 4.59 billion vkm travelled, which averages at 46,580 per annum. This appears to be in line with other estimates of annual mileage.

Rigid chassis vehicles between 7.5 to 24 tonnes come in a variety of formats, including curtain sided, rigid box and refrigerated units. They are the work-horse of goods distribution at the local level, and used extensively by parcel delivery companies. TSGB records 100,443 such vehicles and an annual distance travelled for this fleet of 4.59 billion vkm. This equates to 45,724 km pa, which is a rather low estimate (with typical high-intensity users averaging 75,000 km pa).

The study has used the vkm noted above (derived from TSGB) in order that consistent figures are used for the total emissions saving per vehicle sub-sector. These vkm estimates have been carried forward into the cost-estimates as well, but some sensitivity testing has been done using vkm figures closer to the typical user figure.

Broadly, fleets above 50 vehicles will practice depot based fuelling, and fleets below 50 vehicles are more likely to use forecourts with fuel card accounts. The large fleet operators tend to have a network of depots across the country and even with regional or cost-centre operations they will practice strict depot-based fuelling to ensure the best price for their fuel. This could involve cross-billing from one part of the business to another when a vehicle from one region fills at a depot in another region. This means the large fleets can manage closely the fuel they use and it cost, and has most control over what type of fuel they choose to use.

The largest fleets will purchase all vehicles from new and therefore will be constrained by the warranty exclusions for non-standard vehicle operation (e.g. using high-blend biofuel when not approved for that vehicle). Conversely, large organisations also have some ability to negotiate with the vehicle manufacture/dealer over warranty terms and conditions, should they wish to pursue high-blend biofuels. Operators of the large fleets will comprise both hire-and-reward operators and own-account operations. They could comprise the largest potential market for this sub-sector of the vehicle parc.

A number of truck engine manufacturers will warranty their vehicles for use with high-blend biodiesel. Daimler-Chrysler, Scania, MAN and Daf produce engines for various models of truck that can be operated with B100. Renault will warranty the majority of their engines for use with B30 and Iveco will do likewise with a number of engine types. However, some key manufacturers such as Volvo will only warranty their vehicles for B5. For other fuels the current OEM offer to UK markets is much lower. Mercedes offer the Econic CNG HGV (which can be used in small artic, small rigid or RCV forms) and Volvo is working with CAP to develop dual fuel (CNG/diesel) technology to fit from new. The first potential bioethanol trucks are now being tested by Scania in Sweden, and are not included in this option assessment. Retrofit options from after-market suppliers support some PPO use in the UK in the HGV fleet.

The market expansion scenario illustrated here is that 30% of the largest fleet owners (50 vehicles and upwards) could operate with high blend biofuels. This equates to:

- 23,541 HGV artic large (21% of the total HGV artic large fleet);
- 2,034 HGV artic small (21% of the total);
- 15, 238 HGV rigid large (21% of the total) and
- 23,140 HGV rigid small (23% of the total).

These comprises 21.7% of the total HGV parc of 295,059 vehicles.

For comparison the impact of the using high-blend fuels for the entire sub-sector of each HGV fleet is included, as a ‘maximum’ scenario.

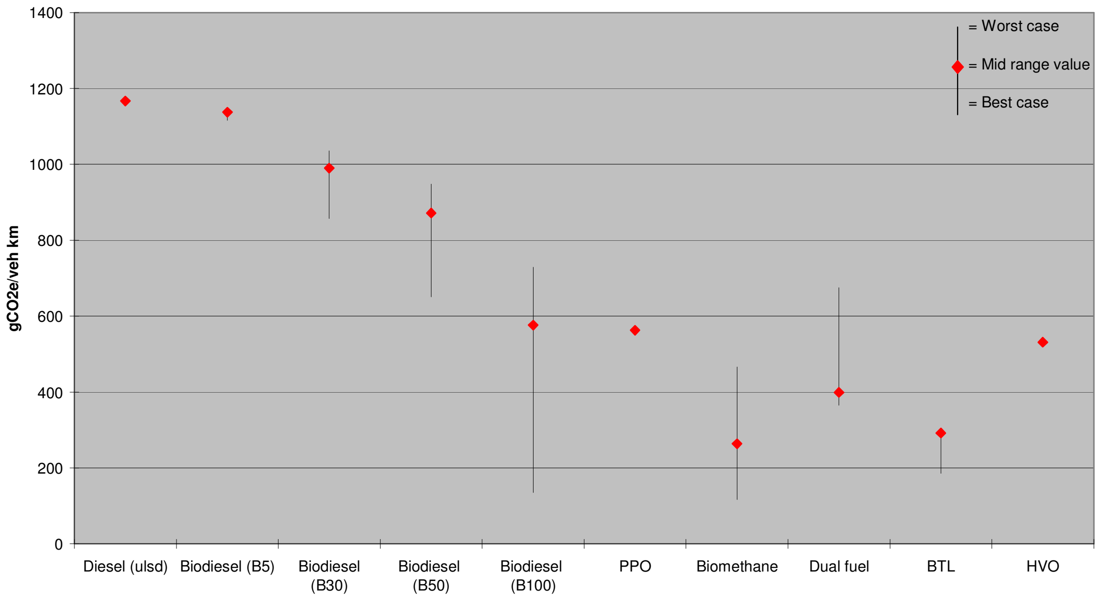
4.4.2 Benefits and Greenhouse gas reduction

This section illustrates savings of GHG emissions (W2W estimates) against a baseline (Euro V vehicle). Reductions are estimated for an individual vehicle (g/km CO_2e) and for the entire fleet and market expansion scenario outlined above.

4.4.2.1 Reductions per vehicle

GHG values for each fuel are combined with the fuel consumption values to determine the gCO_2e per vehicle km (veh km). The result of this assessment is a range of figures for best-case, worst-case and a mid-range value for each fuel.

Figure 4.7: Relative GHG emissions per vehicle km by fuel – HGV (large artic)



It can be seen that a relatively large range in emissions can be produced from the high-blends fuels, based on variations in their carbon emissions on a WTW basis.

Taking the Euro V HGV large artic operating with diesel (B0) as the baseline it produces approx 1167 gCO_2e/km. A more realistic baseline for diesel given the effects of the RTFO could be standard diesel contained 5% FAME (B5), which provides a similar baseline figure of approx 1137 gCO_2e/km.

Reductions in GHG emission to 85% and 75% of the B0 value is possible by using B30 and B50, with emissions per vkm of 872 and 990 gCO_2e/km respectively.

B100 and PPO default values are quite comparable and show a further potential reduction to 49% and 48 % of the B0 baseline respectively, based on emission per vkm of 577 and 563 gCO_2e/km respectively.

For dual-fuel vehicles such as PPO and biomethane an assumption has been made about the ratio of standard diesel and biodiesel. The exact ratio will depend on many things including type of vehicle, type of operation and which version of the technology is in use. It is assumed that PPO fuelled HGV will use 87% PPO and 13% diesel[68] and for biomethane dual-fuel the ratio is 85% gas and 15% diesel for large artics and 70% gas for other HGV and MGV.[69] There are obviously examples lower than this (e.g. in stop start conditions), but one of the requisites for optimal dual fuel operation is some degree of steady running to maximise the biofuel ratio. For example, there is a recent report from the John Lewis Partnership of 94% PPO use.

68 Based on information supplied by Matrix Biofuels.
69 Cenex, Biomethane Toolkit, 2008

The very wide range of WTW emissions from B100 is particularly noticeable, with the worst case estimate only as good as the worst B50. The best case, based on used vegetable oil (UVO) or tallow is however very low at below 200 gCO_2e/km. This indicates the importance of encouraging sustainable production of biodiesel, and its significant GHG reduction potential if it can also be produced at an acceptable price. Volumes of the recycled feedstock would reach a limit with increased demand so the best case would not be achievable if the market demand was to expand indefinitely.

Of the currently available high-blend biofuels biomethane in dual fuel operation or better still dedicated gas vehicles widely acknowledged as translating into very low GHG emissions. This is reflected in this studies analysis, with the mid-values selected for onward analysis showing just 264 gCO_2e/km and 399 gCO_2e/km respectively, which is 22.6% and 34.2% of the baseline diesel emissions.
Estimates are included for 100% HVO and BTL which are anticipated to make considerable savings on GHG emissions if they are used in high-blend form.

The data HGV large artic is presented together with the other three HGV sub-sectors in Table 4.5 below.

Table 4.5: Relative GHG emissions per vehicle km by fuel – HGV (all)

Fuel	**HGV large artic**		**HGV small artic**		**HGV large rigid**		**HGV small rigid**	
	gCO_2e/km	% reduction	*gCO_2e/km*	% reduction	*gCO_2e/km*	% reduction	*gCO_2e/km*	% reduction
Diesel	1167	0	1167	0	1098	0	574	0
Biodiesel (B5)	1137	2.5	1137	2.5	1071	2.5	560	2.5
Biodiesel (B30)	990	15.2	990	15.2	932	15.2	487	15.2
Biodiesel (B50)	872	25.3	872	25.3	821	25.3	429	25.3
Biodiesel (B100)	577	50.6	577	50.6	543	50.6	284	50.6
PPO	563	51.8	563	51.8	530	51.8	277	51.8
Biomethane (dedicated)	264	77.4	264	77.4	264	76	204	64.5
Biomethane (dual – fuel)	399	65.8	535	54.2	514	53.2	315	45.1
BTL	292	75	292	75	275	75	144	75
HVO	531	54.5	531	54.5	500	54.5	261	54.5

Note that large artic and small artic figures are largely the same for each fuel, because the fuel consumption is estimated as similar. Large artics are used for steady driving on trunk routes while small artics are lighter, but used in urban areas and for deliveries of specialist goods and as a result suffer a fuel consumption penalty. This has an impact on the dual fuel biomethane estimates for small artic, large rigid and small rigid HGV because a higher proportion of diesel is used in stop-start conditions and with frequent changes in engine load.

4.4.2.2 Reductions per fleet

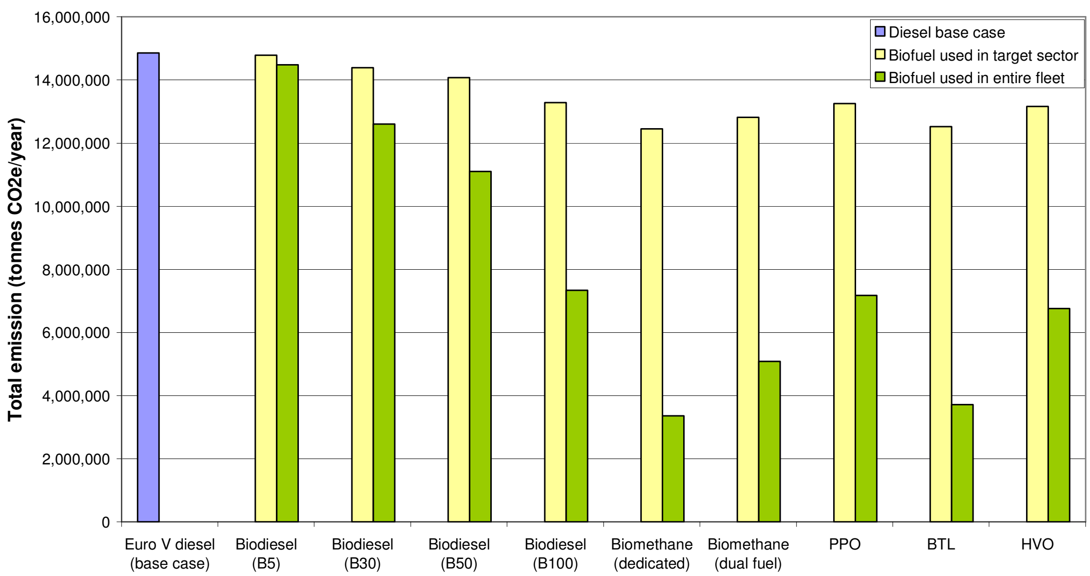
To illustrate the potential of high-blend biofuels a target of 30% use by the organisations with fleets of over 50 vehicles has been set. These organisations are likely to have depot-based fuelling as part their support infrastructure for intensive regional and/or national operations.

For HGV large artic the scenarios used to illustrate the potential GHG reductions possible across a range of high-blend biofuels are:

- Total fleet of 112,255 HGV large artic; and
- Target fleet of 23,541 HGV large artic, which is 30% of vehicles in the largest fleets (and 21% of total HGV large artic fleet)

The total GHG emission of the entire large artic HGV fleet operating on B0 is estimated at a considerable 14.86 m tCO_2e/year.[70] The total emissions from the target 21% total some 3,116,486 tCO_2e/year. The estimated emissions by using high-blend biofuels against this baseline is shown in Figure 4.8 below. The input data and assumptions for this estimation are as for the bus fleet. It is notable that emissions for this sub-sector of the parc are four times larger than the local bus fleet.

Figure 4.8: Potential GHG emissions by fuel by fleet – HGV (large artic)



The same data on potential emissions using different fuels can be seen in table 4.5, quantifying the reduction against baseline in terms of % and also in tCO_2e/year.

[70] Based on a TSGB estimate of 12,200,000,000 total veh km travelled. With a large artic HGV fleet of some 112,255 vehicles this equates to an average distance of 108,681 km p.a. This appears somewhat low given what is know about modern HGV trunking operations (and the figure of 170,000 v.km.p.a. used in cost tables later), TSGB figures will include a number of older vehicles that are not used as intensively as their newer counterparts.

Table 4.6: Potential reduction in fleet GHG emissions – HGV (artic large)

HGV (artic large) & Fuel	Total fleet		Target fleet (21%)	
	GHG W2W	CO_2e (t/yr)	GHG W2W	CO_2e (t/yr)
Euro V diesel (base case)	100.0	14,828,820	100.0	3,109,752
Reduction from base case	Reduction %	Reduction	% reduction vs. total fleet	Reduction
biodiesel (B5)	2.5	375,830	0.5	78,814
biodiesel (B30)	15.2	2,254,979	3.2	472,883
biodiesel (B50)	25.3	3,758,299	5.3	788,139
biodiesel (B100)	50.6	7,516,598	10.6	1,576,278
biomethane (dedicated)	77.4	11,505,236	16.2	2,412,720
Biomethane (dual fuel)	65.8	9,779,451	13.8	2,050,812
PPO	51.8	7,691,699	10.9	1,612,998
BTL	75.0	11,145,894	15.7	2,337,364
HVO	54.5	8,096,254	11.4	1,697,835

Table 4.6 shows estimates that of operating the 20% target fleet with B100 or PPO resulting in savings of around 1.57 million tCO_2e/year, taking 10% of total emissions of the HGV large artic parc. Using B30 in the target fleet would reduce GHG emissions by a relatively small 3.2% (472,883 tCO_2e/year). In comparison, using B30 in the entire large artic HGV fleet could reduce GHG by 15% or 2.25 m tCO_2e/year.

Significant GHG reductions appear feasible solely from the target fleet (20% of total HGV large artic parc) if they are operated with biomethane in dedicated or dual-fuel form. A 14-16% reduction against all HGV large artic emissions from switching just 20% of the fleet to this fuel appears a very effective rate of improvement, with 2 – 2.4 m tCO_2e/year avoided.

To understand the volume of biofuels required to fuel such fleets we can estimate that 23,541 large artic HGV with a fuel consumption of 0.375 litres per km (7.53 mpg) travel a conservative annual vkm of 108,681 km each. This means the 20% target fleet would consume the equivalent in biofuel of some 959,800,133 litres of diesel fuel. The amount of biodiesel required would depend on the blend proportion (B30, B50 or B100), with lower blends requiring less of the biofuel component. Expanding the market from the 20% target fleet to the entire large artic fleet would require the equivalent of 4,799,000,663 litres of diesel, which for B30 would require 1,439,700,199 litres of the biodiesel component.

The NSCA published report by STS on biogas as a road transport fuel examined a low and high production scenario for biomethane in the UK.[71] The low production scenario was sufficient to fuel some 1.5 billion vkm p.a. by HGV and the high production scenario enhanced this significantly, to some 5.2 billion HGV vkm and 1.3 billion LGV vkm. This study has estimated the large artic HGV fleet travels some 12.8 billion vkm and therefore for a target 21% travelling 2.5 billion vkm sufficient biomethane might be produced by a mid production scenario. The high production scenario would add sufficient biomethane for other HGV and most of the other

[71] Biogas as a road transport fuel, NSCA (now EPUK), 2006.

vehicle types recommended as potential markets for biomethane (i.e. other HGV and local bus).

The GHG emissions from the total HGV fleet are significant, and using the study methodology is estimated in excess of 20 m tCO_2e/year. The total GHG emissions savings from biofuels used in the entire HGV fleet has been compiled from the sub-sectors of HGV Artic (small and large) and HGV Rigid (small and large), in Table 4.6. The scenarios for each of these sub-sectors was similar to the HGV artic large sub-sector, that 30% of the largest fleets could use a high-blend biofuel, meaning the target fleet components are made up as:

- 23,541 HGV artic large (20% of the total HGV artic large fleet);
- 2,034 HGV artic small (22% of the total);
- 15, 238 HGV rigid large (21% of the total); and
- 23,140 HGV rigid small (23% of the total).

The GHG reducing potential of high-blend biofuels in the HGV sector can be seen, even when focussed on a target fleet of around 21% of all HGV. With B30 or B5 in the target fleet (approximately 20% of HGV vkm) CO_2e reductions might equal 0.75 and 1.25 m tCO_2e/year.

With B100 or PPO in the target 21% fleet CO_2e reductions might equal 10% of total HGV fleet GHG emissions, saving some 2.5 m tCO_2e/year.

Biomethane used by 21% of the HGV fleet could reduce GHG emissions by between 3 and 3.7 Mt/CO_2e a year.

In due course, fuel such as HVO and BTL might take GHG reduction even further: even if focussed on 20% of the HGV fleet they might produce GHG reductions of 12% and 16% respectively of the total fleet emissions.

Table 4.7: Potential reduction in fleet GHG emissions – HGV (all)

HGV artic & rigid (small & large)	**Total fleet**		**Target fleet (21.7%)**	
Fuel	GHG W2W as % of baseline	CO_2e (t/yr)	GHG W2W as % of baseline	CO_2e (t/yr)
Euro V diesel (base case)		23,287,265		4,966,734
Reduction from base case	Reduction %	Reduction	% reduction vs. total fleet	Reduction
biodiesel (B5)	2.5%	588,920	0.5%	125,605
biodiesel (B30)	15.2%	3,533,519	3.2%	753,633
biodiesel (B50)	25.3%	5,889,198	5.4%	1,256,055
biodiesel (B100)	50.6%	11,778,397	10.8%	2,512,110
biomethane (dedicated)	75.7%	17,634,823	16.1%	3,755,526
Biomethane (dual fuel)	61.2%	14,242,772	13.0%	3,021,255
PPO	51.8%	12,052,777	11.0%	2,570,630
BTL	75.0%	17,465,449	16.0%	3,725,050
HVO	54.5%	12,686,708	11.6%	2,705,835

4.4.3 Cost and practicability

This section considers the cost per vehicle of achieving the GHG reductions shown in the section above, based on the range of high-blend biofuels, and the practicability of doing so. An estimate is made of the cost-effectiveness of using fuels to achieve the different levels of GHG reduction.

4.4.3.1 Costs

A cost estimate has been made based on vehicle purchase cost, fuelling infrastructure costs (if applicable), maintenance costs and fuel consumption/costs over the defined amortisation period at the annual vehicle mileage (vkm p.a.). The key output is the Overall Cost column showing £/vkm. High and low cost estimates have been made based on different vkm pa estimates.

It can be seen from Table 4.8 that the overall cost (£/vkm) varies quite considerably depending on the fuel. High-blend biodiesels (and PPO) are estimated to result in high overall costs because of the fuel cost combined with the maintenance costs of doubling service intervals. HGV operators, in common with most vehicle owners, wish to extend service intervals for as long as practicable given the cost of both servicing and the lost working time while the vehicle is off the road. This contrasts with the bus industry which tends to practice a short-interval service regime of approximately 28 days/3,300 miles so that additional servicing for biodiesel is estimated to incur such large costs to the operator.

Table 4.8: Vehicle cost estimates – HGV (large artic)

	Capital outlay		Overall cost		Fuel						
Fuel	Vehicle cost (£)	Fuel equip. £/veh	Total cost £/vkm	Mainten-ance £/vkm	£ per litre / kg	Efficiency (l or kg / km)	Amorti-sation (years)	Vkm p.a.	Fuel £p.a.	Maintenance £p.a.	Capital £ p.a.
Euro V diesel (base case	50,000	0	£0.24	0.050	0.31	0.38	6	113,455	£13,194.3	£5,697.4	£8,333.3
Biodiesel (B5)	50,000	0	£0.25	0.050	0.33	0.38	6	113,455	£13,945.0	£5,697.4	£8,333.3
Biodiesel (B30)	50,000	300	£0.32	0.090	0.42	0.38	6	113,455	£18,217.7	£10,255.3	£8,383.3
Biodiesel (B50)	52,290	300	£0.35	0.090	0.47	0.39	6	113,455	£20,805.3	£10,255.3	£8,765.0
Biodiesel (B100)	52,290	300	£0.41	0.090	0.59	0.40	6	113,455	£27,154.8	£10,255.3	£8,765.0
Biomethane (dedicated)	85,000	14500	£0.37	0.065	0.51	0.31	6	113,455	£17,880.9	£7,406.6	£16,583.3
Biomethane (dual fuel)	73,000	14500	£0.35	0.065	0.51	0.31	6	113,455	£17,177.9	£7,406.6	£14,583.3
PPO	53,600	300	£0.38	0.090	0.57	0.38	6	113,455	£24,178.2	£10,255.3	£8,983.3
BTL	50,000	0	£0.48	0.050	0.96	0.38	6	113,455	£40,963.9	£5,697.4	£8,333.3
HVO	50,000	0	£0.42	0.050	0.79	0.38	6	113,455	£33,561.8	£5,697.4	£8,333.3

Fuel costs are before duty and VAT, in order to show the situation without any policy intervention. A high and low cost estimate has been made, by varying the vkm p.a. to test if the relative position of fuel options changes in either scenario.

As anticipated, without any duty incentives conventional diesel fuelled vehicles have the lowest fuelling cost and produce the lowest overall cost on a £/vkm basis, and this forms the base case from which to measure other fuels.

Comparing the various high blend fuels this analysis suggests biomethane (dual) fuelled vehicles are estimated to have some of the lowest overall costs (total cost £/vkm), due a combination of fuel costs and consumption. Dedicated biomethane vehicles, being more costly to purchase have a higher overall cost on a £/vkm basis.

While biomethane fuelling requires the largest investment in capital costs, the fuel efficiency/price mix means this can be more than offset during the operating life of a HGV used for trunking movements. HGV carrying out long-distance duties on trunk roads can make the best use of dual-fuel operation as the steady running lends itself to the highest proportion of biomethane vs. diesel. The lower capital cost of a dual-fuel conversion vs. a dedicated gas engine makes this option more attractive. A overall cost advantage from biomethane/CNG vs. diesel for artic HGV trunking movements is borne out by current practice from a few haulage companies and own account operators, aided by the current duty incentive.

B100 can be a costly fuel if a more sustainable and available RME version is used, which forms the basis for the cost estimates in this analysis. PPO operation is also towards the top end of cost range as it's a 100% vegetable oil. High fuel cost (vs. diesel) plus conversion costs for PPO and some additional cost for running on B100 has been added to the capital cost estimate, which compounds the additional fuel cost vs. diesel. B50 and B30, with their progressively lower levels of bio-content have reduced costs compared to B100, and are not anticipated to require additional engine or fuel line modifications.

There are no known UK commercial users of 100% BTL or HVO fuels and the cost of purchasing these fuels is not publicly available for high-blend variants. Low-blend BTL exists in some premium diesel products and low-blend HVO is on sale (in the form of Neste Oils NExtBTL™) in parts of Finland and in Thailand. Therefore, estimates are included for illustration only and the results should be viewed with due caution. We have used figures of 130 ppl for HVO and 150 ppl for BTL (inc duty, ex VAT).

High mileage vehicles, such as large artic HGV, will perform less well on a total cost £/vkm basis with high per litre priced fuels. Conversely, as shown by this analysis (and experience of using biomethane), high-mileage operations provide the opportunity to offset capital costs if the ongoing costs such as fuel are lower than other low carbon fuels. The sensitivity testing with high-mileage inputs (170,000 vkm p.a.) do not alter the ranking of costs for different fuels, but do close the gap for biomethane operations compared with the average mileage of 113, 455 vkm pa.

Tables 4.9 to 4.111 provide the same cost information for each of the other three sub-sectors of the HGV fleet.

Table 4.9: Vehicle cost estimates – HGV (small artic)

	Capital outlay		Overall cost		Fuel		Financial				
Fuel	**Vehicle cost (£)**	**Fuel equip. £/veh**	**Total cost £/vkm**	**Mainten-ance £/vkm**	**£ per litre / kg**	**Efficiency (l or kg / km)**	**Amorti-sation (years)**	**Vkm p.a.**	**Fuel £p.a.**	**Mainten-ance £p.a.**	**Capital £ p.a.**
Euro V diesel (base case)	48,000	0	£0.20	0.046	0.31	0.375	6	195,107	22,690	9,046	8,000
Biodiesel (B5)	48,000	0	£0.21	0.046	0.33	0.376	6	195,107	23,981	9,046	8,000
Biodiesel (B30)	48,000	300	£0.29	0.083	0.42	0.383	6	195,107	31,329	16,283	8,050
Biodiesel (B50)	50,290	300	£0.31	0.083	0.47	0.389	6	195,107	35,779	16,283	8,432
Biodiesel (B100)	50,290	300	£0.37	0.083	0.59	0.403	6	195,107	46,698	16,283	8,432
Biomethane (dedicated)	73,000	14500	£0.29	0.060	0.51	0.310	6	195,107	30,750	11,760	14,583
Biomethane (dual fuel)	66,000	14500	£0.28	0.060	0.51	0.310	6	195,107	29,541	11,760	13,417
PPO	51,600	300	£0.35	0.083	0.57	0.397	6	195,107	44,025	16,283	8,650
BTL	48,000	0	£0.45	0.046	0.96	0.375	6	195,107	70,445	9,046	8,000
HVO	48,000	0	£0.40	0.046	0.79	0.397	6	195,107	61,111	9,046	8,000

Table 4.10: Vehicle cost estimates – HGV (large rigid)

	Capital outlay		Overall cost		Fuel						
Fuel	**Vehicle cost (£)**	**Fuel equip. £/veh**	**Total cost £/vkm**	**Mainten-ance £/vkm**	**£ per litre / kg**	**Efficiency (l or kg / km)**	**Amorti-sation (years)**	**Vkm p.a.**	**Fuel £p.a.**	**Mainten-ance £p.a.**	**Capital £ p.a.**
Euro V diesel (base case)	48,000	0	£0.31	0.048	0.31	0.353	7	46,580	£5,099	£2,255	£6,857
Biodiesel (B5)	48,000	0	£0.31	0.048	0.33	0.354	7	46,580	£5,389	£2,255	£6,857
Biodiesel (B30)	48,000	300	£0.39	0.087	0.42	0.361	7	46,580	£7,040	£4,059	£6,900
Biodiesel (B50)	50,290	300	£0.41	0.087	0.47	0.366	7	46,580	£8,040	£4,059	£7,227
Biodiesel (B100)	50,290	300	£0.47	0.087	0.59	0.379	7	46,580	£10,494	£4,059	£7,227
Biomethane (dedicated)	78,000	14500	£0.50	0.063	0.51	0.310	7	46,580	£7,341	£2,932	£13,214
Biomethane (dual fuel)	68500	14500	£0.46	0.063	0.51	0.310	7	46,580	£6,668	£2,932	£11,857
PPO	51,600	300	£0.46	0.087	0.57	0.374	7	46,580	£9,893	£4,059	£7,414
BTL	48,000	0	£0.54	0.048	0.96	0.353	7	46,580	£15,830	£2,255	£6,857
HVO	48,000	0	£0.49	0.048	0.79	0.374	7	46,580	£13,733	£2,255	£6,857

Table 4.11: Vehicle cost estimates – HGV (small rigid)

	Capital outlay		Overall cost		Fuel						
Fuel	**Vehicle cost (£)**	**Fuel equip. £/veh**	**Total cost £/vkm**	**Mainten-ance £/vkm**	**£ per litre / kg**	**Efficiency (l or kg /km)**	**Amorti-sation (years)**	**Vkm p.a.**	**Fuel £p.a.**	**Mainten-ance £p.a.**	**Capital £ p.a.**
Euro V diesel (base case	24,000	0	£0.18	0.046	0.310	0.185	6.5	45,724	£2,617	£2,126	£3,692
Biodiesel (B5)	24,000	0	£0.19	0.046	0.327	0.185	6.5	45,724	£2,766	£2,126	£3,692
Biodiesel (B30)	24,000	175	£0.24	0.084	0.419	0.189	6.5	45,724	£3,613	£3,826	£3,719
Biodiesel (B50)	26,290	175	£0.26	0.084	0.472	0.191	6.5	45,724	£4,127	£3,826	£4,072
Biodiesel (B100)	26,290	175	£0.29	0.084	0.594	0.198	6.5	45,724	£5,386	£3,826	£4,072
Biomethane (dedicated)	39,000	14500	£0.36	0.060	0.508	0.240	6.5	45,724	£5,579	£2,763	£8,231
Biomethane (dual fuel)	38,000	14500	£0.34	0.060	0.508	0.240	6.5	45,724	£4,690	£2,763	£8,077
PPO	26,290	175	£0.28	0.084	0.568	0.195	6.5	45,724	£5,078	£3,826	£4,072
BTL	24,000	0	£0.30	0.046	0.962	0.185	6.5	45,724	£8,125	£2,126	£3,692
HVO	24,000	0	£0.28	0.046	0.789	0.195	6.5	45,724	£7,048	£2,126	£3,692

4.4.3.2 Practicality

The practicability of using high-blend biofuels in the UK HGV fleet is considered in Table 4.12. This draws on the information used in this study, interpreted by the study team to provide a guide to the practicability considerations that will be of most concern to a fleet operator.

Table 4.12: Practicality considerations – HGV (all)

	B0	B5	B30	B50	B100	Bio-methane	PPO	BTL	HVO
PRACTICABILITY									
Availability of vehicles in UK	High	High	Medium	Low	Medium	Low	Medium	High	High
Availability of fuel in UK	High	High	Low - Medium	Low - Medium	Low Medium	Low	Low-Medium	Low	Low
Fuelling equipment changes	None	None	Low	Medium	Medium	High	Medium	None	None
Maintenance	Normal	Normal	Raised	Raised	Raised	Norm to raised	Raised	Normal	Normal
ENVIRONMENT									
GHGe WTW emissions (% of baseline)	97%	85%	75%	49%	24%	39%	48%	25%	46%
Air-quality: NO_x/ PM vs. baseline	1.0	1.004 / 0.981	1.024 / 0.886	1.04 / 0.81	1.08 / 0.62	0.21 / 0.17	1.0 / 0.6	0.85 / 0.82	0.9 / 0.7
Noise	Norm	Norm	Norm	Norm	Norm	Lower	Norm	Norm	Norm
VEHICLE COSTS									
Capital	Norm	Norm	Raised	Raised	Raised	V.raised	Raised	Norm	Norm
Operating	Norm	Norm	Norm to raised	Norm to raised	Norm to raised	Lower to raised.	Raised	Dependant on fuel price.	Dependant on fuel price.
Overall	Norm	Norm	Norm to raised	Norm to raised	Norm to raised	Varies with opex: Lower to raised.	Raised	Likely to be raised	Likely to be raised

4.4.3.3 Cost effectiveness

For cost effectiveness, two methods of presenting the combined cost/emission data are used. Estimations are made of:

- kgCO_2e reduced per £ spent over the baseline (i.e. standard diesel) and
- £'s spent (over the baseline) per tonne gCO_2e reduced.

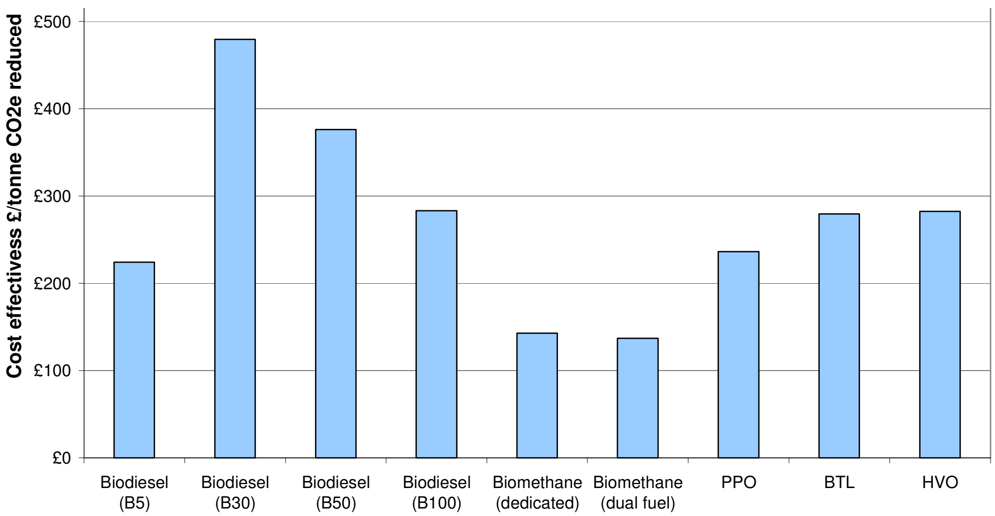
Of the currently available high-blend biofuels B100 perform better than lower blends because the servicing costs are likely to be the same as B50 or B30, but the GHG emission savings are proportionately greater.

PPO performs similarly to B100 in this analysis because even though the fuel price is slightly lower the servicing and capital costs are similar to standard diesel.

This cost-effectiveness of biomethane appears to be good because the cost of operating an HGV on biomethane is similar to other 100% blend fuels *and* a greater GHG emission saving is possible.

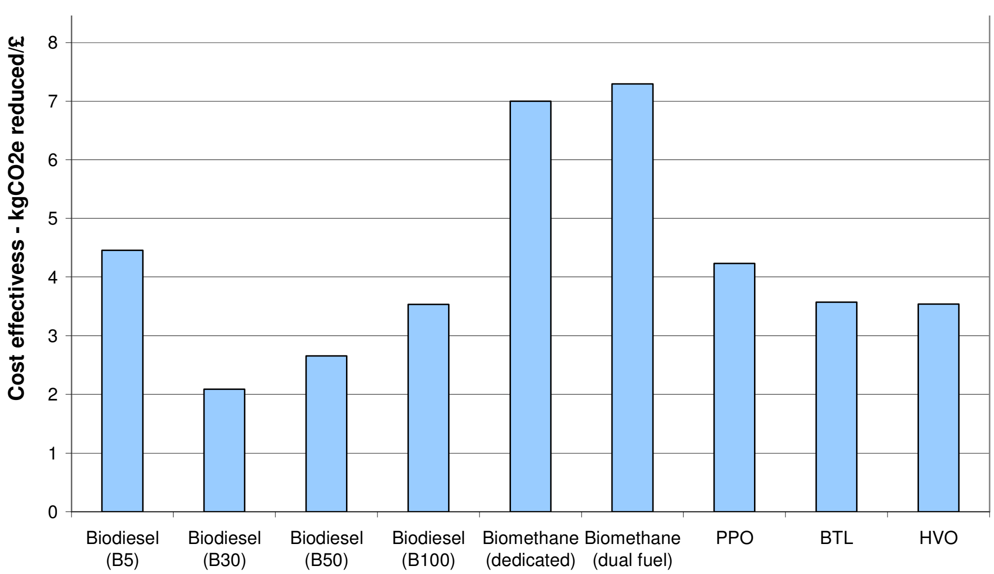
The previous caveats over the BTL and HVO cost estimates should be noted.

Figure 4.9: Cost effectiveness of reducing GHG emissions from fleet (£ per tonne CO_2e reduced) – HGV (large artic)



Cost effectiveness can be viewed in terms of kg of emissions reduced per £ spent. With the estimate of kgCO_2e reduced per £ spent (over the baseline) we can see that the best performing liquid fuel appears to be B5. This is largely because of no additional infrastructure costs or maintenance costs and a fuel price the same as B0. Therefore, none of the GHG saving is offset by any additional cost. In contrast, B30 to B100 are estimated to require considerable increase in servicing costs (by a factor of 1.8) due to the halving of service intervals to change oil and filters as recommended by the OEM who warranty their vehicles for these fuels.

Figure 4.10: Cost effectiveness of reducing GHG emissions from fleet (kg CO_2e reduced per £) – HGV (large artic)



4.4.4 Conclusions

The analysis shows that significant GHG savings can be made across the HGV fleet, modelled on a 21% sub-sector that is likely to practice own-tank fuelling and therefore able to choose fuel supplied, given sufficient incentives. If a choice is made to mover to high-blend biofuels the most effective (both in GHG and cost terms) are the higher blend biofuels (B100, PPO and biomethane) due to their lower carbon content compared to lower blends (e.g. B30).

Truck manufacturers currently warranting their vehicles for biodiesel operation are divided into those allowing up to B30 and then those allowing B100. There are a number of biomethane (dedicated or dual fuel) and PPO (retrofit) options. In terms of practicability B100 or PPO requires a similar investment in fuelling infrastructure and servicing than lower blends of biofuel (e.g. B30). There would generally need to be greater care needed for cold-weather operations of B100 compared to B30. Without a duty incentive B100 currently costs more than B30, due to the higher cost of biodiesel vs. standard diesel. The same factors apply to PPO, which would also require retrofit of an additional fuel tank for on-board storage along-side conventional diesel as the two are operated in tandem.

HGV operations are very cost-sensitive. In cost terms all high-blend options are more costly that diesel operation (apply fuel costs excluding duty or VAT). In the current duty regime (2009) all high-blend biofuels suitable for use in HGVs, other than biomethane, have had a selling price (at the pump) greater than standard diesel, even with duty incentives. Biomethane used in high-mileage vehicles with considerable trunking movements have been shown to save costs over a range of operations.[72] This, combined with the cost-effectiveness rating for GHG savings, suggests that biomethane is a very promising fuel for selected HGV operations in terms of a return on the subsidy that would be required. Liquid biofuels, such as B100 or PPO, appear less cost effective than biomethane, but still appear to be the fuels to consider if high-blends are chosen.

B100 does not perform quite as well as PPO on environmental grounds, but is a probably a more practicable option for HGV operators as it can be mixed with standard diesel if necessary (in fuelling equipment and on vehicle). PPO would however seem to suit HGV quite well, given the greater flexibility to configure on-board fuel tanks.

4.5 MGV

4.5.1 Background

Vehicles between 3.5 and 7.5 tonnes are used for a range of duties, and normally comprise large panel vans, Luton vans, drop-sided vans and vehicles based on these chassis (including mini-buses).

[72] E.g. Commercial Motor, Test of Volvo/ CAP dual-fuel, 11 June 2009.

In terms of large goods vehicle fleets, the UK government and public sector fleets operate a minimum of 35,000 commercial vehicles (over 3.5 tonnes).

MGV will tend to be owned by a range of organisations and individuals, and some of the former will use return to base patterns of fuelling and overnight storage at depots. For example, BT, Royal Mail, British Gas, plus many of the courier companies operate return to base fuelling and overnight parking at depot.

Vehicle availability to match with high-blend biofuels tends to currently favour biodiesel, and specifically B30. Iveco vehicles with the Cursor engine range can use B30, all PSA Group Hdi engines since 1998 can use B30 and Vauxhall Movana vehicle (with Renault engines) is also warranted to B30. PPO conversion kits matched to MGV manufacturers are available. For biomethane, the current options are the largest Iveco Daily and MB Sprinter models (the latter expected to be available during 2009). Worldwide there are more vehicles, including a range of gas trucks in Japan (which are right-hand drive).

Based on TSGB the size of the UK MGV fleet is some 151,164 vehicles which travel some 6,911,875,926 km p.a. which averages at 45,724 km p.a. per vehicle. This average appears somewhat high compared to the typical user, which will affect the resulting estimates of total GHG savings from the sector.

4.5.2 Benefits and Greenhouse gas reduction

This section illustrates savings of GHG emissions (W2W estimates) against a baseline (Euro V vehicle). Reductions are estimated for an individual vehicle (g/km CO_2e) and for the entire fleet and market expansion scenario outlined above.

4.5.2.1 Reductions per vehicle

GHG values for each fuel are combined with the fuel consumption values to determine the $gC0_2e$ per vehicle km (veh km). The result of this assessment is a range of figures for best-case, worst-case and a mid-range value for each fuel. These results are shown in Figure 4.11, with Table 4.13 showing the mid-range estimates in tabulated form, compared to the baseline fuel (B0).

Figure 4.11: Relative GHG emissions per vehicle km – MGV

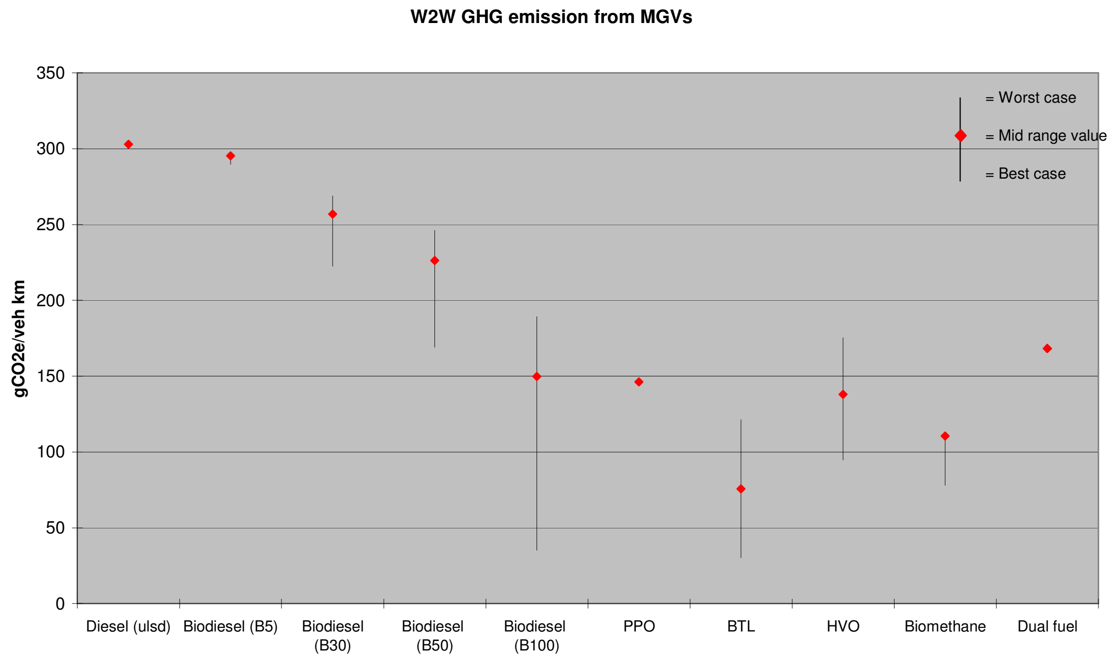


Table 4.13: Relative GHG emissions per vehicle km – MGV

Fuel	gCO_2e/km	% of baseline	% reduction
Diesel	303	100.0	0.0
Biodiesel (B5)	295	97.5	2.5
Biodiesel (B30)	257	84.8	15.2
Biodiesel (B50)	226	74.7	25.3
Biodiesel (B100)	150	49.4	50.6
PPO	146	48.2	51.8
BTL	76	25.0	75.0
HVO	138	45.5	54.5
Biomethane (dedicated)	111	36.5	63.5
Biomethane (dual fuel)	168	55.5	44.5

A relatively large range in emissions can arise from most biofuels, however, a pattern can be seen between the fuels assisted by estimated mid-range values.

The baseline fuel for a MGV can be considered diesel (B0). The mid-range value for a Euro V MGV operating with diesel (B0) is estimated as 303 gCO_2e/km. A more realistic baseline for diesel may be 5% FAME (B5), which provides a slightly lower figure of 295 gCO_2e/km, however for purposes of the comparisons B0 is the baseline. B30 and B50 have the potential to reduce the GHG to 85% and 75% of the baseline level (or 257 and 226 gCO_2e /km), respectively.

Looking at the high blends, significantly lower GHG emissions are estimated from both B100 and PPO, with 150 and 146 gCO_2e /km respectively (which are 48-49% of the B0 baseline). Both these fuels would require either modifications or non-warranted operation of vehicles given the current offer to UK vehicle purchasers. Dual fuel biomethane vehicles offer a similar level of benefit to PPO and B100, although this analysis is theoretical as dual fuel biomethane MGV are not currently in operation as far as the study team is aware.

Biomethane (dedicated operation) is estimated to provide the greatest GHG reductions of the currently available biofuels. Biodiesel made from UVO could equal or even exceed the reductions seen from biomethane, shown by the best-case figure for this fuel, but more commonly available RME or SME cannot reach the GHG reductions. The mid-range value for biomethane is 111 gCO_2e /km, 37% of the B0 baseline.

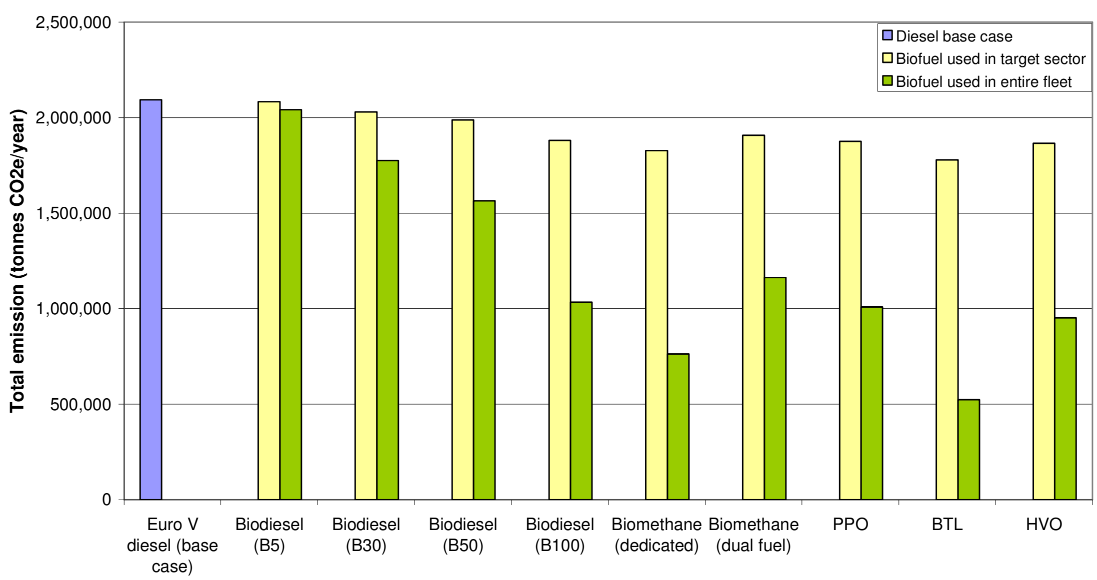
Were HVO available in 100% blend format then it is estimated to achieve similar GHG savings to PPO or B100 mid-range values. BTL is estimated to achieve the greatest GHG savings, down to just 25% of the baseline at 76 gCO_2e /km. However the gaps in information about this fuel mean these estimates are much less robust than for currently available and utilised high-blend biofuels.

4.5.2.2 Reductions from the MGV fleet

The proposed market expansion scenarios illustrated is that 20% of MGV use a form of high-blend biofuel fleets, which given a fleet of 151,164 vehicles equals 30,232 vehicles.

The illustration in Figure 4.12 shows the potential impact of 20% of the fleet using each type of high-blend biofuel, as well as the boundary impact of *all* MGVs using a biofuel.

Figure 4.12: Potential reduction in fleet GHG emissions – MGV



The overall estimated GHG emissions from the MGV fleet is just over 2 m tCO_2e/year. This is of a similar magnitude to the contributions from the HGV artic small and HGV rigid small fleets. The total emissions from the target 20% total around 0.4m tCO_2e/year. The estimated emissions by using high-blend biofuels against this baseline is shown in Table 4.14.

Table 4.14: Potential reduction in fleet GHG emissions – MGV

MGV (3.5 to 7.5t)	Total fleet		Target fleet (20%)	
	GHG W2W	CO2e (t/yr)	GHG W2W	CO2e (t/yr)
Euro V diesel (base case)	100.0	2,094,165	100.0	418,833
Reduction from base case	Reduction %	Reduction	% reduction vs. total fleet	Reduction
biodiesel (B5)	2.5	52,960	0.5	10,592
biodiesel (B30)	15.2	317,760	3.0	63,552
biodiesel (B50)	25.3	529,601	5.1	105,920
biodiesel (B100)	50.6	1,059,202	10.1	211,840
biomethane (dedicated)	63.5	1,330,403	12.7	266,081
Biomethane (dual fuel)	44.5	931,282	8.9	186,256
PPO	51.8	1,083,876	10.4	216,775
BTL	75.0	1,570,624	15.0	314,125
HVO	54.5	1,140,884	10.9	228,177

Focussing on the impact of operating the 20% target fleet with the currently available highest blend liquid biofuels (B100 and PPO) the analysis shows savings of 211,840 and 216,775 tCO_2e/year, respectively – a reduction of around 10%. Using a B30 blend in the target fleet would reduce GHG emissions by 63,552 tCO_2e/year; 3% of the total. In comparison, using B30 in the entire MGV fleet would reduce GHG emissions by 0.3m tCO_2e/year, around 15% of the total.

Using dual fuel biomethane within the target fleet gives similar benefits as B100 and PPO, however using a dedicated biomethane vehicle can give more significant reductions. Operating the target fleet on biomethane would give a reduction of 266,081 tCO_2e/year, a reduction of almost 13%.

4.5.3 Cost and practicality

This section considers the cost per vehicle of achieving the GHG reductions shown in the section above, based on the range of high-blend biofuels.

A cost estimate has been made based on vehicle purchase cost, fuelling infrastructure costs (if applicable), maintenance costs and fuel consumption/costs over the defined amortisation period at the annual vehicle mileage (vkm p.a.). The key output is the Overall Cost column showing £/veh km in Table 4.15.

Table 4.15: Vehicle cost estimates – MGV

	Capital outlay		Overall cost		Fuel						
Fuel	Vehicle cost (£)	Fuel equip. £/veh	Total cost £/vkm	Mainten-ance £/vkm	£ per litre / kg	Efficiency (l or kg / km)	Amorti-sation (years)	Vkm p.a.	Fuel £p.a.	Mainten-ance £p.a.	Capital £ p.a.
Euro V diesel (base case)	21,800	0	£0.20	0.047	0.310	0.097	4	45,724	£1,381	£2,171	£5,450
biodiesel (B5)	21,800	0	£0.20	0.047	0.327	0.098	4	45,724	£1,459	£2,171	£5,450
biodiesel (B30)	21,800	175	£0.25	0.085	0.419	0.099	4	45,724	£1,906	£3,908	£5,494
biodiesel (B50)	23,000	175	£0.26	0.085	0.472	0.101	4	45,724	£2,177	£3,908	£5,794
biodiesel (B100)	23,000	175	£0.27	0.085	0.594	0.105	4	45,724	£2,842	£3,908	£5,794
biomethane (dedicated)	25,800	4000	£0.29	0.062	0.508	0.130	4	45,724	£3,022	£2,822	£7,450
Biomethane (dual fuel)	24,800	4000	£0.27	0.062	0.508	0.130	4	45,724	£2,530	£2,822	£7,200
PPO	23,250	175	£0.27	0.085	0.568	0.103	4	45,724	£2,679	£3,908	£5,856
BTL	21,800	0	£0.26	0.047	0.962	0.097	4	45,724	£4,287	£2,171	£5,450
HVO	21,800	0	£0.25	0.047	0.789	0.103	4	45,724	£3,719	£2,171	£5,450

As seen in the analysis of HGV costs, without any duty incentives conventionally fuelled vehicles will return the lowest overall cost on a £/vkm basis. The B0/B5 base case from which to compare other fuels is £0.20 per vkm. Currently available high blends are all calculated to cost £0.27 per vkm, which is around 35% higher than the baseline costs. B30 and B50 are only slightly cheaper at £0.25 and £0.26 per vkm, respectively. Currently available high-blends deliberately exclude BTL and HVO.

The study has taken a somewhat conservative position on costs incurred to operate with high-blend biofuels, based on experience to date from across a range of operations and vehicle models. Some operators will be able to operate with lower costs. For example, it is possible to operate some vans with lower on-costs as (e.g. Vauxhall is the one OEM without a requirement to increase the servicing regime. If the van operator could always take advantage of existing B30 forecourt refuelling or converted existing own-tanks to biodiesel (rather than buying a new tank to run part of their fleet on B30), then capital costs would be reduced. These factors are taken into account in the study conclusions in Chapter 5, when recommending combinations of vehicle and fuels.

For cost effectiveness, two methods of presenting the combined cost/emission data are used. Estimations are made of:

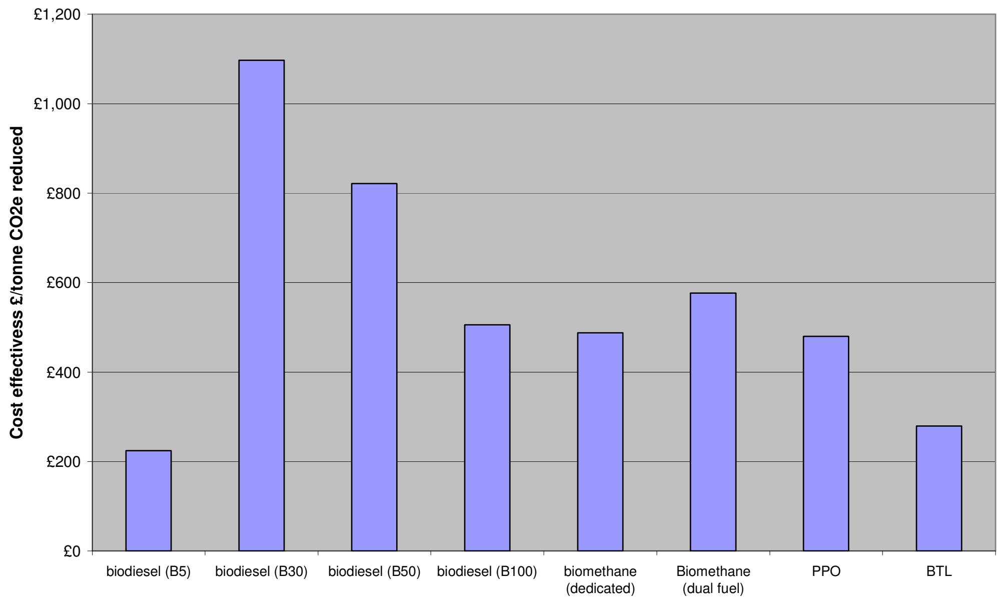
- kgCO_2e reduced per £ spent over the baseline (i.e. standard diesel) and
- £'s spent (over the baseline) per tonne gCO_2e reduced.

Of the currently available high-blends of biodiesel B100 performs better than lower blends because the servicing costs are the same as B50 or B30, but the GHG emission savings are proportionately greater.

PPO performs similarly to B100 in this analysis because even though the fuel price is lower the servicing costs are fixed at the same as standard diesel.

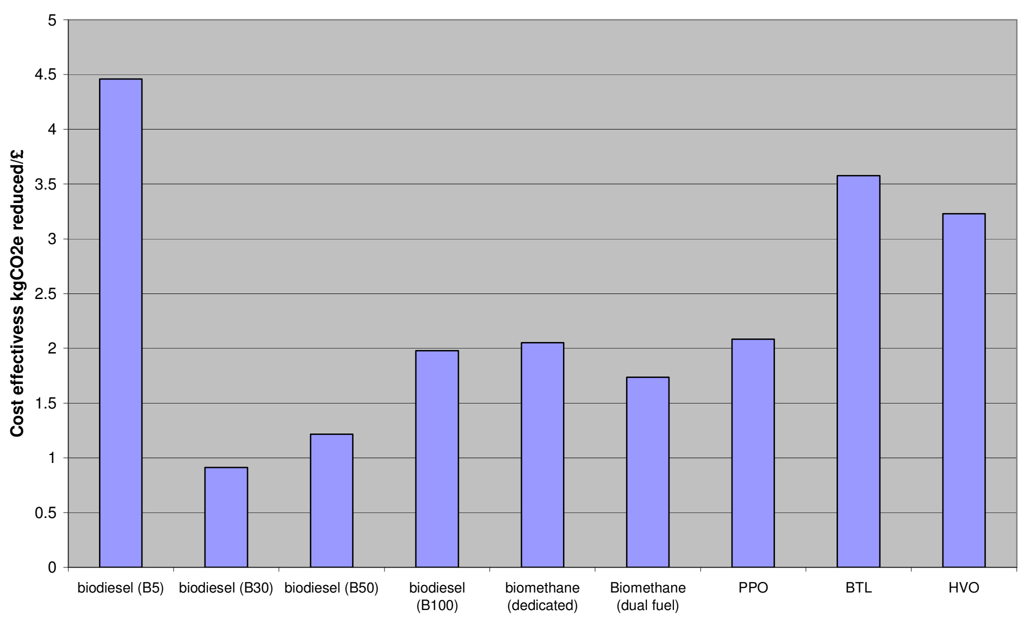
For biomethane the cost-effectiveness is slightly better than B100 because although the cost of operating an MGV on biomethane is similar to B100 a greater GHG emission saving is possible. The previous caveats over the BTL and HVO cost estimates should be noted.

Figure 4.13: Cost effectiveness of reducing GHG emissions from fleet (£ per tonne CO_2e reduced) – MGV



Cost effectives can be viewed in terms of kg of emissions reduced per £ spent. With the estimate of kgCO_2e reduced per £ spent (over the baseline) we can see that the best performing liquid fuel appears to be B5. This is largely because there are no additional infrastructure costs or maintenance costs and a fuel price the same as B0. Therefore, none of the GHG saving is offset by any additional cost. In contrast, B30 to B100 are estimated to require considerable increase in servicing costs (by a factor of 1.5) due to the halving of service intervals to change oil and filters as recommended by the OEM who warranty their vehicles for these fuels.

Figure 4.14: Cost effectiveness of reducing GHG emissions from fleet (kg CO_2e reduced per £) – MGV (3.5 – 7.5t)



Practicability issues for MGV will be very similar to those faced by HGV and LGV operations. In terms of vehicle availability however, there is a strong bias towards biodiesel in what manufacturers are offering (purchased from new with warranty) and specifically towards B30. Major fleet operators will tend to practice depot fuelling, sometimes alongside HGV fleets, so there may be opportunities for different types of vehicle to use the same fuel(s) supply.

4.5.4 Conclusions

Choosing to operate a sub-sector of the MGV fleet with high-blend biofuels generate significant emission savings, particularly with higher blend fuels (B100, PPO and Biomethane). An analysis of cost-effectiveness (using fuel price excluding duty or tax) shows the higher the blend the more cost effective, once the decision into use a high blend over B5 has been made, which can be anticipated given the lower carbon content compared to lower blends (e.g. B30 or even B50).

Comparing this against the practicability of obtaining suitable vehicles we see, however, a strong bias towards B30 over other fuels. PSA Group warranty all their diesel vehicles for B30 and two others warrant key models.

Larger fleet operators will wish to keep fuelling at depot the norm to benefit from lower prices from their bulk purchase of fuels, therefore B30 has been demonstrated (on a small scale) to be deliverable through a limited number of filling stations, which may give these medium sized commercial vehicles a non-depot fuelling option, but the more likely option ‘emergency fuelling’ option is that such vehicles will simply be re-fuelled with the cheapest standard diesel available to the operator given such vehicles flexibility.

Gas vehicles suitable for biomethane are either available or to be shortly available from two major manufacturers. The base engine and chassis from these can be configured to a wide range of models (including mini-buses). The option of running gas powered MGV alongside other types of vehicle (particularly HGV) would be the most practicable and cost-effective arrangement.

4.6 LGV

4.6.1 Background

Light goods vehicles (up to 3.5 tonnes) include the smallest car derived vans up to Ford Transit sized panel vans. 50% of LGV are company owned, with the remaining 50% owned by private individuals (with a large proportion of these likely to be used in small businesses). Therefore, the fuelling profile of the LGV fleet is likely to include a high degree of forecourt re-fuelling, compared to HGV fleets, with a smaller core of commercial operators practicing own-tank fuelling for larger fleets.

Based on TSGB the size of the UK LGV fleet (commercial vehicles not exceeding 3,500kg in weight) is 318,700 vehicles which travel some 64,300,000,000 km p.a. which averages at 20,176 km p.a. per vehicle. This linear average seems in line with a typical user.

As for MGV there is a strong bias towards B30 when considering the availability of vehicles, with the PAS Group offering warranties for biodiesel use for a considerable number of years. Gas powered smaller vans from the Iveco Daily and MB Sprinter range are suitable for use with biomethane as is the small (car derived) VW Caddy CNG/petrol bi-fuel. Ethanol vans are currently available based on the Ford FFV (ethanol) models (e.g. Focus). A range of established PPO conversion kits are available for vans.

4.6.2 Benefits and Greenhouse gas reduction

This section illustrates savings of GHG emissions (W2W estimates) against a baseline (Euro V vehicle). Reductions are estimated for an individual vehicle (g/km CO_2e) and for the entire fleet and market expansion scenario outlined above.

4.6.2.1 Reductions per vehicle

GHG values for each fuel are combined with the fuel consumption values to determine the $gC0_2e$ per vehicle km (veh km). The result of this assessment is a range of figures for best-case, worst-case and a mid-range value for each fuel. These results are shown in Figure 4.15, with Table 4.16 showing the mid-range estimates in tabulated form, compared to the baseline fuel (B0).

Figure 4.15: Relative GHG emissions per vehicle km – LGV (light van)

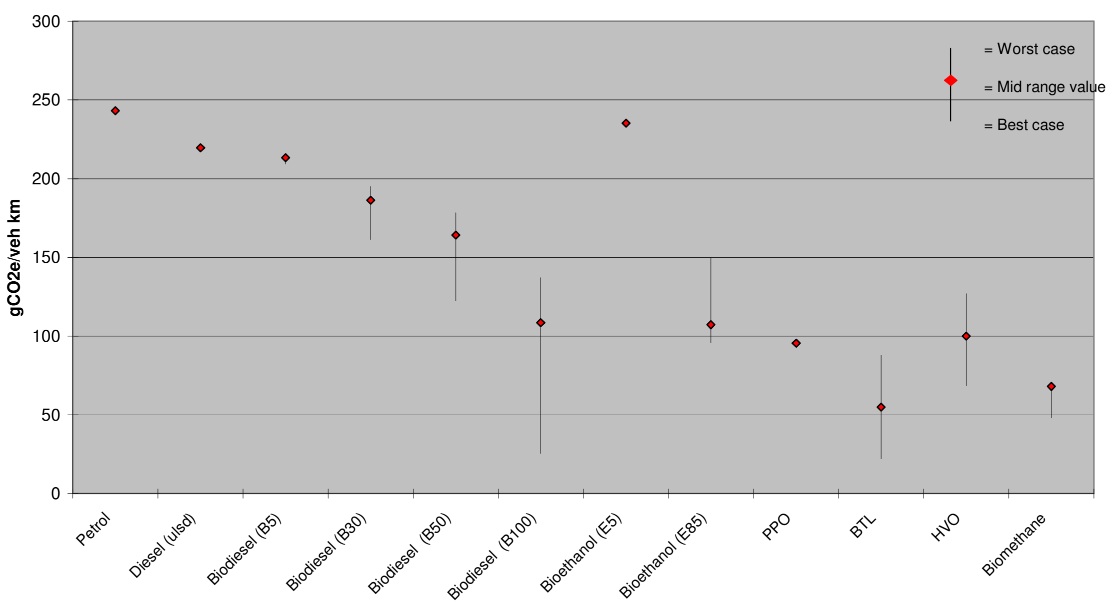


Table 4.16: Relative GHG emissions per vehicle km (mid-range value) – LGV (light van)

Fuel	g CO_2e /km	% of baseline	% reduction
Petrol	243	110.7	-10.7
Diesel	220	100.0	0.0
Biodiesel (B5)	213	97.1	2.9
Biodiesel (B30)	186	84.8	15.2
Biodiesel (B50)	164	74.7	25.3
Biodiesel (B100)	109	49.4	50.6
Petrol (E5)	235	107.1	-7.1
Bioethanol (E85)	107	48.8	51.2
PPO	96	43.5	56.5
BTL	55	25.0	75.0
HVO	100	45.5	54.5
Biomethane	68	31.0	69.0

A relatively large range in emissions can arise from most biofuels. However, a pattern can be seen between the fuels assisted by estimated mid-range values.

The baseline fuel for a LGV can be considered diesel (B0). The mid-range value for a Euro V van operating with diesel (B0) is estimated as 243 gCO_2e/km. A more realistic baseline for diesel may be 5% FAME (B5), which provides a slightly lower figure of 213gCO_2e/km, however for purposes of the comparisons B0 is the baseline. B30 and B50 have the potential to reduce the GHG to 85% and 75% of the baseline level (or 186 and 164 gCO_2e /km).

Petrol (E0) is included to enable a comparison to be made with E85 fuelled vehicles, which can both be used in a few car derived models of van. As might be anticipated, operating vans on petrol (E0 or E5 blend) produces more GHG emissions than diesel due to the lower efficiency of the spark ignition engine compared to typical compression ignition technology. However, when the calculations are made for E85 as significant reduction (around 50%) is estimated to result, despite the still greater increase in volumetric fuel consumption of petrol engines using ethanol. For comparison, this study uses estimates for a diesel van fuel of 0.0706 litres/km, a petrol van 0.0907 litres/km and a van using E85 a much greater volume at 0.128 litres/km.

Significantly lower GHG emissions are estimated from both B100 and PPO, with 109 and 96 gCO_2e /km respectively (49 and 44% of the B0 baseline), respectively. Both these fuels would require either modifications or non-warranted operation of vehicles given the current offer to UK vehicle purchasers.

Biomethane (dedicated operation) is estimated to provide the greatest GHG reductions of the currently available biofuels. Biodiesel made from UVO could approach the reductions seen from biomethane, shown by the best-case figure for this fuel, but more commonly available RME or SME cannot reach the GHG reductions. The van characteristics modelled by this study provide a mid-range gCO_2e /km value for biomethane of just 68, which is just 31% of the B0 baseline.

Were HVO available in 100% blend format then it is estimated to achieve similar GHG savings to PPO or B100 mid-range values. BTL is estimated to achieve the greatest GHG savings, down to just 25% of the baseline at 55 gCO_2e /km. However the gaps in information about this fuel mean these estimates are much less robust than for currently available and utilised high-blend biofuels, and there are LowCVP members that put forward arguments that challenge this level of reduction.

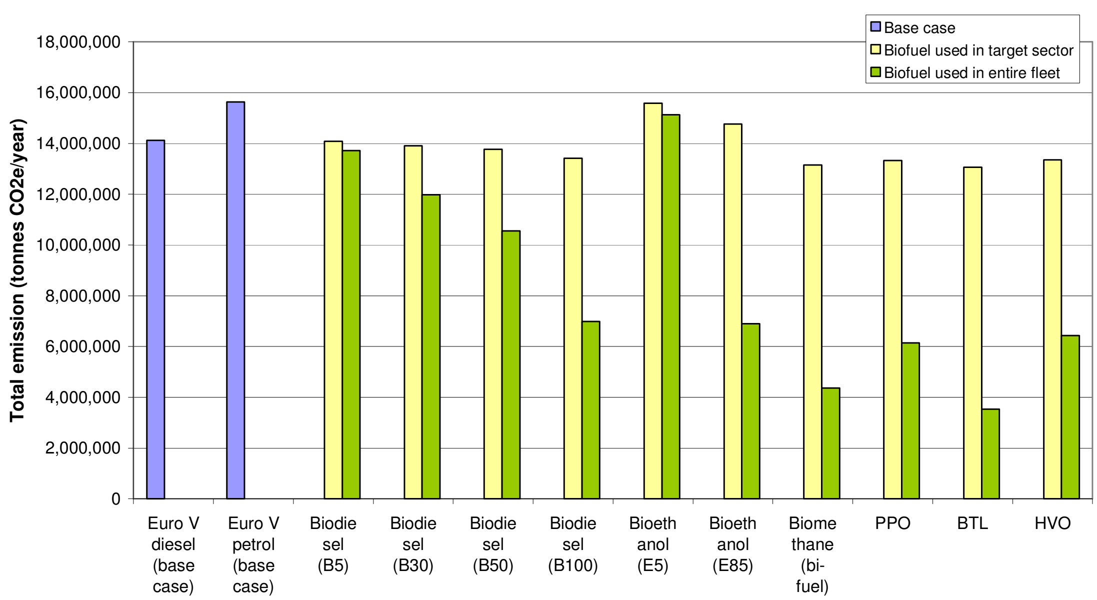
4.6.2.2 Potential reductions across the fleet.

The proposed market expansion scenario illustrated is that 10% of light goods vehicles use a form of high-blend biofuel fleets, which given a fleet of 3.18 million vehicles equals 318,700 van. The proportion of vans registered to private individuals rather and companies (a 50:50 ratio) suggests many vans are operated by small traders and individuals, meaning forecourt fuelling is the norm. Therefore, the 10% figure for a target fleet would undoubtedly require a combination of both forecourt expansion of biofuel(s) provision (and take up) combined with a large number of the potential depot-based fleet vehicle pool.

In addition, it should be noted that the current van fleet are predominantly diesel engine vehicles. As described in Chapter 2 the largest market for high-blend biofuels within the *current* UK van fleet would be for B30, based on technical compatibility with existing products from selected OEM. To reach a 10% take up for other fuels such as B100, E85, biomethane or PPO would require operators to buy new vehicles compatible with these fuels or undertake retrofit conversions. The forecasts for these fuels are therefore based on potential market expansion of a suitable vehicle fleets *as well* as take up of the appropriate fuel.

The following illustration shows the potential impact of 10% of the target fleet using one type of high-blend biofuel, as well as the boundary impact of *all* LGV using a biofuel.

Figure 4.16: Potential reduction in fleet GHG emissions – LGV



The overall estimated GHG emissions from the light van fleet is considerable at around 14 m tCO_2e/year. The total emissions from the target 10% total some 1.4 million tCO_2e/year. The estimated emissions by using high-blend biofuels against this baseline is shown in Figure 4.16 above. The input data and assumptions for this estimation are as for the HGV fleet. It is notable that emissions for this sub-sector of the parc are broadly similar to the HGV large artic fleet although smaller than the entire HGV fleet (including rigid body vehicles), which total some 23.2 m tCO_2e/year.

Table 4.17: Potential reduction in fleet GHG emissions – LGV (light goods)

LGV (van)	**Total fleet**		**Target fleet (10%)**	
	GHG W2W	CO_2e (t/yr)	GHG W2W	CO_2e (t/yr)
Euro V diesel / petrol (base case)	100.0	14,124,203	100.0	1,412,420
Reduction from base case	Reduction %	Reduction	% reduction vs. total fleet	Reduction
Biodiesel (B5)	2.9	404,994	0.3	40,499
Biodiesel (B30)	15.2	2,143,152	1.5	214,315
Biodiesel (B50)	25.3	3,571,919	2.5	357,192
Biodiesel (B100)	50.6	7,143,839	5.1	714,384
Bioethanol (E5)	3.3	514,169	0.3	51,417
Bioethanol (E85)	55.9	8,740,878	5.6	874,088
Biomethane bi-fuel	69.0	9,751,803	6.9	975,180
PPO	56.5	7,982,464	5.7	798,246
BTL	75.0	10,593,153	7.5	1,059,315
HVO	54.5	7,694,748	5.4	769,475

Take up of high-blend biofuels by the majority of van operators is unrealistic in the short to medium term given current availability and costs of vehicles and fuels. Therefore, focussing on the impact of operating the 10% target fleet with the highest blend liquid biofuels (B100 and PPO) the analysis shows savings of 0.7 m and 0.8 m tCO_2e/year. Using a more realistic B30 blend in the target fleet would reduce GHG emissions by a relatively small 2.5% (214,315 tCO_2e/year). In comparison, using B30 in the entire LGV fleet could reduce GHG by 15% or 2.14 m tCO_2e/year.

More significant GHG reductions appear feasible solely from the 10% target fleet if they are operated with biomethane. A near 7% reduction against all light van emissions from switching 10% of the fleet to this fuel is a very effective rate of reduction, with nearly a million tonnes of GHG avoided (975,180 tCO_2e/year).

Operating light vans on bioethanol (E85) can save significant GHG emissions. This is borne out by a number of trials, and in this analysis a 10% take up in the van fleet is estimated to reduce overall van fleet emissions by 5.5% (from a reduction of 874,088 tCO_2e/year. The level of effectiveness in reducing GHG emissions falls somewhere between operating on B100 or PPO and biomethane.

4.6.3 Cost and practicality

This section considers the cost per vehicle of achieving the GHG reductions shown in the section above, based on the range of high-blend biofuels.

A cost estimate has been made based on vehicle purchase cost, fuelling infrastructure costs (if applicable), maintenance costs and fuel consumption/costs over the defined amortisation period at the annual vehicle mileage (vkm p.a.). The key output is the Overall Cost column showing £/veh km. Note, that the van servicing costs include labour and value of down-time, and so will appear higher than perceived by a small operator or private individual.

It should be noted that fuel costs are before duty and VAT, in order to show the situation without any policy intervention. Given limited but national availability of E85 and B30 from the forecourt we have not included any fuel-storage costs for these fuels.

Table 4.18: Vehicle cost estimates – LGV (light goods)

LGV (1.3 to 3.5 t)	Capital outlay		Overall cost		Fuel						
Fuel	Vehicle cost (£)	Fuel equip. £/veh	Total cost £/vkm	Mainten-ance £/vkm	£ per litre / kg	Efficiency (l or kg / km)	Amorti-sation (years)	Vkm p.a.	Fuel £p.a.	Mainten-ance £p.a.	Capital cost £ p.a.
Euro V diesel (base case)	12,500	0	£ 0.18	0.029	0.310	0.071	5	20,176	£441.7	£589.4	£2,500.0
Euro V petrol (base case)	12,250	0	£ 0.18	0.026	0.323	0.091	5	20,176	£591.1	£530.4	£2,450.0
biodiesel (B5)	12,500	0	£ 0.18	0.029	0.327	0.071	5	20,176	£465.2	£589.4	£2,500.0
biodiesel (B30)	12,500	0	£ 0.21	0.053	0.419	0.072	5	20,176	£609.9	£1,060.8	£2,500.0
biodiesel (B50)	13,450	150	£ 0.22	0.053	0.472	0.073	5	20,176	£696.5	£1,060.8	£2,720.0
biodiesel (B100)	13,450	150	£ 0.23	0.053	0.594	0.076	5	20,176	£909.1	£1,060.8	£2,720.0
bioethanol (E5)	12,250	0	£ 0.18	0.026	0.332	0.092	5	20,176	£618.4	£530.4	£2,450.0
bioethanol (E85)	12,500	0	£ 0.22	0.039	0.413	0.128	5	20,176	£1,068.4	£795.6	£2,500.0
biomethane bi-fuel	14,500	4000	£ 0.25	0.029	0.508	0.080	5	20,176	£820.6	£589.4	£3,700.0
PPO	13,950	150	£ 0.23	0.053	0.568	0.075	5	20,176	£857.0	£1,060.8	£2,820.0
BTL	12,000	0	£ 0.22	0.029	0.962	0.071	5	20,176	£1,371.4	£589.4	£2,400.0
HVO	12,000	0	£ 0.21	0.029	0.789	0.075	5	20,176	£1,189.6	£589.4	£2,400.0

As shown in Table 4.18 the analysis of LGV costs without any duty incentives results in conventionally fuelled vehicles returning the lowest overall cost on a £/vkm basis, and the values of £0.18 per vkm form the base case from which to measure other fuels. Currently available high blends are falling in the range of £0.23 to £0.25, which is adding around 37% onto baseline costs. Currently available high-blends deliberately exclude BTL and HVO. The cost-effectiveness of petrol (E5) vans comes out well in this analysis, because the lower cost of the petrol vehicle and its servicing costs offset the lower fuel efficiency compared to diesel.

Interestingly, in this analysis B30 – B100, PPO, E85 and biomethane bi-fuel costs all fall within a quite narrow range cost per vkm of between £0.21 and £0.25. This is in contrast to the HGV analysis the overall cost (£/veh km) where there were clearer differences between the cost of operating on different high-blend fuels. High-blend biodiesels and PPO are estimated to result in rather high overall costs because of the fuel cost combined with the cost of increased service intervals. Lower-blend biodiesel (B50 and B30) then span the small cost range. Bioethanol vehicles are reported to also require more frequent servicing[73] than their conventionally fuelled counterparts (but not as much as biodiesel) and in addition will consume more fuel due to lower energy content of ethanol compared to diesel or petrol. Biomethane vehicles are more costly, and they require investment in fuelling infrastructure, but the cost of fuel combined with efficiency counteract to some degree part of the up-front costs during the operating life.

[73] Communication with Ford Motor Co, in relation to Somerset Bioethanol in-fleet trials (BEST Project).

There are no known UK commercial users of 100% BTL or HVO fuels and the cost of purchasing these fuels is not publicly available for high-blend variants. Therefore, estimates are included for illustration only and the results should be viewed with due caution.

High cost estimates have been estimated by inputting an annual mileage of 15,000 km p.a. and cost estimates based on 30,000 km p.a. The ranking of fuels based on cost per vkm does not change and is therefore not overly sensitive to this parameter, although relative costs and relationships between two fuels will change.

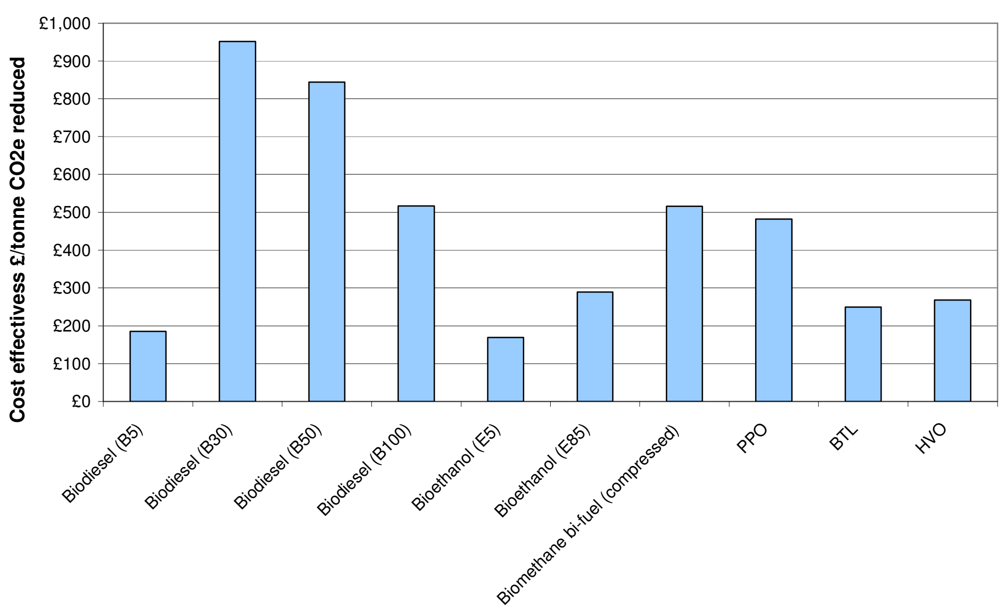
For cost effectiveness, two methods of presenting the combined cost/emission data are used. Estimations are made of:

- kgCO_2e reduced per £ spent over the baseline (i.e. standard diesel) and
- £'s spent (over the baseline) per tonne gCO_2e reduced.

Of the currently available high-blends of biodiesel B100 performs better than lower blends because the servicing costs are the same as B50 or B30, but the GHG emission savings are proportionately greater.

PPO and biomethane perform similarly to B100 in this analysis. For PPO, even though the fuel price data used in the study shows a selling price that is slightly lower the capital and services costs are very similar to standard diesel. For biomethane a lower fuel price and greater GHG savings are balanced by higher servicing costs.

Figure 4.17: Cost effectiveness of reducing GHG emissions from fleet (£ per tonne CO_2e reduced) – LGV



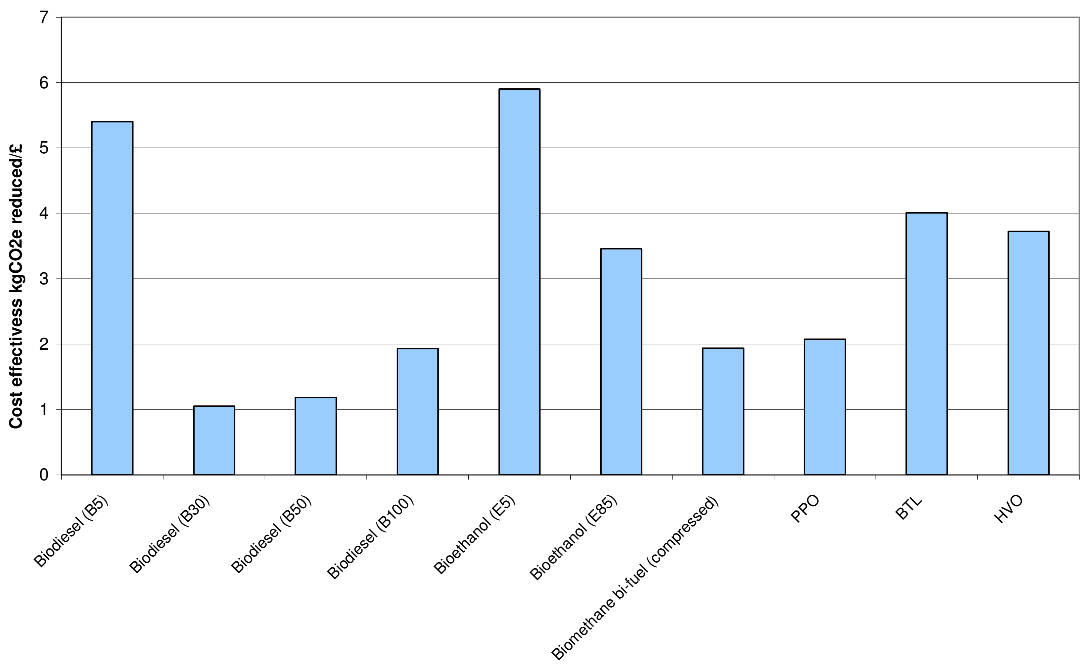
Bioethanol (E85) performs better than B100, with the cost per tonne reduced being around 20% lower. This is because the costs of operating on E85 are lower than on

B100, and the GHG emissions savings are greater. The analysis suggests that bioethanol is relatively more cost-effective in light-duty vehicles than buses.

The previous caveats over the BTL and HVO cost estimates should be noted.

Cost effectives can be viewed in terms of kg of emissions reduced per £ spent. With the estimate of kgCO_2e reduced per £ spent (over the baseline) we can see that the best performing liquid fuels appear to be E5 and B5. This is largely because there are no additional infrastructure costs or maintenance costs and a fuel price the same as the baseline in each case. Therefore, none of the GHG saving is offset by any additional cost. In contrast, B30 to B100 are estimated to require considerable increase in servicing costs (by a factor of 1.5) due to the halving of service intervals to change oil and filters as recommended by the OEM who warranty their vehicles for these fuels.

Figure 4.18: Cost effectiveness of reducing GHG emissions from fleet (kg CO_2e reduced per £) – LGV (light goods up to 3.5t)



The practicability of using high-blend biofuels in van fleets and by individual owners is considered in Table 4.19 below as a guide to the practicability considerations. This draws on the information contained in Annex B onwards and from other studies interpreted by the study team. Fuel availability has been rated by taking a view of both forecourts and own-tank re-fuelling, which improves the rating compared to simply forecourt re-fuelling alone.

Table 4.19: Practicability considerations – LGV

	B0	B30	B50	B100	E85	Bio-methane	PPO	BTL	HVO
PRACTICABILITY									
Availability of vehicles in UK	High	Medium	Low	Low	Low	Low	Medium (if retrofit)	High	High
Availability of fuel in UK	High	Low - Medium	Low - Medium	Low Medium	Low	Low	Low-Medium	Low	Low
Fuelling equipment changes	None	None - Low	Low	Low	Medium	High	Medium	None	None
Maintenance	Normal	Slightly Raised - Raised	Raised	Raised	Raised	Norm to raised	Raised	Normal	Normal
ENVIRONMENT									
GHGe WTW emissions (% of baseline)	97%	85%	75%	50%	45%	31%	44%	25%	46%
Air-quality NO_x/PM vs. baseline diesel (E5 emission limits).	1.0 / 1.0	1.024/0.886	1.04 /0.81	1.08 / 0.62	0.33 / 0.8	0.21 / 0.17	1.0 / 0.6	0.85 / 0.82	1.0 / 0.82
Noise	Norm	Norm	Norm	Norm	Lower (vs. diesel)	Lower	Norm	Norm	Norm
VEHICLE COSTS									
Capital	Norm	Norm	Raised (retrofit)	Raised (retrofit)	Slightly raised	V.raised	Raised (retrofit)	Norm	Norm
Operating	Norm	Norm to raised	Norm to raised	Norm to raised	Raised (fuel consumption)	Raised.	Raised	Dependant on fuel price.	Dependant on fuel price.
Overall	Norm	Norm to raised	Norm to raised	Norm to raised	Raised	Varies with opex: norm to raised.	Raised	Likely to be raised	Likely to be raised

4.6.4 Sensitivity testing

The importance of proper servicing should be emphasised where required to keep the vehicle in warranty and operating properly. Most OEM currently require additional servicing for B30 and above and the service cost uplifts in the study were verified during this study by team members from Fleetsolve and corroborated by the SMMT.

A sensitivity test has been done for operating a van with B30, but incurring lower servicing costs than applied in the main analysis. This is because one OEM (Vauxhall) does not requiring a 'harsh-conditions' servicing regime for their vans (Vivaro and Movano ranges) and the positive experience of the BSkyB operations with B30 biodiesel. Applying standard servicing costs reduces the cost per vkm to £0.18, the same as baseline cost for a diesel vehicle. This demonstrates the potential for making high-blend compatible vehicles much cost-effective if they can operate reliably and in warranty without additional servicing.

Table 4.20: Vehicle cost estimates – LGV (light goods) – no uplift on maintenance for B30

LGV (1.3 to 3.5 t)	Capital outlay		Overall cost		Fuel						
Fuel	Vehicle cost (£)	Fuel equip. £/veh	Total cost £/vkm	Mainten-ance £/vkm	£ per litre / kg	Efficiency (l or kg / km)	Amorti-sation (years)	Vkm p.a.	Fuel £p.a.	Mainten-ance £p.a.	Capital cost £ p.a.
Euro V diesel (base case)	12,500	0	£ 0.18	0.029	0.310	0.071	5	20,176	£441.7	£589.4	£2,500.0
Euro V petrol (base case)	12,250	0	£ 0.18	0.026	0.323	0.091	5	20,176	£591.1	£530.4	£2,450.0
biodiesel (B5)	12,500	0	£ 0.18	0.029	0.327	0.071	5	20,176	£465.2	£589.4	£2,500.0
biodiesel (B30)	12,500	0	£ 0.18	0.029	0.419	0.072	5	20,176	£609.9	£589.4	£2,500.0
biodiesel (B50)	13,450	150	£ 0.22	0.053	0.472	0.073	5	20,176	£696.5	£1,060.8	£2,720.0
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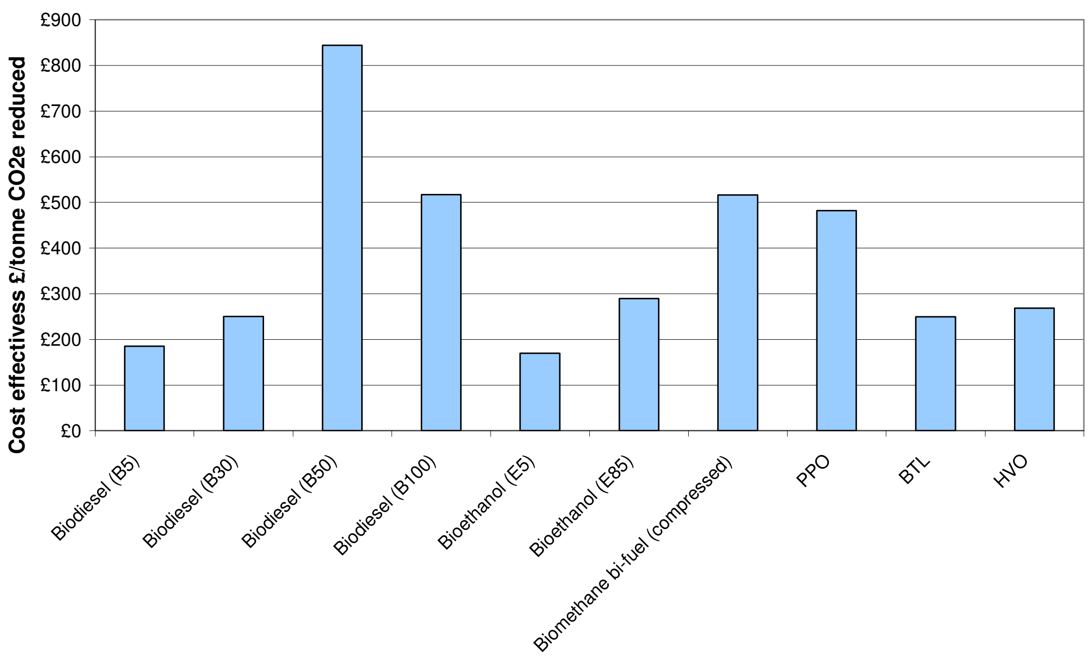
bioethanol (E5)	12,250	0	£ 0.18	0.026	0.332	0.092	5	20,176	£618.4	£530.4	£2,450.0
bioethanol (E85)	12,500	0	£ 0.22	0.039	0.413	0.128	5	20,176	£1,068.4	£795.6	£2,500.0
biomethane bi-fuel	14,500	4000	£ 0.25	0.029	0.508	0.080	5	20,176	£820.6	£589.4	£3,700.0
PPO	13,950	150	£ 0.23	0.053	0.568	0.075	5	20,176	£857.0	£1,060.8	£2,820.0
BTL	12,000	0	£ 0.22	0.029	0.962	0.071	5	20,176	£1,371.4	£589.4	£2,400.0
HVO	12,000	0	£ 0.21	0.029	0.789	0.075	5	20,176	£1,189.6	£589.4	£2,400.0

The reduced servicing costs impact on the £ per tonne of CO_2e estimate, which changes from £995 to a much more attractive £250 per tonne (see Figure 4.19) This makes B30 the most cost-effective high-blend.

Figure 4.19: Cost effectiveness of reducing GHG emissions from fleet – LGV – no uplift on maintenance for B30



4.6.5 Conclusions

Given the large number of light vans (LGV) registered and operated in the UK the potential from using biofuel in even a small proportion such as 10% of the fleet is quite significant. For example B100 in 10% of the van fleet could reduce GHG emissions by 714,384 t p.a., PPO 798,246 t p.a., bioethanol (E85) 874,088 t p.a. and biomethane 975,180 tonnes. These represent between 5 and 7% of all van emissions. The van sector has shown the largest growth in mileage in recent years in the UK so can be anticipated to become increasingly important.

Examining the performance of specific fuels B100, PPO, E85 and biomethane (used in bi-fuel vehicle) some variance in estimated GHG reductions is seen, but the estimated values fall within a much tighter range than found for heavy duty vehicles. This feeds into cost-effectiveness analysis to give a slightly different picture than for bus, for example. In the case of vans, bioethanol is estimated to have cost-effectiveness similar to B100 and PPO.

On practicability grounds, the compatibility of van manufacturers engine technology available in the UK points strongly towards biodiesel, particularly at a B30 blend. PSA Group warranty all their diesel vehicles for B30 and two others warrant key models. Vauxhall will warranty their Vivaro and Movano models without the requirement for increased servicing, which has been borne out by BSkyB.[74] These are the same engines as used in Renault vehicles, demonstrating the varied approach to warranties, and the potential to reduce costs for B30 use quite considerably. For the sensitivity test carried out on B30 with reduced servicing uplift the £ per tonne of CO_2e reduced was also reduced from £995 to a much more attractive £295 per tonne. This makes B30 the most cost-effective high-blends.

Some key manufacturers are starting to offer gas and ethanol vehicles, so there is potential but the range is currently more restricted than for biodiesel (and appear will remain so even with the additional gas vehicles anticipated shortly for UK markets). However, to reach a target 10% of the market for biogas or ethanol would require new vehicles purchased specifically for these biofuels, whereas diesel engine vehicles will always have the fall-back of standard diesel fuel. If a good network of E85 re-fuelling stations was developed (on the back of the car market) then this fuel could become more attractive to van operators. It would be more realistic to target a smaller proportion of the van fleet for these particular fuels, in addition to a strategy to increase take up of high-blends for diesel engine vehicles.

The split of vehicle ownership between private, commercial small-medium enterprises (SME) and large organisations (with large commercial vehicle fleets) and the difference in fuelling profile indicates a twin-track approach would be required to encourage high-blends in the UK van sector. It suggests that a strategy of encouraging B30 at forecourts for private/SME use and for large fleets promoting B30 for vehicles that must remain in-warranty could be most relevant.

Large fleet operations provide a number of additional opportunities for high-blend biofuels. For vehicles which can be operated out of warranty, then PPO or B100 (with retrofitting) would be more cost effective in GHG reduction terms, although more costly overall for the vehicle operator without increased incentives. Biomethane (with warranted OEM vehicles) could form part of a strategy to fuel commercial vehicles, but likely to work best in selected locations with good potential for utilisation (and therefore pay-back) on re-fuelling infrastructure.

[74] Information supplied by Joule Vert.

The discussion above assumes that incentives are offered to offset the additional costs of operating with biofuels and that they remain in place in the medium term.

4.7 Car

4.7.1 Background (to sector)

The new car market is divided between private car sales (44%) and fleet or company car sales (56%).[75] Company car sales include very large fleet buyers for daily car hire companies and vehicle lease companies who provide them to employees for use in their work or as part of their remuneration package. The purchasing patterns of these two segments (private/business) vary and the influences on purchasing behaviour are quite different. Crucial among these is that company car taxation rate is based on CO_2 levels[76] whereas the private buyer is only influenced by the variable VED rate.

Fuel purchase is generally done on public forecourts, with many ‘company car’ drivers using fuel cards to pay for fuel. Some car drivers will have access to depot fuelling, although this will be a minority of vehicles. In such situations there could be scope for the operating/owner organisation to co-ordinate decisions about biofuel policy for both HGV and light duty fleets. The new car market is split 60:40 for petrol and diesel, with less than 1% of sales being alternative fuel (or hybrid) vehicles.

Vehicle ranges compatible with biofuels shows signs of expansion for UK buyers. Significant numbers of existing PSA Group diesel vehicles will operate on B30 and joining them is Renault with commitment to both E85 and B30 for 50% of new vehicles in Europe. Bioethanol used in FFV is an option given models from Ford and Saab. PAS Group sell some 200,000 Peugeot and Citroen cars a year in the UK and Renault some 160,000 cars (based on 2006 sales figures).[77] Assuming 40% are diesel, in line with average UK car sales, then there are some 144,000 additional cars able to operate on B30 each year, and probably in excess of 1 million in current use based on past sales. This represents a small, although growing, proportion of the UK car parc of some 27 million vehicles.

The target population for potential take-up of high-blend biofuels has been selected as 5% (of all cars), or 1.35 million vehicles, to illustrate potential impacts. This is irrespective of whether they are likely to be used in vehicles with a petrol (FFV) engine or a diesel engine. Ethanol blended fuels (E85) or biodiesel/PPO blended fuels are used in vehicles with largely petrol or diesel engine technology. Therefore, a 5% take-up of E85 will only be suitable for those vehicles based on petrol engine technology, so this means a higher proportion petrol vehicles using the relevant high-blend option, to make up 5% of the total fleet. Recent sales of new cars have been divided 60:40 for petrol and diesel and if this trend continues that will be the eventual split in the current car parc. However, the current division (based on fuel consumed) suggests 78:22 split.[78]

[75] SMMT, Automotive Focus, 2007.
[76] Driven – a review of the passenger car market in the UK, EST, 2008.
[77] SMMT, Automotive Focus 2007.
[78] DfT, TSGB, Table 3.1 Petroleum consumption: by transport mode and fuel type: United Kingdom 1997-2007

Based on TSGB the size of the UK car fleet is 27,000,000 (i.e. 27 million) vehicles which travel some 402,000,000,000 km p.a (or 4.2 billion km) which averages at 14,899 km p.a. per vehicle. This linear average does not seem out of line with a typical cars annual mileage. This figure is used in the analysis to estimate impacts of 5% of the car fleet using a particular fuel, which is based on average mileage.

4.7.2 Benefits and Greenhouse gas reduction

This section illustrates savings of GHG emissions (W2W estimates) against a baseline (Euro V vehicle). Reductions are estimated for an individual vehicle (g/km CO_2e) and for the entire fleet and market expansion scenario outlined above.

4.7.2.1 Reductions per vehicle

GHG values for each fuel are combined with the fuel consumption values to determine the $gC0_2e$ per vehicle km (veh km). The result of this assessment is a range of figures for best-case, worst-case and a mid-range value for each fuel. These results are shown in Figure 4.20, with Table 4.21 showing the mid-range estimates in tabulated form, compared to the baseline fuel (B0).

Figure 4.20: Relative GHG emissions per vehicle km – car

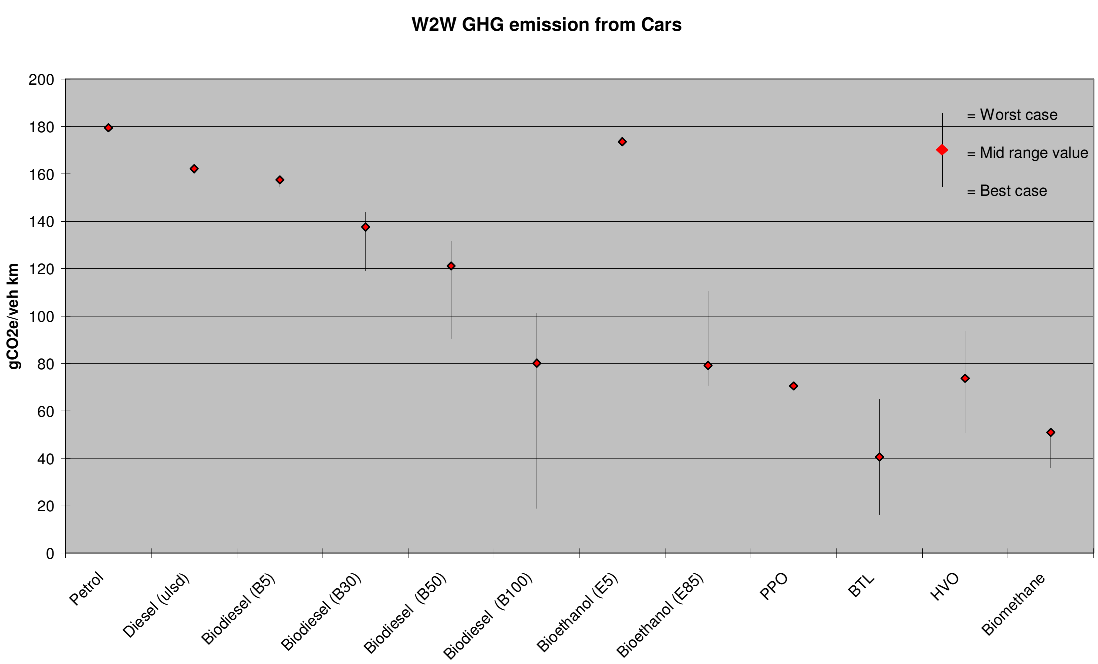


Table 4.21: Relative GHG emissions per vehicle km – Car

Fuel	***g*** **CO_2e */km***	**% of baseline**	**% reduction**
Petrol	180	110.7	-10.7
Diesel	162	100.0	0.0
Biodiesel (B5)	157	97.1	2.9
Biodiesel (B30)	138	84.8	15.2
Biodiesel (B50)	121	74.7	25.3
Biodiesel (B100)	80	49.4	50.6
Bioethanol (E5)	174	107.1	-7.1
Bioethanol (E85)	79	48.8	51.2
PPO	70	43.5	56.5
BTL	41	25.0	75.0
HVO	74	45.5	54.5
Biomethane	51	31.5	68.5

Figure 4.20 shows that a relatively large range in emissions can arise from most biofuels. However, a pattern can be seen between the fuels, assisted by estimated mid-range values (in Table 4.21).

The choice of baseline fuel for the car fleet is not obvious, as the fleet is made up of both diesel and petrol fuelled vehicles. Furthermore, a more realistic baseline for diesel may be 5% FAME (B5), and for petrol may be petrol with 5% ethanol (E5). However, for the purpose of making comparisons, the baseline fuel for use in cars has been selected as diesel (B0), following that used for other vehicle types. The other fuels and blends are all considered as part of the comparison.

The mid-range value for a Euro V car operating with diesel (B0) is estimated at 162 gCO_2e/km. Using B30 and B50 has the potential to reduce the GHG to 85% and 75% of the baseline level (138 and 121 gCO_2e /km), respectively.

Cars running on petrol (E0 or E5 blend) produce more GHG emissions than diesel due to the lower efficiency of the spark ignition engine compared to typical compression ignition technology. The mid-range value for a Euro V car operating with petrol (E0) is estimated at 180 gCO_2e/km; this is 11% higher than the emissions for diesel. However, when the calculations are made for E85 a significant reduction (around 50% compared to the diesel baseline) is estimated to result, despite the increase in fuel consumption of petrol engines using ethanol. For comparison, this study estimates fuel usage for a diesel car to be 0.052 litres/km, for a petrol car to be 0.067 litres/km and for a car using E85 to be 0.095 litres/km.

A slightly greater reduction in GHG emissions is estimated from both B100 and PPO, with potential reductions in emissions compared to the B0 baseline of 51% and 57% (80 and 70 gCO_2e /km), respectively. The use of PPO would first require modifications to made to the vehicles. There are a small number of older VAG vehicles that were warranted to run on B100, however for the majority of the UK car fleet, use of B100 would currently require non-warranted operation of vehicles - given the current availability of B100 compatible vehicles to UK vehicle purchasers.

Biomethane is estimated to provide the greatest GHG reductions of the currently available biofuels, based on a comparison of mid-range values. The mid-range GHG emission value for biomethane is 51 gCO_2e /km, 32% of the B0 baseline. Biodiesel made from UVO could approach the reductions seen from biomethane, shown by the best-case figure for this fuel. This comparison depends on the source of the biodiesel; more commonly available RME or SME cannot provide the same level of GHG reductions.

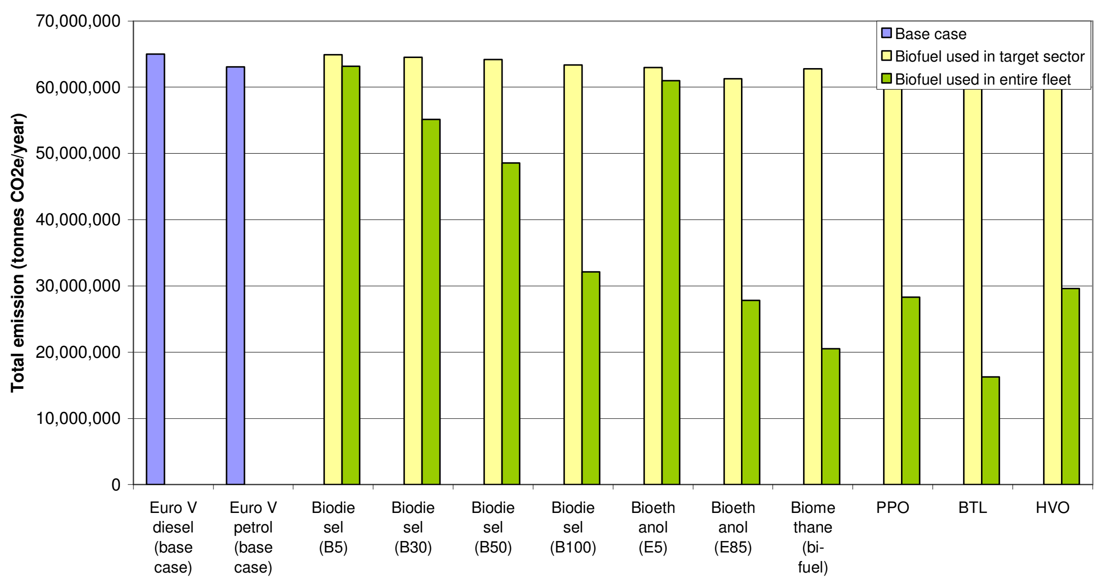
HVO and BTL are shown to have the potential to provide significant reductions in GHG emissions. Were HVO to become available in 100% blend format then it is estimated to achieve similar GHG savings to PPO or B100 mid-range values (a 55% reduction in emissions). BTL is estimated to achieve the greatest GHG savings, down to just 25% of the baseline at 41 gCO_2e /km. However the gaps in information about this fuel mean these estimates are much less robust than for currently available and utilised high-blend biofuels, and LowCVP members that put forward arguments that challenge this level of reduction.

4.7.2.2 Potential reductions across the fleet.

The proposed market expansion scenarios illustrated is that 5% of passenger cars use a form of high-blend biofuel fleets, which given a fleet of 27 million vehicles equals 1,350,000 cars.

The illustration in Figure 4.21 shows the potential impact of all 5% of the target fleet using one type of high-blend biofuel, as well as the boundary impact of all 27million vehicles using a biofuel.

Figure 4.21: Potential reduction in fleet GHG emissions – car



The overall estimated GHG emissions from the car fleet is estimated to be around 65m tCO_2e/year. The total emissions from the target 5% total 3.25 million tCO_2e/year. The estimated emissions by using high-blend biofuels against this baseline is shown in Figure 4.19.

Take up of high blend biofuels across the majority of the car fleet is unrealistic in the short to medium term given current availability, the costs of vehicles and fuels and that the major part of the car fleet is privately owned. It makes sense, therefore, to focus on a realistic target of 5% of the sector.

In addition, it should be noted that the current car fleet are predominantly petrol engine vehicles, with the split of petrol/diesel consumption at a ratio of 78:22. New car sales show a growth in the proportion of diesel vehicles, with current estimates around 40% of new cars sold. As described in Chapter 2 the largest market for high-blend biofuels within the *current* UK car fleet would be for B30 and E85, based on technical compatibility with selected OEM products. To reach a 5% take up for other fuels such as B100, biomethane or PPO would require operators to buy new vehicles compatible with these fuels or undertake retrofit conversions. The forecasts for these fuels are therefore based on potential market expansion of a suitable vehicle fleets *as well* as take up of the appropriate fuel.

Finally, another way of considering how to reach the illustrative 5% target would be combine smaller proportions of different high-blend fuels, appropriate to the petrol / diesel car markets. The analysis that follows is therefore illustrative, and some benefits may be more difficult to achieve than others. This is taken into account in conclusions and recommendations made in Chapter 5 of this report.

Table 4.22: Potential reduction in fleet GHG emissions – car

LDV (car)	**Total fleet**		**Target fleet (5%)**	
	GHG W2W	CO_2e (t/yr)	GHG W2W	CO_2e (t/yr)
Euro V diesel / petrol (base case)	100.0	65,019,802	100.0	3,250,990
Reduction from base case	Reduction %	Reduction	% reduction vs. total fleet	Reduction
Biodiesel (B5)	2.9	1,864,362	0.1	93,218
Biodiesel (B30)	15.2	9,865,852	0.8	493,293
Biodiesel (B50)	25.3	16,443,086	1.3	822,154
Biodiesel (B100)	50.6	32,886,173	2.5	1,644,309
Bioethanol (E5)	3.3	2,073,259	0.2	103,663
Bioethanol (E85)	55.9	35,245,398	2.8	1,762,270
Biomethane (bi-fuel)	68.5	44,517,802	3.4	2,225,890
PPO	56.5	36,746,724	2.8	1,837,336
BTL	75.0	48,764,851	3.8	2,438,243
HVO	54.5	35,422,246	2.7	1,771,112

Operating the 5% target fleet with the highest blend liquid biofuels (B100 and PPO) produces savings of 1.6m and 1.8m tCO_2e/year, respectively. Using a more realistic B30 blend in the target fleet would reduce GHG emissions by a relatively small 0.8% (0.49m tCO_2e/year). Using E85 in the fleet gives a similar reduction the other higher blend biofuels, of 1.7m tCO_2e/year (based on mid-point GHG WTW values selected for this study).

Slightly more significant GHG reductions appear feasible from the 5% target fleet if operated on biomethane. The predicted reduction of 2.2m tCO_2e/year represents a reduction of 3.4% compared to the total emissions from the car fleet.

4.7.3 Cost and practicality

This section considers the cost per vehicle of achieving the GHG reductions shown in the section above, based on the range of high-blend biofuels.

A cost estimate has been made based on vehicle purchase cost, fuelling infrastructure costs (if applicable), maintenance costs and fuel consumption/costs over the defined amortisation period at the annual vehicle mileage (vkm p.a.). The key output is the Overall Cost column showing £/vkm. Note that the maintenance costs for cars are lower than for other vehicle types, as it is assumed that the majority are privately owned and therefore no allowance is made for the value of down-time. Maintenance costs vary by fuel type, with high-blend biodiesel, PPO and bioethanol estimated to require increased servicing with costs raised by a factor of 1.5 compared to the standard diesel or petrol equivalents. This is subject to a sensitivity test and results reported.

It should be noted that fuel costs are before duty and VAT, in order to show the situation without any policy intervention. In addition fuel prices are based on spot prices (from April/May 2009) wherever possible, in order to gain a comparable basis for fuels. Combining these two facts means that the early 2009 forecourt price differential between petrol and diesel in favour of petrol (by up to 7ppl) is largely removed. A similar spot price for petrol and diesel was, by August 2009 feeding through to much closer selling prices at the forecourt for the two fuels.

Finally, in this analysis a petrol fuelled car appears the same cost to run as a diesel car. At higher mileages and when duty and VAT are factored in the diesel cars become marginally cheaper to run than petrol, as would be anticipated.

High blends liquid fuels that are not currently available on a national basis on the forecourt (PPO, B100 and B50) are estimated to require on-site storage at the home or at business premises, which is factored into the fuel equipment costs. Biomethane is shown to incur a cost similar to home-filling equipment for a CNG vehicle. E85 and B30, with a limited but national coverage, do not incur fuelling equipment costs.

Servicing costs are based on manufacturers' recommendations and feedback on current pilots.

Table 4.23: Vehicle cost estimates – car

	Capital outlay		Overall cost		Fuel (no duty)						
Fuel	Vehicle cost (£)	Fuel equip £/veh	Total cost £/vkm	Mainten-ance £/vkm	£ per litre / kg	Efficiency (l or kg / km)	Amorti sation (years)	Vkm p.a.	Fuel £p.a.	Mainten - ance £p.a.	Capital cost £ p.a.
Euro V diesel (base case	15,500	0	£0.25	0.027	0.310	0.052	5	14,889	£241	£400	£3,100
Euro V petrol (base case	15,000	0	£0.25	0.025	0.323	0.067	5	14,889	£322	£367	£3,000
Biodiesel (B5)	15,500	0	£0.25	0.027	0.327	0.052	5	14,889	£253	£400	£3,100
Biodiesel (B30)	15,500	0	£0.27	0.040	0.419	0.053	5	14,889	£332	£600	£3,100
Biodiesel (B50)	16,450	150	£0.29	0.040	0.472	0.054	5	14,889	£379	£600	£3,320
Biodiesel (B100)	16,450	150	£0.30	0.040	0.594	0.056	5	14,889	£495	£600	£3,320
Bioethanol (E5)	15,000	0	£0.25	0.025	0.332	0.068	5	14,889	£337	£367	£3,000
Bioethanol (E85)	15,000	0	£0.28	0.037	0.413	0.095	5	14,889	£582	£550	£3,000
Biomethane bi-fuel	17,500	4000	£0.35	0.027	0.508	0.060	5	14,889	£454	£400	£4,300
PPO	17,000	150	£0.30	0.040	0.568	0.055	5	14,889	£467	£600	£3,430
BTL	15,000	0	£0.28	0.027	0.962	0.052	5	14,889	£747	£400	£3,000
HVO	15,000	0	£0.27	0.027	0.789	0.055	5	14,889	£648	£400	£3,000

Similar to the analysis of HGV costs, without any duty incentives conventionally fuelled vehicles will return the lowest overall cost on a £/vkm basis. For cars a value of £0.25 per vkm forms the base case from which to measure other fuels. Currently available high blends are falling in the range of £0.27 to £0.35, which is adding some 8 – 40% onto baseline costs. Currently available high-blends exclude BTL and HVO.

The analysis shows that liquid fuels cost per vkm (B30, B50 B100, PPO and E85) all fall within a quite narrow range cost per vkm of between £0.27 and £0.30. This is similar to the case for LGVs, and in contrast to the HGV analysis the overall cost (£/veh km) where there were clearer differences between the cost of operating on different types of high-blend fuels. In contrast, vehicles operating with biomethane are estimated to have the highest costs, noting that showing all fuels without duty does not factor in the current duty incentive biomethane receives over other fuels. The reasons for this are broadly the same as for LGVs: high-blend biodiesels and PPO give high overall costs because of the fuel cost combined with the cost of increased service intervals, with lower-blend biodiesel (B50 and B30) then span the small cost range; bioethanol vehicles consume more fuel and indications are they require some additional servicing; and biomethane vehicles are more costly, and they require investment in fuelling infrastructure.

There are no known UK users of 100% BTL or HVO fuels and the cost of purchasing these fuels is not publicly available for high-blend variants. Therefore, estimates are included for illustration only and the results should be viewed with due caution.

For cost effectiveness, two methods of presenting the combined cost/emission data are used. Estimations include:

- kgCO_2e reduced per £ spent over the baseline (i.e. standard diesel); and
- £'s spent (over the baseline) per tonne gCO_2e reduced.

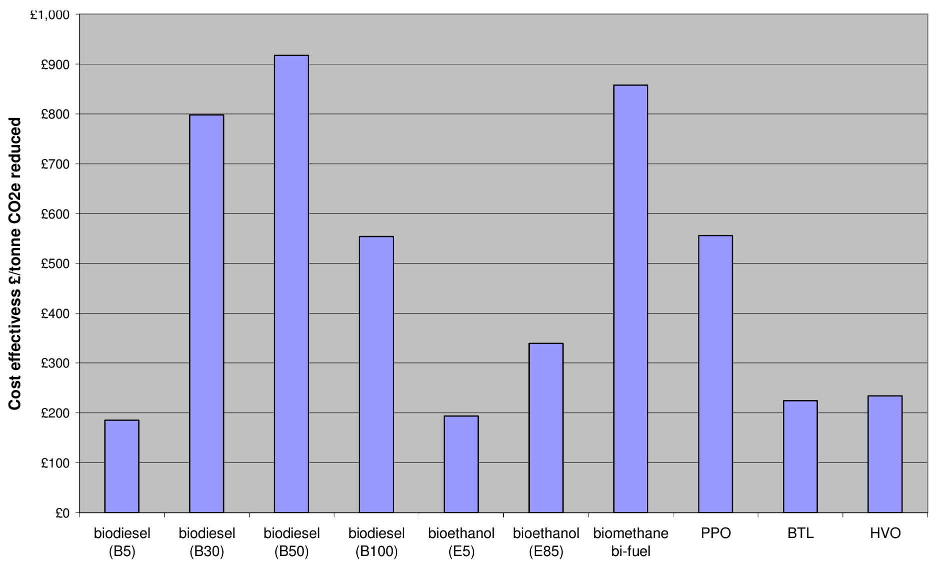
Of the currently available high-blends of biodiesel B100 performs better than lower blends because the servicing costs are the same as B50 or B30, but the GHG emission savings are proportionately greater.

PPO performs similarly to B100 in this analysis because even though the fuel price is slightly lower the servicing costs are fixed at the same as standard diesel.

Bioethanol (E85) performs best in this analysis. E85 has better GHG savings than B100 and similar to PPO. While E85 fuelled cars are estimated to incurr higher fuel costs, the availability of forecourt fuelling and lower price for a new vehicle combine into a lower cost per km overall. Clearly, if B100 and PPO were available via the forecourt the nominal cost included in the estimate for fuelling equipment would be removed.

The cost-effectiveness of biomethane is not as good as B100 in this analysis, because while biomethane can provide larger GHG emissions savings the capital costs of the vehicles and fuelling infrastructure are higher.

Figure 4.22: Cost effectiveness of reducing GHG emissions from fleet– Car

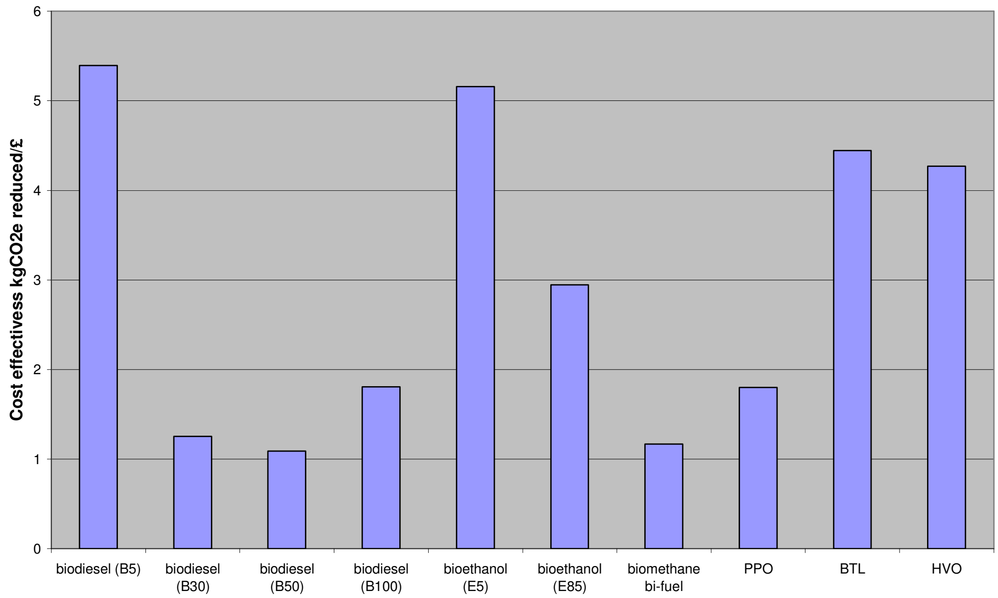


Overall, the cost effectiveness of using high-blend biofuels in cars is lower than when the same fuel is used in heavy duty vehicles because the volumes of fuel used are many times less in the average car.

Cost effectives can also be viewed in terms of kg of emissions reduced per £ spent. With the estimate of kgCO_2e reduced per £ spent (over the baseline) we can see that the best performing liquid fuel appears to be B5. This is largely because there are no additional infrastructure costs or maintenance costs and a fuel price the same as B0. Therefore, none of the GHG saving is offset by any additional cost. In contrast, B30 to B100 are estimated to require considerable increase in servicing costs (by a factor of 1.5) due to the halving of service intervals to change oil and filters as recommended by the OEM who warranty their vehicles for these fuels.

Of the high blends, E85 shows the greatest reduction per £ spent of nearly 3kg, whereas PPO and B100 are in the range of 1.7 – 1.8 kg CO_2e per £.

Figure 4.23: Cost effectiveness of reducing GHG emissions from fleet (kg CO_2e reduced per £) – car



The practicability of using high-blend biofuels in car fleets and by individual owners is considered in Table 4.24 as a guide to the practicability considerations. This draws on the information contained in Annex B onwards and from other studies interpreted by the study team. Fuel availability has been judged from the standpoint of forecourt availability (where this is currently commonplace) or direct purchase from a supplier (e.g. B100 from small scale supplier).

Table 4.24: Practicability considerations – car

	B0	B30	B50	B100	E85	Bio-methane	PPO	BTL	HVO
PRACTICABILITY									
Availability of vehicles in UK	High	Medium	Low	Low	Low-Medium	Low	Medium (if retrofit)	High	High
Availability of fuel in UK	High	Low - Medium	Low	Low	Low	Very low	Low	Low	Low
Fuelling equipment changes	None	None – Low	Low - Medium	Low - Medium	Low - Medium	High	Low - Medium	N.A.	N.A.
Maintenance	Normal	Raised	Raised	Raised	Raised	Norm to raised	Raised	Normal	Normal
ENVIRONMENT									
GHGe WTW emissions (% of baseline)	97%	85%	75%	50%	45%	31%	44%	25%	46%
Air-quality: NO_x/ PM vs. baseline diesel (E5 emission limits).	1.0 / 1.0	1.024/0.886	1.04 /0.81	1.08 / 0.62	0.33 / 0.8	0.21 / 0.17	1.0 / 0.6	0.85 / 0.82	1.0 / 0.82
Noise	Norm	Norm	Norm	Norm	Lower (vs. diesel)	Lower	Norm	Norm	Norm
VEHICLE COSTS									

Capital	Norm	Norm	Raised (retrofit)	Raised (retrofit)	Slightly raised	V.raised	Raised (retrofit)	Norm	Norm
Operating	Norm	Norm to raised	Norm to raised	Norm to raised	Raised (fuel consump tion)	Norm to Raised.	Raised	Depend ant on fuel price.	Depend ant on fuel price.
Overall	Norm	Norm to raised	Norm to raised	Norm to raised	Raised	Varies with opex: norm to raised.	Raised	Likely to be raised	Likely to be raised

4.7.4 Sensitivity tests

Various information was gathered on maintenance requirements during the course of the study, and different evidence was put forward on the question of maintenance frequency and costs. Staying within OEM warranty conditions means undertaking additional servicing in nearly all cases. The assumptions used in the study for the analysis to this point are outlined in Annex A1.6 (vehicle cost data).

There is however some reported experience of operating vehicles with high-blends without additional servicing or significant costs (e.g. John Lewis partnership experience with PPO). It has already been noted that Vauxhall produce light and medium vans with diesel engines that can use B30 under warranty without additional servicing. It has also been noted how some operators are thought to have negotiated on warranty conditions, how larger operators are allowed more leniency over warranties and that those able to monitor engine oil conditions have safely extended service intervals from those recommended. These all point towards potential scope for reducing the cost of operating with high-blend fuels.

The study has particularly found conflicting evidence and stated requirements for bioethanol cars. Most websites providing information on ethanol use in passenger cars state there is no need to increase servicing over a standard gasoline/petrol vehicle. In contrast, information gathered about a current UK pilot (from Ford Motors supporting Somerset Fleets in the BEST project) was that servicing of their vehicles was taking place at half the normal interval. The BEST project website, representing demonstrations/pilots across a number of countries across Europe, report that their ongoing assessment is showing that FFVs are as reliable as conventional cars but need more frequent regular maintenance compared to petrol or diesel vehicles, with oil changes necessary 1.5 times as often (see Annex 3.3.2 on Bioethanol for full text).[79]

In order to test the sensitivity of the results to servicing costs the cost estimates and cost-effectiveness analysis is presented in Table 4.25 with no uplift for biodiesel, PPO or E85. In this analysis the only additional costs are the fuel price and a nominal cost for fuel-equipment (for those fuels without national forecourt distribution at the current time).

Table 4.25: Vehicle cost estimates – car (no maintenance uplift)

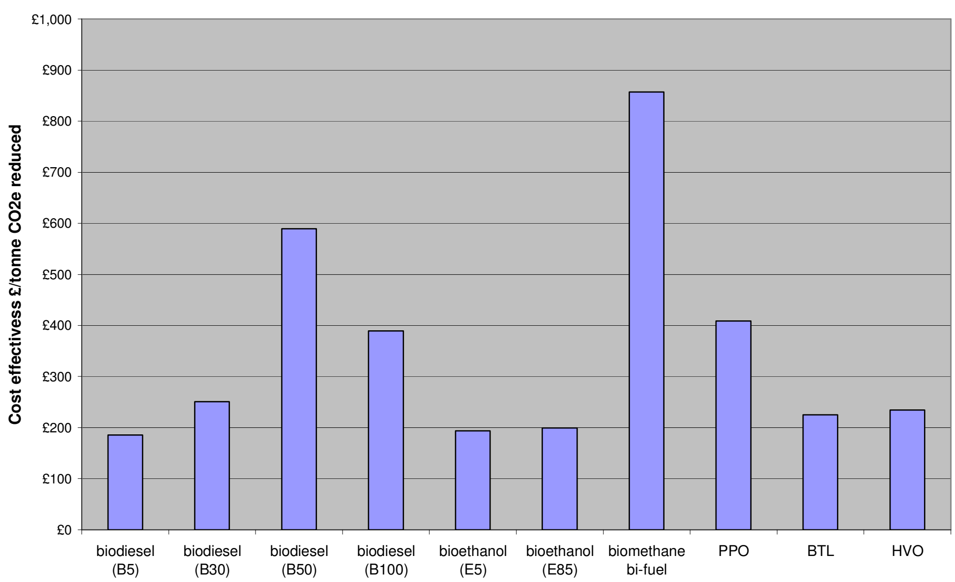
[79] http://www.best-europe.org/Pages/ContentPage.aspx?id=584

	Capital outlay		Overall cost		Fuel (no duty)						
Fuel	**Vehicle cost (£)**	**Fuel equip £/veh**	**Total cost £/vkm**	**Mainten-ance £/vkm**	**£ per litre / kg**	**Efficiency (l or kg / km)**	**Amorti sation (years)**	**Vkm p.a.**	**Fuel £p.a.**	**Mainten - ance £p.a.**	**Capital cost £ p.a.**
Euro V diesel (base case	15,500	0	£0.25	0.027	0.310	0.052	5	14,889	£241	£400	£3,100
Euro V petrol (base case	15,000	0	£0.25	0.025	0.323	0.067	5	14,889	£322	£367	£3,000
Biodiesel (B5)	15,500	0	£0.25	0.027	0.327	0.052	5	14,889	£253	£400	£3,100
Biodiesel (B30)	15,500	0	£0.26	0.027	0.419	0.053	5	14,889	£332	£400	£3,100
Biodiesel (B50)	16,450	150	£0.28	0.027	0.472	0.054	5	14,889	£379	£400	£3,320
Biodiesel (B100)	16,450	150	£0.28	0.027	0.594	0.056	5	14,889	£495	£400	£3,320
Bioethanol (E5)	15,000	0	£0.25	0.025	0.332	0.068	5	14,889	£337	£367	£3,000
Bioethanol (E85)	15,000	0	£0.27	0.025	0.413	0.095	5	14,889	£582	£367	£3,000
Biomethane bi-fuel	17,500	4000	£0.35	0.027	0.508	0.060	5	14,889	£454	£400	£4,300
PPO	17,000	150	£0.29	0.027	0.568	0.055	5	14,889	£467	£400	£3,430
BTL	15,000	0	£0.28	0.027	0.962	0.052	5	14,889	£747	£400	£3,000
HVO	15,000	0	£0.27	0.027	0.789	0.055	5	14,889	£648	£400	£3,000

Examining the overall cost (expressed in a total cost per vkm) there is a much smaller increase in cost for operating high-blend biofuels compared with their petrol or diesel counterparts at £0.25 per km each. B100 in this analysis provides a figure of £0.28 per km (compared to £0.30 with a 1.5 x maintenance cost uplift) and E85 is at £0.27 per km, down from the £0.28 resulting from a 1.5 x maintenance cost uplift.

The impact on cost effectiveness is to improve the performance of these high-blend biofuels over the standard diesel or petrol counterparts, as shown in Figure 4.24. In particular bioethanol become very cost effective, costing no more per tonne of $C0_2$e abated than low blend E5.

Figure 4.24: Cost effectiveness of reducing GHG emissions– Car (no maintenance uplift)



4.7.5 <u>Conclusions</u>

The car sector of the UK vehicle parc forms the largest proportion, and therefore encouraging even a small proportion, as tested in this study, could be significant in GHG terms for a road transport measure.

As illustrated, operating B100 in 5% of the car fleet could reduce GHG emissions by 1,644,309 t p.a., bioethanol (E85) by 1,762,270 p.a., PPO by 1,837,336 t p.a., and biomethane 2,225,890 t p.a. These represent between 2.5 and 4.4% of all car emissions.

Given a PSA Group diesel vehicle population approaching a million vehicles it is likely that nearly 4% of the UK car fleet could use B30, with more likely to be added each year with the addition to market of planned Renault vehicles. The potential GHG savings of operating 5% of the UK car fleet on B30 is estimated at 493,293 t p.a. or some 0.8% of total car emissions, which is clearly much less than for higher-blends. Added to this is some potential for high-blend ethanol, in E85 form.

The initiative by Renault for a reasonable proportion of their petrol vehicles to run with E85, plus the progress of Ford to increase E85 compatibility across a wider range of mid-sized models suggest technical barriers are low and vehicle availability could improve in the short-term. As noted above, 5% of the UK car fleet operating with E85 would reduce GHG emissions by some 1.7 mt p.a.

Examining the performance of specific fuels B100, PPO, E85 and biomethane (used in bi-fuel vehicle) some variance in estimated GHG reductions is seen, but the estimated values fall within a much tighter range than found for heavy duty vehicles. This feeds into cost-effectiveness analysis to give a slightly different picture than for bus, for example. In light duty fleets, bioethanol appears more cost-effective and similar to B100 or PPO. It has already been noted how E85 compatibility is relatively straightforward for vehicle manufacturers of petrol engines, and ethanol use in vehicles worldwide is expanding rapidly.

As for other types of vehicle all high-blend biofuels are currently more costly to operate in cars than using conventional petrol or diesel. Therefore the discussion of cost-effectiveness is a relative one (between the high-blend options) and any strategy for increasing the market size assumes that incentives are offered to offset the additional costs of operating with biofuels likely to remain in the short-medium term.

Bioethanol emerges the most cost-effective of the high-blend fuels, which also require relatively low-cost changes to forecourt infrastructure to make available to the private motorist in the UK. Issues of capacity constraints remain however, meaning that relatively low-cost fuel pump changes are not the major barrier.

For biomethane the fuelling equipment costs are significant. Therefore to make car markets viable local and small scale networks might be envisaged, ideally building up from sites of biomethane production or commercial fleet usage.

For those owners wishing and willing to retrofit their vehicles B100 or PPO become viable options, but this market is likely to remain limited even with incentives, given the value most motorist place in OEM warranties and support through the normal dealer networks. Some key manufacturers are starting to offer gas vehicles, so there is potential, but the range is currently more restricted than for biodiesel (and is likely to remain so even with new VW models being introduced).

On grounds of practicability, in particularl the compatibility of car manufacturer's engine technology, plus GHG performance a strategy to encourage high-blend biofuel use in cars in the UK points strongly towards biodiesel (B30) and bioethanol (E85).

4.8 Emissions relevant to local air quality

It is important to consider changes in emissions of toxic pollutants that might arise from using high-blend biofuels in bus fleets. Air quality is poor in many urban areas and road transport contributes to this problem. Information is included on two of the main toxic emissions of concerns that arise from road transport, total Particulate Matter (PM) and Oxides of Nitrogen (NO_x) which gives rise to Nitrogen Dioxide (NO_2) in the air.

It should be noted that elements of NO_x emissions are considered as green-house gases. This will have been taken into account via the GHG WTW analysis as this is done with CO_2 equivalent values which include gases such as N_2O.

For toxic emissions (NO_x and PM) there are gaps in reliable data on in-service emission factors for some vehicle and high-blend fuel combinations. Few vehicle testing studies cover both a range of vehicles and a range of fuels, and there are conflicting results from some tests/ studies.

To allow for the variation in data available, a set of emission scaling factors has been compiled based on a review of available data. The major input to this has been a study by AEA Energy & Environment which reviewed road transport emissions from biofuel consumption on behalf of Defra. This information is required for biofuel consumption to be accounted for in the National Atmospheric Emissions Inventory (NAEI).[80] The AEA report does caveat the results saying that further research on emission effects is required on high blend biofuels in particular. It notes that most tests on biodiesel emissions have to date been based on heavy duty vehicles with older engines. Further emission tests are required on diesel light duty vehicles and vehicles, engines and technologies relevant to the UK fleet to improve the reliability of the biodiesel emission scaling factors. Accordingly, we have updated the figures with test data where this appears to be reliable and from trusted sources.

These scale factors have been derived based on reported data. As far as possible, these factors represent the range of data available. However, specific test data for vehicles can be found that is different to the factors presented here. For example test results from the BEST project includes emissions figures for a flexi-fuel vehicle running on petrol and then on E85. The results show no reduction in emissions of PM when the car is operated on E85 compared to petrol, but that emissions of NO_x are reduced by a further 50%. This is in contrast to the scale factors found from the

[80] AEAT Road Transport Emissions from Biofuel Consumption in the UK, AEAT/ENV/R/2662, Issue 1, July 2008

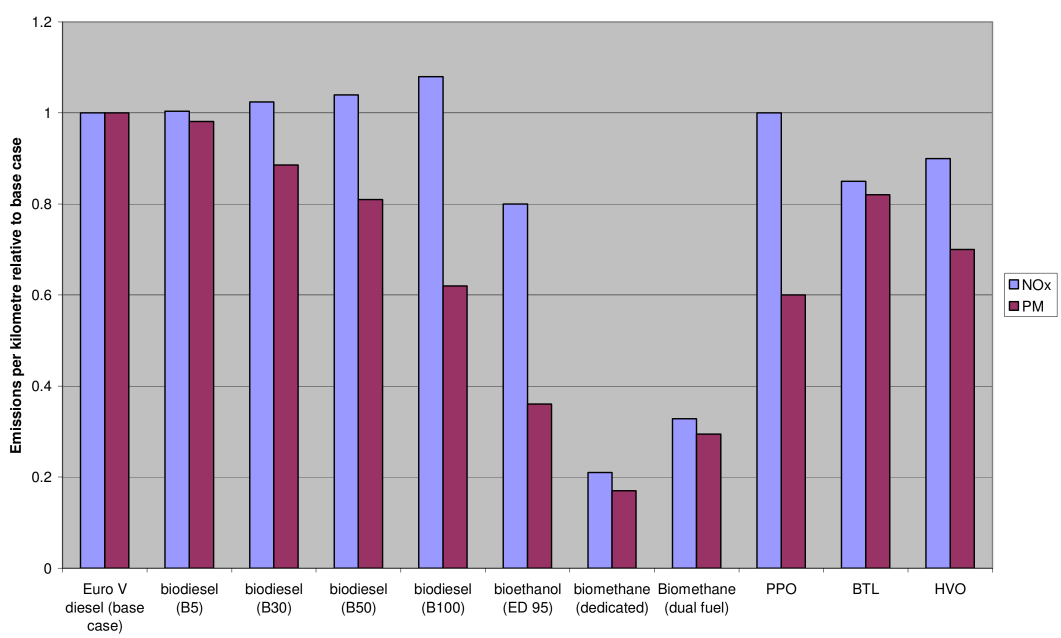
AEA review of test data which concluded on values of 20% reduction in PM emissions, and no reduction in NO_x emissions.

The scaling factors divide the parc into just heavy duty and light duty vehicles with no further differentiation between types of vehicle.

The scaling factors show the impact of different biofuel blends relative to the emissions operating on diesel. The scaling factors for heavy and light vehicles are given in Figures 4.25 and 4.26, respectively. The factors and information on the sources used to derive these estimates is provided in Annex A of this report.

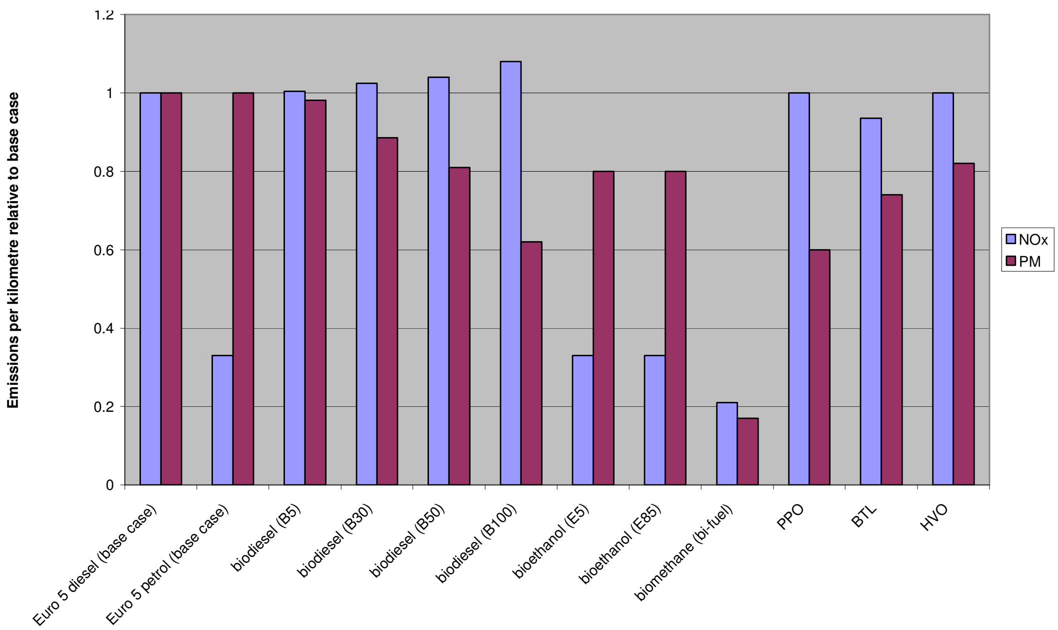
For at NO_x emissions, increased emissions are anticipated from high-blends of biodiesel, which results a slight increase in emissions in both heavy and light duty vehicles, up to a maximum of 8% for B100. One explanation is that biodiesel combusts with a higher temperature than standard diesel which helps to reduce particulate matter, but produces more NO_x. This is in line with a number of studies, including testing done recently in the SMILE project in Norwich on a variety of vehicles and blend levels. For this study we have applied a linear trend from B0 to B100. However, there is recent test data for using B20 and B100 in modern buses from the SMILE project Norwich that showed NO_x levels for the B20 were the same as for standard diesel. Applying this evidence to the AEA review results could result in B30 NO_x emissions being reduced from their slightly elevated levels compared to baseline diesel.

Figure 4.25: Emissions scaling factors for heavy duty vehicles



The graphs show that the impact of biofuel use on toxic emissions varies a great deal, and that the impacts on emissions of NO_x and of PM are very different. There are also some significant differences between the performance of different fuels in heavy and light vehicles.

Figure 4.26: Emissions scaling factors for light duty vehicles



For both heavy and light duty vehicles there is no variation in NO_x emissions when running on PPO, based on Matrix Biofuels information. Operating light duty vehicles on HVO gives no change in NO_x emissions, whereas operating heavy duty vehicles on HVO gives a reduction in emissions of around 10%.[81] Both heavy and light duty vehicles show a reduction in NO_x emissions operating on BTL; 15% for heavy vehicles and 6% for light vehicles.[82]

Using ED 95 in heavy duty vehicles gives a 20% reduction in NO_x emissions and using E85 in light duty vehicles gives a reduction in NO_x emissions of 67% emissions. It should be noted, however, that this reduction is relative to diesel emissions, rather than petrol emissions, whereas in light vehicles E85 is used as a replacement for petrol. If the emissions using E85 are compared to emissions using petrol, light duty vehicles show no reduction in NO_x emissions.

The fuel which leads to the largest change in NO_x emissions is biomethane (which is typical of gaseous fuels); using biomethane reduces NO_x emission by 79%. For dual-fuel heavy vehicles operating on biomethane the reduction in NO_x emissions is 67%.[83]

The data illustrates that a number of biofuels used in high-blends can reduce PM emissions considerably against the baseline. This is significant for B100 and ED 95 and very significant for the gaseous fuel biomethane.

The AEA review concluded that virgin plant oil (PPO) had been shown to increase PM emissions. However, the report also notes the factor applied to PPO is rather

[81] Data supplied by Neste Oil and a research paper on 'Biodiesel Fuel of the Second Generation' , Leena Rantanen for Neste Oil Corporation, 2005.
[82] ASFE Position Paper, Emissions from Synthetic Fuels, 2007.
[83] Cenex, Biomethane Toolkit, 2008.

uncertain, that further measurements are needed for this fuel. Accordingly, this study has used information supplied by Elsbett Ltd (one supplier of PPO conversion equipment) from 2008 emission on tests undertaken at Millbrook with a DAF HGV operated by the John Lewis Partnership. These showed a decrease in PM emissions (in line with B100) and no statistically significant increase in NO_x emissions. These data are shown the Figures above. Further testing at Millbrook, conducted for Elsbett in June 2009 included some additional NO_x reducing techniques and showed marked reductions in NO_x to 0.28 of the comparable standard diesel vehicle. This suggests there are benefits to be achieved from equipment changes done with well-designed and implemented retrofitting.

In both heavy and light duty vehicles the use of biodiesel results in a decrease in PM emissions, up to a maximum of 38% for B100. For both heavy and light duty vehicles there is also thought to be a 40% reduction in PM emissions when running on PPO. This assumes that a properly fitted and adjusted retrofit technology is used. PPO should not be used straight into the fuel tank of any vehicles if regulated emissions are to be kept within normal limits. Using HVO is predicted to give a reduction in PM emissions of 30% in heavy vehicles, and a lower reduction of 18% in light duty vehicles. Using BTL shows the opposite picture, with a reduction in PM emissions of 18% in heavy vehicles, and a greater reduction of 26% in light duty vehicles.

ED 95 in heavy vehicles gives a significant reduction in emissions of 64% compared to standard diesel. Using E85 in light duty vehicles gives a reduction in PM emissions of 20%.

As was the case for NO_x emissions, the use of biomethane leads to the largest change in PM emissions, by 83%. For dual-fuel heavy vehicles operating on biomethane the reduction in NO_x emissions is similarly large, at 71%.

4.9 Analysis of fuel duty as an option to promote uptake of high blend biofuels

4.9.1 Introduction

Duty derogation has provided a consistent compensatory mechanism for early adopters of biofuels since 2002. From April 2010 this duty derogation will be removed, with a compensatory mechanism of 30 pence per litre penalty implemented via the Renewable Transport Fuels Obligation being the sole incentive and support. At present there is no market value for any carbon savings that could be realised through use of higher blend biofuels however, as reported by this study, these carbon savings could be substantial.

To determine the viability of duty derogation as an option for incentivising high blend biofuel adoption, and focussing of the greatest opportunity of the HGV (large artic) class of vehicles, the levels of duty derogation necessary to compensate for additional capital and operation costs with various biofuels have been estimated. A similar analysis of car costs and carbon savings has also been made.
Duty derogations in the study have been calculated on a break-even basis, considering amortised costs of vehicle ownership and operation. However it is worth

noting that operators are likely to seek shorter payback periods and financial advantage before adopting such fuels and higher derogations than those estimated may be necessary in order to encourage market adoption and expansion.

For this part of the study only, the analysis has considered fuel duties, as at Spring 2009 and duty derogations has been estimated with respect to these values. VAT has still been excluded.

4.9.2 HGV estimates

A major opportunity for saving CO_2 from transport exists within the HGV class of vehicles. However, pending market value for CO_2 saving, adopters must meet additional capital costs for suitable vehicles or conversions plus additional operating costs from conventional operational profits. Such additional costs present a dissuasive case for adopting biofuels and are likely to hinder resultant CO_2 savings.

Vehicle duty of 113,000 km per annum and a 6 year lifecycle operation has been used for the HGV estimates and variations in fuel consumption and equipment costs have been considered and estimated.

Table 4.26: Vehicle capital and operating costs (HGV)

Fuel	Vehicle cost £	Fuel equip. £/veh	Fuel Consumption ltr/annum
Euro V diesel (base case)	50,000	0	42562
Biodiesel (B5)	50,000	0	42710
Biodiesel (B30)	50,000	300	43468
Biodiesel (B50)	52,290	300	44093
Biodiesel (B100)	52,290	300	45738
Biomethane (dedicated)	85,000	14500	35171
Biomethane (dual fuel)	73,000	14500	35171
PPO	53,600	300	42562

Fuel costs used are shown in Table 4.27. HVO and BTL are not included in this analysis due to uncertainty of selling price of these fuels in high-blend form.

Table 4.27: Fuel costs used in the analysis (HGV/Car)

Fuel	w/o duty £/l	Duty £/l	with duty £/l	with VAT £/l
Euro V diesel (base case)	*0.3100*	*0.5419*	*0.8519*	*0.9797*
biodiesel (B5)	0.3265	0.5319	0.8584	0.9872
biodiesel (B30)	0.4191	0.4819	0.9010	1.0362
biodiesel (B50)	0.4718	0.4419	0.9137	1.0508
biodiesel (B100)	0.5937	0.3419	0.9356	1.0759
biomethane (dedicated)	0.5084	0.1926	0.7010	0.8062
Biomethane (dual fuel)	0.5084	0.1926	0.7010	0.8062
PPO	0.5681	0.3419	0.9100	1.0465

For this part of the study only, the analysis has considered fuel duties, as at Spring 2009 and duty derogations have been estimated with respect to these values. VAT has still been excluded. On this basis the estimated additional costs associated with each fuel, relative to a standard Euro V diesel vehicle have been calculated.

Table 4.28: Additional costs associated with each fuel (HGV)

Fuel	Additional Fuel Cost £pa	Additional Capital Cost £pa	Additional Maintenance Cost £pa	Total Additional Cost £pa
Biodiesel (B5)	£404	£0	£0	£404
Biodiesel (B30)	£2,906	£50	£4,558	£7,514
Biodiesel (B50)	£4,031	£432	£4,558	£9,021
Biodiesel (B100)	£6,534	£432	£4,558	£11,524
Biomethane (dedicated)	-£11,604	£8,250	£1,709	-£1,645
Biomethane (dual fuel)	-£11,604	£6,250	£1,709	-£3,645
PPO	£2,471	£650	£4,558	£7,679

Through considering fuel consumption and additional costs, the duty derogations necessary to offset the extra costs have been calculated (compared with the current market price for a Euro V truck operated on diesel).

Table 4.29: Duty derogation needed to offset additional costs (HGV)

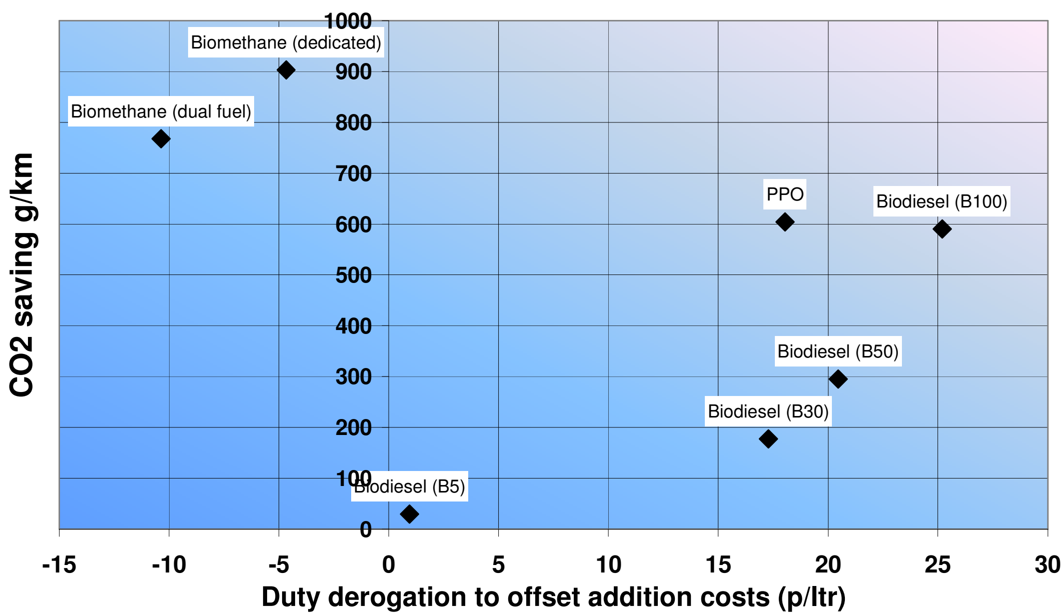
Fuel	Duty derogation needed (pence/ltr)
Euro V diesel (base case)	*0*
Biodiesel (B5)	0.95
Biodiesel (B30)	17.29
Biodiesel (B50)	20.46
Biodiesel (B100)	25.19
Biomethane (dedicated)	-4.68
Biomethane (dual fuel)	-10.36
PPO	18.04

These levels of incentive have been estimated using current costs for capital and for fuel, both of which are likely to reduce in proportion to speed of introduction and market expansion.

The potential saving in CO_2 that could be realised by use of high blend biofuels varies by fuel as does the amount of duty derogation needed to offset the additional cost of this CO_2 saving. The two variables are shown plotted in Figure 4.274.

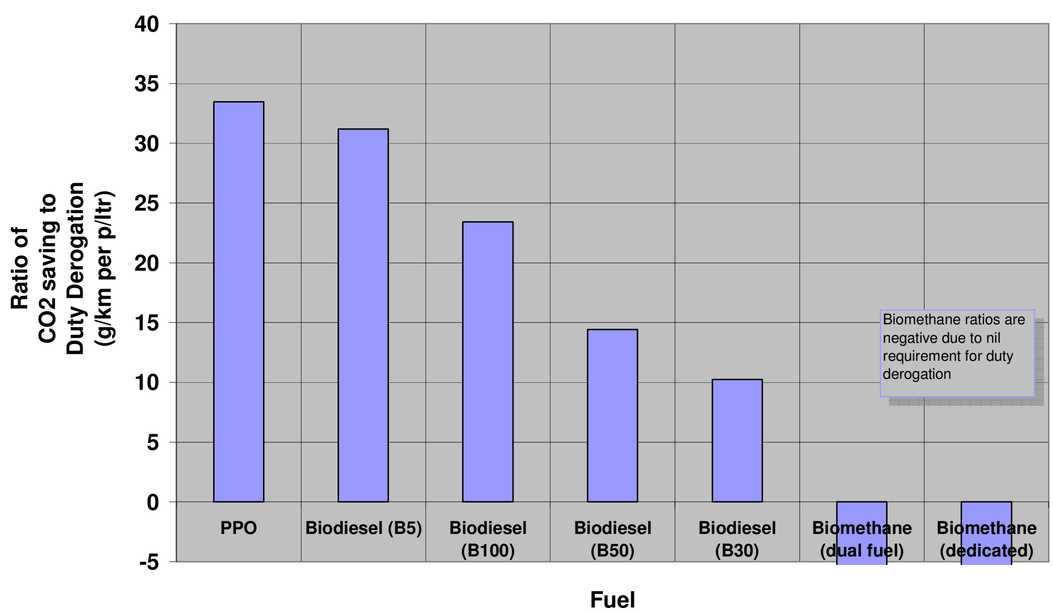
For HGV, it is estimated that all high blend biofuels could be incentivised through a mechanism of 27 pence per litre derogation in fuel duty. Without any incentive the additional cost incurred by operators for adopting higher blend biofuels can reach £13,961 p.a. However, biomethane appears on the negative side of the scale, as it is estimated to save costs compared to standard diesel in a Euro V HGV.

Figure 4.27: Duty derogation to offset additional costs (p/ltr) vs. CO_2 saving



The values estimated also permit a cost to benefit analysis of levels of duty derogation (p/ltr) ‘cost’ and CO_2 saving (g/km) ‘benefit’. The ratio between these, as the figure below, indicates the CO_2 saving per pence of duty derogation. It should be noted that these figures are comparative only since duty thresholds may be considered as minimums.

Figure 4.28: Ratio of GHG saving to duty derogation - HGV



This analysis indicates that incentivising the use of biomethane in HGVs could realise the most significant CO_2 savings. For liquid biofuels, PPO and B5 provide the greatest benefits, the higher CO_2 saving of PPO countering additional costs associated with capital. Also, although the carbon saving potential of PPO and B100 are similar, the duty derogation needed to support the implementation of B100 may be greater than that of PPO, arising primarily from higher fuel price and consumption of B100 by comparison.

Interim blends such as B30 and B50 appear to be less cost effective, following the rationale that if changes to infrastructure and vehicles are necessary it is less cost-effective to then use a fuel with a lower carbon saving potential.

4.9.3 Car estimates

The same analysis method has been applied to cars, because while the practical barriers to introducing high blends via fuelling networks appear higher than for HGV a lower proportion of total fleet take-up is required to have a significant impact, due to the greater number of registered vehicles.

To determine the viability of duty derogation as an option for incentivising high blend biofuel adoption the levels of duty derogation necessary to compensate for additional capital and operation costs with various biofuels have been estimated.

Vehicle duty of 14,899 km per annum and a 5 year lifecycle of operation has been used for these estimates and variations in fuel consumption and equipment costs have been considered and estimated.

Table 4.30: Vehicle capital and operating costs (Car)

Fuel	**Vehicle cost £**	**Fuel equip. £/veh**	**Fuel Consumption ltr/annum**
Euro V diesel (base case)	15,500	0	776
Euro V petrol (base case)	15,000	0	997
Biodiesel (B5)	15,500	0	776
Biodiesel (B30)	15,500	0	793
Biodiesel (B50)	16,450	150	804
Biodiesel (B100)	16,450	150	834
Bioethanol (E5)	15,000	0	1014
Bioethanol (E85)	15,000	0	1408
Biomethane bi-fuel	17,500	4000	893
PPO	17,000	150	822

Fuel costs used are shown in Table 4.31, as per HGV but with addition of petrol and bioethanol blended fuels.

Table 4.31: Fuel costs used in the analysis (Car)

Fuel	w/o duty £/l	Duty £/l	with duty £/l	with VAT £/l
Euro V diesel (base case)	0.3100	0.5419	0.8519	0.9797
Euro V petrol (base case)	0.3230	0.5419	0.8649	0.9946
biodiesel (B5)	0.3265	0.5319	0.8584	0.9872
biodiesel (B30)	0.4191	0.4819	0.9010	1.0362
biodiesel (B50)	0.4718	0.4419	0.9137	1.0508
biodiesel (B100)	0.5937	0.3419	0.9356	1.0759
Bioethanol (E5)	0.3321	0.5319	0.8640	0.9936
Bioethanol (E85)	0.4132	0.3719	0.7851	0.9029
Biomethane bi-fuel	0.5084	0.1916	0.7000	0.8050
PPO	0.5681	0.3419	0.9100	1.0465

Note that for bioethanol E5 and E85 the derogation and carbon benefits are calculated relative to petrol, whereas for all other fuels the calculations are relative to diesel.

For this part of the study only, the analysis has considered fuel duties, as at Spring 2009 and duty derogations have been estimated with respect to these values. VAT has still been excluded. By considering fuel consumption and additional costs the duty derogations necessary to reduce against the current market price for EuroV diesel/petrol, have been calculated.

Table 4.32: Duty derogation needed to offset additional costs (Car)

Fuel	Duty derogation needed (pence/ltr)
Euro V diesel (base case)	*0.00*
Euro V petrol (base case)	*0.00*
biodiesel (B5)	0.65
biodiesel (B30)	31.92
biodiesel (B50)	61.39
biodiesel (B100)	64.65
Bioethanol (E5)	1.40
Bioethanol (E85)	30.32
Biomethane bi-fuel	130.33
PPO	75.04

These levels of incentive have been estimated using current costs for capital and for fuel, both of which are likely to reduce in proportion to speed of introduction and market expansion. It is notable that the duty derogation needed is much higher than for HGV.

The potential saving in CO_2 that could be realised by use of high blend biofuels varies by fuel, as does the duty derogation needed to reduce costs to the same as baseline fuels. The relationship is shown in Figure 4.29.

Figure 4.29: Duty derogation to offset additional costs (p/ltr) vs. CO2 saving - Car

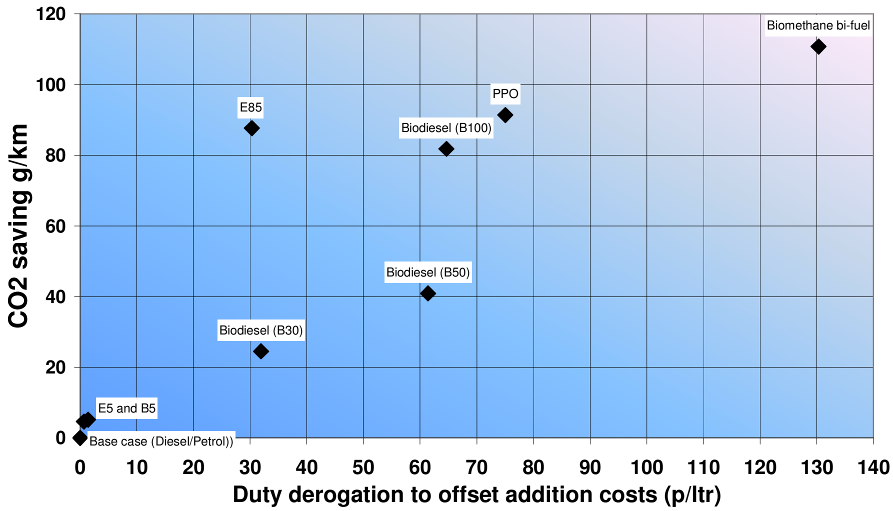
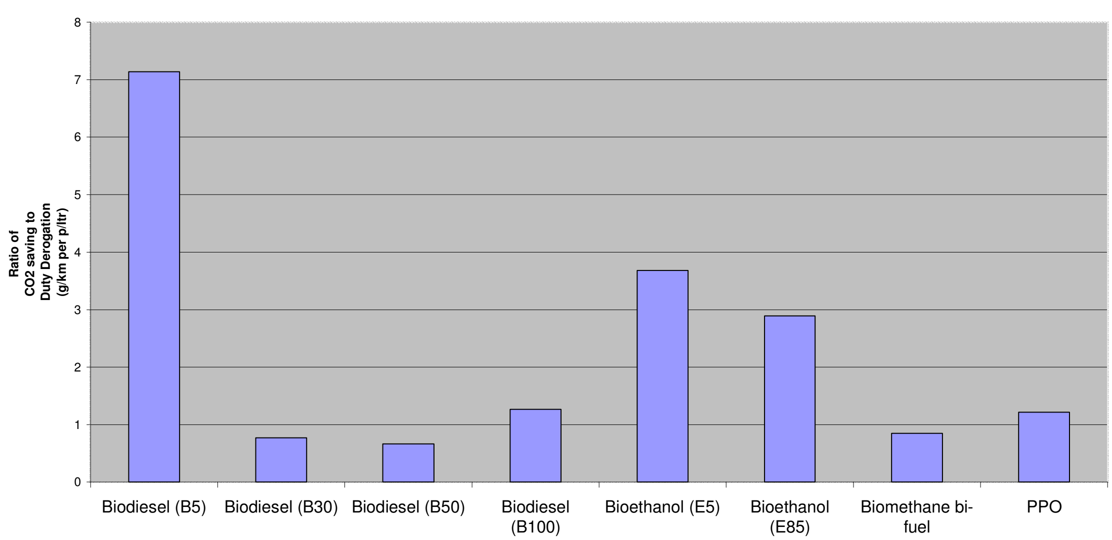


Figure 4.29 shows that the highest carbon benefit is from biomethane, but this also requires the highest derogation to make this zero cost (relative to diesel). The high-blend biofuels with the best combination of GHG savings and duty derogation required to offset additional costs is bioethanol (E85), which could be incentivised through 30 pence per litre duty derogation. Biodiesel (B30) requires 32 pence per litre, based on data and assumptions in this study, but has lower GHG savings.

The values also permit a cost to benefit analysis of levels of duty derogation (p/ltr) 'cost' and CO_2 saving (g/km) 'benefit'. The ratio between these indicates the CO_2 saving per pence of duty derogation. Overall, the ratios are much lower than for HGV, indicating a lower cost-effectiveness. It should be noted that these figures are comparative only since duty thresholds may be considered as minimums.

Figure 4.30: Ratio of GHG saving to duty derogation - Car



The analysis supports the cost-effectiveness argument for using low-blend biofuels in cars, as well as highlighting the most effective high-blend fuel (E85). Incentivising the use of bioethanol (E85) in cars could also realise the most significant CO_2 savings. B100 and PPO require similar levels of incentives (to each other), but are not as cost-effective as E85. Interim blends such as B30 appear to be less cost effective due to experiences to date of increased infrastructure and vehicle servicing costs which when necessary will undermine with lower carbon saving potential. Reducing servicing and supply costs of any biofuel, such as B30 or E85, would impact very positively on its performance in this analysis.

4.10 Summary of results and conclusions

Vehicle operators of all types will perceive some generic barriers to using high-blend biofuels, such as:

- Fuel quality, availability, price;
- Availability of suitable vehicles;
- Fuelling infrastructure;
- Fuel economy and range;
- Servicing;
- Whole life cost (inc residual value);
- Training for different vehicle driver/maintenance requirements; and
- Possibility of unintended impacts on toxic emissions from vehicles.

Action is needed on the following topics to overcome such concerns:

- Development of the supply chain / availability issues;
- Fuel quality control for high blends;
- Sustainability issue;
- Long term policy and government direction; and
- Long term incentives.

The range and depth of actions required is significant. However, as acknowledged in the UK's Biomass Strategy[84] biofuels offer one of the few routes in the short term to reduce carbon emissions from transport, where emissions are rising.

The potential for high-blend biofuels should be viewed in the context of the other measures being considered by Government. As already noted in Chapter 3 of this report, current Defra GHG emissions (2007) estimated transport GHG emissions at 156 MT CO_2e p.a. from final users. High-blend biofuels have a potentially significant role in contributing to a reduction of this total, as yet not fully exploited.

A summary of the potential GHG reductions from the range of vehicle types and fuels considered in the option assessment is shown in Table 4.33.

[84] Defra, UK Biomass Strategy, 2007.

Table 4.33: Summary of emission reductions (against baseline) by vehicle type and fuel CO2e (t/yr) – for each target sub-sector

	HGV artic (L) (21%)	HGV artic (S) (21%)	HGV rigid (L) (21%)	HGV rigid (s) (23%	Bus (20%)	MGV (20%)	LGV (10%)	Car (5%)	Total CO2e (T/yr)
Biodiesel (B30)	472,883	70,264	118,288	92,198	104,069	63,552	214,315	493,293	**1,628,862**
Biodiesel (B50)	788,139	117,106	197,146	153,663	173,449	105,920	357,192	822,154	**2,714,770**
Biodiesel (B100)	1,576,278	234,213	394,292	307,327	346,898	211,840	714,384	1,644,309	**5,429,541**
Biomethane (dedicated)	2,412,720	358,496	592,533	391,776	527,690	266,081			**4,549,297**
Biomethane (dual fuel)	2,050,812	304,722	414,773	250,947		186,256			**3,207,511**
PPO	1,612,998	239,669	403,478	314,486	354,979	216,775	798,246	1,837,336	**5,777,967**
Biomethane (bi-fuel)							975,180	2,225,890	**3,201,070**
Ethanol (E85)							874,088	1,762,270	**2,636,358**
Ethanol (ED 95)					469,424				**469,424**
BTL	2,337,364	347,299	584,672	455,715	514,394	314,125	1,059,315	2,438,243	**8,051,127**
HVO	1,697,835	252,274	424,699	331,027	373,650	228,177	769,475	1,771,112	**5,848,249**
Biodiesel (B5) in all diesel vehicles	375,830	52,381	94,009	66,700	86,725	52,960	404,994	410,160	**1,543,758**
Bioethanol (E5) in all petrol vehicles								1,617,142	**1,617,142**

Note: shaded cells denote combinations of vehicle and fuel judged not applicable.

A number of points should be noted when considering these results, which relate to the current compatibility of the vehicle fleets and the need to purchase new vehicles for operation with selected fuels.

For HGV, there is compatibility within the current parc for B100 and B50 via selected OEM products in the used vehicle market. To expand operations with biomethane future purchases of dedicated gas vehicles would be necessary or a retrofit of existing/future diesel vehicles to allow dual-fuel biomethane or PPO operations. These factors would also apply to bus fleets.

For vans, a 5% take up of E85 and biomethane would require significant purchases of new vehicles compatible with these fuels in the face of current buying patterns of diesel vehicles.

B5 and E5 are presented in the analysis of target fleets with 100% uptake due to the RTFO. The petrol/diesel split of car fleet emissions is based on a 78:22 split in volume of fuel consumed.

For cars, results are also presented for 5% uptake of each fuel. The petrol/diesel vehicle ratio means that (for biodiesels) the figures are presented for 5% of the fleet that is diesel powered fleet, which is clearly more than 5% of the diesel fleet. Therefore, the 5% target fleet operating with one fuel is used as an illustration of the *relative* impact of operating a given proportion of the fleet with a particular fuel.

The forecasts for GHG reducing impact of high-blend biofuels are therefore based on potential market expansion of a suitable vehicle fleets *as well as* take up of the appropriate fuel. This is taken into account in Chapter 3 on barriers and support mechanisms, as well as the recommendations on the most promising combinations of fuel and vehicle types in the conclusions of Chapter 5.

The considerable GHG savings from the HGV (large artic) fleet can be seen when placed in the context of other sub-sectors of the UK vehicle parc. If B100, PPO or biomethane were deployed successfully in this sector it could result in GHG reductions equalling something between 1.6 and 2.1 MT CO_2e p.a., depending on the biofuel.

The other HGV sub-sectors assessed generate smaller GHG savings in comparison to large artics. The fuelling profile of each HGV sub-sector will have much in common with HGV large artics, and there will be cases where different types of vehicle share depot facilities. This will also arise for some MGV and LGV fleets. A strategy to encourage biofuel infrastructure for fuelling HGV should give rise to additional co-benefits from access by other types of vehicle.

Bus fleets are estimated to generate comparable GHG savings to some of the HGV sub-sectors, but from fewer vehicles due to the high fuel consumption of buses in urban driving conditions. Therefore, while the assumed target fleet of 20% does not make a major impact on its own, it should be very cost-effective.

The other high impact standalone combination of vehicle/fuel from among the scenarios modelled during the study is bioethanol (E85) in 5% of the car fleet. This generates a GHG saving of 1.7 MT CO_2e p.a. It should be noted that to achieve this would actually require a greater take up rate from the petrol car fleet than 5% to allow for 30-40% diesel vehicles in the UK car fleet.

It is useful to compare the scenarios evaluated against the GHG savings of B5 were it used in entire parc to see the additional benefit that might be obtained from selected deployment of high blend biofuels. Based on the same vehicle numbers used throughout the study it is estimated that B5 for 100% of the fleets described generates a GHG saving of between 3 and 3.6 MT CO_2e. Therefore, even a much targeted take-up of high-blend biofuels by a minority proportion of HGV large artic and cars is estimated to match the impact of B5.

As anticipated the cost per tonne of carbon abated from using high-blend biofuels is calculated to be well in excess of the value assigned by Governments as the social cost of carbon.

A summary of cost effectiveness (£ per T CO_2e over baseline costs) is compiled and presented in Table 4.34. This illustrates the relative cost effectiveness of targeting high-blend biofuels at HGV fleets, particularly with biomethane, B100 and PPO. Using high-blend biofuels in buses is estimated to be a similarly cost-effective option.

Light duty vehicles are generally less cost effective candidates for investment in clean technologies, as they produce fewer emissions per vehicle on a per km basis and they tend to travel shorter distances in any given year than HGV or local buses. Any investment in capital costs are therefore not diluted at the same speed as with heavy vehicles using the same or similar technologies or fuel. This can be seen from comparing LGV or MGV with the HGV results.

Table 4.34: Cost effectiveness summary - £ per tonne of CO2e over baseline fuel cost/carbon

	HGV artic (L) (20%)	HGV artic (S)	HGV rigid (L)	HGV rigid (s)	Bus	MGV	LGV (10%)	Car (5%)	Average
Biodiesel (B5)	£224	£224	£224	£224	£224	£224	£185	£185	£214
Biodiesel (B30)	£479	£461	£488	£684	£476	£1,097	£951	£797	£679
Biodiesel (B50)	£376	£361	£395	£541	£374	£821	£844	£918	£579
Biodiesel (B100)	£283	£275	£293	£365	£282	£505	£517	£554	£384
Biomethane (dedicated)	£143	£98	£239	£481	£186	£488			£272
Biomethane (dual fuel)	£137	£121	£266	£599		£576			£283
PPO	£236	£248	£270	£334	£255	£480	£482	£556	£358
Biomethane (bi-fuel)							£516	£857	£687
Ethanol (E5)								£194	£194
Ethanol (E85)							£289	£339	£314
Ethanol (ED 95)					£448				£448
BTL	£280	£280	£280	£280	£280	£280	£250	£225	£269
HVO	£282	£310	£310	£310	£310	£310	£268	£234	£292

Note: shaded cells denote combinations of vehicle and fuel judged not applicable.

However, from the analysis of MGV and LGV same fuel combinations as for HGV appear most cost-effective. Unfortunately, B30, which is warranted for use in a significant number of MGV and LGV could be rather expensive in terms of carbon reduction. This is due to most van manufacturers requiring harsh-servicing regimes for vehicles operating with high-blends. Opting for an OEM that does not require this could reduce costs and improve cost-effectiveness for B30 in van markedly (as shown by the sensitivity tests).

Examining some of the biofuel options within the car scenario it is estimated E85 is comparatively cost-effective compared to other fuels.

When considering additional environmental impacts of biofuels two that are obvious are ILUC and regulated emissions affecting air quality. ILUC is outside of the scope of this study, but a review of key exhaust emissions has been conducted. The evidence from a range of studies points towards a reduction in particulate matter across the full range of biofuels. This is very relevant given the health impacts of PM (for which it is acknowledged there is no 'safe' limit) and the regulatory response which will lead to lower targets for concentrations of PM in the near future. For NO_x emissions the picture is more mixed, with some trials indicating a slight increase in emissions from biodiesel, which can be explained by the combustion temperature being raised compared to standard diesel. While trial data on PPO used in unmodified vehicles indicates raised pollutant levels there is experience of properly fitted and adjusted retrofit equipment that provides better performance than indicated for B100 in a warranted but un-adjusted vehicle. Future high-blend biofuels, such as BTL and HVO have been subject to some trials or testing and indicate some reduction on both key pollutants consider here. The lowest emission biofuel is biomethane by some margin, given the inherently clean properties of a gaseous fuel in a properly set-up engine. This analysis could change in the future as petrol and diesel vehicles become cleaner, and if retrofit dual-fuel technologies (biomethane and PPO) are developed further.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter contains the study conclusions on: current barriers to use of high-blend biofuels; suggestions for methods to support market expansion; and recommendations about which biofuels are most promising for developing strategies to increase take up by type of vehicle.

5.2 Potential benefits and cost effectiveness

A set of GHG emissions has been calculated based on combinations of 8 types of vehicles and 13 fuels, generating 72 separate options in total that can be compared against a baseline of the conventional fuels, petrol and diesel. These options are based on a limited number of vehicles from that type: the concept of a target sub-sector where a proportion (ranging from 5 - 20%) of all vehicles of that type is judged appropriate and has potential to be switched to high-blend biofuel operation. HGV, PSV (bus) and MGV have been modelled with a 20% take up, LGV with 10% and car with 5%.

Considerable GHG emission savings might be achieved from each combination of vehicle type and fuel, ranging from a few hundred thousand tonnes to over 2.4 million tonnes p.a, noting that within one vehicle type these are probably not additive although might be achieved by mixing smaller proportions of different vehicle/fuel combinations.

At the top of the range there are considerable GHG savings estimated for the HGV (large artic) fleet if B100, PPO or biomethane were deployed successfully in 20% of total vehicles. This could generate savings of between 1.6 and 2.1 MT CO_2e p.a. from just 20% of this sub-sector of HGV. The other sub-sectors of HGV such as large rigid chassis vehicles generate smaller GHG savings in comparison to large artic's, although in many cases fleet operators will mix vehicle sub-types in their operations so co-benefits could arise from a general strategy to encourage high-blend biofuel supplies to own-tank fuelling operations.

Bus fleets are estimated to generate quite comparable GHG savings to some of the HGV sub-sectors, but from fewer vehicles. This is due to the high fuel consumption of buses over a typical operating year, due to large engines, high mileage and the poorer fuel efficiency that can be achieve in urban driving conditions.

The other high impact combination of vehicle/fuel from among the scenarios modelled during the study is bioethanol (E85) in 5% of the car fleet. This is estimated to generate a GHG saving of 1.7 MT CO_2e p.a.

Based on the same vehicle numbers used throughout the study it is estimated that E5 and B5 is used for 100% of the fleets described generates a GHG saving of around 3 – 3.5 MT CO_2e p.a. Therefore, even a highly targeted take-up of high-blend biofuels by a minority proportion of large articulated HGV and cars is estimated to match the impact of E5/B5.

With the best combinations each equalling around 1.5% of total UK domestic transport emissions (of 156 MT CO_2e) the potential for reducing GHG emissions is significant (particularly if more than one type of vehicle is targeted for use of high-blend biofuels, resulting in a larger cumulative impact).

The evidence from a range of studies points towards a reduction in particulate matter across the full range of biofuels. For NO_x emissions the picture is more mixed, with some trials indicating a slight increase in emissions from biodiesel. Given reported experiences with PPO - where NO_x emissions have been kept down - the option for fine tuning vehicles using biodiesel to mitigate the normal rise in NO_x levels (however slight) could form a valuable research topic. The lowest emission fuel is biomethane by some margin, given the inherently clean properties of gaseous fuels in a properly set-up engine. This analysis could change in the future as petrol and diesel vehicles become cleaner, and if retrofit of dual-fuel technologies (biomethane and PPO) are developed further.

While the economic benefits of high-blend biofuels have not been a specific focus of this study it could be useful to understand whether there is an overall economic benefit from production and supply chain development for such fuels, which by its nature has strong attraction to UK based SME and innovators in the field of technology and environmentally focussed sectors.

The costs of operating most vehicle / high-blend biofuel combinations are higher than with conventional fuels, based on current selling prices. Higher costs of biofuels are therefore due to one or more cost elements (e.g. re-fuelling equipment, the vehicle and/or the fuel itself) being raised. Duty differentials have been used in the UK to reduce duty and narrow the gap in selling price between conventional and alternative fuels (including high-blend biofuels). This study's analysis is based on costs without duty and tax to show the cost-effectiveness without this policy intervention, and so the relative cost of high-blend is not offset by any duty differential.

The current policy to encourage low-blends among all the vehicle parc is very cost effective, as is facilitated by existing re-fuelling infrastructure and standard, warranted vehicle technology (due to the fact it is mandatory and moves technology requirements forward in an incremental manner). This policy probably also has the advantage of requiring consultation and co-working with a much smaller group of organisations (focussed on the petroleum refining and distribution industry), compared to high-blend biofuels.

Going above low-blends will inevitably require greater investments and now that the low-blend markets are operating (albeit with some specific problems over the number of RTFO certificates in circulation) it is the right time to consider if encouraging high-blend biofuel use is a sensible strategy option now or in the near future.

As outlined in the policy section of Chapter 3 there are established mechanisms via the development of CEN standards to support progress towards RED 2020 targets for 10% biofuels by energy via lower-blend biofuels sold under conventional fuel standards (EN590 and EN228). The understanding of the petroleum industry is that progression of standards to encompass E10 and B7 (and hopefully beyond) provides time to make further changes to fuels in line with technology developments therefore progressing steadily towards 2020 targets. A counter-argument is that there will be a short-fall from low-blend take up, because while newly registered vehicles can use the latest EN standard fuel (with its increasing proportion of biofuel) not all existing vehicles can/will be able to operate on this. Hence, a shortfall, and the need to maximise use of high-biofuels in appropriate types of vehicle. Despite the findings of the Gallagher review, Government has kept the EU target of 10 % by 2020 and it is recognised that by 2010 it will need a mechanism in place to support the Renewable Energy Directive.

Given the stringent targets set in the Climate Change Act 2008 (CCA) to reduce UK CO_2 emissions in 2050 by 80% it is likely that more significant actions on transport emissions will needed. These may be more expensive to implement than options favoured to date. Waiting for technological developments to reduce the cost for a steady stream of options may not be feasible while working to the timescales set by the CCA.

If the choice to use high-blend biofuels is to be made then it makes sense to consider which of the vehicle/fuel combinations are most cost-effective. This has been done using cost effectiveness analysis (CEA) and presented in Chapter 4 under the options assessment. Each combination of vehicle and biofuel has been compared to the baseline cost of operating that same vehicle with conventional fuels.

Cost effectiveness analysis suggests that targeting high-blend biofuels on the heaviest vehicles is likely to produce a better return for costs incurred over and above the baseline case (of no biofuels, or low-blend only) compared to light-duty vehicles. HGV (large artic) and bus emission reductions are estimated to be the most cost effective options for targeting use of high blend biofuels. Interestingly, biomethane performs best in the cost-effectiveness analysis, despite heavy upfront investment costs. Higher blends of biodiesel (B100) and PPO perform better than lower blends (e.g. B30) because there are similar infrastructure and vehicle support costs for both blends, but a higher biofuel content means lower well to wheels carbon emissions.

Light duty vehicles are generally less cost effective candidates for investment in clean technologies/fuels as smaller engines produce less emissions, such vehicles tend to travel fewer miles and overall they use less fuel. However, OEM vehicle ranges are expanding to include more options for running high-blends as standard, specifically B30 and E85. While currently the advice is to service these engines more frequently when using high-blends the overall message is that the barriers to vehicle availability may be lowering.

To determine the viability of duty derogation as an option for incentivising high blend biofuel adoption, and focussing of the greatest opportunity of the HGV (large artic) class of vehicles, the levels of duty derogation necessary to compensate for additional capital and operation costs with various biofuels have been estimated. A similar analysis of car costs and carbon savings has also been made. For HGV, it is estimated that all high blend biofuels could be incentivised through a mechanism of

27 pence per litre derogation in fuel duty. The analysis of cars supports the argument that GHG savings can be made, but at a greater cost. For example, bioethanol (E85) is estimated to require an incentive equivalent to 45 pence per litre derogation in fuel duty.

5.3 Overcoming barriers to market expansion

A considerable number of producers, suppliers, distributors and users of high-blend biofuels currently exist in the UK. End-users are largely motivated by environmental concerns (of their own or their customers) with the objective to reduce the carbon footprint of their organisation. Cost saving is a motivation for a smaller number of actors, but with side benefits seen by some as improved vehicle performance and reduced engine wear (compared to conventional fuels). For organisations involved in supplying and distributing fuels it is demand from their customers and potential for market expansion that motivates them to participate in supply chains.

However, a number of barriers exist which limit the take up of high-blend biofuels, including:

1. Constraints in the existing fuel distribution network, including forecourt capacity;
2. Lack of guidance on high-blend fuel quality control;
3. The availability of vehicles;
4. Additional capital and operational costs;
5. Uncertainty on the sustainability of some biofuels and related policy;
6. The present public perception/ media image of biofuels;
7. Lack of long term policy and government direction for high blend biofuels;
8. Lack of long term incentives (financial support mechanisms).

Feedback through the stakeholder engagement elements of this study has generated a number of suggestions for how to address key barriers and what support mechanisms should comprise. It should be acknowledged that most of these are not easy to implement, but some fundamentals still need to be put in place to overcome quite considerable barriers in what is a fragmented and relatively immature market compared to that for conventional fuels.

Chapter 3 has examined a number of support mechanisms, and includes a range of suggestions under the each of the barrier headings.

Fuel supply chain:

- Support fuels consistently based on GHG reduction potential.

Fuel quality, standards and blends:

- Establish fuel quality guidelines for distribution and storage sections of supply chain for high blends;
- Support one blend level per high-blend fuel for the mass-market (i.e. retail/forecourt).

Vehicle availability:

- Set up forum of major vehicle purchasers and suppliers for target vehicles to understand long-term requirements and matching supply strategies aimed at lowering cost of new technologies;
- Fund grant programme for manufacturers to test their vehicles for standard ranges of high-blend biofuels with objective of increasing proportion of vehicles offered with warranty;
- Set a minimum specification for biofuel use in vehicles (i.e. an EC Regulation or Directive for beyond B10);
- Focus on manufacturers who use same engines, but offer reduced/no warranty for high-blend biofuel;
- Improve access to accurate information on warranty/approvals, including for existing/older vehicles; and

Sustainability:

- Continue to progress sustainability standards and reporting;
- Link GHG intensity of fuels to a number of RTFO certificates issued;
- Support opportunities for grid injection of biomethane and a green certification system, to facilitate the low-cost distribution of this fuel through an existing network.

Long term policy and government direction:

- Consistent long term policy, provide confidence to the market from legislation and clear strategy for meeting GHG targets from road transport;
- Link fuel support policy to air quality strategy refresh, which will need to address the evidence that bus and HGV emissions are significant sources of air pollution.

Long term incentives:

- Link fuel duty to GHG savings/energy values for long-term technology neutral stance on fuels;
- Link VED more comprehensively to high-blend biofuels (VED for cars and vans, Reduced Pollution Certificates for HDV);
- Use company car taxation to further incentivise low-carbon fuels and fuel-efficient vehicles;
- Widen BSOG and the LCEB fund to include more low-carbon fuels; and
- Use the Alternative Fuels Framework to support more types of high-blend biofuels.

Underlying the discussion of barriers and support mechanisms is always the issue of cost, as biofuels tend to cost more than conventional fuels. This is true at the present time and may continue to be the case while oil remains available at current levels of supply.

Market expansion of biofuel demand could lead to opportunities for more efficient supply chains; increased producers could bring efficiencies through competition and lead to investment in production techniques. On the other hand, increased standards and quality assurance have been found by some producers to introduce additional costs to their operations which could eventually reduce their ability to participate if market growth does not occur.

Therefore, many of the support mechanisms are reliant on a commitment by Government to offset increased costs of biofuels and put in place mechanisms that bring efficiencies to the market and assist its expansion in an increasingly efficient way. Unfortunately, the Government decision to remove the duty differential for biofuels in 2010 will undermine the use of high-blend biofuels and constrain further opportunities for market expansion quite severely. This is just at a time when the UK may need to keep open a variety of options for reaching carbon reduction targets, including those in the transport sector.

5.4 Vehicles and fuels

This section contains conclusions on the most promising opportunities by vehicle type and fuel.

5.4.1 Local bus

5.4.1.1 Opportunities

Local bus fleets should provide a good potential market for targeting high-blend biofuels for a number of reasons:

- High-mileage, high fuel consumption and a long vehicle life means impact of additional vehicle and capital costs can be amortised over a longer period and the greater of vehicle km travelled;
- Return to base fuelling, with depots generally in the more accessible areas of any given region;
- Regular in-house maintenance, undertaken on a rolling short-interval basis;
- A small number of very major operators, enabling Government policy/strategies to be rolled out potentially quickly and with effective take up;
- Public subsidy of a high proportion of vehicle operation and the powers of Local Transport Authorities to enter into agreements, partnerships, schemes and contracts.

From the option assessment analysis of carbon content and fuel consumption the greatest GHG savings over the baseline can be made with biomethane, followed by bioethanol. B100 and PPO are estimated to have similar savings, with PPO slightly higher of the two. B50 and B30 blends of biodiesel show proportionally smaller GHG reducing potential. In a target fleet comprising 20% of local bus services the deployment of biomethane or bioethanol could reduce GHG emissions by around 0.5 million tCO_2e/year. This is significant from a target fleet comprising just over 6 thousand vehicles. A target of 20% of local buses might be achievable with strong incentives over a number of years, to influence new vehicle purchases and efforts to use high-blend biofuels in older vehicles with suitable retrofit modifications.

However, in terms of costs-effectiveness the analysis suggests B100, PPO and biomethane vehicles could be operated at a similar cost per vkm. Bioethanol appears to be more costly from this analysis, when used in ED95 form *and* at a lower cost in line with greater volumes seen in the E85 market. This means, when a cost-effectiveness analysis is applied (combining cost above baseline with level of GHG saving) the low carbon properties of bioethanol are offset by the higher costs, and biomethane emerges the more cost effective from the trio compared to B100 and PPO. The latter two fuels appear the next most cost-effective.

Overall, using high-blend biofuels in buses is estimated to be more cost-effective than using it in other sectors of the vehicle parc, even when compared with other heavy duty vehicles.

5.4.1.2 Barriers

Recent announcements on reform of BSOG and the support fund will incentivise low carbon emission buses (LCEB) if they achieve a 30% plus saving in GHG emissions. However, vehicles will not qualify as a LCEB simply by using a low carbon fuel such as B100, unless the fuel used is biomethane.

From the LowCVP Bus Subsidy Advisory Group work leading up the April BSOG announcement it was evident that DfT was concerned not to give a double subsidy/incentive to biofuels and that "the level of overall biofuels in the UK will be wholly determined by the RTFO". Therefore, it was proposed in the BSOG April announcement that a bus will not be allowed to qualify as a LCEB on the basis that it runs on biofuel. This is understandable for B5, but is it appropriate for higher blends B30, B90?[85] Additional costs arise from using bioethanol or PPO and the development of good practice and the cost efficient methods and engine technologies for operating will be important for increasing the proportion of biofuels probably needed to meet RED targets.

Given that biomethane appears currently to be the most favoured biofuel by Government for bus operations a strategy for market expansion could sensibly be based on this fuel. The analysis from this study suggests considerable potential.

5.4.1.3 Support mechanisms / market expansion

In addition to a number of the generic support mechanisms described in section 5.3 a strategy to increase uptake of biomethane in bus fleets could include these specific strands:

- Increasing BSOG payment for LCEB achieved using biomethane to 12ppkm, recognising the significant investment required in fuelling infrastructure and additional air quality benefits from biomethane; and/or
- Consider graduated BSOG that tops-up incentive for biomethane and other low carbon fuels in recognition that they can go beyond the minimum 30% GHG saving of the LCEB threshold;
- Set up a grant programme to fund demonstrations or give access to existing grant programmes for low carbon vehicles to bus operators for biomethane vehicle;
- Support grid injection of biomethane and green certificates to enable bus operators to reduce the transport cost of the fuel and improve reliability of supply and ensure fuel with a stable specification;

[85] BWG-P-09-07 - Defining a Low Carbon Bus.

- Work with vehicle manufacturers to set up long-term offer to reduce prices via volume purchase and ongoing service support caps.

As well as efforts by Government a contribution from other sectors is required, for example:

- Fuels industry should promote standards that are available, discourage cheaper poor quality products, and actively educate in fuel handling and storage;
- Vehicle manufacturers should devise a long-term plan for supply and support of vehicles fitting LCEB specifications based on volume sales to enable planning;
- Bus Operators should recognise their role in creating GHG emissions and poorer air quality and take opportunities to reduce their contribution to both.

5.4.2 HGV

5.4.2.1 Opportunities

It has been identified that operators with own tank fuelling provide the more promising opportunities for high-blend biofuels. This fuelling profile is very likely to be prevalent among vehicle operators with larger fleets, generally over 50 vehicles. Organisations with vehicle fleets of this size account for around 20% of HGV numbers.

The analysis presented in the option assessment chapter suggests that significant GHG reductions can be achieved with currently available higher-blend biofuels (B100, PPO and biomethane), viewed both in total tonnes and as a proportion of total HGV GHG emissions. Lower blends, such as B30 or B50 could make a lower, but significant contribution.

5.4.2.2 Barriers

There exists a body of experience from UK HGV operators using high-blend biofuels of different varieties, with lessons learned from both positive and negative outcomes. There is a commitment among some organisations of not always choosing the lowest cost option, if GHG savings can be made. On the other hand, there are reported concerns of HGV operators about a loss of quality and consistency in diesel supplies from the introduction of low-blends (B5) via the RTFO mechanism[86].

However, HGV operators are concerned about obtaining reliable supplies and quality of fuels. Their preference tends to be for liquid fuels, ideally blendable with diesel, so they can source the best priced fuels, fill their vehicles with conventional diesel if necessary (or a lower blend) and retain residual values. This points towards high-blend biodiesel, or possibly PPO if the need to retrofit and deal with warranty issues is acceptable.

Mono-fuel operations based biomethane fit best with HGV fleets practicing return to base fuelling, operating on a local/regional basis with access to their own or

[86] Motor Transport, April 2009.

bunkered supplies on a daily basis if necessary. Therefore, HGV operators working regular long-distance routes may form a viable and expandable market biomethane, but this will tend to be smaller in size because the cost and effort of maintaining dual fuelling infrastructure in more than one location starts to weight the balance sheet against these fuels. The refuelling equipment requirements for biomethane is more of a step change for fleet operators compared to the more familiar format PPO or biodiesel (as a liquid non-pressurised fuel).

Analysis carried out in this study indicates that high-mileage vehicles such as HGV could generate sufficient payback on the lower operating costs of biomethane (vs. B100 or PPO) to offset considerable upfront capital investment costs in fuelling infrastructure. This approach would put in reach biomethane as the fuel that probably has the best carbon reduction, sustainability and energy-security credentials of those examined in this study.

5.4.2.3 Support mechanisms / market expansion

In addition to the generic support mechanisms described in section 5.2 above, which could be targeted at the HGV markets, a strategy to increase take up of high-blend biofuel could include these specific strands:

- Develop retrofit markets for PPO and B100 for older vehicles;
- Increase storage/handling expertise and raised standards as part of a robust supply line of B50 and B100;
- Build on current experience for warranting high blend biodiesel to increase new vehicle availability and accessibility for high-blends;
- Enable cost efficient biomethane distribution and support selected infrastructure development to specifically target high-consumption fleets.

The commercial vehicle fleet has been lobbying for changes to fuel duty on economic grounds, and to enable fair competition with hauliers based in mainland Europe who can buy cheaper fuel on their way to the UK. If the fuel duty regime for commercial vehicles was to be examined for potential revision then including the opportunities for incentivising low carbon fuels (and those with lower contributions to air pollution) in the scope would be sensible .

5.4.3 MGV

5.4.3.1 Opportunities

Focussing on the impact of operating 20% of the MGV sector with currently available highest blend liquid biofuels (B100 and PPO) the analysis indicates savings of 211,840 and 216,775 T CO_2e/year, respectively – a reduction of around 10%. Using a B30 blend in the target fleet would only reduce GHG emissions by 63,552 T CO_2e/year; or 3% of the total. Using dual fuel vehicles and biomethane within the target fleet gives similar benefits as B100 and PPO, however using a dedicated biomethane vehicle is expected to provide greater reductions. The number of MGV in the 20% target fleet actually exceeds any of the HGV sub-sectors (large artic, small rigid etc).

5.4.3.2 Barriers

The absolute values of CO_2 reduction are smaller than for other sectors of the goods vehicle parc because of the lower annual mileage of MGV and better fuel efficiency compared to heavier commercial vehicles. As a result of lower-fuel consumption/mileage the cost-effectiveness of operating MGV with high-blend biofuels is significantly poorer than for HGV, at approximately double the cost.

5.4.3.3 Support mechanisms / market expansion

These findings indicate strongly that MGV should not be the first choice vehicle type in a strategy to expand the market for high-blend biofuels. However, they could be a useful part of a longer term strategy targeted at goods vehicles, if incentives to promote high-blend biofuels via own-tank filling were pursued (for PPO, B100 or biomethane).

5.4.4 LGV

5.4.4.1 Opportunities

Given the large number of light vans (LGV) registered and operated in the UK (3.2 million) the potential from using high-blend biofuel in even a small proportion such as 10% of the fleet is quite significant.

For example B100 in 10% of the van fleet could reduce GHG emissions by 714,384 T p.a., PPO 798,246 t p.a., bioethanol (E85) 874,088 t p.a. and biomethane 975,180 tonnes. These represent between 5 and 7% of all van emissions. A B30 blend in the target fleet would reduce GHG emissions by proportionally less - 2.5% (214,315 T CO_2e/year) – so would not provide a major impact on its own. However, the van sector has shown the largest growth in mileage in recent years in the UK so can be anticipated to become increasingly important.

The full range of fuels was assessed and bioethanol (included due to availability of car derived FFV vans) was estimated to have cost-effectiveness similar to B100 or PPO. As for MGV, the relative cost effectiveness of high-blend operations is low in LGV compared to heavy commercial vehicles.

The split of vehicle ownership between private, commercial small-medium enterprises (SME) and large organisations (with large commercial vehicle fleets) and the difference in fuelling profile indicates a twin-track approach would be required to encourage high-blends in the UK van sector.

5.4.4.2 Barriers

On practicability grounds, the compatibility of van manufacturers' engine technology available in the UK points strongly towards biodiesel. Some key manufacturers are starting to offer gas and ethanol vehicles, so there is potential, but the range is currently more restricted than for biodiesel. (It appears likely that it will remain so even with the additional gas vehicles anticipated shortly for UK markets). However, to reach a target 10% of the market for biogas or ethanol would require new vehicles purchased specifically for these biofuels, whereas diesel engine vehicles will always have the fall-back of standard diesel fuel. It would be more realistic to target a smaller proportion of the van fleet for these particular fuels, in addition to a strategy to increase take up of high-blends for diesel engine vehicles.

For the sensitivity test carried out on B30 with reduced servicing uplift the £ per tonne of CO_2e reduced was also reduced from £951 to a much more attractive £250 per tonne. This makes B30 the most cost-effective high-blend. The importance of proper servicing should be emphasised where needed to keep the vehicle in warranty and operating properly. Most OEM currently require additional servicing for B30 and above. However, the positive impact a reduced service requirement can have on the cost-effectiveness of a high-blend fuel emphasises the need for a thorough and co-ordinated examination of warranties vs. actual technical requirements across Europe.

5.4.4.3 Support mechanisms / market expansion

The strong division into two different fuelling profiles, the comparably low cost-effectiveness of biofuels and the current vehicle availability indicates a twin-track approach could be required to encourage high-blends in the UK van sector. The lower cost-effectiveness of using biofuels in vans suggests expanding this part of the market makes most sense as a second step in strategies that are built on the most cost-effective types of vehicle in light and heavy duty sectors:

- If B30 or E85 is supplied via forecourts and expanded as part of a strategy to serve car owners this could be a basis for promotion to individual and small van fleet owners; and/or
- large fleet operations with HGV could add van re-fuelling in a relatively cost-effectiveness manner, once the investment in own-tank fuelling for HGV has been made.

5.4.5 Car

5.4.5.1 Opportunities

The overall estimated GHG emissions from the car fleet is estimated to be around 65m T CO_2e/year. Given a fleet of 27 million vehicles targeting 5% for high-blend biofuels this equals 1,350,000 vehicles with total emissions from a target 5% total 3.25 million T CO_2e/year. For cars, the petrol/diesel ratio of the current parc means that 5% of the total fleet is more than 5% of petrol vehicles or diesel vehicles.

Operating a 5% target fleet with highest blend liquid biofuels (B100 and PPO) shows savings of 1.6m and 1.8m T CO_2e/year, respectively. Slightly more significant GHG reductions appear feasible from the 5% target fleet if operated on biomethane, but the practicality analysis of this fuel suggests it is a considerably more difficult strategy to adopt for mass-market take-up. Using a more realistic B30 blend in the target fleet would reduce GHG emissions by a relatively small amount 0.8% (0.49m T CO_2e/year). However, using a potentially realistic E85 blend in 5% of the car fleet gives a significant GHG reduction of 1.7m T CO_2e/year. Alternatively, given the petrol/diesel ratio a 5% take up of high-blend biofuels in the car fleet might be reached with a combination of fuels each with smaller contributory percentages

5.4.5.2 Barriers

Fuel purchase is generally done on public forecourts, with many 'company car' drivers using fuel cards to pay for fuel. A minority of car drivers will have access to depot fuelling for their vehicle. The need to provide high-blend biofuels through the forecourt networks adds additional barriers to market expansion.

The new car market is divided between private car sales (44%) and fleet or company car sales (56%).[87] Company car sales include very large fleet buyers for daily car hire companies and vehicle lease companies who provide them to employees for use in their work or as part of their remuneration package. The purchasing patterns of these two segments (private/business) vary and the influences on purchasing behaviour are quite different.

OEM vehicle ranges compatible with high-blend biofuels show some sign of expansion for UK buyers. Significant numbers of existing PSA Group diesel vehicles will operate on B30 and joining them is Renault with a commitment to both E85 and B30 for 50% of new vehicles in Europe. FFV is available from Ford and Saab and VW promise one or two gas engine models in 2009/10.

Given the barriers to market expansion the target fleet scenario was set lower than for other types of vehicle, at 5% of passenger cars.

5.4.5.3 Support mechanism / market expansion

In the cost-effectiveness analysis PPO, B100 and E85 performed similarly. Based on the cost inputs and assumptions made, bi-fuel vehicles (with biomethane) did not compare as well as these three, and as might be anticipated B30 was ranked lower again.

When considering purely technical (or usability) barriers then E85 appears the more suitable fuel when compared to B100 or PPO as these latter options require either retrofit technology and/or some specialist knowledge. E85 is also relatively cost-effective, when GHG emissions savings are factored in. B30 is less cost effective largely because of increased operating costs assumed under the 'harsh-conditions' servicing regime recommended as part of the relevant OEMs warranty guidance. However, B30 does have the advantage of otherwise being relatively straightforward for the average person to use in their vehicle if they have a suitable make and model.

Based on a mixture of practicality, potential for GHG reduction and cost effectiveness a strategy to encourage high-blend biofuel use in cars in the UK should strongly consider bioethanol (E85) and biodiesel (B30).

[87] SMMT, Automotive Focus, 2007.

5.5 Future work

This study has generated a number of questions that would benefit from further research, including:

- Fully document technical compatibility of vehicles produced with high-blend biofuels for the whole EU, as the basis for potential discussion between the EC, OEMs and fuel producers about what options there already exist for high-blend biofuels and are likely in the near future;
- Develop the cost-analysis work done in this study from its CEA basis into a full CBA in order to properly value the benefits, in a manner that makes carbon reduction from high-blends comparable against complementary or alternative measures (in other sectors);
- Further develop the studies cost effectiveness assessment tools, to include more dynamic handling of fuel price and enable the forecast of changes on relative and absolute impacts
- Undertake further work with the UK fuel retailer representatives (and their member companies both large and small) to understand the costs of expanding high-blend biofuel provision via forecourts, explore the constraints in more detail and understand the organisational and geographical capacity for both protection grades required to progress RED and go above mandated minimums to high-blends.

A1 OPTION ASSESSMENT INPUT DATA

A1.1 Toxic emissions

Table A.1 Scale factors for heavy duty vehicles

Fuel and blend	Scale factors		Source
	NO_x	PM	
Euro V diesel (base case)	1	1	
Biodiesel (B5)	1.004	0.981	AEAT
Biodiesel (B30)	1.024	0.886	AEAT
Biodiesel (B50)	1.04	0.81	AEAT
Biodiesel (B100)	1.08	0.62	AEAT
Bioethanol (ED 95)	0.8	0.36	JET (bus data)
Biomethane (dedicated)	0.21	0.17	Cenex
Biomethane (dual fuel)	0.3285	0.2945	Cenex
PPO	1	0.6	Matrix Biofuels, Millbrook, John Lewis Partnership
BTL	0.85	0.82	ASFE
HVO	0.9	0.7	Neste (factor for buses)

Table A.2 Scale factors for light duty vehicles

Fuel and blend	Scale factors		Source
	NO_x	PM	
Euro V diesel (base case)	1	1	
Euro IV petrol (base case)	0.33	1	Relative to diesel (E5 emission limits)
Biodiesel (B5)	1.004	0.981	AEAT
Biodiesel (B30)	1.024	0.886	AEAT
Biodiesel (B50)	1.04	0.81	AEAT
Biodiesel (B100)	1.08	0.62	AEAT
Bioethanol (E85)	0.33	0.8	AEAT, adjusted to be relative to diesel
Biomethane (bi-fuel)	0.21	0.17	Cenex
PPO	1	0.6	Matrix Biofuels
BTL	0.936	0.74	BTL data 07 Nannen: VW trials, Cars only
HVO	1	0.82	Neste, Conclusions were there was no clear decrease in NO_x, but a decrease in PM from 18 to 30% depending on whether a catalytic converter is fitted or not. With-cat figure has been used.

AEAT: Road Transport Emissions from Biofuel Consumption in the UK, AEAT/ENV/R/2662, Issue 1, July 2008.
Cenex: Biomethane Toolkit, 2008.
JET: Derived from TTR JET model, based on COPERT 4 emissions data
PPO HGV figures: Millbrook testing for John Lewis Partnership
PPO LGV figures: Matrix biofuels.
Neste: Data supplied by Neste Oil plus paper on 'Biodiesel Fuel of the Second Generation'. Author(s): Leena Rantanen - Neste Oil Corporation (2005).
ASFE Position Paper, Emissions from Synthetic Fuels, 2007

A1.2 Greenhouse gas emissions

Table A.3 Greenhouse gas values, source and methodology

Fuel	MJ/litre or kg	gCO_2e/MJ	gCO_2e/MJ	gCO_2e/MJ	Source
	RED values	mid-range	best case	worst case	
Petrol	32.0	83.8	83.8	83.8	RED
Diesel (standard diesel)	36.0	86.4	86.4	86.4	RED
Biodiesel (B5)	35.9	84.215	82.58	84.78	RED; calculated from diesel and B100
Biodiesel (B30)	35.3	73.29	63.48	76.68	RED; calculated from diesel and B100
Biodiesel (B50)	34.8	64.55	48.2	70.2	RED; calculated from diesel and B100
Biodiesel (B100)	33.5	42.7	10	54	RED; Mid-range values calculated using information on in-use volumes of UK biofuels (RFA report April - October 2008)
Bioethanol (E5)	31.5	81.045	80.81	81.91	RED; calculated from petrol and E100
Bioethanol (E85)	22.7	36.965	32.97	51.67	RED; calculated from petrol and E100
Bioethanol (ED 95)	20.0	27.265	22.8	43.7	RED; calculated from petrol and E100
Bioethanol (E100)	21.0	28.7	24	46	RED; Mid-range values calculated using information on in-use volumes of UK biofuels (RFA report April - October 2008)
PPO	34.0	35	35	35	RED; Mid-range values calculated using information on in-use volumes of UK biofuels (RFA report April - October 2008)
BTL	36.0	21.6	8.64	34.56	ASFE Position Paper Emissions from Synthetic Fuels, January 2007; mid-range is mean of best and worst case figures
HVO	34.0	39.33	27	50	RED. No in use data, so mid-range values calculated based on assumptions about future in-use figures.
Biomethane	50	17	12	17	RED; Mid-range values calculated using information on in-use volumes of UK biofuels (RFA report April - October 2008)

Biodiesel

The method used to arrive at biodiesel (B100) gCO_2e/MJ figure was:

- RED values were initially used and combined with RFA reported in-use volumes for UK biodiesel (March to October 2008) - linear averaging gives 39 gCO2e/MJ;
- Oilseed rape, Soy, Palm and Tallow represent 95% of all feedstocks reported by RFA for Apr-Oct 08;
- However, the prominence of Soy may reduce due to new policy measures. It seems reasonable to hypothesise that oilseed and palm will fill the void;
- The average of palm and oilseed is the same as soy and assuming there are no radical shifts to feedstocks outside of palm, soy, oilseed, the variance caused by a shift will not have significant effect;
- A weighted average of these gives 42.7 gCO_2e/MJ.

Note, the estimation method above already removed UCO as the stocks are finite. If tallow is also considered finite it would not be able to keep pace with an expanded biodiesel market. If tallow is completely removed then the average gCO_2e/MJ goes up to 46.8 based on the method above. This indicates that in the longer-term, under a significant market expansion scenario, biodiesel GHG performance could worsen.

HVO

Given no in-use figures for HVO mid-range values calculated by assuming equal use of HVO rape seed (41 gCO_2/MJ), HVO palm oil (process unknown) (50 gCO_2/MJ) and HVO palm oil (methane capture at plant) (27 gCO_2/MJ). HVO from sunflower seed (29 gCO_2/MJ) was not included in the average due to it being very unlikely this will be used (primarily cost reasons).

Bioethanol

Applying a linear average of relevant ethanol RED figures gives 34.2 gCO_2/MJ MJ (after removing feedstocks that do not achieve 35% or better GHG reductions, i.e. plant powered by 'lignite' and 'process fuel not specified'). However, the present RFA in-use quantities will not consider plant coming on-stream in the near-term and does not consider wheat. In fact, sugar cane represents 82% of ethanol feedstock reported by RFA. Adding sugar beet to sugar cane represent 98% of ethanol feedstock reported by RFA. Applying this weighting gives a GHG value close to 25 gCO_2/MJ due to low GHG RED value of sugar cane, ex ILUC).

The method used in the study is to assume reduced proportions of sugar beet ethanol in a future expanded market, and therefore include wheat. Production methods from RED provide a variety of values:

- wheat ethanol (natural gas as process fuel in conventional boiler) - 46 gCO_2/MJ;
- wheat ethanol (natural gas as process fuel in CHP plant) – 39 gCO_2/MJ; and
- wheat ethanol (straw as process fuel in CHP plant) – 26 gCO_2/MJ.

An assumption could not be made on prominent wheat plant configuration, so an average of wheat plant is 37 gCO_2e/MJ. It can be noted that this average wheat value is the same as the corn/maize RED figure.

- The study method is based on the proposal that sugar beet use is as present and 30% substitution of sugar cane to wheat or maize corn. 30% substitution may be optimistic, but on the other hand there are arguably limits to the bioethanol that Brazil will export given its domestic requirements.

Table A.4 – Bioethanol in-use volumes (RFA) and RED figures

Values	**gCO2eq/MJ (RED)**	**Volume (l)**		
Source	RED		Proportion	Weighted value
Sugar beet	33	16800511	0.163	5.38
Sugar cane	24	60375489	0.586	14.06
Average wheat	37	25875209	0.251	9.29
Total		**103051209**	**1**	**28.73**

Assuming future substitution of sugarcane will most likely occur by use of sugar beet or wheat/corn then a weighted average of these gives 28.7 gCO2eq/MJ, which is lower than a weighted average based on 2008 RFA in-use volumes

A1.3 Fuel consumption data

The starting point for fuel consumption data for diesel vehicles has been in-use monitoring by study partner Fleetsolve combined with FTA cost table data from 2009. For diesel vehicles this provides the baseline, from which fuel consumption of biofuels has been estimated, based on relative energy content. The result is a general trend for high-blend biofuels to lead to higher fuel consumption, compared to diesel. The degree of uplift in fuel consumption from applying the energy content method is supported by a number of trials/tests of high-blend biofuels that have resulted in increased fuel consumption. However, it is acknowledged that some trials and tests of high-blend biofuels (notably B30 and PPO) have found no increase in fuel consumption.

For fuel consumption figures for vehicles types operated with bioethanol the study has drawn on test data from the BEST project (for car) and from Nottingham University's ongoing evaluation support to the Nottingham City Transport's trial of bioethanol buses.

For vehicles operating on biomethane the study has greatly benefited from the Biomethane Toolkit produced by Cenex, with fuel consumption values for HGV, car, van and bus.

Table A.5 – Fuel consumption data inputs

Fuel (l per vkm)	HGV artic (3axle)	HGV artic (2axle)	HGV rigid large	HGV rigid small	MGV	LGV (van)	Car	PSV (bus)
Petrol	Na	na	na	na	na	0.091[7]	0.067[3]	na
Diesel	0.375	0.375	0.353	0.185	0.097	0.071[5]	0.052[4]	0.474
Biodiesel (B5)	0.376	0.376	0.354	0.185	0.098	0.071[1]	0.052[1]	0.476
Biodiesel (B30)	0.383	0.383	0.361	0.189	0.099	0.072	0.053	0.484
Biodiesel (B50)	0.389	0.389	0.366	0.191	0.101	0.073	0.054	0.491
Biodiesel (B100)	0.403	0.403	0.379	0.198	0.105	0.075	0.056	0.509
Bioethanol (E5)	Na	na	na	na	na	0.092[6]	0.068[6]	na
Bioethanol (E85)	Na	na	na	na	na	0.128[6]	0.094[6]	na
Bioethanol (ED 95)	Na	na	na	na	na	na	na	0.855
Bioethanol (E100)	Na	na	na	na	na	na	na	na
PPO	0.397	0.397	0.374	0.195	0.103	0.075	0.055	0.502
BTL	0.375	0.375	0.353	0.185	0.097	0.071	0.052	0.474
HVO	0.397	0.397	0.374	0.195	0.103	0.075	0.055	0.502
Biomethane (kg per vkm) [2]	0.310	0.310	0.310	0.240	0.130	0.080	0.060	0.400

Notes:
1 - Assumed no fuel consumption penalty. If include a penalty this combines with gCO_2e/MJ value to create a gCO_2e vkm value greater than B0.
2 – Source is Cenex Biomethane Toolkit: 0.310 value as for 'Heavy Truck' / 0.240 value as for 'Medium Truck'.
3 – Based on Ford Focus 1.6 Zetec with 42.2 mpg.
4 – Based on Ford Focus 1.8 diesel with 53 – 54 mpg.
5 – Source is Fleetsolve.
6 – Estimated against petrol, based on energy content of E5/E85 vs. petrol. Increase in consumption broadly in-line with that found by testing by BEST project.
7 – Assumed fuel consumption increase for petrol van over diesel in same proportion as for car (diesel vs. petrol).

The estimation of gCO_2e per vehicle km has been calculated by combining the fuel consumption data with the gCO_2e/MJ values described in the section above.

For dual-fuel biomethane vehicles and operations on PPO a combination of standard diesel and the respective biofuel has been used to arrive at a composite gCO_2e per vehicle km. For dual fuel HGV we assumed 85% gas utilization for large artics and 70% for other HGV types (given acceleration changes and greater prevalence of stop-start conditions). For PPO we assume 87% biofuel use and 13% diesel for all HGV, bus and MGV and 95% PPO for light duty cars and vans (car, LGV).

For dual-fuel vehicles such as PPO and biomethane an assumption has been made about the ratio of standard diesel and biodiesel. The exact ratio will depend on many things including type of vehicle, type of operation and which version of the technology is in use. There are obviously examples of lower biofuel ratios than this (e.g. when used in stop start conditions), but one of the requisites for optimal dual fuel operation is some degree of steady running to maximise the biofuel ratio. Examples of greater ratios exist too, for example there is a recent report from the John Lewis Partnership of 94% PPO use.

A1.4 Fuel cost data

Fuel prices have been estimated for the range of biofuels considered by the study. This has been done wherever possible using up to date spot prices (April-May 2009).

The objective of the fuel cost estimation process has been to arrive at prices that a bulk purchaser might expect to pay at the current time for operating large fleets of vehicles. A finished price is estimated for delivery to the user, blended if appropriate.

In practice a vehicle operator can sometime pay for new fuelling infrastructure via a small increment per litre/kg on the fuel. However, the basis of the fuel cost data obtained for this study does not to include infrastructure costs, and these are identified separately.

Since spot prices will continue to vary and the relationship between them keeps changing the variability of fuel costs will effect the outcome of the analysis at any given time.

Table A.6 – Fuel price data inputs

	Ex-plant/ refinery[1]	Transport to customer	Pre-dist costs (& margin)[2]	Finished price	Current duty	VAT	Current selling price
DERV (EN590)[3]	0.250	0.05	0.01	0.310	0.542	0.128	0.980
B5[4]	0.262	0.05	0.015	0.327	0.532	0.129	0.987
B30 (RME)[5]	0.329	0.06	0.03	0.419	0.482	0.135	1.036
B50 (RME)[6]	0.382	0.06	0.03	0.472	0.442	0.137	1.051
B100 (RME)[7]	0.514	0.06	0.02	0.594	0.342	0.140	1.076
B100 FAME 0 [8]	0.480	0.06	0.02	0.560	0.342	0.135	1.037
PPO [9]	0.488	0.06	0.02	0.568	0.342	0.136	1.046
Bioethanol E100 [10]	0.346	0.06	0.01	0.416	0.342	0.114	0.871
E85 [11]	0.366	0.06	0.02	0.446	0.372	0.123	0.940
ED95 [12]				0.600	0.352	0.143	1.095
Petrol [13]	0.263	0.05	0.01	0.323	0.5419	0.130	0.995
E5 [14]	0.190	0.05	0.01	0.250	0.5319	0.117	0.899
Biomethane [15]				0.508	0.192	0.105	0.805

Notes:
1) Spot prices, generally delivered to port ready for onward tanker transport into North West Europe.

2) Costs including blending of biofuel with petrol/diesel and additive packs.
3) April/May spot prices (at £298 £ MT)
4) DERV and FAME 0 (UVO)
5) DERV and B100 RME
6) DERV and B100 RME
7) Various spot price data: April 2009, AG Member supplied early May, and mid-May spot prices (AG Member) - used 660 Euro MT

8) Used May spot prices of 590 Euro MT (0 °C cfpp). Biofuels Corp. price (FAME 0 UVO) from April 2009 in line with this (source: Biofuels Corp.). Another AG Member data suggests a finished price of closer to 53ppl, so some discrepancy. However, using FAME 0 as a component of B5, so differential in data makes little impact.
9) April 2009 spot prices from (600 Euro MT), plus discussion with FWG Members. UK sourced PPO seems to be more expensive than this, but given spot price data and need for consistency with B100 this price assumed and used.
10) April/May spot prices for T2 (sugarcane) at 430 Euro per m3 plus wheat/sugar beet at £297 m3 (source: Ensus). Combined at rate of 58.6% sugar cane and 41.4% wheat (based on RFA in-use values) = £345.63

11) Combined petrol and E100 at 15:85 ratios.
12) Information from supplier, note that small current volume mean costs are higher than other ethanol fuel products.
13) Spot price of £263 tonne (Source: Ensues quoting EIC average spot price for April and May 2009).
14) Combined petrol and E100 data at 95:5 ratios.
15) Agreed with Cenex after pooling range of price information from various sources and reference studies.

For biomethane a range of costs from the study team's research has been combined with data from Cenex to arrive at a representative price per kg supplied (by road tanker). In some cases gaseous fuels are supplied at a price that pays back the supplied fuelling infrastructure. This approach has not been used in this study, the infrastructure costs are listed and accounted for separately.

It should be noted that ED95 is estimated from current prices as supplied to a small UK market. The price does not appear consistent with bulk E85 prices or E100 spot prices, probably due to the small volumes currently being sourced and supplied into the UK. For this reason a sensitivity test has been carried out for bus costs based on a finished price of £0.45ppl (see bus section in Chapter 4).

In a comparison of spot prices for PPO and biodiesel the study found only a small difference e.g. PPO cost was 57ppl and (high quality) B100 RME is 59ppl, so the difference is only 2ppl. The industry accepted on-cost for transesterification is reported as being $200/tonne, c. 14ppl. However, spot prices for each fuel show a much smaller differential than 14ppl, checked on more than one month through 2009. The reason for this is unknown. It is possible that bulk purchasers of PPO for transesterification can obtain discounts on PPO spot price. Three UK-suppliers of PPO were asked to qoute for bulk-supplies and in all cases this was significantly *higher* than B100 spot price.

A1.5 Vehicle cost data

Cost data has been collated from a number of sources, some directly and some via previous studies and reports. Where possible a number of sources have been collated and compared to verify a more accurate estimate.

In the case of fuelling/infrastructure costs the estimate is based on the price of own-tank fuelling (depot or at the place of business/residence). This provides an indication of cost that aligns well with the commercial vehicle market. The study has not made a separate estimate of the costs of equipping forecourt to supply high-blend biofuels (in order to compare the price per vehicle figure with own-tank filling).

Table A.7 – Cost data PSV (bus)

Fuel	Euro V diesel	Biodiesel (B5)	Biodiesel (B30)	Biodiesel (B50)	Biodiesel (B100)	Bioethanol (ED95)	Biomethane (dedicated)	PPO	BTL	HVO
New vehicle cost (£)	£120,000	£120,000	£120,000	£122,500	£122,500	£140,000	£150,000	£123,450	£120,000	£120,000
Notes and Reference	Standard 12m bus, various sources (TfL, Merseytravel etc)			Plus cost of fuel heater for reliable winter operation. Source is Fleetsolve.		Scania 12 OminCity, source E4 Tech TfL 2006 report.	Source: E4 Tech TfL 2006 report and Cenex Biomethane Toolkit	Source: Matrix Biofuels estimate for supply and fitting PPO kit to HDV.	Assumed as for dieesl	Assumed as for diesel
Fuelling infrastructure £/vehicle	£0	£0	£300	£300	£300	£1,700	£14,500	£300	£0	£0
Notes and Reference			Additional storage tank costs for biodiesel (with long-payback), based on running part of fleet on convential diesel. Inlcudes civils/install costs.			Tech TfL 2006 report and TTR pteg bus emission report (update/upra ting value from E4	Source: E4 Tech TfL 2006 report and TTR pteg bus report 2008 (source John Baldwin).	As for biodiesel	No change	No change
Maintenance Costs	£0.22	£0.22	£0.27	£0.27	£0.27	£0.27	£0.30	£0.27	£0.22	£0.22
Notes and Reference	TfL (via E4 Tech 2006		Experience from HGV/Vans is that doubling servicing interval increases costs by factor or 1.8. This assumed to be less likely with bus, given normal 28 day rolling service shedule. Applied factor of 1.225.			Source: E4 Tech TfL 2006 report.	Source: E4 Tech TfL 2006 report. TTR obtained some supporting evidence from current experience in France.	Assumed as for diesel, supported by Fleetsolve experience.	No change	No change

Note, biomethane fuelling costs are based on the following sources:

a) Indirect sources (based on E4Tech report for TfL 'Economic And Environmental Evaluation Of Bioethanol, Biomethane And Diesel-Electric Hybrid Buses'):

- "Report of the Alternative Fuels Group of the Cleaner Vehicles Task Force page 50, £250,000 per 16 buses = £15,600;
- IANGV "Natural Gas Transit Buses - World Review for IANGV": page 17 - Sacramento US$3.5M for 136 buses (£ 14,300 per bus).
- Nb: both includes "Storage" costs.

b) Direct source, personal communication with John Baldwin CNG Services, who shared a cost estimate spreadsheet for estimating total capex and opex costs for fuelling 50 CNG buses, producing results of: £638,000 (total capex, including civils) = £12,760 per vehicle.

Table A.8 – Cost data HGV (large artic)

Fuel	**Euro V diesel (base case)**	Biodiesel (B5)	Biodiesel (B30)	Biodiesel (B50)	Biodiesel (B100)	Biomethane (dedicated)	Biomethane (dual fuel)	PPO	BTL	HVO
New vehicle cost (£)	£50,000	£50,000	£50,000	£52,290	£52,290	£85,000	£73,000	£53,600	£50,000	£50,000
Notes and Reference	Price for standard tractor unit only			Plus cost of fuel heater for reliable winter operation. Source is Fleetsolve.		Source: Cenex Biomethane Toolkit	Source: Cenex Biomethane Toolkit	Source: Matrix Biofuels and Verdant Fuels. Estimate for supply and fitting PPO kit to HDV.	Assumed as for dieesl	Assumed as for diesel
Fuelling infrastructure £/vehicle	£0	£0	£300	£300	£300	£14,500	£14,500	£300	£0	£0
Notes and Reference			Additional storage tank costs for biodiesel (with long-payback), based on running part of fleet on convential diesel. Inlcudes civils/install costs.			Source: E4 Tech TfL 2006 report and TTR pteg bus emission report (source John Baldwin) which confirmed value from E4 Tech).		As for biodiesel	No change	No change
Maintenance Costs	£0.05	£0.05	£0.09	£0.09	£0.09	£0.07	£0.07	£0.09	£0.05	£0.05
Notes and Reference	Source: Fleetsolve. Base case data is from the Freight Transport Association Cost Tables (Jan 09).		Experience from commerical veh operation is that doubling servicing interval increases costs by factor or 1.8, so applied for B30 and above. Intermediate service is partial, therefore slightly cheaper but oil and filter change plus time are some of the more costly items in a regular service.			TTR estimated based on bus experience. Increased using factor of 1.2 to 1.3 for HGV.		Assumed as for diesel, supported by Fleetsolve experience.	No change	No change

Table A.9 – Cost data MGV

Fuel	Euro V diesel (base case)	biodiesel (B5)	biodiesel (B30)	biodiesel (B50)	biodiesel (B100)	biomethane	PPO	BTL	HVO
Vehicle cost (£) - MGV	£21,800	£21,800	£21,800	£23,000	£23,000	25,800/24800	£23,350	£21,800	£21,800
Notes and Reference				Add cost of fuel heater for reliable winter operations.		Cenex Toolkit. MGV cost for dedicated/dual-fuel options.	Matrix Fuels estimate of a Elsbett PPO kit and fitting cost.	As diesel	As diesel
Fuel equip. £/veh	£0	£0	£175	£175	£175	£4,000	£175	£0	£0
Notes and Reference			Purchase and install costs of extra fuel storage, assuming some fleets will run conventional diesel as well. Proportions based on HDV fuel infrastructure costs for bio diesel/ethanol.			cost, assuming LGV/MGV run on biomethane alongside HGV. Value equates to approximate cost of HomePhil system for natural gas filling from grid.	As for biodiesel.	No change	No change
Maintenance £/vkm - MGV	0.047	0.047	0.085	0.085	0.085	0.062	0.085	0.047	0.047
Notes and Reference	Source: Fleetsolve. Base case data is from the Freight Transport Association Cost Tables (Jan 09).	As for diesel	Experience from commercial veh operation for B30 and above is that halfing servicing interval increases costs by factor or 1.8. Intermediate service is partial, therefore slightly cheaper but oil and filter change plus time are some of the more costly items in a regular service.			Estimate based on bus experience. Applied factor of 1.3 to uplift	As for biodiesel	No change	No change

Table A.9 – Cost data LGV

Fuel	Euro V diesel (base case)	Euro V petrol (base case)	biodiesel (B5)	biodiesel (B30)	biodiesel (B50)	biodiesel (B100)	bioethanol (E85)	biomethane	PPO	BTL	HVO
Vehicle cost (£) - LGV	£12,500	£12,250	£12,500	£12,500	£13,450	£13,450	£12,500	£14,500	£13,950	£12,000	£12,000
Notes and Reference	LGV cost lies between small car-derived van and 3.5 t (Transit/Sprinter)				Add cost of fuel heater for reliable winter operations.			Cenex Toolkit. MGV cost for dedicated/dual-fuel options.	Matrix Fuels estimate of a Elsbett PPO kit and fitting cost.	As diesel	As diesel
Fuel equip. £/veh	£0	£0	£0	£0	£150	£150	£0	£4,000	£150	£0	£0
Notes and Reference				Assumed will fill from (limited) national network of forecourt. Low cost for swithing a pump to this fuel. Does not take into account cost of overcoming	Purchase and install costs of extra fuel storage, assuming some fleets will run conventional diesel as well. Proportions based on HDV fuel infrastructure costs for bio diesel/ethanol.		Assumed will fill from (limited) national network of forecourt. Low cost for swithing a pump to this fuel. Does not take into account cost of overcoming forecourt	Proportion of full cost, assuming LGV/MGV run on biomethane alongside HGV. Value equates to approximate cost of HomePhil system for natural gas filling from grid.	As for B50 and B100	No change	No change
Maintenance £/vkm - LGV	0.029	0.026	0.029	0.053	0.053	0.053	0.039	0.029	0.053	0.029	0.029
Notes and Reference	Source: Fleetsolve. Base case data is from the Freight Transport Association Cost Tables (Jan 09).		As for diesel	Experience from commercial veh operation is that doubling servicing interval increases costs by factor or 1.8, so applied for B30 and above. Intermediate service is partial, therefore slightly cheaper but oil and filter change plus time are some of the more costly items in a regular service.			LGV based on service interval change (x2) for Ford Focus FFV, with cost factor of 1.5 applied.	Estimated based on bus experience. Applied factor of 1.3.	As for biodiesel	No change	No change

Table A.10 – Cost data Car

Fuel	Euro V diesel	Euro V petrol	Biodiesel (B5)	Biodiesel (B30)	Biodiesel (B50)	Biodiesel (B100)	Bioethanol (E5)	Bioethanol (E85)	Biomethane bi-fuel	PPO	BTL	HVO
Vehicle cost (£)	£15,500	£15,000	£15,500	£15,500	£16,450	£16,450	£15,000	£15,000	£17,500	£17,000	£15,000	£15,000
Notes and Reference	Ford Focus 1.6 Diesel	Ford focus petrol			Add cost of fuel heater for reliable winter operations.			Majority of FFV in 2009 incur no premium.	Premium for gas vehicle. Source: Cenex toolkit.	Cost of PPO kit (fuel heater and storage tank).	As diesel	As diesel
Fuel equip. £/veh	£0	£0	£0	£0	£150	£150	£0	£0	£4,000	£150	£0	£0
Notes and Reference				Assumed will fill from (limited) national network of forecourt. Low cost for swithing a pump to this fuel. Does not take into account cost of overcoming forecourt capacity constraints.	Purchase and install costs of extra fuel storage, assuming some fleets will run conventional diesel as well. Proportions based on HDV fuel infrastructure costs for bio diesel/ethanol. Value concurs with cost of home storage solutions (e.g. 1000 litre IBC).		As petrol	Assumed will fill from (limited) national network of forecourt. Low cost for swithing a pump to this fuel. Does not take into account cost of overcoming forecourt capacity constraints.	Proportion of full cost, assuming fleet LGV/MGV run alongside HGV. Value also equates to approximate cost of HomePhil system for filling from grid.	As biodiesel	No change	No change
Maintenance £/vkm	0.027	0.025	0.027	0.040	0.040	0.040	0.025	0.037	0.027	0.040	0.027	0.027
Notes and Reference	Based on maintenance cost for first 3 years ' What car' magazine (£700 diesel, £600 petrol) plus some uplift. Hence, costed for private individual, rather than fleet operator.			Applied a factor of 1.5. Experience from HGV/Vans is that doubling servicing interval increases costs by factor or 1.8 for B30 and above. Intermediate service is partial, therefore slightly cheaper but oil and filter change plus time are some of the more costly items in a regular service.			As petrol	Based on service interval change (x2) for Ford Focus FFV, with cost factor of 1.5 applied.	Estimate based on bus experience. Applied factor of 1.3.	As biodiesel	No change	No change

A2 BIODIESEL (FIRST GENERATION)

A2.1 Summary assessment

Biodiesel represents an opportunity for fuelling all types of diesel engine vehicle. However, even in appropriate proportions and quality for the engine design increased filter and oil changes are commonly required to ensure adequate maintenance. Barriers to be overcome include ensuring sufficient and consistent quality, plus concerns over some experience of increased fuel consumption and servicing requirements.

A2.2 Background

Biodiesel is produced from the vegetable oils from crops such as rapeseed or soy, or can be reclaimed from recycled waste cooking oil. Biodiesel is made by reacting natural vegetable oils or animal fats with a lower alcohol (such as methanol) in the presence of a catalyst, producing the biodiesel fatty acid methyl esters (FAME) and releasing glycerol as a by-product. There are many types of vegetable oils or animal fats available for conversion to biodiesel. The two most common biodiesels are soybean methyl ester (SME) and rapeseed methyl ester (RME), which are derived from soybean oil and rapeseed oil. Other potentially useful raw materials include palm oil and used cooking oil, sometimes known as Waste Vegetable Oil (WVO).

Biodiesel can be blended with conventional diesel in varying proportions. In low blends, diesel vehicles can be refuelled in the same way as conventional diesel vehicles and therefore major new infrastructure is not required, although care is required during storage of the fuel to prevent water absorption.

Low-blend fuels containing 5% biodiesel (B5) are widely available and can generally be used in the same way as conventional diesel. Higher blends (e.g. B10, 20, 30, 50 and B100) are available to varying specifications, but their suitability depends on the vehicle requirements. Reliable use will depend on the specification (and blend limit) the vehicle manufacturer has defined as acceptable.

Biodiesel has been known to break down deposits of residue in the fuel lines where mineral diesel has been used. As a result, fuel filters may initially need changing as they clog with particulates as the initial high-blend biodiesel is made.

Owing to the high boiling point of FAME compared with diesel FAME transfers into the engine oil and as a result leads to dilution of the lubricating oil. To avoid decline in the viscosity of the engine oil most manufacturers that warranty for high-blend biodiesel require that the interval between oil exchanges applicable for operation with diesel should be reduced by roughly half.

Some of the specific issues relating to use of higher blends of biodiesel of concern to vehicle manufacturers, are:

- Higher viscosity stresses the high pressure fuel pump;
- Oxidation degradation with time;

- Moisture content leading to microbial growth;
- Solvency of biodiesel on seals.

However, some experiences of biodiesel have been that the improved lubrication means lower maintenance costs.

One key factor is that the source raw material has a significant impact on the handling, use and performance properties of a given biodiesel fuel. In particular, the oxidative stability of the biodiesel is affected by the degree of unsaturation.

Avoiding microbe growth and high viscosity are necessary to address the operational concerns of both vehicle manufacturer and those responsible for maintenance of vehicle. Higher blends of biodiesel sometimes have anti microbial agents added (not recommend as a disposal problem is then created) and a Cold Flow Plugging Point (CFPP) improver to guard against effects of cold and to keep the viscosity within EN590. Without care, even B5 can experience CFPP if the biodiesel element is palm oil and unsuitable anti-CFPP products are used.

Splash blending biodiesel into standard diesel at the customers site has been linked with a number of problems with fuel quality, so proper blending and storage is preferred (in warmed tanks if very cold weather is expected).

Fuel specifications for biodiesel have been defined, such as ASTM D6751 in the United States and EN 14214 in Europe. Fuel quality issues and the variability of biodiesel from differing or even similar raw material sources are a concern to the vehicle manufacturing, engine design and lubrication industries.

Biodiesel is low in sulphur and aromatics, has low toxicity and biodegrades quickly. Biodiesel fuels possess high cetane numbers and therefore deliver good combustion properties. As an oxygenate, biodiesel helps to reduce emissions of carbon monoxide, hydrocarbons and particulate matter, but tends to produce higher emissions of nitrogen oxides.

Because there is about 11 percent by weight of oxygen in biodiesel it has a slightly lower energy content compared with petroleum diesel on an equal volume basis and this slightly reduces the fuel economy achievable.[88]

Production costs of biodiesel are not strongly linked to the crude oil price, but are dependent on prices of vegetable oils. However, the selling price of biodiesel is strongly linked to the crude oil price as major buyers (i.e. refineries blending into B5) estimate the price to pay based on a premium over oil. Therefore economic case for biodiesel is more favourable if oil prices are high, as was the case during parts of 2007/2008.

[88] The Effect of Biodiesel on Engine Lubricants, Lubes ‘n’ Greases Magazine, June 2007 (Article by Infineum International Ltd)

A2.3 Examples of high-blend use

A 2.3.1 Heavy goods vehicles

DHL Express undertook a trial of B100 in two Euro III Mercedes Benz vehicles – a 6 x 2 Actros and a 6 x 2 Axor – both used for trunking movements. Interim results from mid-2008 were that fuel consumption had risen 4% and there had been 8% uplift in repair and maintenance costs, mainly due to the two additional oil and filter changes required each year. DHL estimate that they have reduced carbon emissions by 60%.[89]

A 2.3.2 Public service vehicles (bus and coach)

A trial of B100 derived from WVO has taken place in Stagecoach bus fleets, using eight vehicles serving the Kilmarnock area in Scotland. The trial began at the end of October 2008 due to run for about 6 months. The biodiesel is supplied by Argent Energy from recycling and processing tallow (animal fat) and used cooking oil, both by-products of the food industry.[90]

In 2007 Arriva trialled B20 biodiesel on 75 buses, running from Arriva's Blyth Garage in Northumberland. The aim was to reduce total carbon emissions by around 14 per cent by using FAME biodiesel as a 20 per cent blend, the FAME being predominantly a mixture of sustainable soya products, along with used cooking oil and tallow.[91]

Some bus companies have encountered problems using biodiesel. First Eastern Counties Buses, which runs services in Norfolk, Suffolk and Cambridgeshire, encountered problems during cold weather in February 2008. The bio-diesel turned waxy in sub-zero temperatures, and the thicker consistency of the diesel meant fuel lines became blocked.[92]

In 2007 National Express were planning to run a trial of B20 or B30 in their UK coach fleet, but called this off due to concerns over sustainability.

A 2.3.3 MGV and LGV (own-tanks)

The Environment Agency are currently running comprehensive trials of B22 in the Environment Agency fleets, with a view to publishing the results of the trial to help fleet decision makers and manufacturers draw some firm conclusions on high blend biodiesel use.[93]

[89] Freight magazine, September 2008
[90] http://www.argentenergy.com/articles/news/article_65.shtml

[91] http://www.arriva.co.uk/arriva/en/media_centre/press_releases/2007/2007-07-26/

[92] http://news.bbc.co.uk/1/hi/england/7250962.stm

[93] Simon Dawes, Environment Agency

BSkyB have been operating 130 Vauxhall Vivaro vans with B30, supported by the Morrisons forecourt network. This has been done with low or no on-costs as the vehicles from Vauxhall do not required increased servicing as part of the warranty conditions.[94]

Commercial Group (CG) operate a fleet of about 20 cars and vans running on variable blend biodiesel from B5 to B100 (typically B50), and plan to roll this out to the whole fleet of about 70 vehicles. Positive impacts have been: better vehicle performance, much reduced carbon footprint, employee engagement, lower running costs, environmental credentials and brand positioning. Negative findings have been: variability of supply, particularly measured against quality and sustainability criteria. As a result CG is using local supply of WVO feedstock.[95].

A 2.3.4 Private cars and van fleets (public filling stations)

Morrison's currently sells B30 at 130 forecourts across the UK. Much work has been done on the blending process behind this fuel to obtain the best performance. Morrison's has been supplying B30 biodiesel partly to support a trial with BSkyB-operated Vauxhall vans. It is unclear how many private users are operating their vehicles on this B30 but there is a lot of discussion on web forums on this topic, indicating significant interest amongst private users.

PSA group (Peugeot Citroen) have approved the use of B30 for their HDI engined vans and cars. Renault approve their vans for B30 (with increased servicing regime) and supply engines for two Vauxhall vans (Vivaro and Movano). Vauxhall do not then require increased servicing for B30 operation under their vehicle warranty.

A2.4 Environmental impacts

Life-cycle CO_2 emissions vary depending on the source of the biodiesel. If land use change is not considered and assuming today's production methods, 100% biodiesel from rapeseed and sunflower oil produces 45%-65% lower greenhouse gas emissions than normal diesel. Lower blend biodiesel produces proportionately lower GHG savings.

Biodiesel is low in sulphur and aromatics, has low toxicity and biodegrades quickly. The low toxicity can be useful in marine applications or in areas of sensitive habitat. Biodiesel fuels possess high cetane numbers and therefore deliver good combustion properties. As an oxygenate, biodiesel helps to reduce emissions of carbon monoxide, hydrocarbons and particulate matter, but tends to produce slightly higher emissions of nitrogen oxides.

[94] Information supplied by Joule Vert
[95] Simon Graham, Commercial Group

A3 BIOETHANOL

A3.1 Summary assessment of fuel and relevance

Bioethanol represents an opportunity for fuelling buses and cars. There is some potential for HGVs at a later date (as engines are being produced and trials are underway) although this needs further investigation. The technology for cars and buses is available and well proven; the key barriers seem to be putting in place the refuelling infrastructure and the costs of the fuel.

A3.2 Background

Bioethanol is produced from the fermentation of plant-based materials, such as corn, wheat and sugar cane.

Bioethanol can be blended with petrol in varying proportions for use in spark-ignition engines. The more common blends are E5 (5% ethanol, 95% petrol) and E85 (85% ethanol, 15% petrol). E5 can be used in all petrol-fuelled engines without any modifications to engines or refuelling infrastructure. Current European specification petrol (EN228) can contain up to 5% ethanol. Higher blends require modified engine designs, known as ‘flex-fuel’ vehicles.

Some petrol sold in the UK already has 5% ethanol in it, for example Tesco standard unleaded as supplied to forecourts in the South East of England from April 2006.

Bioethanol can also be used in compression ignition engines, suitable for heavy duty vehicles such as buses such as those manufactured by Scania, designed or modified to handle the different characteristics of ethanol as a vehicle fuel. Bioethanol as a bus fuel requires some ignition improvement additives to complement the normal 95% ethanol proportion. Etamax-D and Greenergy’s ED95 are examples of fuel produced for dedicated compression ignition engines.

For higher blends of bioethanol, special transport, storage and refuelling infrastructure is needed, because ethanol can corrode equipment designed for diesel or petrol. Ethanol and water can dissolve into one another, degrading the properties of the fuel, which requires precautions in fuel storage and handling not needed for diesel.

The fuel costs per litre of bioethanol are generally slightly lower than from diesel (<5%) but fuel consumption on a volumetric basis is higher than gasoline by about 50-60% for pure ethanol (25- 40% for E85), due to the lower energy density. As a result, fuel consumption of bioethanol vehicles will tend to be higher than their diesel or petrol counterparts.

A3.3 Availability of vehicle and examples of high-blend use

Across the globe, Brazil, the USA, India and China are the largest producers and consumers of bioethanol. In Europe, France is one of the bigger producers and the consumption of bioethanol is largest in Germany, Sweden, France and Spain. By 2007, in Sweden there were 792 E85 filling stations and in France 131 E85 service stations with 550 more under construction.

In terms of bus fleet operations, most experience in Europe is found in Sweden, using Scania-manufactured vehicles. Ethanol buses are widely used in Sweden, particularly in Stockholm where the fleet numbers in the hundreds. Ethanol buses are also in operation on a smaller scale in Spain, Italy and Poland.

Flexi Fuel Vehicles (FFVs) can use blends up to E85, available from a limited number of Morrison's forecourts – 21 in total. The fuel at Morrison's forecourts is supplied by Harvest Energy.

The use of high-blend bioethanol in UK bus fleets can be considered to be in the demonstration phase. Recent UK initiatives include:

- The UK's first 95% bioethanol bus route, Ecolink 30, was launched in Nottingham in April 2008 with 3 Scania buses (using wood-based fuel from Sweden) which exceed the emissions standards for Euro 5 and meet the higher EEV in-service vehicle standards;
- Reading Borough Council took delivery of the first of 13 bioethanol buses in spring 2008, for use by Reading Buses on the number 17 major bus route;

On the production side, the following initiatives are significant:

- British Sugar, trading as British Bio-ethanol, began production of bioethanol in the UK in September 2007 in Wissington, Norfolk. British Bio-ethanol report a 71% reduction in life-cycle carbon emissions compared to conventional fuel.
- British Sugar has also entered into a joint venture, Vivergo Fuels Limited, with BP and DuPont to build and operate a world-scale bioethanol plant at Saltend, Hull. Expected to come on stream in 2009, this plant will produce 420 million litres of bioethanol each year from UK-grown wheat.

A 3.3.1 Public service vehicles (bus and coach)

Bioethanol buses are used for large scale operations in Sweden. Stockholm has been running bioethanol buses for 15 years and now has a fleet of approximately 400. Smaller fleets of bioethanol-fuelled buses are run in 11 other Swedish cities including Umeå, Gävle, Örnsköldsvik, Falun and Sundsvall.

Bioethanol bus fleets are also operated on a smaller scale trial basis, as part of the EC-supported BEST project, in a number of other European cities including Madrid in Spain, La Spezia in Italy and Slupsk in Poland. Initial feedback from the BEST project indicates that the main barriers were lack of regulations, technical issues and fuel taxes, making the costs for driving on bioethanol unfavourable. Once regulations (or subsidies) were put in place, this effectively removed these barriers for future bioethanol fleets. Similarly, the technical issues generally concerned which materials to use in the fuel station and storage tanks and this information can usefully be transferred to other sites. The BEST project reports that the ethanol buses consume about 60% more ethanol than diesel (by volume) due to the lower energy content in ethanol. The taxation regime for ethanol is therefore an important consideration in making the fuel cost-efficient.[96]

There are two bioethanol fleets currently operating in the UK: Reading and Nottingham.

In Reading, a fleet of 14 bioethanol (ED95)-powered buses has been operating on Route 17 since May 2008. The route runs from Tilehurst to Wokingham Road via the town centre and is the most used route in Reading, with around six million passengers every year. The bioethanol used in the fleet is produced in the UK by British Sugar, at their plant in Wissington in Norfolk, and the supply contract will guarantee the availability of the fuel to the entire bus fleet for the next 10 years, with an option for a further 10. A bioethanol fuelling station has been built within the Reading Bus Depot. The Council funded the station with a view to making it available to other bus operators and also using the fuel to run council-owned vehicles.[97]

In Nottingham, the City Council secured £520,000 capital funding from the East Midlands Development Agency (emda) to pay for the purchase of 3 Scania 'Omnilink' bioethanol (ED95) buses and associated fuelling infrastructure. The trial is a partnership between the Council and Nottingham City Transport; it began in April 2008 and will run for 18 months. The buses are being trialled on NCT service 30 (City Centre – Ilkeston Rd – University Jubilee campus – Wollaton Pk - Wollaton). The route uses 3 buses, has limited existing branding and stable recent growth. A marketing plan, branding the buses as Ecolink, has been put in place to publicise the trials of bioethanol buses on the route.

The fuelling infrastructure for the Nottingham trial has been installed at the NCT Lower Parliament St Depot, and includes the installation of dedicated underground tanks and pumps.

The stated aims of the trial are "to assess the technical, environmental and business case for the use of ethanol, particularly focusing on:

- whether ethanol-powered buses can be introduced under Nottingham specific local conditions;
- if the ethanol pumping station can be used by other vehicle types in the future; and
- What the technical, environmental and financial challenges are for further expansion of the scheme."[98]

The only manufacturer of compression ignition engines to run with (bio)ethanol has been found to be Scania.

A 3.3.2 Light duty vehicles (cars and vans)

Flexi Fuel Vehicles (FFVs) can run on E85, petrol only, or a mix of both fuels in one fuel tank. A number of manufacturers produce FFVs. In the UK, models from Ford

[96] www.best-europe.org
[97] Press Release: First in Fleet of Bio-Ethanol Buses Comes To Reading Tomorrow 23/04/2008
[98] http://www.nctx.co.uk/about/news/2008/Ecolink.asp

and Saab are available, including Ford Focus Flexi-Fuel, Ford Focus C-Max Flexi-Fuel, Saab 9-5 BioPower 2.0t (180bhp), Saab 9-5 BioPower 2.3t (210 bhp) and Saab 9-3 BioPower. The total number of FFV cars sold in the UK during 2008 was estimated by Saab to be around 2,000 vehicles.[99]

In June 2006 the Somerset Biofuel Project operating as part of the BEST project introduced 41 Flexi-Fuel Vehicles into the fleets used by Somerset County Council, Avon & Somerset Constabulary, Wessex Water, Wessex Grain and the Environment Agency.

Most sources of information on FFV and use of E85 suggest there should be no increase in servicing requirements or costs. However, the current EC supported BEST project has stated their regular reporting on maintenance shows that FFVs are as reliable as conventional cars but that more frequent regular maintenance is required for FFVs compared to petrol or diesel vehicles.

BEST project indicates that FFVs running on E85 are as reliable as conventional vehicles and suffer no technical problems that may get in the way of their functionality. However, more frequent regular maintenance is required for FFVs compared to petrol or diesel vehicles. Further, energy consumption and performance are directly linked to keeping regular maintenance schedules. Oil and oil filters must be changed 1,5 as often in FFVs than in petrol or diesel vehicles. The reason is that bioethanol droplets absorb water from the combustion and get in to the oil, causing it to loose its lubrication performance. This might be solved by developing engine oils that are more compatible with bioethanol.[100]

A 3.3.3 Heavy goods vehicles (HGV)

We understand from Scania that "ethanol trucks for distribution and refuse collection are now entering final testing by customers" (Scania).[101]

In addition, Volvo trucks – one of the leaders in alternatively-fuelled HGVs - seem to be focussing its attention on DME[102] a second generation biofuel. The BioDME project runs for four years from September 2008, with field tests of 14 trucks. This is not considered to be near to market[103].

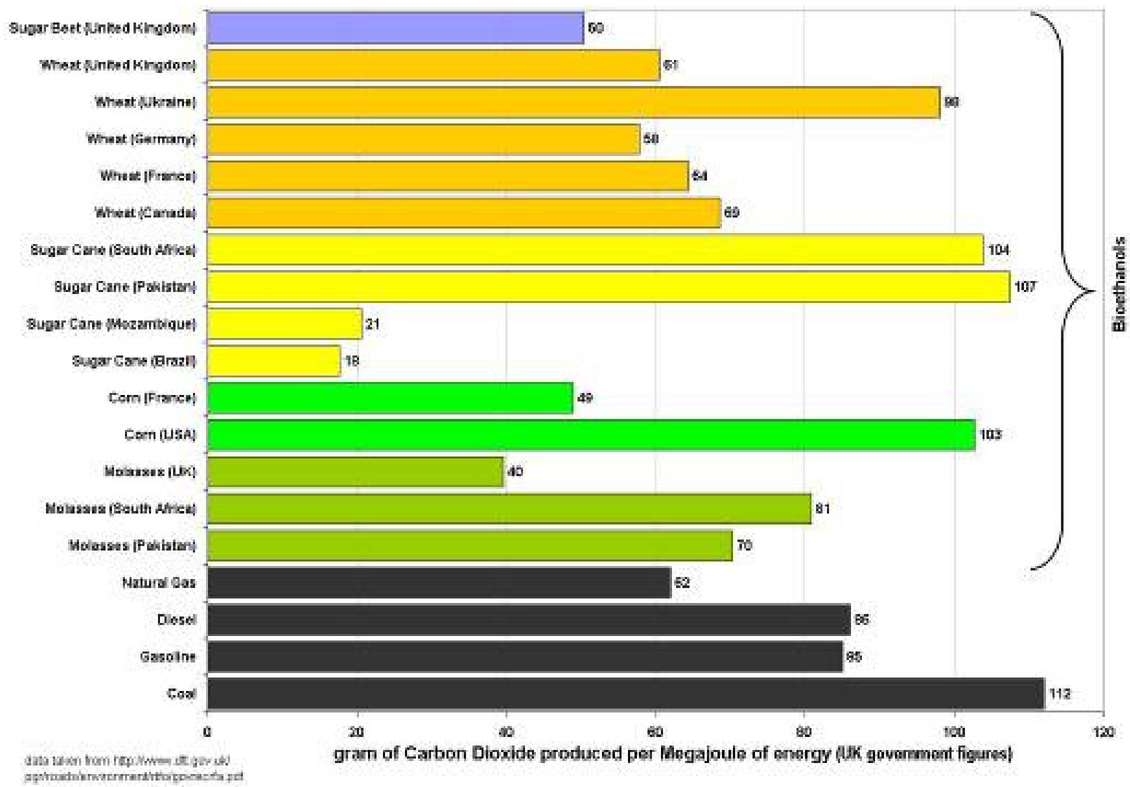
A3.4 Environmental impacts

Estimates of the GHG savings of bioethanol vary widely, mainly depending on the type of feedstock and manufacturing process. Depending on the production method

[99] Personal communication with Ian Bright, BEST Project and North Somerset County Council. To be verified.
[100] http://www.best-europe.org/Pages/ContentPage.aspx?id=584
[101] . http://campaign.scania.com/ethanol/#
[102] http://www.volvo.com/group/global/en-
[103] http://www.biodme.eu/doc/080923_Volvo_FINAL.pdf

and source, the best-performing bioethanol gives a 70 per cent carbon dioxide reduction, which means 3.5 per cent in a 5 per cent blend or 50 per cent in an E85 blend.[104] UK-sourced bioethanol gives around a 25 to 50% reduction, depending on whether the feedstock is wheat or the more effective sugar beet. The graph below is based on figures calculated by the UK government for the purposes of the Renewable Transport Fuel Obligation (assuming the bioethanol is burnt in its country of origin and that previously existing cropland is used to grow the feedstock).[105]

Figure A2.1: Carbon intensity of bioethanol and fossil fuels



Regarding regulated emissions, for high petrol-bioethanol blends, carbon monoxide, particulate emissions and tailpipe hydrocarbons are generally reduced. In theory, bioethanol vehicles should emit fewer nitrogen oxides (as alcohol fuels burn at a lower temperature than petrol). In practice, the compression ratio is often increased to improve engine efficiency, which raises the combustion temperature and offsets any NO_x emission benefit.

[104] Energy Saving Trust – Alternative Fuels web-page viewed July 2008.
[105] Defra (2008) - Carbon and Sustainability Reporting Within the Renewable Transport Fuel Obligation.

A4 BIOMETHANE (COMPRESSED)

A4.1 Summary assessment of fuel and relevance

Biomethane can provide among the highest greenhouse gas savings of any biofuel when produced from waste materials (as is common). The use of biomethane in vehicles has many of the same benefits, and barriers, as using natural gas. It provides a potential opportunity for HGV, MGV, LGV and car fleets, given the need for significant investment in fuelling infrastructure and/or high-mileages to pay back capital costs. This section focuses on compressed biomethane gas (CBG).

A4.2 Background

Biomethane is the term used for upgraded and cleaned biogas (the raw gas) produced from anaerobic digestion of organic matter, or decomposition in land-fill sites. Biomethane is chemically very similar to natural gas (the key ingredient being methane: CH_4) and therefore can be stored in the same way and used in the same vehicles. Biomethane is available in compressed and liquid forms (as per natural gas). The use of biomethane in vehicles has many of the same benefits, and barriers, as using natural gas.

There is increasing interest in the UK (and Europe) in the production of biomethane, which is the cleaned and upgraded form of 'biogas' resulting from Anaerobic Digestion (AD) in either a plant or a land-fill. The UK Energy White Paper[106] puts considerable emphasis on AD for the production of renewable energy (combined heat power) and for a vehicle fuel. Biomethane fits with the recommendations of the Gallagher Review that proposes that biofuel production must be focused on idle and marginal land and increasingly use wastes and residues. The sustainability credentials of biomethane are extremely good.

The NSCA published report by STS on biogas as a road transport fuel examined a low and high production scenario for biomethane in the UK.[107] The low production scenario was sufficient to fuel some 1.5 billion vkm p.a. by HGV and the high production scenario enhanced this significantly, to some 5.2 billion HGV vkm and 1.3 billion LGV vkm. This study has estimated the large artic HGV fleet travels some 12.8 billion vkm and therefore for a target 20% travelling 2.5 billion vkm sufficient biomethane might be produced by a mid production scenario. The high production scenario would add sufficient biomethane for other HGV and most of the other vehicle types recommended as potential markets for biomethane (i.e. other sub-types of HGV and local bus).

Biogas can be upgraded to biomethane in order to meet the relevant natural gas quality standards and used in natural gas vehicle (NGVs). Compressed natural gas (CNG) vehicle technology is well known and understood on a worldwide basis, with millions of vehicles in operation. At the end of 2005, there were more than 5 million

[106] HMG UK Energy White Paper (2008)
[107] Biogas as a road transport fuel, NSCA (now EPUK), 2006.

NGVs worldwide. Public transport or authority service vehicles driven on gas such as buses and waste trucks are to be found in considerable numbers worldwide. In total 210,000 heavy duty vehicles are operated, comprising 70,000 buses and 140,000 trucks.[108]

One common route to powering vehicles by biomethane has been to develop a market for natural gas and then to gradually replace this fossil fuel with (or expand based upon) biomethane some time after the use of Natural Gas Vehicles (NGV). Markets for gas vehicles are well developed in Italy, France and Germany. Natural gas can be stored as a vehicle fuel either as compressed natural gas (CNG) or liquefied natural gas (LNG). The same fuel dispensing and vehicles that operate with CNG can be used for Compressed Biomethane Gas (CBG).

CNG vehicles can be designed to run either solely on gas using dedicated gas engines (mono-fuel), on gas and diesel in the same modified diesel engine (dual-fuel) or by switching between petrol and gas (bi-fuel), with petrol used as a back-up fuel and to extend range. Mono-fuel and dual-fuel are the most common designs for heavy duty vehicles such as buses, while bi-fuel designs tend to be used in light duty vehicles and are based on petrol engines.

Gas vehicles can be purchased new or converted from existing diesel vehicles to run as dual-fuel. The best emissions performance tends to comes from dedicated gas engines. Fuel storage tanks on the vehicle add weight, which can reduce the overall payload for certain types of vehicle (such as buses). The additional fuel storage requirements and specialist engine modifications/design mean higher costs for a new vehicle. Maintenance costs for gas buses, for example, have tended to be higher than for conventional diesel buses due to higher parts costs and increased maintenance requirements, although there is some experience of this being dealt with through negotiation at the procurement stage. Fuel costs are lower so it is possible for high-mileage fleets to benefit financially from this fuel, particularly when covering high mileages. The best financial case for CNG tends to be for use in long-distance freight haulage operations in the UK (for quickest payback of the capital costs).

There are the same barriers to using biomethane as a road fuel in the UK as exist for natural gas: the availability of suitable vehicles and the need for a dedicated refueling infrastructure. Fuel costs depend on the production and distribution methods, but the price of biomethane often mirrors the price for natural gas which is generally lower than diesel, so offsetting some of the extra capital costs associated with setting up a gas-fuelled fleet.

A4.3 Vehicle availability and examples of high-blend use

For vehicles which store their fuel as CBG / CNG there are two main types of gas engine technology:

- dedicated gas engines – either stoichiometric or lean burn; and
- bi-fuel vehicles – where the gasoline fuelling system is retained.

[108] Biogas Upgrading to Vehicle Fuel Standards and Grid Injection, IEA Bioenergy Task 37 (2006)

The ideal combinations of vehicle type and engine technology for use with CBG/CNG are:

- Light duty, using a bi-fuel petrol/gas engine;
- Heavy duty (urban) using a dedicated gas engine;
- Heavy duty (inter-urban), using a dedicated gas engine.

It is also possible to modify diesel engine vehicles to operate as dual-fuel, using a varying mixture of both gas and diesel in a modified compression ignition engine. These vehicles store their fuel as Liquefied Gas (LBG or LNG) and are covered in the subsequent section of this report. Heavy duty vehicles (urban and inter-urban) are suitable options for dual-fuel engines, with long-distance steady speeds particularly good for increasing the proportion of gas used (vs. diesel) and therefore improving payback.

European experience of producing high-quality biomethane for use in gas vehicles includes:

- Lille in France has operated 127 of the region's bus fleet on biomethane (in gas vehicles) proving the reliability and cost-effectiveness and aim to move 100% of their bus fleet to biomethane by 2011;
- 30+ CBG filling stations in Sweden for use with private LDV (3000+ cars and 40+ buses);
- Supply of CBG via filling stations and via the gas grid though use of 'green certificates' in Bern (Switzerland).
- Fuelling of gas-powered Refuse Collection Vehicles (RFC) in Rome with CBG produced from municipal land-fill.

In addition, the use of gas vehicles fuelled by CNG is widespread, particularly in Germany and Italy. Outside of Europe there are large markets in South America (Argentina) and Asia (India, Pakistan and Bangladesh) where vehicles run on Natural Gas as well as a limited market in Japan for light trucks and commercial vehicles (stimulated by the introduction of the Greater Tokyo 'low emission zone'). The vehicle technology is the same whether running natural gas or biomethane.

Nearly every vehicle manufacturer produces gas variants of some models; although very few are available in the UK. The following sub-sections outline relevant experience, focussed, where possible, on use of biomethane in gas vehicles.

A 4.3.1 Medium / Light Goods Vehicle

UK's largest biomethane facility is the Gasrec site at Aldbury, Surrey, based on purified gas from landfill, which supplies a number of gas vehicles. Organic Power operates a small AD plant, Mercedes Vito vans/minibuses and is developing a gas filling station (initially with planning permission in 2008). A number of Local Authorities are actively investigating the development of AD plants for production of biomethane.

From August 2008, Veolia has been trialling CBG produced from gas extracted from a landfill site in one of the Cage street-cleansing vehicles used in fulfilling its refuse collection, recycling and street cleansing contract with Camden Council. The natural gas-powered Daily light commercial vehicle in use for the trial is one of the latest generation of natural gas-powered vehicles manufactured by Iveco and was supplied by Gasrec to Veolia Environmental Services. Gasrec will provide CBG for a trial lasting six months and the performance of the fuel will be measured against existing vehicles running on Compressed Natural Gas (CNG). The vehicle will be refuelled at a CBG refuelling station installed by Gasrec at Camden Council's York Way depot.[109]

VW are producing the Sprinter van in left hand drive (for German markets), and some right hand-drive versions are now available in the UK (e.g. Organic Power)

A 4.3.2 Cars

While Volvo recently stopped CNG car production, VW are currently producing left-hand drive Caddy LDV/MPV and Passat passenger car models for sale in Germany and Sweden, with promises of UK sales in 2009.

A 4.3.3 PSV

There are no known bus or coach operators currently using biomethane. Historically, there have been some limited demonstrations of CNG buses in the UK, and long-term use by Travel West Midlands of a fleet of gas buses. The majority of the early trials of CNG-fuelled buses did not produce convincing results, with initial problems over reliability and maintenance costs. The variable quality/specification of gas used may have been a factor. In addition, the configuration of the Fuel Duty Rebate (FDR) and its replacement, Bus Service Operators' Grant (BSOG), meant that fuel costs were higher overall than for diesel vehicles. There has been some experience of running minibuses for Community Transport services, for example in Camden. Experience with the technology has improved performance, but there are few CNG buses operating in the UK at this time and no known biomethane users.

A 4.3.4 HGV

A range of gas engines are produced for HGV (Cummins, Westport etc). There is some UK experience of running refuse collection vehicles (RCVs) and HGVs on natural gas. Safeway (as was, prior to take-over by Morrison's) and Sainsbury's supermarkets both have a long-standing experience of operating large artics with CNG. The majority of experience in using biomethane in gas-powered HGVs has been in use of LNG, which will be covered in the next chapter.

A4.4 Environmental impacts

Natural gas is made up of a mix of propane and butane and is derived from natural gas fields or from oil refining and is therefore not a renewable fuel. Life-cycle CO_2 emissions are approximately the same as for diesel (perhaps 10-15% lower) but NO_2 emissions are significantly lower (80 per cent lower) and particulate matter is virtually non-existent. These natural advantages are being eroded as diesel engine exhaust

[109] Trial of Iveco Daily 65C14G (3 litre engine) in Camden with Gasrec supplied CBG (article and details of full range of Daily models and sizes via weblink http://www.gasrec.co.uk/mediadetails.php?ID=13)

abatement technology improves in response to successive Euro standards, although the very best gas engines can still outperform the best diesel engines on most relevant emissions. Noise levels are lower than for equivalent diesel engines.

The major additional advantage of biomethane compared to natural gas (and many other road transport fuels) is that biomethane is a renewable fuel produced from waste materials and therefore the life-cycle carbon emissions are significantly reduced. Using biomethane in vehicles can give a reduction in life-cycle CO_2 emissions of around 80-90% compared to conventional diesel, with highest figures based on use of animal manure (which would otherwise release methane into the atmosphere).

A5 BIOMETHANE (LIQUEFIED)

A5.1 Summary assessment of fuel and relevance

Biomethane as a vehicle fuel has many of the same benefits, and barriers, as using natural gas. In liquefied form it seems to the provide the greatest opportunity for HGV, MGV and LGV fleets, given the need for significant investment in fuelling infrastructure and/or high-mileages to pay back capital costs. This section focuses on liquefied biomethane gas (LBG).

A5.2 Background

Liquefied Biomethane Gas (LBG) is a cooled version of biomethane so it forms a cryogenic liquid of -162 degrees Celsius. LBG is formed from 96%+ pure methane (CH4). The handling, storage and dispensing requirements are common with Liquefied Natural Gas (LNG), of which there is considerable experience in the UK. Cooling the gas and storing it under medium pressure has the effect of concentrating its energy content (to a greater extent than Compressed Natural/Biomethane Gas), therefore making storage and transport more efficient. Refuelling between station and vehicle using LNG/LBG is rapid. However, LNG/LBG tanks will suffer from very slow fuel loss as the heat enters the tanks and starts to 'boil off' the stored LNG. Filling stations can be designed to capture/create gaseous fuel and dispense it as CNG/CBG. The storage time limit on LNG/LBG means vehicles need to be using up fuel rather than storing on-board for too long.

LBG can be dispensed to vehicles for storage on-board and used in modified diesel engines (compression ignition) operating as dual fuel engines. Modifications are offered, in conjunction with certain OEMs, by two companies: Clear-Air Power and the Hardstaff Group. Both have focussed on HGVs, although they may be able/ willing to fit equipment to PSVs and MGVs.

Heavy duty vehicles (urban and inter-urban) seem to be the most suitable options for dual-fuel modification and use with gaseous fuel. Long distances and steady speeds are particularly good for increasing the proportion of gas used (vs. diesel) in a dual-fuel engine and therefore improving payback.

The Hardstaff Group have a lot of experience of operating own HGVs (large artics and large rigid). Hardstaff are supplied with LBG in tankers by Gasrec who produce LBG from a landfill site.

Gasrec and BOC are providing LBG/CBG filling stations to Veolia (waste management) in Camden to trial RFCs and an Iveco Daily van fuelled with CBG. Fuel is transported as LBG by tanker to the filling station in Camden.

Clean-Air Power are a major vehicle modifier in the US and have modified a number of vehicles for the UK, the latest being a Sainsbury's articulated HGV.

Chive Fuels have a network of 9 motorway service based LNG refuelling facilities in the UK plus a further 2 depot based facilities (one at Robert Wiseman Dairies), demonstrating a business model for gas distribution and fuelling (albeit with natural gas rather than biomethane).

A5.3 Vehicle availability and examples of high-blend use

A 5.3.1 HGV (rigid and artic)

Hardstaff Group have a significant amount of experience operating their own HGVs fuelled by LBG (large artics and large rigid trucks) as a fully commercial third party haulage, as well as own-account operation, supporting their group activities. Hardstaff run about 80 of their vehicles with dual-fuel technology, on a mixture of LBG and LNG. By the start of 2008, Hardstaff-adapted vehicles had travelled some 19 million miles using LNG/LBG. Hardstaff are currently supplied with LBG in tankers by Gasrec who produce LBG from a landfill site. Hardstaff now offer vehicle adaptation and filling stations/storage products as a result of their own successful trials.

Hardstaff currently offer conversions for the following vehicles (with more in development):[110]

- Volvo FH12
- DAF 55
- DAF 65
- DAF 85
- Vehicles with Caterpillar C12 engine
- Mercedes Benz Axor

Clean-Air Power offers two main products. Genesis is developed for aftermarket retro-fit of existing Euro 3 to 5 heavy-duty commercial vehicles. Genesis enables robust operation on natural gas without relying on OEM cooperation (to access the ECU). Genesis is available on Mercedes Axor, DAF CF85. Genesis can be adapted to operate on any electronically-controlled diesel engine and work is ongoing for a Euro 5 version in 2009.

[110] http://www.hardstaffgroup.co.uk/site/hardstaff-dual-fuel-technologies/available-vehicles

CAP's second product range is known as Interfaced Dual-Fuel™. Clean-Air Power offers Caterpillar engines in Australia with Interfaced Dual-Fuel™. With this system, Clean-Air Power's ECU communicates directly with Caterpillar's ADEM engine controller while operating in Dual-Fuel mode. Engine availability includes the C-12 and C-15, with ratings from 400 to 500 horsepower. CAP have a letter of intent from Volvo to develop Interfaced Dual-Fuel with their products which will serve the European market and have demonstration vehicles available based on Volvo and Mack HGV, for the European and US markets.

CAP has recently adapted a Sainsbury's artic to run on LBG. Announced in August 2008, the Sainsbury's lorry will make a daily 500km round trip from the Sainsbury's depot in Bristol to the supermarket's new environmental store in Dartmouth. LBG is supplied by Gasrec working with BOC. The study team is waiting for further information on the success of the trial.

As a general point, it should be stated that the use of LNG as a road transport fuel is fairly common worldwide and most of the same technologies, issues and experience are relevant to LBG. For example, in the UK, Hardstaff supply LNG to a number of other commercial vehicle operators. The PGS Kingston Natural Gas fuelling station supplies 30 T. Baden Hardstaff vehicles, as well as some third party hauliers. The filling station supplies natural gas fuel in both LNG and CNG states.

A5.4 Environmental impacts

As for compressed biomethane gas, LBG provides for low emissions of PM, sulphur and NO_x compared to diesel. In addition, GHG emissions can be extremely low if the feedstock source for biogas production is a waste material that would otherwise emit methane upon normal decomposition.

A6 PURE PLANT OIL

A6.1 Summary assessment of fuel and relevance

Pure plant oil (PPO) is produced by crushing and filtering oil-based crops such as rapeseed or palm. This neat oil can then be used in many diesel engine vehicles with appropriate modifications, generally a second fuel tank and a fuel line heater. The lack of public fuelling for PPO, as for most high-blend biofuel, points towards fleet operators with own-tanks or access to bunkered fuel services that may stock PPO. Examples have been found of all types of (diesel) vehicle being used with PPO. Vehicles generally mix diesel fuelling with PPO, so range constraints should not exist. Storage requirements are slightly different for PPO than diesel.

A6.2 Background

Pure plant oil (PPO) is produced by crushing and filtering oil-based crops. PPO in Europe is generally from rapeseed because of the low temperature performance PPO can also include a proportion of waste vegetable oil (WVO) and can be mixed with diesel.

The essence of the PPO approach (over biodiesel) is that:

- Conversion of the engine is done once, rather than converting biomass into each litre of fuel (e.g. biodiesel);
- Saving of processing cost of transesterification from vegetable oil (PPO) into biodiesel;
- PPO rapeseed typical carbon saving from RED is 58% (at 46 gCO_2e/MJ) and rapeseed B100 (RME) is 45% (at 35 gCO_2e/MJ), which makes it about a 30% more carbon efficient method of using the same feedstock.

Vehicles require modifications to run on PPO: a basic approach is to ensure safe and efficient operation, comprising a fuel heater and a second fuel tank (to store PPO on-board). However, more sophisticated approaches will tend to produce more reliable and better results, as a good conversion will cater for the other special characteristics of vegetable oil, by including the following features:[111]

- Pre-warming of the fuel, fuel lines or engine,
- Modifications to the fuel system / pumps,
- Additional filter stages,
- Adjustment of the electronic engine control,
- With a (1-tank conversion), possible modification to the injection system
- Control elements and relays.

[111] http://www.elsbett.com/gb/elsbett-conversion-technology/fundamentals.html

For diesel vehicles to use PPO reliably they require a conversion which can cost anywhere between £1000 and £3600.[112] A number of companies produce the conversion kits and support operators who wish to operate diesel vehicles on PPO. Most types of vehicle can be converted, from domestic cars and commercial lorry fleets to agricultural machinery, construction equipment, boats and trains. Elsbett for example, a long-standing German company that designs and supplies PPO conversion kits, can fit a wide range of vehicles and lists a few hundred that can be converted.

Most road vehicles are not designed or warranted to use PPO. An exception is for UK bus operations where Optare offers PPO-ready vehicles. In agriculture where there is a long term regime for the use of PPO, so Deutz and Fendt have introduced warranted PPO tractors.[113] Some key suppliers of PPO retrofit equipment offer warranties to purchase or a guarantee of performance on a range of the vehicles they can adapt.

Following conversion, the vehicle should be able to run on PPO or normal diesel. Generally diesel is used for the start up phase of operation, and often at the end of operations to flush fuel lines. PPO, supplied from a separate tank is used in the main operating phase.

There are reports of un-modified vehicles being run on PPO, but it is very likely that regulated emissions (PM and/or NO_x) will increase markedly from such an approach.

PPO is not widely used in the UK at present, although trials and regular users exist, assisted by a number of supporting organisations. There is currently no public refuelling infrastructure for PPO so users buy fuel directly from a supplier. A number of suppliers are able to supply quantities of 28,000 litres, duty paid, anywhere in the UK via a standard road tanker. Smaller quantities are available for small business or personal storage. Small scale users can benefit from the rules that allow duty to be avoided on the first 2,500 litres of biofuels.

PPO is more popular in other European countries, in particular Germany where there is a fuel standard for Pure Plant Oils: EU standard DIN 51605. In Germany, there exists a refuelling network for PPO, which developed after government incentives for its use. In tandem, companies like Elsbett have converted approximately 2000 HGVs since 2004 and approx 5000 cars since the year 2000.[114]

There are some storage considerations for PPO:

- It is processed from organic matter and therefore has a shelf life, but this is typically not less than 10 months from the date of delivery;
- Some oils become viscose when subjected to sub-zero temperatures for any length of time, and can become difficult to manage. This problem can be overcome by insulating during the winter months. Use of rapeseed PPO, more common in the UK, should negate these issues;

[112] Low cost: UKPPOA, Contribution to the Review of the fiscal definition of biodiesel Submission to HMRC, 31st August 2006; High cost: Matrix Biofuels ltd, quoting cost of ELSBETT PPO kit for HGV, including fitting.
[113] James Scruby, Matrix Biofuels.
[114] James Scruby, Matrix Biofuels

- Storage is governed by the Oil Storage Regulations, so even domestic users only running 1 or 2 cars will need to take these regulations into consideration.

A6.3 Vehicle availability and examples of high-blend use

PPO seems most suitable for small to medium sized fleets of HGVs, LGVs or cars that operate locally rather than nationally, because of the need to store the fuel on site and benefits of operating with the biofuel (so within the range of a tank of fuel). However, converted vehicles can also use diesel when PPO is not available, so vehicles remain flexible. PPO is less likely to attract private car owners because of the need to store deliveries of fuel (e.g. 200 to 1,000 litre Intermediate Bulk Container) and have a vehicle converted.

A number of companies provide PPO or conversions for diesel vehicles in the UK. . Verdant Fuels and Regenatec are providers of conversions and support services, working with the support of vehicle manufacturers Dennis Eagle, Optare and Alexander Dennis Limited. Blooming Futures has a number of similar customer case studies, generally trials with small fleets or using with PPO with a sub-fleet. Phoenix Fuels have been supplying PPO to a number of users and have trialed a number of conversion kits from German manufacturers in a range of vehicles.

The following are a selection of UK based experience from use of PPO.

A 6.3.1 HGV (artic)

John Lewis Partnership has been trialling PPO in five DAFCF75 artic tractor units. At 300,000 km into the trial, they had used 6% conventional diesel (for starting and stopping) and 94% PPO. At the time of the source report (September 2008) there had been no difference in fuel consumption, no loss of performance and no noticeable effect on engine life. The firm was looking to extend the trial to a further 10 vehicles.[115]

A 6.3.2 HGV (rigid)

Various RCV applications:[116]

- Accord Group - converted a brand-new DAF 'Whale' gully emptier; since converted 9 more;
- Poole Borough Council - owners and operators of a 6-litre EURO3 Dennis Eagle that Regenatec converted to run on RG179 Biofuel;
- SITA UK plc - after successful trials with an ERF ES6 refuse truck, further vehicles are being converted as part of an extended evaluation under more demanding conditions.

[115] Ray Collington, Fleet Engineer at John Lewis Partnership, report in Freight magazine (September 2008)
[116] Regenatec case study (from Regenatec website).

A 6.3.3 PSV (bus and coach)

- Courtney Coaches – operators of a business park bus service; one bus converted, plan is to convert another 45 Courtney vehicles over the next 12 months;
- Hunts Coaches - Since August 2006, Hunts Coaches has been operating a converted Volvo Plaxton Prima B7R on Regenatec RG179 biofuel. The vehicle now only uses diesel at the beginning and end of the day as part of the start up and shut down process.[117]

A 6.3.4 LGV/MGV

- Able & Cole – run a converted Iveco Daily 2.3 HPi on PPO (Regenatec RG179 biofuel).[118]

A 6.3.5 Car

Conversion kits are available for a range of vehicles, starting at around £700 plus fitting. Small scale users can benefit from the rules that allow duty to be avoided on the first 2,500 litres of biofuel.

A6.4 Environmental impacts

On GHG emissions PPO performs well. In comparison to biodiesel (e.g. B100) the carbon footprint of PPO production is slightly lower because PPO does not undergo the same level of processing. Distributed production, as per small scale biodiesel production, reduces the transport component of well-to-wheel emissions, and UK produced rapeseed provides a feedstock source. WVO and sunflower oils all provide a basis for PPO, which would lower GHG further (if blended into rapeseed oils for example) but this practice is currently limited by availability and cost respectively.

On regulated emissions there is no sulphur in PPO, so SO_2 emissions are zero. Finding consistent reported results for NO_x and PM emission testing of PPO operation has not been straightforward. It might be anticipated that emissions would be similar to B100 RME, with slightly raised NO_x and considerable lower PM compared to conventional diesel. Some test results have shown the opposite however (e.g. Danish Folkescentre), and an AEA review of emission scaling factors recommended that further work was required as there existed considerable uncertainty. Testing PPO in unmodified vehicles may be a cause of this mixed picture.

Accordingly, this study has used information supplied by Elsbett Ltd (one supplier of PPO conversion equipment) from 2008 emission on tests undertaken at Millbrook with a DAF HGV operated by the John Lewis Partnership. These showed a decrease in PM emissions (in line with B100) and no statistically significant increase in NO_x emissions. Further testing at Millbrook, conducted for Elsbett in June 2009

[117] Regenatec case study
[118] Regenatec case study

included some additional NO_x reducing techniques and showed marked reductions in NO_x to 0.28 of the comparable standard diesel vehicle. This suggests there are benefits to be achieved from equipment changes done with well-designed and implemented retrofitting.

A7 BIODIESEL (SECOND GENERATION)

A7.1 Summary assessment of fuel and relevance

Most (if not all) second generation biofuels can be used as direct replacements for conventional fuels, therefore no special vehicles or vehicle modifications are needed. This makes second generation biodiesel suitable for use in all diesel powered vehicles. The timescales of availability depend on the development of the production technology and the commercial viability of the resulting fuels in terms of cost.

A7.2 Background

First generation biofuels such as RME (rapeseed oil methyl ester) and ethanol are generally made using the same parts of plants (rapeseed, grain or sugar cane crops) that are also used in food production. In contrast, second generation biofuels are produced from other feedstocks – for example ligno-cellulosic ethanol is produced from parts of plants not used in food production. This means that farmers can use different parts of a crop as food and fuel simultaneously, or use land that is not suitable for food crops.

There are a number of second generation biofuels and these have different characteristics and are at different timescales in their production. Some serve as a direct replacement for their first generation equivalents – i.e. the resulting fuel is essentially the same but it is derived and produced in a different way. Others are new types of fuel entirely.

A report by E4 Tech reviewing second generation biofuels considers the following fuels as relevant[119]:

- Lignocellulosic ethanol;
- Syndiesel or Biomass-to-Liquids (BTL);
- Hydrogenation routes;
- Pyrolysis to transport fuels;
- Other advanced biofuel technologies such as Biobutanol and Algal biofuels;
- “New crops” for first generation technologies – Jatropha, cassava, sorghum.

Most (if not all) second generation biofuels can be used as direct replacements for conventional fuels, therefore no special vehicles or vehicle modifications are needed.

The timescales of availability depend however on the development of the production technology and the commercial viability of this.

[119] Biofuels Review: Advanced Technologies Overview For the Renewable Fuels Agency, E4Tech, May 2008

A7.3 Examples of high-blend products

Second generation fuels are at various different stages of development and face a number of challenges:

- Relatively high production costs (currently higher than those for both mineral oil-based petrol and conventional bio-ethanol) mean that second-generation biofuels cannot yet be produced economically on a large scale; and
- Technological breakthroughs still required: key developments are needed on enzymes, pre-treatment and fermentation in order to make processes more cost- and energy-efficient.

Lignocellulosic ethanol: there are currently a few commercial plants in development; in the longer term, competitiveness of lignocellulosic ethanol plants will depend upon the availability of low cost feedstocks. E4 Tech report that "lignocellulosic ethanol plants could potentially be being built at commercial scale (beyond first of a kind) by 2015-2018. However, it is not expected that the plants would be fully commercial by this stage; some financial support would still be likely to be needed as it is not envisaged that the costs could come down so significantly in this short period to make them cost competitive."

Syndiesel or Biomass-to-Liquids (BTL): there is significant investment in this technology. Choren Industries, in partnership with VW and Shell, are producing a synthetic BtL second generation fuel from biomass feedstocks and marketed as SunFuel®. The fuel is supported by carmakers Volkswagen and DaimlerChrysler because it can be used without modification in any diesel engine without compromising performance and with a substantial reduction in harmful emissions. Choren are building a demonstration BtL plant in Freiberg/ Saxony, Germany of 15,000 tonnes of diesel per year, and plans to build five commercial scale plants with a capacity of 200,000 tonnes diesel per year each. Construction on the first of these is expected to start in 2011. It is likely that the pilot plant will give a better idea of the commercial viability of this type of fuel. Shell currently supplies a diesel fuel with a low proportion of BTL included, as Shell V-Power via 5,000+ filling stations in Western Europe.

Hydrogenation routes: Neste Oil is producing a 2nd generation fuel via hydrogenation. Note, hydrogenated biodiesel routes do not easily fall into the categorisation either "first generation" or "second generation" biofuel: the process takes a vegetable oil feedstock and produces a higher quality product than first generation biodiesel which can be blended with fossil diesel at higher volumes. The company which has furthest developed this technology is probably Neste. The Neste NExBTL process has been producing 170,000t/yr at its plant in Finland. Field testing of NExBTL fuel in Helsinki bus fleets has produced a range of results from different Euro standard vehicles with varying blends of Neste Oil's NExBTL and regular low sulphur diesel. As a follow-up, Neste planned to launch a 10% NExBTL blend diesel in service stations around Helsinki in 2008.

Pyrolysis is a process in which the biomass is rapidly heated in the absence of oxygen to produce a gas, char and organic vapours. When the gas is cooled it forms a low quality but energy dense liquid called a bio- or pyrolysis-oil. Pyrolysis of feedstocks for transport fuel is at the R&D stage.

Other advanced biofuel technologies: Biobutanol such as Algal biofuels are the subject of research and interest but are not expected to have significant contributions to the biofuel mix by 2020 (E4 Tech).

"New crops" for use in first generation technologies: Jatropha, cassava, and sorghum are thought to produce less carbon in production than existing conventional crops used for biofuel production.

Testing of small-scale production and laboratory-produced second generation biodiesel is underway, but for the purpose of this study the relevance of the fuel will be when it is commercially available at an acceptable price.

A7.4 Environmental impacts

As noted, second generation biodiesel is being produced for use in demonstration and test vehicles and the environmental performance is promising.

Second generation biofuels are anticipated to have a very favourable GHG balance. Cellulose ethanol could produce 75% less CO_2 than normal petrol, whereas corn or sugar-beet ethanol reduces CO_2 levels by just 60%. As for diesel, Biomass-to-Liquid (BtL) technology could slash CO_2 emissions by 90%, compared with 75% for currently-available biodiesel.[120]

Summarising previous assessments (by E4 Tech) of GHG performance we find:

- Lignocellulosic ethanol - 76-81% reduction compared with gasoline. Will vary depending on feedstock and technology;
- Syndiesel or Biomass-to-Liquids (BTL) - 93-96% reduction compared with diesel. Savings will vary depending on feedstock used (e.g. residues or energy crops);
- Hydrogenation routes – approximately a 50% GHG advantage over conventional diesel (therefore no further reduction from 1st generation biofuel), plus food crops are still used in production;
- Pyrolysis to transport fuels – unknown;
- Other advanced biofuel technologies: Biobutanol – probably similar to ethanol; Algal biofuels – unknown;
- "New crops" for first generation technologies likely to be similar to palm oil;

Field testing of Neste hydrogenate biodiesel fuel in Helsinki bus fleets has produced a range of results from different Euro standard vehicles with varying blends of Neste Oil's NExBTL and regular low sulphur diesel. The average emission reductions with 100% NExBTL diesel (compared to 10 ppm S diesel fuel) were:

- NO_x emissions approximately - 10%;
- PM emissions approximately - 30%;
- CO emissions approximately - 35%;

[120] http://www.euractiv.com/en/energy/biofuels-generation/article-165951

- Energy consumption approximately - 0.5%;
- Volumetric fuel consumption approximately + 4 % (as a result of lower density).

Neste claim a 50% reduction in CO_2 emissions, compared to conventional diesel. The effect of the second generation fuel on emissions correlated linearly with the concentration.

A8 HYDROGEN

A8.1 Summary assessment of fuel and relevance

At present we consider that liquid hydrogen is not a near–to-market technology and while the use of gaseous pressurised hydrogen (in fuel cell) is more advanced, it is unlikely to be close to market. Both, therefore, fall outside the scope of this study for more detailed assessment of GHG savings, operational requirements and costs.

A8.2 Background

Hydrogen fuel is produced from the breakdown of a hydrocarbon source (e.g. ethanol or natural gas) or though the electrolysis of water. It can be burned in an internal combustion engine or used in fuel cell vehicles. Hydrogen can also be used like CNG or as a blend with CNG, and trials of blending with diesel have also taken place.

At present there is only one type of vehicle that can run on liquid hydrogen, the BMW 7 series. This is an experimental vehicle and it is felt that it will be a long time before this will even approach marketability. In developing the vehicles it is reported that BMW wants to "lead the way to encourage governments and investors to provide a regulatory framework and an infrastructure that can make a hydrogen economy a reality."

Gaseous pressurised hydrogen vehicles using fuel cell technology are nearer to market, as both General Motors and Honda have begun to look into this and invest in its development. Honda began limited mass production of a fuel cell car – the FCX Clarity -in June 2008; however it is planned that only 200 of these are produced over three years. There are a number of trials with fuel cell vehicles both in the UK and abroad, but at this stage other than the Clarity the production of hydrogen-fuelled vehicles has been limited to a small number of demonstration fuel cell projects made by a few vehicle manufacturers. Currently such vehicles can cost up to 10-20 times more to produce than their conventional-fuelled equivalents (e.g. £1m+ per bus).

A8.3 Examples of high-blend use

There are a number of fuel cell demonstration projects. The largest of these is in the US, where Honda is operating approximately 20 FCX Clarity fuel cell demonstrator vehicles. These are mostly run by organisation fleets, but two are leased to individual users at $500/month. Media reports note that this is a loss-leader and a publicity effort by Honda as the cars are currently very costly to produce. Honda began limited mass production of this fuel cell car in June 2008 but it is planned that only 200 of these are produced over three years.

In California a number of filling stations have been installed to form a hydrogen highway, and there is also one filling station in Washington DC. Honda is reportedly working with Shell, Chevron, and BP to look at delivering increased numbers of hydrogen filling stations.

In London the CUTE project demonstrated hydrogen buses, and a total of 33 hydrogen buses are being operated across the CUTE, ECTOS and STEP programmes. The CUTE project acknowledges that the next steps are to put in place comprehensive, large-scale demonstration projects to stimulate technology development, secure further funding, build up infrastructure and develop a policy framework. This is working towards closing the gap to market introduction. Market introduction itself appears a lot further down the line.

In Sweden, there have been trials of Hythane (CNG and hydrogen mixed) to fuel buses using the existing CNG infrastructure. They have used two blends (8% and 20% hydrogen), operating with normal CNG engines, the latter with only software adjustments. Benefits are reported to be higher efficiency, more stable combustion and a slight power increase.[121]

At the present stage of development, the cost of the vehicles and associated refuelling infrastructure is high, and little information is available about how much the fuel would cost. Existing refuelling infrastructure has been installed purely in conjunction with the pilot projects that are taking place.

A8.4 Environmental impacts

Hydrogen produces no exhaust emissions of CO_2, CO or HC. When combusted it produces water and NO_x and when in a fuel cell, just water. However, the production of hydrogen can be very energy intensive unless renewable sources are used (e.g. biomethane and renewable electricity).

[121] Study on the provision of biodiesel to LA members of SWELTRAC, Jessica Sherlock/SEA, 2008.

A9 E-DIESEL

A9.1 Summary assessment of fuel and relevance

It is recommended not to consider E-diesel further, due to the strong objections and safety concerns of manufacturers. In addition, the maximum blend is only around 15%. It looks most likely that rather than safety concerns being addressed the fuel will simply be overtaken by alternatives.

A9.2 Background

E-diesel is the name given to blends of ethanol and diesel fuel in which up to 15 percent ethanol is used to displace diesel in an unmodified engine. A small (around 1-2%) additive is needed.

In theory it can be used in any unmodified diesel vehicle – however there are concerns about safety and most engine/vehicle manufacturers and fuel industry representatives have negative views on it as a fuel:

"E diesel is likely to remain an experimental fuel until flammability concerns and health effects testing are addressed, and the economic infrastructure developed. Until the safety and other issues outlined in this document are resolved, use of E diesel or other alcohol/diesel blends should not be used [in Cummins products]."[122]

A9.3 Examples of high-blend use

A pilot E-diesel production plant is being setup through the BEST project, which planned that three sites, BioFuel Region, La Spezia and Rotterdam will demonstrate the blending of ethanol in diesel fuel. The fuel will be demonstrated in approximately 30 heavy and light vehicles. The function, reliability and safety of E-diesel will be monitored and the exhaust emissions will be characterised (NO_x, HC, PM etc). The emission tests will be performed by Motortestcenter in Sweden, which will also analyse and report on the data on performance and service. The effects on greenhouse gas emissions will be analysed.

The current technology for blending ethanol into diesel fuel is "direct injection," which is done at the pump and dispenses the proper amounts of ethanol, additives and diesel fuel into the vehicle's tank.

There is some evidence of more widespread E-diesel use in the US, but there is no evidence of E-diesel use in the UK.

[122] http://www.cummins-uk.com/sa/pages/en/customerassistance/faq/answers.cfm?uuid=00099E71-550E-1B8E-BCF080C4A8F00000

A9.4 Environmental impacts

It could be assumed that GHG savings equivalent to 15% bioethanol (in a regular diesel blend) could be achieved. The exact GHG savings will therefore depend on the source of the bioethanol.

A10 BIOBUTANOL

A10.1 Summary assessment of fuel and relevance

Biobutanol appears to provide good opportunities for the future but at this stage is not close to market. There are no published data on vehicle trials, but some practical experience from field trials has been noted (as well as conference presentations) and positive results reported from laboratory testing.

A10.2 Background

Biobutanol is produced from the same agricultural feedstocks as bioethanol (e.g. sugarcane, corn, wheat, sorghum or cassava).

Biobutanol seems a promising option as it has all the benefits of bioethanol, but also stores more energy per litre, is less prone to water contamination, is less corrosive to pipelines, fuel systems and can be blended into petrol at higher concentrations without having to modify vehicles.

Work is ongoing at overcoming production issues. There are a few different labs focussing on this including Green Biologics, a UK-based company in Oxfordshire. Rather more advanced a partnership of BP and DuPont have started construction of a demonstration plant to scale up biobutanol technology. This is being built at the site as the commercial-scale BP/DuPont/British Sugar bioethanol plant currently under construction in Hull.

Laboratory testing of Biobutanol is being reported positively:
"Fuel testing conducted over the last 12 months by BP demonstrates that high octane biobutanol can deliver the exceptional performance characteristics the partnership has previously communicated (including its use in existing fuels infrastructure) at fuel blends greater than the current 10 percent ethanol blend limit."[123]

A10.3 Examples of high-blend use

There is no published data from vehicle trials; however a field trial has taken place at the Northampton terminal supplying the BP retail network. This trial was originally set up to test the logistics infrastructure effects

[123] http://www.azom.com/news.asp?newsID=11296

A11 STUDY QUESTIONS

A series of study questions were set by the LowCVP for this piece of work, which have been addressed below. It is included at this point in the report as a checklist against the work done.

Table 5.1: Study questions and findings

Questions set in study brief	Findings
What are the potential GHG savings that could be delivered from high blend liquid and gaseous biofuels in buses, commercial vehicles and passenger cars? How cost-effective are these savings?	See Chapter 4, options assessment.
Is it more cost-effective to pursue high blends (i.e. greater than 10%), increase the low-blend to 10% in petrol and diesel? How cost-effective is this compared to biomethane?	In summary, it is probably more cost effective to use low-blends (B5 and E5) and increase these gradually, as these can be used in vehicles without changes to servicing costs. There are reported to be slight loss in fuel economy and some problems arising from B5 (likely due to poor storage) but these are minor compared to challenges of high-blends. Much of the costs are with the major fuel companies. However, total GHG savings are lower and may not be sufficient to reach 2020 RED targets of 10%. The analysis suggests that the highest high-blend fuels are in fact more cost effective than lower blends (i.e. B100 vs. B30) because the fixed costs are the same for more GHG reduction potential.
Why are some companies/parties in each of these sectors moving forward with the use of high blends and biomethane and some not? What are the main drivers for those who are using these fuels and what are the issues for those who are not or are unwilling to?	See Chapter 3, barriers and drivers.
What pilots and trials have been conducted for biofuels and what are their experiences and results? Attention should be paid to experiences with different feedstock types (and at different blends for liquid biofuels) on the different technical parameters: o Tailpipe emissions o Engine mechanical performance - drivability of the vehicle o Operation and maintenance o Effect on the sophisticated after-treatment (particularly diesel DeNox systems) o Fuel performance at different ambient temperatures	These have been used. Note, it has been difficult to obtain data from many of the recent/ongoing trials in the UK despite contact details being known or provided by LowCVP members.
Are there areas of consensus and areas of	There are uncertainties still around engine

uncertainty with the use of high blend liquid and gaseous biofuels? Is the technical information that is publicly available, peer reviewed and sufficient to develop consensus on these issues? What are the activities that need to be carried out in order to a) improve the evidence base and b) obtain consensus?	performance and durability. There is a lack of information from comparative trials undertaken in the same timeframe with comparable vehicles.
Is there a need to develop a specification for different liquid biofuel blends B25, B30 etc or a need for one specification for a single blend? Does the absence of an agreed high blend specification hinder take-up?	Specifications already do exist, for biodiesel, bioethanol, and biomethane (if Swedish standards were adopted). In addition, the specifications that until recently have only been met by conventional fuels are actively being developed (by CEN working groups) to enable higher proportions of biofuels to be included (i.e. B7, E10). What doesn't exist is one standard that covers both conventional petrol/diesel and high-blend biofuels, precisely because their properties differ. This is being worked on, incrementally, but in the meantime a work-around solution would be to apply the conventional fuel standard to the conventional fuel element and the biofuel standard to the biofuel proportion of any blended fuel, if it does not meet the conventional fuel standard.
How would a UK standard (s) for a high-blend or gaseous biofuel relate to European standards?	Fuel standards need to be developed on a European basis, as done to date.
What technologies do vehicle manufacturers currently have which may point towards certain high blend products?	See Chapter 2 Sector Assessment, and in brief: • HGV: some support for biodiesel (B30 or B100), currently only one dedicated OEM gas vehicle in the UK (so route likely to be retrofit of dual-fuel); PPO retrofit available. • Bus: some compatibility with biodiesel (B30 and B100; some mainland Europe gas vehicles and Optare offer dual fuel in UK spec; 1 bioethanol vehicle (Scania); some PPO ready vehicles (Optare); • MGV/LGV: compatibility with B30 for PAS Group, some Vauxhall/Iveco; 2 OEM gas vehicles, FFV (E85) via Ford car-derived van; • Car: B30, E85, and some renewed interest in gas engine variants. While some OEM are warranting use of biodiesel and ethanol in car and van fleets a number of other OEM (VAG and MB in particular) are strongly backing 2nd generation biofuels. These promise an easy transition for OEM, and fine-tuning of engines could take vehicle environmental performance even higher.
Which existing mechanism(s) holds the greatest potential for stimulating the market for high-blend liquid and gaseous biofuels? What are the other alternatives? O Could the RTFO be restructured in a way to encourage these fuels? Is this the right mechanism? O How could the alternative fuels framework be designed to stimulate (or at least not disadvantage) these fuels?	See Chapter 3 on support mechanisms, but in brief: Could RTFO be restructured to value certificates more highly for high-blend products? AFF might be used by Treasury to justify duty differential incentive, targeted at specific sectors of the UK vehicle parc.

O What effect does the BSOG currently have on stimulating alternative fuels? How do proposed modifications (in the recent consultation) provide an incentive for using these fuels? O To what extent are vehicle and infrastructure programmes providing the necessary incentives? What, if any, are the limitations of these mechanisms and how should they be overcome?	BSOG has until now been a major **disincentive** to bus operators using biofuels (above 5% blend). Revisions to BSOG clearly favour biomethane over other fuels, which is not consistent or in line with the claims for being technology neutral. However, it probably is better to focus available resources/incentives on one (or two) fuels given the barriers to overcome. Vehicle infrastructure programmes are virtually non-existent, since the demise of EST grant programmes. The IGP with a funding pot of £1.5m will be of most use if it's an initial phase to a much bigger scheme. Other suggestions for mechanisms to support high-blend biofuels include: • Taking commercial vehicles out of the current fuel duty system and incentivise them to improve fuel efficiency and GHG reductions, awarding rebates on that basis (rather like BSOG). • Applying duty on all fuels on basis of carbon content, given this would also incentive fuels with lower regulated pollutant emissions.
Does the proliferation of different liquid biofuel blend proportions help or hinder the penetration of these fuels?	Strong views received from key stakeholders are that it hinders. Wide variety keeps high-blends as niche products, expensive to move and store, more difficult to explain/promote and ultimately impossible to offer as a full range via forecourt fuelling.
Would the availability of 'advanced biofuels' alter any of the conclusions reached in the study?	Yes. If second generation biofuels were available in commercially viable forms (i.e. cheaply) and now rather than (post?) 2020. In such a case we might conclude skip all first generation biofuels (other than biomethane). But they are not likely to be available, and it seems likely something else is required in the meantime.