Assessment of the existing UK infrastructure capacity and vehicle fleet capability for the use of biofuels

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Executive summary

Transport biofuels are an important part of the UK's plan to meet the recently agreed target in the Renewable Energy Directive (RED) to obtain 15% of its total final energy demand from renewable sources by 2020. In particular the Directive includes a further sub-target for 10% of transport fuels (by energy content) to be delivered from renewable sources, mainly through the use of biofuels. To fully realise the potential of biofuels to reduce emissions from transport, DfT recognises that modifications to, and innovations in the UK supply infrastructure and in the capacity of the UK vehicle fleet to use biofuels may be required. As such, the main objective of this project is to produce a comprehensive baseline assessment based on sound evidence of UK covering two core topic areas: current vehicle fleet capability and current infrastructure capability to handle biofuels.

The project comprised three tasks:

- Establishing the current UK fleet biofuel capability (reported in Chapter 2, and Appendices 1 and 2).
- Establishing the current UK infrastructure capabilities, with particular reference to the handling of biofuels (reported in Chapter 3, and Appendices 3 and 4).
- An audit of biogas capacity that could be migrated to road transport fuel use.

The first two of these tasks built on current knowledge by augmenting this with detailed consultations with key stakeholders. The last task was predominantly based on other studies commissioned by DfT.

Establishing the current UK fleet biofuel capability
For each of the transport modes rail, marine, aviation and road transport, the questions answered in this study were:

- What is the current biofuel usage by this transport mode and what is the maximum permitted if only fuel meeting the current fuel specifications was used?
- What is the biofuel capability of the current fleet if all the vehicles used the maximum biofuel concentrations they are capable of handling?
- What is the biofuel capability of the most recently sold models if they all used the maximum biofuel concentrations they are capable of handling?

This provides:

- The current biofuel usage, in the context of current fuel specifications.
- The biofuel capability of the current fleet, taking into account its age profile and the differing biofuel capabilities of equipment of different ages.
- The biofuel capability of the fleet in, for example around 2020, when older, possibly less biofuel compatible vehicles have been replaced by current models.

Table ES1 contains data on the current usage of biofuels by the different modes of transport, together with the limit specified in their current fuel specifications. These data were taken from the UK greenhouse gas inventory for 2008, and the RFA quarterly report April 2008 – April 2009 (i.e. they come from authoritative sources).

The discussions with the principal stakeholders for each of the modes of transport indicated that vehicles are warranted to use, or can use, five different biodiesel strengths (0%, 7%, 20%, 30% and 100%) which can be considered for all four transport modes, and four different bioethanol strengths (0%, 5%, 10% and 85%) which are only used in road transport. The vehicle capabilities given in Table ES2 summarises the fraction of the fleets for the different transport modes that can use these different blend strengths.

Table ES1: Current biofuel usage across the different transport modes

Mode	Fuel	Current biofuel usage k tonnes /year	Total fuel usage k tonnes /year	% biofuel of all fuel used	Max % biofuel permitted in fuel specification
Road transport					
Passenger cars	Petrol	170.2	15,836	1.07%[2]	5%
Passenger cars	Diesel	312.4	7,077	4.41%[1]	7%
Light commercial vehicles	Petrol	3.4	321	1.07%[2]	5%
Light commercial vehicles	Diesel	205.7	4,659	4.41%[1]	7%
Rigid trucks	Diesel	156.6	3,548	4.41%[1]	7%
Articulated trucks	Diesel	172.8	3,915	4.41%[1]	7%
Buses and coaches	Diesel	68.1	1,542	4.41%[1]	7%
Mopeds and motor cycles	Petrol	2.1	196	1.07%[2]	5%
Domestic Ships	Gas oil	0	1,687	0%	0%
Trains	Gas oil	0	683	0%	7%
Domestic Aviation	Jet A1	0	687	0%	0%

Table ES2 Biofuel capability of current fleet and new vehicles across the different transport modes

Mode	Fuel	Biofuel blends				
Current fleet capability						
Road transport		Bioethanol				
		E0	E5	E10	E85	
Passenger cars	Petrol	100%	100%	84.0%	0.0025%	
Light commercial vehicles	Petrol	100%	100%	84.0%	0.0%	
Mopeds and motor cycles	Petrol	100%	100%	0%	0%	
		Biodiesel				
		B0	B7	B20	B30	B100
Passenger cars	Diesel	100%	100%	6.8%	6.8%	0%
Light commercial vehicles	Diesel	100%	100%	11.0%	11.0%	0%
Rigid trucks (Note 1)	Diesel	100%	100%	31.0%	11.7%	8.2%
Articulated trucks (Note 2)	Diesel	100%	100%	61.6%	61.6%	43.3%
All heavy goods vehicles (Note 3)	Diesel	100%	100%	47.0%	37.8%	26.7%
Buses and coaches (Note 1)	Diesel	100%	100%	31.0%	11.7%	8.2%
Other transport modes						
Domestic Ships	Gas oil	100%	0%	0%	0%	0%
Trains	Gas oil	100%	100%	100%	0%	0%
Domestic Aviation	Jet A1	100%	0%	0%	0%	0%

Capability of current models weighted by sales volume						
Road transport			Bioethanol			
		E0	E5	E10	E85	
Passenger cars	Petrol	100%	100%	93.9%	0.008%	
Light commercial vehicles	Petrol	100%	100%	93.9%	0.008%	
Mopeds and motor cycles	Petrol	100%	100%	0%	0%	
		Biodiesel	Biodiesel			
		B0	B7	B20	B30	B100
Passenger cars	Diesel	100%	100%	9.1%	9.1%	0%
Light commercial vehicles	Diesel	100%	100%	20.4%	20.4%	0%
Rigid trucks (Note 1)	Diesel	100%	100%	45.9%	17.3%	12.1%
Articulated trucks (Note 2)	Diesel	100%	100%	91.2%	91.2%	64.3%
All heavy goods vehicles (Note 3)	Diesel	100%	100%	69.7%	56.1%	39.5%
Buses and coaches (Note 1)	Diesel	100%	100%	45.9%	17.3%	12.1%
Other transport modes						
Domestic Ships	Gas oil	100%	0%	0%	0%	0%
Trains	Gas oil	100%	100%	100%	0%	0%
Domestic Aviation	Jet A1	100%	0%	0%	0%	0%

Notes to table

1 The survey expressed HDV capability in terms of engines fitted with unit injectors and those using common rail fuelling systems. The assumption made here is that rigid trucks, buses and coaches do not use unit injectors.
2 See Note 1. The assumption made here is that articulated trucks all use unit injectors.
3 Weighted averages based on fuel use by rigid and articulated trucks

It is probable that in the near future, e.g. in five years time, the difference between gas oil and DERV will disappear. In this case from the table above the total fleet capability for using biodiesel would be 4,388 kt per year in the context of a total diesel usage of 26,310 (around 16.7%) and the total fleet capability for using bio-ethanol would be 1,267 kt per year in the context of a total petrol usage of 13,154 (9.6%). For all transport fuel excluding aviation, this would be a biofuel capability of 14.3% across the three modes.

It will be seen in the Biofuels Modes 2 and Biofuels Mode 3 projects that the for the diesel fuelled vehicles that the aggregated fuel supplied by depot fuelled fleet vehicles was estimated to be 37.6%, with the majority, 62.4% of diesel being supplied from forecourts.[1]

The above two tables list the current (or near term) UK transport fleet's biofuel capability, as required. However, in collecting this information we also researched barriers to using higher percentage biofuel blends. Some of the barriers are technological challenges of using FAME[2] biodiesel and bioethanol rather than petroleum derived diesel and petrol. Other barriers are more focussed on approaches and policies. The key points are as follows:

- The users of biofuels are not willing to pay a significant premium for this, i.e. the economics of using higher biofuel blends needs to commercially attractive.
- Vehicle manufacturers require a long term plan/policy that is adhered to because of the time required to design, develop and introduce a new vehicle (or engine) to the market and the duration of the production run that is required to make the whole cycle economically viable.
- Because vehicles are manufactured for European and global markets there should be a harmonised approach across Europe rather than bespoke country-specific biofuel strategies.
- Each vehicles development cycle requires significant development, and so vehicle manufacturers do not want gradual increases in permitted biofuel blend concentration limits. Bold, but technologically viable step changes that last for at least a decade would be preferred.

[1] The derivation of this split is outside the scope of the Biofuel Mode 0 project, but is described fully in the Modes 3 report
[2] Fatty Acid Methyl Ester

- Fuel specifications need to be revised and developed to reduce the variability of fuels permitted.
- FAME and bioethanol fuels lead to engineering and practicality challenges relative to their petroleum derived counterparts, whereas it is anticipated that second generation biofuels will be more compatible with current transport equipment.
- In addition to the economics and engineering being favourable, increased biofuel usage also requires users to be able to buy the fuel, i.e. the biofuel infrastructure needs to be in place.

Establishing the current UK infrastructure capabilities

The key elements of the biofuel infrastructure have been identified. These are:

- the origination of fuel (import terminals, oil refineries and biofuel production plant);
- the intermediate storage (both coastal and inland);
- the wholesale and fleet end use supply infrastructure (where the fleet use is for all rail, airports, marine and road use); and
- the retail fuel supply infrastructure.

Connecting these different elements is the transportation of fuel by pipeline, sea, road and rail.

Information regarding all these aspects, auditing the current practices and how the biofuel elements of transport fuel supply fit in to the overall infrastructure capability was undertaken using the knowledge of the team, information in the public domain, and engaging with stakeholders. From all this information some common themes regarding the current infrastructure capability were found. These are given below.

Prior to the removal of the duty incentive for biofuels there was significant investment in certain sectors to allow the utilisation of higher percentage blend biofuels. Higher blend biofuels (primarily B30, B50 and E85) were successfully being produced, transferred and utilised by a small number of dedicated fleets and retail forecourts. The cessation of the duty incentive stopped the investment and halted the movement that was being seen towards an expansion in the use of higher blend biofuels. However, what this demonstrated was that the use of higher blends within the UK infrastructure was possible.

The current production of biofuels in the UK from feedstocks is not sufficient to meet the demand and consequently a large proportion of transport biofuels are imported. The research carried out for this study found that there is an intention within the industry to increase the UK's biofuel production capacity. However, a number of planned production facility construction projects have been cancelled for primarily financial reasons and a number of small facilities have closed due to a lack of feedstock.

Enquiries highlighted potential spare capacity to handle increased biofuel imports were not limited by the capacity of import facilities because an increase in biofuel usage was envisaged to be accompanied by a reduction in fossil fuel usage and no overall increase in capacity was necessary. Similarly, the majority of the UK oil refineries and import terminals have the ability to handle biofuels and so this is not seen as a significant barrier to expansion.

The primary distribution routes are via pipeline, rail or road. There was no evidence of any higher blend biofuels being transported via pipeline. With respect to future utilisation there are concerns over the technical ability of the pipeline network to carry biofuels. For higher ethanol blends their corrosive nature, and propensity to absorb water and impurities means pipeline transportation is problematic. There is some experience in the US that is could be drawn on. For higher blend biodiesel fuels a key concern is the potential contamination of jet fuel. Evidence is provided on some worst case scenario testing, and its implications for the transporting of biofuels by pipelines.

The transport of fuels via road and rail was not found to be a barrier to distribution. Both modes have the flexibility to transport a mixture of blends and to meet any increase in overall fuel capacity demanded with the UK. The only limitations were the need to modify the seals and linings of tankers. All companies surveyed were either already equipped with tankers which had these modifications or did not see these modifications as any barrier to increasing biofuel distribution provided there was a customer driven economic case for this investment.

End-users were split into retail forecourt refuelling and on-site depot refuelling. The retail forecourts are an important link in the chain because this sector supplies fuel to a large proportion of the end user market. This includes private individuals and increasingly haulage companies and public service organisations which are moving towards refuelling their vehicles at retail forecourts with payments charged to company/organisation fuel cards. The key findings from the survey of this sector are as follows:

- There is no spare storage capacity available either at small or large retail sites;
- Smaller and rural retailers have the tank capacity to supply one blend of petrol and diesel only;
- Larger retailers are not prepared to allocate storage space to higher percentage blended biofuels at the expense of more profitable and higher demand standard products;
- Installation of additional tank space is costly and logistically difficult at most sites;
- The costs associated with additional tank cleaning and improved water management when storing higher blend biofuels is another barrier to uptake. There is evidence of a need for these costs already with the B7 and E5 blends.
- There was a desire to move to higher blends via slowly increasing the volume in standard pump fuel in step changes. This would eliminate any economic disadvantage that would be incurred by any one company attempting to make a change to higher blends.

The ability for on-site depots to handle multiple blends was variable. The majority of respondents from all sectors stated that the standard set up at a depot is one fuel tank, although there were some exceptions. The use of this one tank to store higher blend biofuels was not generally thought to be an issue. Those respondents who had experience of trialling biofuels had incurred additional cleaning costs with higher blend biodiesels as well as requirements to install electric heating within the tanks. Furthermore, some general feedback suggested that even with the current B7 blend additional cleaning costs were being incurred.

Therefore for all end-user supply routes there is a real restriction to the potential to supply multiple blends of biofuel – both in terms of infrastructure and economic viability. Dispensing higher percentage biofuel blends within the standard pump fuel is also not without financial outlay but is feasible within the current infrastructure.

Finally, the common feedback across all of the survey work undertaken was that without an economic incentive which feeds throughout the supply chain there will be no move towards higher blend biofuels. A number of companies had started to supply and utilise biofuels when there was a duty incentive to do so and without this the uptake has become economically unviable.

Similarly, without warranties from vehicle manufacturers to approve the use of higher blend biofuels there is no confidence within the haulage and public service sector, or the private sector to move towards higher biofuel blends.

Audit of biogas capacity currently used for electricity and gas grid injection that could be migrated to road transport fuel use

The production and use of biomethane as a fuel for road transport is an option that is being seriously investigated by the UK Government. DfT has commissioned separate research in this area, with a study entitled “Feasibility study for a road vehicle biomethane demonstration project” reporting in June 2010, and this new study draws on the findings from that research. Whilst the production of biomethane from organic wastes via anaerobic digestion is well developed, most of this is used for electricity or for injection into the gas grid for commercial and domestic use.

The study found that the potential biomethane production capacity of the UK from waste (using anaerobic digestion) is 3,060 kilotonnes per year. At present the sole source of biomethane for road transport is from a landfill site, whose capacity is 5 kilotonnes per year, a small fraction of the potential biomethane production capacity of the UK from waste. However, the RFA records that only 0.4 kilotonnes were used as transport fuels in the 12 months ending 14th April 2009, and only 0.2 kilotonnes were used in the 12 months ending 14th April 2010.

There are a number of reasons for the very low usage of biomethane in road vehicles in the UK. These include:

- the need for gas cleanup equipment to convert from biogas (which is not compatible with vehicles) to biomethane (which is compatible);
- the need for gas storage, distribution and dispensing infrastructure; and
- the availability in the UK market of vehicle technologies that can use (bio)methane.

All three are important, though it was found that challenges associated with the gas storage, distribution and dispensing infrastructure are the main limiting factors. However, alongside this is the economics of using (bio)methane fuelled vehicles. This too needs to be such that the option of using (bio)methane fuel does not penalise end-users. It is important to note that other countries have taken steps to dramatically increase the use of biomethane as a transport fuel. Most notably, Italy is at the vanguard of biomethane usage in road vehicles.

Glossary

ACEA	The European Automobile Manufacturers Association
ATOC	Association of train operating companies
Bxx	Biodiesel blend containing xx% of biodiesel and (100-xx)% of fossil fuel derived diesel
CAT	Caterpillar Marine Power Systems branded name for a series of marine engines
CFPP	Cold filter plugging point
COMAH	Control of major accident hazards (an HSE information service)
DECC	Department for the Environment and Climate Change
DEMU	Diesel electric multiple unit
DERV	Diesel engined road vehicle
DMU	Diesel multiple unit
DPF	Diesel particulate filter
DUKES	Digest of UK Energy Statistics
EMD	Electro-motive Division of General Motors
EPA	US Environmental Protection Agency
Exx	Bioethanol blend containing xx% of biodiesel and (100-xx)% of fossil fuel derived petrol
FAME	Fatty acid methyl ester
FQD	Fuel Quality Directive
GHG	Greenhouse Gas
GPSS	Government Pipeline and Storage System
GVW	Gross vehicle weight
HGV	heavy goods vehicle (one whose GVW is greater than 3.5 tonnes)
HMRC	Her Majesty
ICAO	International Civil Aviation Organisation
JEC	JRC, EURCAR, CONCAWE Biofuels Programme
LCV	Light commercial vehicles (commonly called vans)
LowCVP	Low Carbon Vehicle Partnership
MAK	Caterpillar Marine Power Systems branded name for a series of marine engines
MAN	German commercial vehicle maker
MDO	Marine diesel oil
MTU	a German manufacturer of large diesel engines
NNFCC	National Non-Food Crop Centre
NRMM	Non-road mobile machinery
ONS	Office of National Statistics
ORR	Office of the Rail Regulator

PME	Palm methyl ester (biodiesel made from palm oil)
PRA	Petrol Retailers Association
RED	Renewable energy directive (Directive 2009/28/EC)
RESTATS	Renewable Energy Statistics database for the UK
RFA	Renewable Fuels Agency
RME	Rape methyl ester (biodiesel made from oilseed rape oil)
ROC	Renewables Obligation Certificate issued to a generator for renewable electricity generated
ROSCOS	Rolling stock companies
RSSB	Rail Standards and Safety Board
RTFO	Renewable transport fuels obligation
RVO	Recycled vegetable oil
SME	Soy methyl ester (biodiesel made from soybean oil)
TEU	Twenty foot equivalent unit, used to describe the size of container vessels
TME	Tallow methyl ester (biodiesel made from tallow)
UKPIA	UK Petroleum Industry Association
ULO	Used lubricating oil
UNFCCC	United Nations
VAG	Volkswagen Audi Group

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Appendices

1 Introduction

1.1 Project aims and objectives

Transport biofuels are an important part of the UK's plan to meet the recently agreed target in the Renewable Energy Directive (RED) to obtain 15% of its total final energy demand from renewable sources by 2020. In particular the Directive includes a further sub-target for 10% of transport fuels (by energy content) to be delivered from renewable sources, mainly through the use of biofuels. First generation biofuels are currently limited to 7% blends (v/v) for biodiesel in fossil diesel and 5% blends (v/v) for bioethanol in petrol (although for bioethanol a recent amendment to the Fuel Quality Directive (FQD) allows separate blends of up to 10% in the future). Second generation biofuels offer greater potential for reducing GHG emissions, but would need to be on-stream in the near future in order to help achieve the Fuel Quality Directive's GHG intensity targets for transport fuels by 2020.

To fully realise the potential of biofuels to reduce emissions from transport, DfT recognises that modifications to, and innovations in, the UK supply infrastructure and in the capacity of the UK vehicle fleet to use biofuels may be required. As such, the main objective of this project is to produce a comprehensive baseline assessment for the UK based on sound evidence covering two core topic areas:

- **Vehicle fleet capability.** This covers the capability of the UK road transport fleet, in particular, to utilise biofuels. The principal objective is to establish data on vehicle types and numbers capable of using biofuels across the four transport modes: travel by rail, sea, road and air. This includes quantifying the existing level of biofuel use within each fleet segment and identifying current warranty issues related to this fleet capability.

- **Infrastructure capability.** This includes both upstream and downstream fuel infrastructure capability of moving, storing and dispensing biofuels.

With a broad scope encompassing road, rail, marine and aviation transport, this project has been built on a wide range of previous studies such as the recent Low Carbon Vehicle Partnership[3] study, and was also informed by ongoing projects such as the work JEC's[4] Biofuels programme. In addition to this public domain information, the project involved extensive engagement with key stakeholders. Much of this engagement was carried out using semi-structured lists of questions, but with interviews conducted over the telephone such that there was flexibility in the approach, allowing additional relevant information to be drawn out where appropriate. These findings were presented at a Stakeholder Workshop (which was held as part of the associated project (Development of illustrative scenarios describing the quantity of different types of bioenergy potentially available to the transport sector in 2020, 2030 and 2050). This both enabled the draft findings to be peer reviewed, and extended the network of individuals and organisations consulted.

1.2 Scope of work

1.2.1 Vehicle capability

This task provides an audit of the **existing** UK biofuels capability for the current vehicle fleet. The task's scope does not extend to future capability, although given an average road vehicle lifetime of ten years, current sales patterns do provide some indication of the likely fleet composition in 2020. Through detailed consultation the project has ensured **that the data presented are current.** However, it is noted that this is in the context of a rapidly changing field.

The audit of vehicle capability covers road transport, rail transport, marine transport and aviation, (though the latter is restricted to the use of drop-in fuels only). Rail transport, marine transport and aviation have been treated as three individual entities with no further subdivision, in keeping with

[3] http://www.lowcvp.org.uk/
[4] JEC is a collaboration between the European Commission's Joint Research Centre, EUCAR, the European Council for Automotive R&D, and CONCAWE, the Oil Companies' European Organisation for Environment, Health and Safety.

current practices, and consistent with their relatively small contribution to the overall transport fuel consumption within the UK.

In contrast, the UK road vehicle fleet has been divided into cars, vans, heavy-goods vehicles (HGVs), buses and coaches and two-wheeled vehicles. Further sub-division, e.g. splitting HGVs not only into rigid and articulated trucks, but also subdividing these groups into several different weight categories was undertaken when the stakeholder consultation indicated that there are different biofuel capabilities, and when the treatment of all rigid trucks as the same would have been an inappropriate oversimplification.

Table 1.1: Fuel usage (derived from the 2008 UK Greenhouse Gas Inventory (GHGI) to DECC)

Mode	Fuel usage	Fuel types	% of all transport CO_2 emissions
Road	37.2 million tonnes	Petrol & diesel	92.3%
Railways	0.7 million tonnes	Gas oil	1.7%
Marine (domestic only)	1.7 million tonnes	Marine gas oil	4.2%
Aviation (domestic only)	0.7 million tonnes	Aviation turbine fuel	1.7%

1.2.2 Infrastructure

In parallel with the assessment of the capability of the vehicle fleet to use biofuels, a second task was designed to undertake an audit of the existing fossil and biofuel production, distribution and supply infrastructure in order to assess the capacity of this infrastructure, and its ability to handle additional volumes of biofuels, and additional fuel grades/blends.

The development of infrastructure is important to the uptake of biofuels because it is the interface between the production and the use of the biofuels, and also between the supply of feedstock and production of the biofuel. It is thus a key part of the supply chain.

In this report two sources of bioethanol and biodiesel in the UK market have been considered:

- import of finished product; and
- processing of biofuel feedstocks, such as rapeseed oil, at UK based facilities to produce a finished product.

Both sources are used to produce products that meet the EU biodiesel (EN 14214) and bioethanol (EN 15376) specifications. The processing of biofuel feedstocks is discussed in more detail in the insert, overleaf.

The estimation of capacity has taken account of existing regional, logistical and commercial fragmentation of the supply chain, and considered the four different infrastructure elements set out below:

- Level 1: Production/Import (Including coastal blending)
- Level 2: Inland Storage/Blending (Major regional distribution centres)
- Level 3: Wholesale/captive end users (including fleets/rail/air)
- Level 4: Retail supply

AEA's recent work for DfT in carrying out the Biofuels Research Gap Analysis revealed that to date, infrastructure has not been a major barrier to the deployment of biofuels in the UK. However, this is primarily because current biofuels can be blended relatively easily into the regular transport fuel infrastructure and the Government has made grants available for capital investment in refuelling needs. In the future, in order to meet the RED and FQD targets, there may be a need for multiple biofuel blends to be available to vehicle operators, which may require additional distribution and supply infrastructure.

Box 1.1: Biofuel definitions

Biodiesel	Processed from a variety of vegetable oils and animal fats such as rapeseed oil, palm oil, soybean oil and tallow. The most cost effective form of processing is transesterification which produces a methyl ester from a vegetable oil or animal fat. The generic name for this product is a fatty acid methyl ester (FAME). For example, rapeseed oil is processed in this manner to produce Rape Methyl Ester (RME). This can then be blended with other Methyl Esters (palm, soy and tallow methyl esters) to meet the EU specification for a FAME (EN 14214). RME is usually more expensive than SME or PME but it exceeds the FAME specification therefore it is usually blended with a cheaper product to meet the specification at the best price point possible.
Bioethanol	Unlike biodiesel, which is a generic term for a product which has variable chemical composition, ethanol is a specific chemical and consequently bioethanol is a specific fuel. Bioethanol production usually involves the microbial fermentation of the sugar or starch components of plants such as wheat and sugar beet. The water is then removed to produce a fuel which can be blended with gasoline at various concentrations. The EU gasoline specification EN 228 currently allows ethanol blends up to 5% (E5). Vehicles can used higher bioethanol concentrations, but to avoid difficulties when starting engines in cold climates the highest effective blend is E85.
Advanced Technologies (2nd generation)	There are a number of advanced technologies aiming to improve on first generation biofuels by processing the currently unused lignin and cellulose (non-food) components of plants. None of the technologies have reached full commercialisation with only small pilot or research plants running. Arguably the closest is a Neste patented technology which is currently installed at their Porvoo oil refinery in Finland. The process involves the direct catalytic hydrogenation of vegetable oils producing a hydrogenated vegetable oil (HVO) which can be used in diesel engines with no modification, i.e. it is a drop-in replacement fuel for petroleum derived diesel. To date no HVO has been supplied under the RFTO.

In the UK and Europe, the biofuels in use at present are ones that fit easily into the current infrastructure for distribution of vehicle fuels. For the UK there has been only limited study of the infrastructure requirements for the UK in response to a large increase in biofuels use. However, work has been undertaken by the LowCVP and also by the NNFCC on the development of biofuels technologies, which also examined infrastructure requirements. The NNFCC work points out that some biofuels can be used through existing infrastructure, but that fuels such as biogas would require a new gas refuelling infrastructure and purpose built vehicles[5].

Outside the UK, the EU has supported a number of networks designed to share information on the development of biofuels and infrastructure needs. One of the most significant of these is the Biofuels Cities European Partnership (www.biofuel-cities.eu/), which closed down in December 2009. This network provided information on experiences of using biofuels in urban environments. The project listed infrastructure projects being supported in cities around Europe, mainly related to first generation biofuels and biogas, and including work on refuelling infrastructure, biofuel transport, storage and distribution; it has also produced a review of biofuels and their infrastructure requirements[6]. This network also surveyed stakeholders (Biofuel-cities 2008) and found that key infrastructure barriers for current biofuels (including biomethane) are:

- Insufficient availability of refuelling infrastructure
- High costs to construct or convert refuelling infrastructure
- Insufficient biofuel production capacity and lack of sufficient feedstock for biofuel production units (this point is examined in more detail in chapter 3).

[5] NNFCC Project 08-017 "International biofuels Strategy Project: Liquid transport biofuels technology status report", G Evans, NNFCC, Published April 2008, available from: http://www.nnfcc.co.uk/metadot/index.pl?id=6597;isa=DBRow;op=show;dbview_id=2457
[6] This mainly covers first generation fuels and biomethane, but there is some discussion of hydrogen, DME and electricity as well (Biofuel cities 2009).

Another EU network, the Euro BEST project, includes examination of the infrastructure needed to support the introduction of bioethanol-fuelled vehicles and flexible fuel vehicles. The network has examined infrastructure available to cars, buses and fleets, together with the experiences of the introduction of ethanol and issues related to infrastructure such as storing and dispensing bioethanol. .

1.2.3 Structure of the report

This remainder of this report is structured into chapters covering:

- Vehicle capability (Chapter 2)
- Infrastructure (Chapter 3)
- Biomethane use in transport (Chapter 4)

It concludes by drawing together the findings and conclusions from these three areas.

To improve the readability of the report, some key sections of detailed information have been placed in appendices, with links to these provided in the main body of the report.

2 Audit of current UK fleet biofuel capability

2.1 Background

2.1.1 Fuel standards

Before considering the biofuel capabilities for the vehicles of individual transport modes, it is important to set out the overall context of fuel standards, combustion science fundamentals and materials and other issues that are common to the use of biofuels for transport.

The overarching legislation is given in the European Commission's Fuel Quality Directive, Directive 2009/30/EC amending the parent Directive 98/70/EC. This provides details regarding the specification of petrol diesel and gas-oil. This legislation is then reflected in the harmonised European Normal standards (designated with "ENxxxxx" identification numbers) as detailed below for different transport modes. In addition, Directive 2009/30/EC also contains requirements regarding the sulphur content of fuel. An important change is that the sulphur content of gas oil for use in non-road mobile machinery, and inland waterways, is to be reduced from the current maximum of 0.1% (1,000 ppm m/m) to 10 ppm from 1st January 2011 (paragraph 2 of Article 4). Another change is the increase in the permitted ethanol concentration from 5% to 10% (Annex I).

Current fuel standards are summarised in Table 2.1.

Table 2.1: Current fuel standards.

Transport mode	Key fuels	Standards that apply
Road	Road diesel, gasoline, (natural gas)	Diesel – EN590 for bulk, and EN14214 for FAME biofuel Gasoline – EN228 for bulk and EN15736 for ethanol
Rail	Gas Oil	BS2869:2010
Aviation	Jet A1	ASTM D 1655 (JET A-1)[7]
Marine	(marine) gas oil, RFO, MDO	ISO 8217: 2010 for MDO and Marine residual fuels Free of used lubricating oil (ULO)
Inland waterways	Gas Oil	BS2869:2010

An important feature of the standards listed in Table 2.1 above is that they evolve over time, i.e. the EN590 for diesel fuel that is relevant now differs from the EN590 standard that applied several years ago. The different standards are characterised by their year of introduction. For the current standards the allowable biofuel contents are as follows:

Road Diesel fuel — EN590:2009 allows up to 7% (vol) biodiesel as FAME only that meets standard EN14214[8]. This replaced EN590:2005 which allowed up to 5% biodiesel (FAME).

Road Petrol — EN228:2008 allows up to 5% bioethanol, which in turn is specified in EN15736. However, the EC Fuel Quality Directive 2009/30/EC, which amends Directive 87/70/EC, aims to make it possible to blend market gasoline with up to 10% ethanol (see Annex 1 of the directive). This may happen from 2011[9]. In order to prevent damage to older vehicles, fuel with a maximum ethanol content of 5 % will be available until 2013. Because of

[7] Specification given in document from: http://www.iocl.com/Products/ATFSpecifications.pdf
[8] See, for example, http://www.dieselnet.com/standards/eu/fuel_auto.php
[9] Detail taken from http://fuel4life-biofuels.com/european_union_bioethanol_european_directive_98_70_EC.html and from the directive http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0088:0113:EN:PDF

	these potential changes, many manufacturers are ensuring their new vehicles are compatible with E10.
Rail	Standard BS 2869 specifies a large range of "fuel oils". For railway locomotives the key gas oil is Class A2. The latest version of BS 2869, due to be introduced in the Autumn of 2010, will allow up to 7% FAME (as for EN590:2009[10]).
Marine	Standard ISO 8217: 2010 applies to Marine Diesel Oil (MDO) and Marine residual fuels, and has been updated in 2010. It specifies that these fuels should be free of used lubricating oil (ULO). It also specifies that it should be from petroleum derived products only, i.e. should contain no biofuel[11].
Aviation	The standard for JET A-1 (ASTM D 1655 (JET A-1)) is also known as DEF STAN 91-91 Issue 5, and is described in IATA Guidance Material for Aviation Fuel Specification - 5th Edition 2005.

2.1.2 Engine and vehicle limitations

In a diesel reciprocating engine the charge air is compressed to a greater extent than in a petrol engine, to at least ratio of 14:1, and often in excess of 20:1. When its temperature is around 800°C, an atomised injection of diesel fuel occurs which creates the ignition. (Hence the name "compression ignition".) These engines are more efficient than petrol engines of the same power and this results in lower fuel consumption. They also can use a greater range of fuels than petrol engines. However, to meet modern emissions limits many diesel engines use very high injection pressures, and sophisticated fuel injection systems. These have been developed to use petroleum based fuel. (This is typically predominantly a single chain hydrocarbon that is around twelve to sixteen carbons long. The chemical name for the latter is hexadecane or cetane.)

In principle, many plant derived oils, and liquid animal tallows, could be ignited using compression ignition. However, in order to obtain the clean burning combustion required to meet emission standards within a modern diesel engine, the properties of many vegetable oils are sub-optimal, e.g. rape seed oil contains around 32 carbon atoms. Thus, whilst older engines with their low pressure, mechanically pumped, injection systems could use pure vegetable oil, processing the vegetable oil to produce shorter chain lengths, known generically as "fatty acid methyl-esters" or FAME is required to produce fuel more compatible with modern diesel engines.

However, whilst appropriate combustion is essential, it is not the only requirement of a fuel. Other factors are important, and for biodiesel these are much more limiting. They include:

- Stability/liquidity at cold temperatures
- Controlling/eliminating microbial growth
- Ability to absorb more water than petroleum based diesel
- Limitations of the engines' fuel injection equipment
- Materials compatibility (low poly-aromatic hydrocarbon (PAH) content affects some rubbers)
- Increased emissions of oxides of nitrogen (NOx)
- Service intervals and breakdowns – issue of diesel particulate filter (DPF) regeneration and reduced lube oil longevity

For spark ignition engines, an air/evaporated fuel mixture is compressed to a much smaller extent, e.g. compression ratios of 9:1 to 10:1 for modern car engines. This is insufficient compression to cause the mixture to ignite, and a spark is used to do this. Hence a key aspect of the fuel for spark ignition engines is that the fuels used (e.g. petrol) are more volatile than diesel fuel. For petroleum based fuels, a single chain hydrocarbon that is around eight carbons long (ocatane) is ideal. However, such engines can run with little modification using smaller hydrocarbon molecules (e.g. three to four carbons long in the case of liquefied petroleum gas, LPG, or even only a single carbon,

[10] See http://www.tycofis.co.uk/bio-diesel/joint-statement-on-biofuel.pdf
[11] See http://www.maritimeandenergy.com/sider/tekst.asp?side=6395

methane). The more common biofuels that are relatively compatible with petrol are ethanol and bio-methane.

However, as for biodiesel, suitable combustion characteristics (and volatility) are not the only requirements of biofuels for use in spark ignition engines. Other factors that are important include:

- Materials compatibility (ethanol at concentrations greater than around 10% is not compatible with some components, e.g. connecting pipe work used in engine fuel system:
- Ethanol is totally miscible with water, and petrol-ethanol mixtures absorb water.

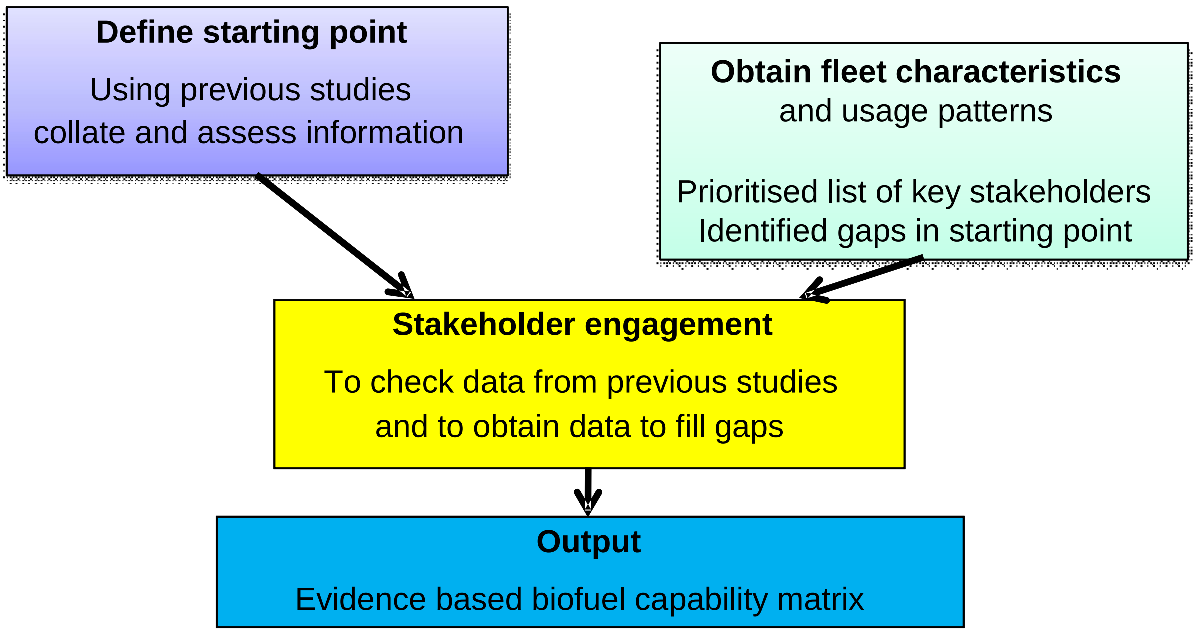
Notwithstanding the above drawbacks, it will be seen that diesel vehicles that can run using 100% FAME (biodiesel) and petrol vehicles that can run using 85% ethanol/petrol mixtures are vehicle options that can be bought for some groups of road vehicles. This demonstrates that these biofuels are potentially useable without a major vehicle development step (this is in contrast to the greening of transport using either hybrid vehicles or battery electric vehicles).

A key issue that will be found to be a recurring theme is the current lack of cumulative experience/confidence in using biofuels. As more trials are conducted, and few major issues are apparent, experience and confidence is gained. This occurs without changes in engine technology.

2.2 Methodology overview

The methodology that was used for auditing the current vehicle fleet capability to use biofuels is shown schematically in Figure 2.1..

Figure 2.1: Schematic overview of the methodology.



Key components of the methodology are:

- A review of the existing literature and assessments to define the knowledge starting point;
- A review of fleet characteristics and usage patterns including, as appropriate, an inventory of the current fleet. This both provides a qualitative understanding of each transport mode,

thereby identifying the key stakeholders, and also, as appropriate, quantitative data to assist in the prioritising of stakeholders;

- Stakeholder engagement, to verify the data obtained from previous studies, to obtain new quantitative data to fill gaps, and further qualitative information to augment the understanding of the sectors;

- The collation and assessment of all information to provide an evidence-based database, or matrix, of current biofuel usage and potential usage based on the current fleet.

The nature of this audit means that the information to be obtained is objective, e.g. a particular mode of transport is currently using “x” ktonnes biofuel per year, and the stakeholders views are that if specific biofuel blends were more widely available to the current fleet, or current models sold in the past year, then at this point in time particular transport modes have the capability to use “y” ktonnes biofuel per year.

This audit did not seek to highlight examples of biofuel demonstrations. Whilst these are important in determining the stakeholder views regarding what might be possible in the future, and in gaining experience regarding the range of biofuels that can be used, they do not represent a significant proportion of the capability of the **current** fleet. Also, this audit did not seek subjective opinions on how biofuel usage might develop in the future. When such information has been offered, it has been used in the associated Biofuels Modes Project 2.

Another aspect of this audit has been to place the information for the different modes of rail, sea, road and air travel, in a wider context (i.e. the current biofuel usage is “x” kilotonnes biofuel per year, in the context of a total fuel usage for this mode of “y” kilotonnes per year, whilst total transport sector fuel consumption is “z” kilotonnes per year). Furthermore, road transport is the largest consumer of fuel in the current UK transport sector and requires disaggregation into the contributions from the various different vehicle types (i.e. passenger cars, trucks, etc). This is achieved by calculating the fuel used in 2008 from the UK CO_2 emissions inventory, as reported to UNFCCC. These data are annually peer reviewed by external international groups. This provides an auditable, objective quantification of the relative importance of the different transport modes to be assessed.

The sections of the report covering rail, sea and road transport all follow the general structure below:
- Current fuel usage starting point;
- Assessment of existing public domain information;
- Fleet characteristics – in terms of current fleet, fuel usage patterns, industry structure and hence stakeholders;
- Identification of key stakeholders and stakeholder engagement plan;
- Conclusions for current models;
- Time evolution of the fleet.

The structure of the section covering aviation differs from this pattern.

2.3 Audit of current UK fleet biofuel capability – road transport

2.3.1 What is the current biofuel usage?

Road transport is the only transport mode using biofuels in significant quantities at present. Data from the RFA[12] indicates that in the year from 15th April 2008 to 14th April 2009 (the best correlation with the usage derived from the most emissions inventories), 1,028.9 million litres of biodiesel, 221.3 million litres of bioethanol and 0.4 million kg of biogas were used in road transport. Using the fuel density properties from a relatively recent CONCAWE study[13] these volumes can be converted into ktonnes

[12] taken from http://www.renewablefuelsagency.gov.uk/carbon-and-sustainability/rtfo-reports
[13] reference to V3.1 TTW Report 07102008.pdf where I used data from Table 2.1 on P6 of the pdf file, 890 kg/m3 for biodiesel, and 794 kg/m3 for ethanol

fuel. This has been done in the final two lines of Table 2.2. (The volumes supplied correspond to 4.41% biodiesel, 1.08% bioethanol).

Data from the RFA for the most recent year, covering 15th April 2009 to 14th April 2010 are that 1,113.2 million litres of biodiesel, 455.1 million litres of bioethanol and 0.2 million kg of biogas were used in road transport during this period.

Table 2.2: Fuel usage by road vehicles as derived from the 2008 GHG (ktonnes fuel).

Type of road vehicles	Petrol	Diesel	Biogas
Cars	15,836	7,077	
Vans	321	4,659	
Trucks - artic		3,915	
Trucks - rigid		3,548	
Buses and coaches		1,542	
Moped and motorcycles	196		
Total	16,353	20,742	
Biofuel supplied in 2008 (from RFA figures for 15/4/08 to 14/4/09)	176	916	0.4
Biofuel supplied in 2009 (from RFA figures for 15/4/09 to 14/4/10)	361	991	0.2

To put this in the context of road transport's total fuel needs, road transport accounts for the largest fraction of transport fossil fuel used, using over 92% of all transport fuel, as consequently being responsible to over 92% of transport related CO_2 emissions, see Table 1.1. Relative to rail or marine transport (which together consume only around 6% of transport fuel) road transport is more diverse, and is best viewed in terms of several categories.
The traditional inventory sub-categories are:

- passenger cars
- light duty commercial vehicles, or vans,
- rigid trucks
- articulated trucks
- buses and coaches
- motorcycles and motorbikes.

(In addition the UK inventory includes two other categories: emissions from all LPG fuelled vehicles, and an "Other" category. However, these contribute such a minor amount that they can be neglected within this study.)

For the petrol and diesel fuelled road transport, the 2008 GHG inventory leads to the fuel usage given in Table 2.2[14]. The value of the data in this table is that it gives the relative importance of different types of road vehicles, and provides the basis for developing future scenarios regarding the distribution of biofuels amongst the different types of road vehicles.

2.3.2 Assessment of biofuel reviews for road transport and public domain information

There have been two recent reviews summarising the capability of road transport vehicles to use biofuels. These are:

- *"Evaluating the opportunities for high blend liquid and gaseous biofuel penetration in the UK*" a study undertaken by Transport and Travel Research Ltd for LowCVP study, and

[14] drawn up from file 2008inventorydatatables_subset.xls
in folder: C:\JOHNWORK\PROJECTS\DfT Biofuels Vehicles & Infrastructures\Tasks\Task 1\Road transport

- "*Vehicle warranties and the use of biofuels*" a report by Biofuel cities, a Coordination Action project funded by the 6th Research Framework Programme for the European Union[15].

Both of these are recent reviews (published in late 2009) and they were used as a starting point for the stakeholder consultation in this study. In addition, to these two studies there is a further study:

- "*Questionnaire for the Department for Transport investigating the compatibility of vehicles operating on biofuels*", undertaken for DfT Cleaner Fuels and Vehicles Division, June 2008,

and

- A key web-site: http://services.autoplus.fr/vehicules-e10.html which contains a list of all vehicles in the French vehicle parc compatible with E10.

Together these four sources provide a valuable reference/ starting point for this study. However, these references do have some limitations:

- The **LowCVP study** focussed on vehicles compatible with blends of biofuels above 10%, but covers all vehicle types.
- The **Biofuel Cities** report needs to be carefully interpreted. For example it says 47 of 49 car manufacturers surveyed "do not have vehicles that can be fuelled by biodiesel" whereas our stakeholder consultation gives a quite different view.
- The **Ricardo** review does not contain Original Equipment Manufacturer (OEM) dependent information as it did not involve a stakeholder engagement component.
- The **Auto-Plus web-site** giving details on vehicles available in France is restricted to the E10 compatibility of vehicles.

Notwithstanding these limitations, these information sources have provided an extremely valuable starting point which many of the manufacturers contacted within the stakeholder engagement process confirmed are substantially correct.

Finally, this study did not focus on gathering highly detailed information on every single vehicle model capable of using biofuels. For example, the Biofuel cities report says the Lotus Exige 265E is E85 compatible in France only. Given that total UK Lotus Exige sales (all models) in 2008 were around 110 vehicles, out of UK petrol car and van sales of around 1.2 million vehicles, this was not included. In contrast, Ford 2.0 litre flex fuel engines (which can also run on E85) are fitted to the Galaxy, Mondeo and S-max models. From the vehicle sales database in 2008, 4825 of these were sold, which constitutes 2.5% of all Ford's petrol vehicle sales, or 0.4% of all petrol vehicle sales.

2.3.3 Fleet characteristics (What is current practice?) and identification of key stakeholders

For inventory purposes the road vehicle fleet can be divided into six general vehicle categories, as given Table 2.3. However, in terms of groups of key stakeholders there are three distinct groups of vehicles:

- light duty vehicles – passenger cars and light commercial vehicles (vans);,
- heavy duty vehicles (HDVs) – rigid and articulated trucks, buses and coaches; and
- two wheeled vehicles.

(These are also the three vehicle groups used for vehicle approval.)

From Table 2.3 it can be calculated that the fuel consumption of two wheeled vehicles is 0.53% of all road transport fuel. Most mopeds and motorcycles can use standard pump petrol, with its 5% bioethanol content. Yamaha and Honda do manufacture flex-fuel (E85 compatible) motor cycles, and there are conversion kits available for other manufacturers. However, in terms of overall biofuel capability motorcycles are only a very small proportion of all road transport. Consequently, this study has focussed on the light-duty and heavy-duty vehicles.

Also evident from Table 2.3 is that HDVs only use diesel fuel (i.e. only the current capability for using biodiesel is relevant), whereas for light duty vehicles both diesel and petrol fuels are used.

[15] Details regarding the Biofuel cities programme are available from: http://www.biofuel-cities.eu/fileadmin/template/projects/biofuels/files/BC_Leaflet_English.PDF

The key stakeholders involved in determining the biofuel capability of road vehicles are the vehicle engine manufacturers. For heavy-duty vehicles this is a small number of companies who produce engines, or chassis, for a larger number of companies who undertake the secondary chassis build. The engine manufacturers are not necessarily the same as the vehicle manufacturers. For light-duty vehicles, engines and vehicle manufacturers are frequently the same, and there are a large number of these.

Consequently, the stakeholder engagement plans differed for the two vehicle sectors. For heavy duty vehicles we contacted seven heavy duty vehicle engine manufacturers who together provide the engines for around 93% of all heavy duty vehicles sold in the UK in 2008.

For light-duty vehicles, a database of vehicle sales in 2008[16] indicated there are 64 different manufacturers of passenger cars and light commercial vehicles. Contacting 13 of these covered 87.3% of sales because some manufacturers make engines for several different vehicle brands (e.g. Volkwagen Group make engines for the Volkswagen (VW), Audi, Skoda and Seat brands). Table 2.3 contains part of the database analysis, listing the companies in order of decreasing market share.

Table 2.3: The 14 largest light vehicle manufacturers (in order of decreasing share of the UK market)

Manufacturer	Percentage share of the market	Percentage cumulative market share
Ford	15.4%	15.4%
Vauxhall	14.4%	29.8%
VW	8.4%	38.2%
Peugeot	5.5%	43.7%
BMW	5.4%	49.1%
Audi	4.8%	53.9%
Toyota	4.6%	58.5%
Renault	4.1%	62.6%
Honda	3.9%	66.5%
Citroen	3.7%	70.2%
Mercedes	3.6%	73.8%
Nissan	3.1%	76.9%
Fiat	2.4%	79.3%
Mazda	2.4%	81.7%

For all stakeholder engagements the strategy was to try to minimise the time required by stakeholders to provide the information we sought. This was achieved by building on knowledge obtained from the recent reviews. Consequently, prior to contacting organisations a bespoke questionnaire was prepared which:

- took the use of current pump fuel as a starting point,
- used the information within the LowCVP and Biofuel cities reports pertinent to the organisation as a reference point, and asked if this was correct.
- If it was not correct the information sought were the exceptions to this starting point.

The majority of road fuel is put into vehicles via retail refuelling stations. Consequently, the biofuel content and maximum specified limits for standard pump fuel represents much of current practice and current capability.
Appendix 1 contains the details of the stakeholder consultation for heavy-duty vehicles and Appendix 2 contains similar details for light-duty vehicles.

[16] Reference to Polk database, a database purchased by DfT for other studies

2.3.4 The current road vehicle biofuel capability

The quantification of the current biofuel capability of the fleet reported here is the output from the detailed stakeholder engagement, and the subsequent data analysis, that are reported in Appendices 1 and 2.

Heavy duty vehicles biodiesel capability
The discussions with the manufacturers of heavy duty engines indicated that they warrant vehicles for use with four different biofuel strengths, as shown in Table 2.4. In terms of the fraction of the heavy duty vehicle fleet, the information from manufacturers was expressed in terms of engines which had unit injectors, and those which did not. For the evaluation of market share the assumption has been made that this divide occurs at 16 tonnes GVW, with the heavier vehicles having engines with unit injectors. From this the percentages of vehicles capable of using the different biodiesel blend strengths can be calculated for current models. Then, from a knowledge of the year of introduction of a higher biofuel blend capability, and the fleet's age profile, the fraction of the whole fleet that can use each blend was calculated.

Table 2.4: The biodiesel blend strengths used by heavy duty vehicles' engine manufacturers

Blend strength	Heavy duty engine manufacturers who warrant some engines to use this blend strength
B7	The maximum blend strength specified in EN590:2009. No manufacturers indicated their vehicles needed a lower blend strength
B20	DAF
B30	Iveco, Renault Trucks, Volvo
B100	DAF, Daimler, MAN, Scania

Table 2.5: The percentages of vehicle capable of different biodiesel blends for current models and the whole heavy duty vehicle fleet.

	Current models		Current fleet	
Blend strength	**% sales that can use this blend**	**% sales for which this is the maximum blend strength**	**% fleet that can use this blend**	**% fleet for which this is the maximum blend strength**
	For tucks which do not use unit injectors			
B7	100%	54.1%[1]	100%	69.0%
B20	45.9%	28.6%	31.0%	19.3%
B30	17.3%	5.2%	11.7%	3.5%
B100	12.1%	12.1%	8.2%	8.2%
	For tucks fitted with unit injectors			
B7	100%	8.8%[1]	100%	38.4%
B20	91.2%		61.6%	
B30	91.2%	26.9%	61.6%	18.2%
B100	64.3%	64.3%	43.3%	43.3%

Notes to table

1 The figure for vehicles which can only use B7 fuel includes the vehicles which are not made by one of the seven principal heavy duty vehicle engine manufacturers (5.1% for tucks which do not use unit injectors and 8.8% for tucks which do use unit injectors)

From these data, the biodiesel capability[17] of the **current fleet** was found to be as follows:
For heavy duty vehicles of 3.5 to 16 tonnes GVW (which includes buses and coaches) 11.3%
For heavy duty vehicles of greater than 16 tonnes GVW 36.1%
This gives an average for all HDVs, weighted by their fuel usage, of 25.1%.

[17] The biodiesel capability is the proportion of biodiesel that would be used if all vehicles were filled using the maximum possible biodiesel concentration they are warranted to use.

These values for the current fleet involve taking a weighted average over vehicles of different ages. If only the current models are considered, then the biodiesel capability of the fleet is:

For heavy duty vehicles of 3.5 to 16 tonnes GVW (which includes buses and coaches) 13.4%
For heavy duty vehicles of greater than 16 tonnes GVW 50.4%
This gives an average for all HDVs, weighted by their fuel usage, of 34.0%.

This can be viewed as the biodiesel capability of the fleet in 2020.

The difference between the two weight ranges reflects the often reported difference between the biodiesel capability of engines with common rail fuelling systems (which are often limited to B7) and engines with unit injectors which are often permitted to use higher blends, up to B100.

Light duty vehicles biodiesel capability

The discussions with the manufacturers of light duty diesel engines indicated that only two different blends are warranted for use with current vehicles. These are B7, the maximum blend strength specified in EN590:2009, and B30. No manufacturers indicated their vehicles needed a lower blend strength than B7, whereas only Peugeot, Citroen (for all their light duty vehicles) and Vauxhall (for Vivaro and Movano light commercial vehicles, using controlled conditions) warranted their vehicles for use with B30.

In terms of the fraction of the light duty diesel engined vehicle fleet which can use each blend, these data are given in Table 2.6. The values for new models were calculated from the information provided by the manufacturers, and from the sales profile for 2008 within the Polk database for diesel cars/vans. (Given the very small number of manufacturers who warrant their vehicles for use with blends of higher strength than B7, for manufacturers that were not surveyed it was assumed their vehicles too are restricted to using only B7).

From a knowledge of the year of introduction of a higher biofuel blend capability, and the fleet's age profile, the fraction of the whole fleet that can use each blend was calculated.

Table 2.6: The percentages of vehicle capable of different biodiesel blends for current models and the whole vehicle fleet.

	Current models		Current fleet	
Blend strength	**% sales that can use this blend**	**% sales for which this is the maximum blend strength**	**% fleet that can use this blend**	**% fleet for which this is the maximum blend strength**
	Passenger cars			
B7	100%	90.9%	100%	93.2%
B30	9.1%	9.1%	6.8%	6.8%
	Light commercial vehicles			
B7	100%	79.6%	100%	84.8%
B30	20.4%	20.4%	11.0%	11.0%

From these data the fleet weighted biodiesel capability of the **current fleet** was found to be 8.9% (for details see Appendix 2).

There is a difference between the average biodiesel capability of passenger cars and light commercial vehicles (vans) because of the different market shares of the manufacturers warranting the use of B30. The disaggregated biodiesel capabilities are:

For passenger cars 8.6%
For light duty commercial vehicles (vans) 9.5%
This gives an average for all diesel fuelled light duty vehicles, of 8.9%.
(weighted by their fuel usage).

For the capability of the current models only, the biodiesel capability of the 2008 sales are: (weighted by sales numbers, and the passenger car/van fuel usage data)

For passenger cars 9.1%
For light duty commercial vehicles (vans) 11.7%
This gives an average for all diesel fuelled light duty vehicles, of 10.1%.

Because of the rate of turnover of the fleet, the capability of the current vehicles can be taken as the potential fleet capability in 2020.

Light duty vehicles bioethanol capability
A similar analysis to that discussed above for biodiesel usage indicated that there are three different bioethanol blends used by light duty vehicles. These are:

- E5 (5% ethanol) required by a relatively small number of current vehicles, and by older vehicles
- E10 (10% ethanol) used by the vast majority of the fleet, and
- E85 (85% ethanol) available a flex-fuel vehicles by a small number of manufacturers.

The importance of petrol fuelled light commercial vehicles is small. Around 6.4% of the van fuel used was petrol in 2008 (see Table 2.2) but this is diminishing with 2008 sales data showing only 0.8% of new vans being petrol fuelled. Consequently, the bioethanol capability of light commercial vehicles is not reported separately.

In terms of the fraction of the light duty spark ignition vehicle fleet which can use each blend, these data are given in Table 2.7. The values for new models were calculated from the information provided by the manufacturers, and from the sales profile for 2008 within the Polk database for petrol, hybrid and flex-fuels cars/vans. (For manufacturers that were not surveyed as part of this study it was assumed that the data in the Biofuels Cities report is accurate and these values were used.)

As before, from a knowledge of the year of introduction of a higher biofuel blend capability, and the fleet's age profile, the fraction of the whole fleet that can use each blend was calculated.

Table 2.7: The percentages of vehicle capable of bioethanol blends for current light duty vehicle models and the whole vehicle fleet.

	Current models		Current fleet	
Blend strength	% sales that can use this blend	% sales for which this is the maximum blend strength	% fleet that can use this blend	% fleet for which this is the maximum blend strength
	Both passenger cars and light commercial vehicles			
E5	100%	6.1%	100%	16.0%
E10	93.91%	93.9%	84.0%	84.0%
E85	0.008%	0.008%	0.0025%	0.0025%

From these data the bioethanol capability of the **current fleet** was found to be 9.2% (for details see Appendix 2).

This is principally determined by virtually all vehicles being compatible with the current pump fuel, i.e. E5 most vehicles being compatible with the E10 blend likely to be introduced in the near future, but very few vehicles being able to use higher blends (with around 0.008% of petrol vehicle sales for 2008 being able to use E85 despite there being a number of models available).

The bioethanol capability of only those vehicles sold in 2008 was found to be 9.7%. The underpinning reasons for this are similar to those for the current fleet, but with a higher fraction of current models being E10 compatible relative to historic models.

2.3.5 Conclusion

The fleet averaged road vehicle capabilities were found to be as summarised in Table 2.8.

Table 2.8: The percentage of different road vehicle categories that can use various biofuel blend strengths, both for current models and averaged for the current fleet

	Biofuel capability for new vehicles on the market (weighted by sales in 2008)				Biofuel capability for the current fleet			
	Biodiesel capability							
Type of vehicle	B7	B20	B30	B100	B7	B20	B30	B100
Passenger cars	100%	9.1%	9.1%	0%	100%	6.8%	6.8%	0%
Light commercial vehicles (vans)	100%	20.4%	20.4%	0%	100%	11%	11%	0%
HDV which do not use unit injectors - incuding buses and coaches	100%	45.9%	17.3%	12.1%	100%	31.0%	11.7%	8.2%
HVD which use unit injectors	100%	91.2%	91.2%	64.3%	100%	61.6%	61.6%	43.3%
	Bioethanol capability							
	E5	E10	E85		E5	E10	E85	
Light duty vehicles	100%	93.9%	0.008%		100%	84.0%	0.0025%	

However, in terms of technological capability, it is noted that:
- for the largest road vehicle diesel engines some are warranted to use B100,
- for smaller, common rail fuelling systems, road vehicle diesel engines some are warranted to use B30, and
- for spark ignition passenger cars, some are warranted to use E85.

Further, where economic and infra-structure conditions encourage the uptake of higher biofuel blends, like in Sweden, it is apparent that widespread adoption of E85 is feasible.

Notwithstanding, it should be noted that there are subtle differences in technology. For example, whilst PSA (the parent company of Peugeot-Citroen) makes B30 compatible light duty diesel engines and their competitors do not offer a similar warranty, the PSA technologies have some differences, especially regarding their diesel particulate filter, relative to other light duty diesel engine manufacturers.

The objectives of this project are to establish the biofuel capability of the current fleet and it is within the objectives of the Modes 2 project (Assessing cost effectiveness scenarios for biofuel deployment options across the UK transport sector to 2020 and to 2050) to look to the future. Notwithstanding the project scope, the stakeholder consultations undertaken in this project have provided the following feedback and comments:

Principal challenges to using biodiesel (FAME) in road vehicles
These include
- The stability/liquidity of FAME at low temperatures may be an issue because biodiesel blends can form a wax at higher temperatures than pump road diesel fuel.
- Biofuel diesel blends absorb/can contain more water than petroleum based diesel.
- The FAME constituent of biofuel blends can hydrolyse to form the fatty acids, which are corrosive and lead to accelerated corrosion relative to petroleum based diesel, or be oxidised, again to form corrosive products, which may produce solid products leading to filter blocking.
- The biofuel blends can support microbes, and lead to microbial growth whereas petroleum based diesel does not to the same extent.
- There can be materials compatibility problems, with the low PAH content of biofuels (FAME) affecting some elastomers.
- The rheological properties of biofuels differs from those of petroleum based diesel, such that the fuel injection equipment, designed to pressurise and control petroleum based diesel at extremely high pressures, experiences excessive signs of wear.
- The combustion of biodiesel can lead to significantly increased levels of NO_X formation, which is a challenge given the strategies engine manufacturers are having to use to reduce NO_X emissions to meet regulatory limits.

- Also, there are examples where the use of biofuels have proved detrimental to the durability of exhaust after-treatment systems, e.g. selective catalytic reduction systems. Phosphorus was identified as one potential catalyst poison.

For FAME it is appreciated that variability of the feedstock used to form the methyl-ester leads to variability in fuel quality and fuel properties. Beyond biodiesel in the form of FAME there was a consensus view that vehicles should not be expected to run using pure vegetable oil, since it is too variable, and has properties that are too different from the petroleum derived diesel for which engines were optimised.

The successful use of biofuels in many road vehicles illustrates how these challenges can be addressed, and overcome. However, this is at the expense of additional operational costs. For example, the increased corrosive nature of biodiesel blends is addressed by some vehicle manufacturers by regularly flushing/cleaning the fuel tank, which is an additional maintenance activity compared to vehicles using only petroleum-based diesel. Similarly, vehicle manufacturers might insist on a higher service frequency relative to when the vehicles only use petroleum-based diesel (typically twice the frequency, or half the interval between services). Another mitigation strategy adopted by some manufacturers is only to permit the use of biodiesel blends higher than pump diesel within specified fleets, where the vehicle manufacturers and the operators work together to ensure that the challenges listed above do not lead to compromised operations.

Principal challenges to using bioethanol in road vehicles

The principal challenges brought to the study team's attention include

- Materials compatibility problems, caused because ethanol has very different solvent properties relative to petroleum based petrol. These compatibility issues could cause problems with fuel pipes and other fuel system components.
- The miscibility of ethanol with water, and indeed the ability of ethanol to strongly absorb water (its hygroscopicity).
- The need to use hardened valves and valve seats with higher strength ethanol blends.
- The calibration of engines; petroleum-derived petrol contains around 87% carbon (w/w), whereas ethanol contains only 55% carbon (w/w). This lead to, for example, a 30% increase in fuel consumption (but not in CO_2 emissions) for a vehicle running on E85 rather than pump petrol.

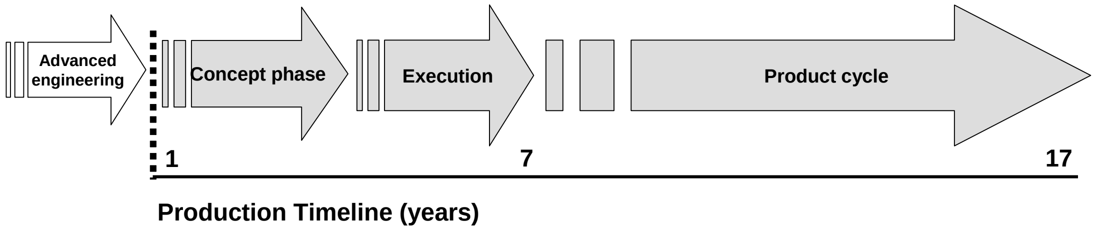
However, as with the use of biodiesels, the example of how Sweden is successfully using E85, with over 50% of its spark ignition passenger car fleet now using E85, is instructive. (Other key factors in Sweden's adoption of E85 include the financial incentives and infrastructure factors.)

Commonly expressed themes from the consultations

- The economics of using higher strength biofuel blends should not penalise the users of biofuels. This is particularly true for use of E85 where the lower carbon intensity of the fuel leads to typically a 30% increase in fuel consumption, in terms of litres of fuel that need to be purchased.
- Vehicle manufacturers require a long term plan/policy that is adhered to because of the timeline for the design and development for new engines/models before they start being produced. This varies for heavy duty vehicles, light commercial vans and passenger cars, becoming shorter for the smaller vehicles. (ACEA's[18] description of the production timeline for light commercial vehicles is given in Figure 2.2.)

[18] ACEA is the European Automobile Manufacturers Association.

Figure 2.2: ACEA's description of the production timeline for light commercial vans.



- Vehicle manufacturers make vehicles for European/global markets. Consequently, they expressed a strong preference for a harmonised approach across Europe rather than bespoke country-specific biofuel strategies.
- Vehicle manufacturers have stressed how gradual increases in the permitted biofuel percentage content limits in transport fuels are costly for them. They have indicated that they would prefer there being a constant protection grade, and a high biofuel content blend (e.g. E85) without a succession of changes in the protection grade.
- Some of the challenges are caused by inadequate detail within the fuel specifications. Therefore there is a need for the fuels and engine manufacturers to continue to work together to develop appropriate standards for biofuels.
- Vehicle manufacturers also expressed the view that the challenges they face using FAME rather than petroleum based diesel, and bioethanol rather than petroleum based petrol would be reduced as the market shifted from "first generation" to "second generation" biofuels, e.g. hydrogenated oils, which are likely to be more of a drop-in replacement for diesel, and butanol, which is more like petrol than ethanol.
- The infrastructure needs to be in place. Currently the only option for organisations wanting to use high strength biofuel blends is that they have to make their own arrangements and bunker the fuel.

2.4 Audit of current UK fleet biofuel capability - rail transport

2.4.1 What is the current level of biofuel consumption in rail transport?

With the exception of a few demonstration/research trials, discussed later, the fossil fuel used by the UK rail transport mode is exclusively gas oil. This is supplied with no biodiesel added, **i.e. the current biofuel consumption of rail transport in the UK is zero apart from the few exceptions noted**.

The specification for the gas oil used in rail locomotives is found in BS EN 2869, which covers fuel oils for agriculture, domestic and industrial engines and boilers. The gas oil used to fuel railway engines is defined in BS EN 2869:2006 Class A2. A key difference in the specification of this fuel relative to that used in diesel engine road vehicles (DERV) is its much higher sulphur level (0.1% or 1,000 ppm for A2 gas oil relative to 10 ppm for DERV). The previous version of BS EN 2869 allowed for double this, 0.2% sulphur content. The reduction reflected compliance with European Commission directive 2003/17/EC (on the quality of petrol and diesel fuels) in which Article 4 lowered the permissible sulphur level from a maximum of 0.2% to 0.1%. However, a more recent amending directive, 2009/30/EC (the Fuel Quality Directive), specifies that generally the permitted sulphur level in gas oil will reduce to 10 ppm from 1st January 2011, although there is a derogation for gas oil used for railways delaying this to 1st January 2012. This background provides the important driver to the research carried out during the stakeholder consultation, and the conclusions on the biofuel capability of the current railway locomotives.

2.4.2 Assessment of rail biofuel reviews and public domain information

It was found that there was very little in the public domain regarding biodiesel use within the UK rail transport. The principal exception to this was a burst of publicity in June 2007 announcing the launch of the UK's first train capable of running on biodiesel. This publicity describes the use of a modified Voyager train (Class 220), operated by Virgin trains, using a 20% biodiesel blend. The first service ran between London and Llandudno on Thursday 7th June 2007. Despite the fanfare of publicity at its launch, searching for subsequent news and updates have found no news since then (sources within the rail industry say this trial was discontinued some time ago).

There are reports of a number of biodiesel fuelled locomotive trials in both the US and Canada.

2.4.3 Fleet characteristics (What is current practice?)

The diesel powered railway fleet can be conveniently categorised into two main types of power unit – Diesel (Electric) Multiple Units[19] (D(E)MU) and locomotives. D(E)MUs have a number of smaller power units, typically rated between 300 and 500 kW, underneath the carriages, and they are used virtually exclusively for passenger travel. Locomotives are discrete power units and can, in principle haul both passenger or freight services, although some are specifically configured for particular passenger train configuration, e.g. the Intercity 125 express passenger trains. These locomotives are typically rates at above 2,000 kW, although some of the smallest locomotives used for shunting are smaller than this.

The UK rail transport fleet comprises a relatively small number of power units (<2,000) whose engines are made by only nine different manufacturers. Details are given in Table 2.9.

Table 2.9: Rail engine manufacturers.

	DMU & DEMU	Locomotives
Cummins	757	
English Electric		138
EMD (General Motors – Electro-motive Division)		443
General Electric		30
Mirrlees		5
MTU (a German manufacturer of large diesel engines)	206	165
Paxman		34
Perkins	144	
Sulzer		22
Total stock	1107	837

2.4.4 Structure of the Industry and the identification of key stakeholders

The UK rail industry has a structure which is, to a large extent, a consequence of the manner in which it was privatised. Some key aspects are shown in Figure 2.3.

Key features are:

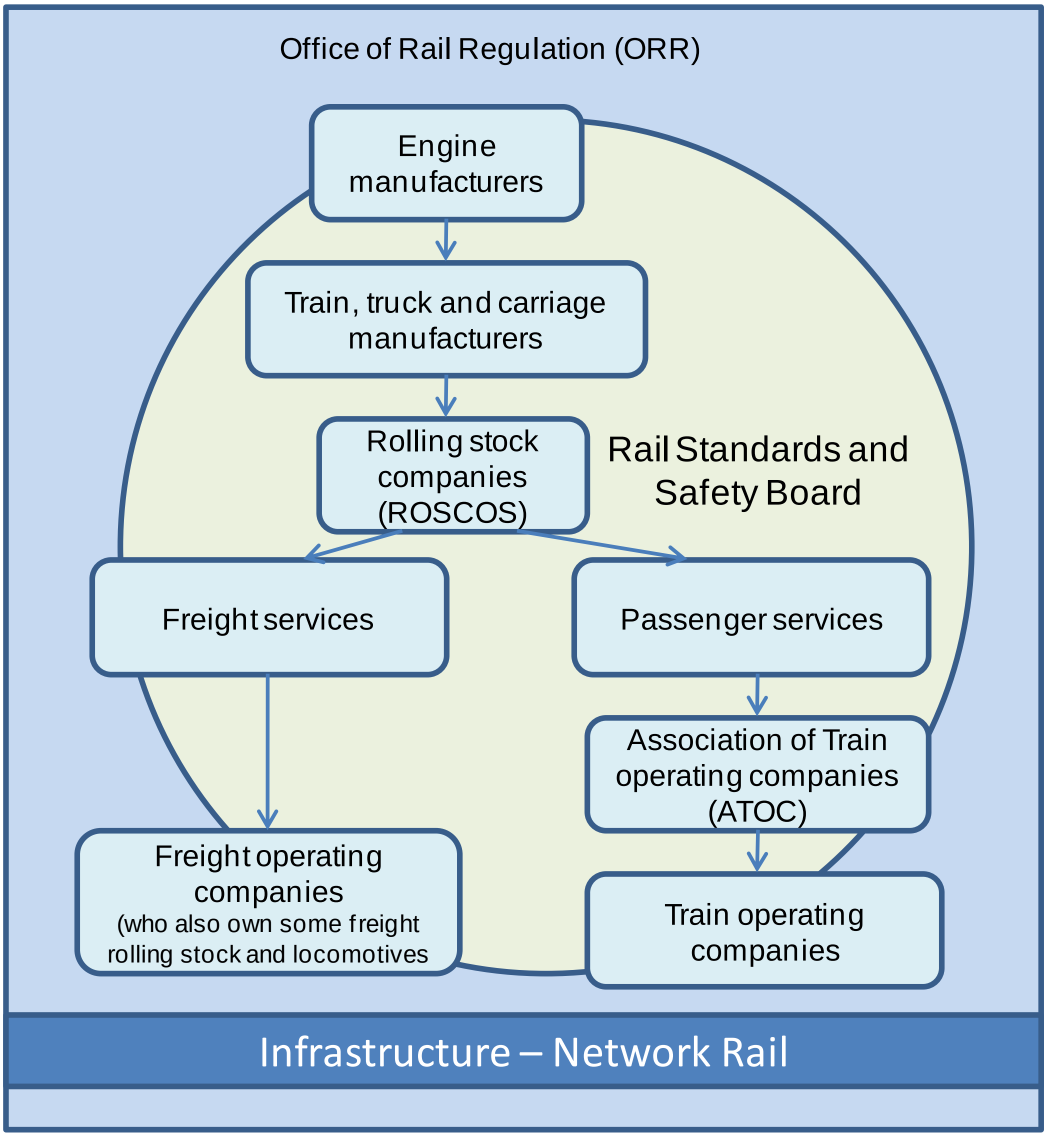
- The whole industry is regulated by the Office of Rail Regulation (ORR).
- The Rail Safety and Standards Board RSSB, (which was established in April 2003) has as its primary objective "to lead and facilitate the railway industry's work to achieve continuous

[19] For the diesel multiple units the power from the diesel engine is either transmitted to the wheels using a mechanical, as in the case of DMU, means, or the diesel engine powers a generator, which, in turn, powers electric motors, as in the case of DEMU.

improvement in the health and safety performance of the railways in Great Britain". It provides underpinning research in addition to the safety and standards followed by all other stakeholders.

- The engines within locomotives are made by a small number of manufacturers.

Figure 2.3: Current structure of the railway industry.



- Originally locomotives and trains were owned by only three Rolling Stock Companies (ROSCOS), Angel Trains Ltd, Porterbrook Leasing Company Ltd and HSBC Rail UK Ltd and were leased to the operators. However, other ROSCOS have entered the market, e.g. Diesel Trains Ltd, and Lloyds TSB General Leasing, and the freight operators also now own some of the freight rolling stock and locomotives.
- Operators can be subdivided into freight and passenger operators. There are five freight companies, with the largest being DB Schenker Rail (UK) Ltd (formerly EWS) and Freightliner Ltd, and twenty seven for passenger services. These are known as train operating companies and include companies like First Great Western, Virgin, Cross Country etc. The operators run trains leased from ROSCOS on a rail network managed by Network Rail.
- Whilst Network Rail owns the infrastructure, some aspects such as the operation of stations or depots may be the responsibility of a Train Operating Company.

Conversations with organisations at various levels within this structure often resulted in the study team being told that "decisions regarding the use of biofuels are not taken at this level". The key stakeholder groups regarding the use of biofuels were identified as the ROSCOS because they owned the trains, ATOC who speak on behalf of all the Train Operating Companies and the Freight Operating Companies. All groups look to the RSSB to provide leadership.

2.4.5 Findings from the Stakeholder consultation

The section on "Current biofuel usage" (Section 2.4.1) described how sulphur levels in the gas oil used by the rail transport mode were reducing. It is also appreciated, by the rail industry, that the addition of biodiesel to gas oil was potentially desirable. The RSSB has an ongoing rail industry research programme to support its objectives. Two key questions concerning fuel are:

- Will the change in sulphur level have any adverse effect on the operation of locomotives? and
- Would the addition of biodiesel have any adverse effect on the rail locomotives' performance?

These questions have been/are being addressed in two of RSSB's research projects: RSSB T536 – "Investigation into the use of sulphur-free diesel fuel on Britain's railways", and RSSB T697 – "Investigation into the use of bio-diesel fuel on Britain's railways".

Both research projects followed the same three stage approach:

- literature survey to better understand the starting knowledge,
- trials on engines running on a test bed, and
- train trials.

The final report of project T536[20] concluded that (in paragraphs 11.5 and 11.7) "*Two of the three service trials carried out using the same engine types as statically tested, have not shown any observable effects on engine performance and reliability in service over periods of 6 to 9 months operation. The third trial did indicate a deterioration in vehicle range as a result of increased fuel consumption, but data scatter made it difficult to be precise as to the magnitude*." Overall it was recommended that performance monitoring of the impact of introducing low sulphur gas oil should be undertaken, but overall it is anticipated to have little operational impact.

The work for Project 697 has been completed, and the final report is being reviewed within the RSSB; it is not yet in the public domain. The trial included running services using a range of biofuel blends from two depots. Conversations with the RSSB project manager have led to the following statements being agreed as a reasonable summary synopsis:

- The results of the biofuel service trials indicate that the use of biodiesel blend up to 20% in all diesel locomotives appears to have little operational impact on engine reliability, but leads to a small increase in fuel consumption.
- However, performance monitoring should occur alongside the introduction of any biofuel blend to quantify the impact of the introduction of biofuel on the train fleet as a whole.

These "pre-publication" preliminary conclusions may change, but **the indication at this time is that the current diesel locomotive fleet is capable of using B20 fuel**.

Another biofuel-relevant fact gleaned during the stakeholder consultation is that DB Schenker (which is predominantly a freight train operator) has been fuelling the Royal train, a Class 67 locomotive with a 3,300 kW EMD engine, with 100% biodiesel. This trial is continuing.

2.4.6 Conclusions for current models and time evolution

The indication at this time is that the current diesel locomotive fleet is capable of using B20 fuel. It may be that following the introduction of biofuel blends up to 20%, if the performance monitoring confirms that the use of B20 has little operational impact then the experience and confidence gained may enable the RSSB to recommend the use of higher blends.

[20] Summary Final Report available from: http://www.rssb.co.uk/SiteCollectionDocuments/pdf/reports/research/T536_summaryrpt_final.pdf - see paragraphs 11.5 amd 11.7.

However, if it were to be found that there is a fundamental engine design change required, rather than a simple retrofitted adaptation, then because the railway locomotive stock is replaced relatively slowly (many engines being in service for at least 30 years), the biofuel capability of the fleet would only increase slowly with the passage of time.

2.5 Audit of current UK fleet biofuel capability – marine transport

2.5.1 What is the current biofuel usage?

As for rail use, the current biofuel usage by **commercial** marine vessels is virtually zero. As noted in Section 2.1.1, the specification for fuels for marine vessels (ISO 8217: 2010) specifies that these fuels should be from petroleum derived products only, i.e. should contain no biofuel. (However, there are a number of biofuel trials being undertaken, e.g. involving a fishing vessel.)

There is a very limited amount of biofuel being used within marine vessels in the context of research trials.

Inland waterway vessels (which consume a very small fraction of the fuel used by vessels on water) are currently using gas oil fuels (the same fuel used by off-road equipment and railway locomotives) containing no biofuel.

2.5.2 Assessment of marine biofuel reviews and public domain information

Research found only limited reviews regarding biofuel usage for marine vessels[21]. These indicate that currently biofuel usage in commercial shipping is restricted to a small number of research trials, although the use of biofuels has a good potential for reducing the carbon footprint of commercial shipping. There were a number of articles extolling the potential benefits of using biofuels, citing financial and environmental benefits. One group of articles/web sites is focussed on the leisure industry[22]. Such sites cover the world (UK, US, Australia etc). One challenge cited in reference 22 is that if of engine manufacturer acceptance of the use of biodiesels.

Caterpillar Marine Power Systems (marketing marine engines under the brands of CAT and MAK) appears to be at the forefront of testing the compatibility of marine engines with biodiesel. An example is a yacht with CAT® C18 marine engines running on B30 biodiesel[23].

On the negative side, an article by the UK Protection & Indemnity Club is entitled: “Biofuels present problems for marine transport, handling and storage”[24]. They describe how the “*P&I club executives are beginning to receive insurance claims stemming from biofuel problems, most of which emanate from FAMEs. Data on the effect of FAME on marine fuel systems is limited. Water contamination is the main problem as FAMEs absorb water via sea water ingress, tank washing residues, atmospheric humidity in tanks’ ullage spaces and other sources. Water can promote hydrolytic reactions, breaking down the FAME to form free fatty acids. Such species are corrosive and may attack exposed metal surfaces. Water can separate out from FAMEs, promoting unwanted microbiological growth, which may lead to filter blocking and corrosion”.*

2.5.3 Fleet characteristics (What is current practice?)

Marine vessels use three fuels, Marine Gas Oil, and Residual Fuel Oil being the two key components. Marine Diesel Oil is a blend of these, usually blended to obtain a particular sulphur content.

[21] For example see study on “Low carbon commercial shipping” available from http://www.dft.gov.uk/pgr/scienceresearch/technology/lctis/reportaeanewcastleunipdf.pdf
[22] For example, a website created to promote the use of biodiesel amongst UK leisure industry is: http://www.leisuremarinebiodiesel.com/?referer=www.clickfind.com.au
[23] Article on CAT® C18 marine engines running on B30 biodiesel is to be found at: http://www.cat.com/cda/components/fullArticleNoNav?m=37586&x=7&id=579822
[24] Biofuels present problems for marine transport, handling and storage, P&I Club, August 2010, http://www.ukpandi.com/ukpandi/infopool.nsf/HTML/ClubPress03082010

There is a wide range of engines used, with a wide range of power ratings. The average main engine power ranges from 3.3 MW for general cargo ships to 16.3 MW for container ships[25]. The largest percentage of installed main engine power is residual fuel oil fuelled, slow speed diesel engines.

However, unlike road vehicles and railway locomotives, a single marine vessel will most probably have several engines fitted; main engines for propulsion (and other services when cruising) and auxiliary engines for use in port. Further, these engines most probably use different fuels. This enables vessels to meet new in-port sulphur emission limits (where they use auxiliary engines running on fuel containing less than 0.1% sulphur) and yet use cheaper, higher sulphur content fuel for their propulsion engines[26].

A recent study by Entec for Defra (in support of the UK national emissions inventories)[27] found that for the baseline year (2007) total fuel consumption by both UK domestic and international shipping was 4,092 ktonnes, of which 727 ktonnes were used at berth (around 17.7% of the whole).

2.5.4 Key stakeholders and findings from the stakeholder engagement plan

Key stakeholders include:

- the vessel owners/ operators
- Diesel engine manufacturers, (though issues are more to do with storage etc than engine compatibility).
- Lloyds Register who provide impartial advice to assess and reduce risk throughout the life of a ship.

Vessel owners and operators appreciate that the sea is a hostile environment. Consequently, they tend to follow the agreed standards, and unless there is a compelling reason (e.g. large financial savings) they are very reluctant to initiate a change, e.g. to start using biofuels.

Some engine manufacturers are advocating the use of biofuels with their engines, e.g. Caterpillar. In a recent article on the use of biofuels[28], it is stated that Caterpillar Marine Power Systems "*predicts growing demand in biodiesel, and naturally it follows a growing demand in motor yachts capable of using biodiesel. For that reason every new marine Caterpillar engine model will be compatible with biodiesel blends. Existing Caterpillar engines are both U.S. EPA- and EU-certified running on commercially available fuels, which includes biodiesel".* In terms of the range of engines this applies to, Caterpillar indicates that "*the CAT product line offers main propulsion engines from 93 to 7,200 kW, auxiliary engines from 162 to 5,420 kWe, and generator sets from 11 to 5,200 kWe"*. Caterpillar's publicity on its products does provide some information on biofuel compatibility, but it is not very comprehensive, or systematic.

Scanning through the product information from other large main engine manufacturers (e.g. Wartsila, MAN marine, Hyundai) has unearthed little information on biofuel compatibility for their engines.

The information provided by makers of smaller (auxiliary) engines, e.g. Cummins and Caterpillar, does indicate some compatibility with biofuels, but generally there is very little evidence obtained in controlled studies to provide guiding experience on the use of biofuels in marine vessels.

To address this Maersk-Lloyds have announced (9th March 2010) a biofuel trial to evaluate the use of biodiesel in marine engines. The trials aim to explore the problems that could be encountered by

[25] Data taken from EMEP CORINAIR 2009 guidebook, the chapter on navigation , Table 3-7 (http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-d-navigation.pdf)
[26] See http://www.motorship.com/news101/ibia-highlights-new-uk-regulations-on-in-port-sulphur-limits
These say from 20/4/10 The UK Merchant Shipping (Prevention of Air Pollution from Ships) (Amendment) Regulations 2010 essentially implement, in the UK, EU Directive 2005/33/EC, which requires that member states must take all necessary steps to ensure that ships at berth in their ports do not use marine fuels with a sulphur content exceeding 0.1 percent by mass. The new regulations amend the Merchant Shipping (Prevention of Air Pollution from Ships) Regulations 2008 and implement the marine fuel elements of the EU Sulphur Content of Liquid Fuels (SCLF) Directive.
[27] UK Ship Emissions Inventory, C Whall, A Stavakaki, C Green et al., Final report to Defra by Entec UK Ltd, October 2008
[28] "Biodiesel rocks", Yachting Magazine, October 2008, available at: http://www.yachtingmagazine.com/article/Biodiesel-Rocks

vessels using the FAME (fatty acid methyl ester) diesel fuel, which has experienced variable results in studies conducted by the automotive industry. Aspects that will be included are storage stability, handling and its subsequent use in the engine. Initially the fuel will be tested aboard the Maersk Kalmar, a 6,690-TEU Maersk Line container ship (deadweight 88,669 tonnes). The trial will use 5% and 7% FAME blends with the percentages gradually increased. Theoretically the fuel can be used neat, though whether the trials will proceed this far will depend on initial results.

Figure 2.4: The Maersk Kalmar, the vessel being used in the Maersk-Lloys marine biofuel trial.

Information from the Lloyds Register project manager is that the engine that will use biofuel is a CAT MAK 3.5 MW auxiliary engine which was built in 1992. This engine consumes 0.4 m^3 (400 litres) of fuel per hour.

Lloyd's Register has recently published a document entitled "Shipping and the environment"[29]. This described how current research in the UK includes a project to power a fishing vessel on 100% bio-diesel and another fishing vessel on pure plant oil. Regarding the more generic issues of biofuels and shipping, Lloyd's Register states that they are currently conducting safety reviews of the use of biofuels on existing ships with industry stakeholders and learning more about the potential future use of biofuel engines.

It is also interesting to note that at the 32nd "Motorship Propulsion & Emissions Conference"[30], Sub-titled "Clean and efficient ships for challenging time" and promoted as the most informative and longest established event in this market, the subject of biofuels does not appear in the programme. Examination of the Conference Programme shows there were no presentations on this subject despite there being sessions on shipping and greenhouse gases and on fuels.

[29] Shipping and the environment, Lloyd's Register, 2010, available from: http://www.lr.org/Images/COL4803_LR_marine_env_report_lo_tcm155-192788.pdf
[30] The 32nd Annual Motorship Propulsion and emissions conference, Hamburg, April 2010

2.5.5 Conclusions

The current quantity of biofuels used for marine shipping is essentially zero. The standard specification for fuel (ISO 8217: 2010) specifies that these fuels should be from petroleum derived products only, i.e. should contain no biofuel.

When the biofuel capability of current vessels was investigated, the unequivocal answer from Lloyd's Register, who provide authoritative, impartial advice for shipping, would be that currently no use of biofuels is approved.

However, there is research intended to extend the use, knowledge and experience of using biofuels in marine vessels. Also, some engine manufacturers, e.g. Caterpillar Marine Engines, do approve the use of biofuels, e.g. as B20, in some of their engines.

Key issues specific to marine usage of biofuels are not concerned with compatibility with the engines, but are issues related to the long term practicalities of using biodiesel. Relative to other modes of transport, marine vessels have the following features:

- Their fuel tanks have a large breather pipe;
- they breathe moist, salty air;
- The fuel can be in the tank for a very long time (years).

This leads to storage issues, including the hydrolysis of the fuel and subsequent corrosion, ingress of water, and microbial growth.

2.5.6 Time evolution

Of the freight carrying transport modes: road trucks and vans, rail, and marine vessels, it is the marine vessels that are the longest lived. There are ferries used daily, albeit at the end of their working life that are over 80 years old; for example, the Scillonian (the daily ferry between the UK mainland and the Isles of Scilly) had its maiden voyage in 1926. Whilst other vessels are younger, the average age of vessels is generally taken as 30 years old[31].

However, a vessel may undergo a major engine refit during its lifetime. Consequently, engine replacement is not equivalent to the rate of vessel replacement.

The comments above about the longevity of vessels have implications concerning any engineering adaptations (either to engines or the vessels fuel tanks or interconnecting pipe work) that may be required to mitigate some problems associated with the use of biodiesel. In general, if a swift uptake of biofuels were to be required in the shipping/water transport sector, retrofitting or adapting existing systems would be required, rather than waiting for the natural cycle of vessel replacement to occur.

2.6 Audit of current UK fleet biofuel capability – air transport

This whole task is concerned with reviewing the biofuel capability of the current "fleet". The scope of the project restricts biofuel use for aviation to **drop in fuels**,

From an ICAO working paper/conference[32] on Aviation and Alternative fuels, held in Rio de Janeiro in November 2009 the following definitions are used,

*"2.6 **Drop-in jet fuel blend**: a substitute for conventional jet fuel, that is completely interchangeable and compatible with conventional jet fuel when blended with conventional jet*

[31] Private communication with C Green, Entec
[32] Found at: http://www.icao.int/CAAF2009/Docs/CAAF-09_WP009_en.pdf

fuel. A drop-in fuel blend does not require adaptation of the aircraft/engine fuel system or the fuel distribution network, and can be used "as is" on currently flying turbine-powered aircraft.

*2.7 **Drop-in neat jet fuel**: a substitute for conventional jet fuel, that is completely interchangeable and compatible with conventional jet fuel. A drop-in neat fuel does not require adaptation of the aircraft/engine fuel system or the fuel distribution network, and can be used "as is" on currently flying turbine-powered aircraft in pure form and/or blended in any amount with other drop-in neat, drop-in blend, or conventional jet fuels."*

Consequently an analysis of current aircraft engine technology and capability is not required for the use of "drop in fuels".

2.7 Audit of current UK fleet biofuel capability – summary for all modes

Combining the information in the preceding sections we can tabulate current biofuel usage (Table 2.10), and the biofuel capability of the existing fleet, and of new models, in terms of the percentages of the fleet, or most recent sales, are warranted to take which biofuel blends Table 2.11).

Table 2.10: The current biofuel usage across all transport modes, both as an absolute and as a fraction of fuel used

Mode	Fuel	Current biofuel usage k tonnes /year	Total fuel usage k tonnes /year	% biofuel of whole
Domestic Ships	Gas oil	0	1,687	0%
Trains	Gas oil	0	683	0%
Domestic Aviation	Jet A1	0	687	0%
Road transport				
Buses and coaches	Diesel	68.1	1,542	4.41%[1]
Articulated trucks	Diesel	172.8	3,915	4.41%[1]
Rigid trucks	Diesel	156.6	3,548	4.41%[1]
Light commercial vehicles	Diesel	205.7	4,659	4.41%[1]
Passenger cars	Diesel	312.4	7,077	4.41%[1]
Light commercial vehicles	Petrol	3.4	321	1.07%[2]
Passenger cars	Petrol	170.2	15,836	1.07%[2]
Mopeds and motor cycles	Petrol	2.1	196	1.07%[2]

Notes to table

1. Data are taken from ratio of RFA biodiesel supplied figure (for 15/4/08 to 14/4/09) divided by the total amount of diesel fuel used (from 2008 GHGI)
2 Data are taken from ratio of RFA bio-ethanol supplied figure (for 15/4/08 to 14/4/09) divided by the total amount of petrol fuel used (from 2008 GHGI)

The discussions with the principal stakeholders for each of the modes of transport have indicated that they warrant vehicles to use, or would support the use of, five different biodiesel strengths (0%, 7%, 20%, 30% and 100%) which can be considered for all four transport modes, and four different bioethanol strengths (0%, 5%, 10% and 85%) which are only used in road transport. Table 2.11 summarises the fraction of the fleets for the different transport modes that can use these different blend strengths. The lower half of the table summarises the fraction of new vehicles that can use these blend strengths, giving an indication as to how the road transport fleet will develop by 2020 based on current sales patterns and vehicle capabilities. (These data are summaries of tables given in the individual sections of Chapter 2.)

Table 2.11: The current biofuel capability across all transport modes, for both the current fleet and new vehicles (current models only)

Mode	Fuel	Biofuel blends				
Current fleet capability						
Road transport		Bioethanol				
		E0	E5	E10	E85	
Passenger cars	Petrol	100%	100%	84.0%	0.0025%	
Light commercial vehicles	Petrol	100%	100%	84.0%	0.0%	
Mopeds and motor cycles	Petrol	100%	100%	0%	0%	
		Biodiesel				
		B0	B7	B20	B30	B100
Passenger cars	Diesel	100%	100%	6.8%	6.8%	0%
Light commercial vehicles	Diesel	100%	100%	11.0%	11.0%	0%
Rigid trucks (Note 1)	Diesel	100%	100%	31.0%	11.7%	8.2%
Articulated trucks (Note 2)	Diesel	100%	100%	61.6%	61.6%	43.3%
Buses and coaches (Note 1)	Diesel	100%	100%	31.0%	11.7%	8.2%
All heavy goods vehicles (Note 3)	Diesel	100%	100%	47.0%	37.8%	26.7%
Other transport modes						
Domestic Ships	Gas oil	100%	0%	0%	0%	0%
Trains	Gas oil	100%	100%	100%	0%	0%
Domestic Aviation	Jet A1	100%	0%	0%	0%	0%
Capability of current models weighted by sales volume						
Road transport			Bioethanol			
		E0	E5	E10	E85	
Passenger cars	Petrol	100%	100%	93.9%	0.008%	
Light commercial vehicles	Petrol	100%	100%	93.9%	0.008%	
Mopeds and motor cycles	Petrol	100%	100%	0%	0%	
		Biodiesel	Biodiesel			
		B0	B7	B20	B30	B100
Passenger cars	Diesel	100%	100%	9.1%	9.1%	0%
Light commercial vehicles	Diesel	100%	100%	20.4%	20.4%	0%
Rigid trucks (Note 1)	Diesel	100%	100%	45.9%	17.3%	12.1%
Articulated trucks (Note 2)	Diesel	100%	100%	91.2%	91.2%	64.3%
All heavy goods vehicles (Note 3)	Diesel	100%	100%	69.7%	56.1%	39.5%
Buses and coaches (Note 1)	Diesel	100%	100%	45.9%	17.3%	12.1%
Other transport modes						
Domestic Ships	Gas oil	100%	0%	0%	0%	0%
Trains	Gas oil	100%	100%	100%	0%	0%
Domestic Aviation	Jet A1	100%	0%	0%	0%	0%

Notes to table

1. The survey expressed HDV capability in terms of engines fitted with unit injectors and those using common rail fuelling systems. The assumption made here is that rigid trucks, buses and coaches do not use unit injectors.
2. See Note 1. The assumption made here is that articulated trucks all use unit injectors.
3. Weighted averages based on fuel use by rigid and articulated trucks

Caveats and assumptions in the data provided in Table 2.11 are as follows.

- These data for road transport have principally been derived from stakeholder consultations with the engine or vehicle manufacturers. These data may be systematically somewhat low because a manufacturer is likely to be somewhat conservative in the biofuel blends they permit for obvious commercial risk reasons.

- The above assumes marine use of biodiesel remains zero.
- There are a number of trials, across all modes, where vehicles are trialling higher strength biofuel blends, often quite successfully. This demonstrates there is no **intrinsic** engineering reason as to why transport can not use higher strength biofuel blends.
- A key determinant in the **agreed capability** of transport vehicles to use biofuels comes from a combination of experience and confidence. It is likely that in the future, successful trials will provide both more experience and confidence, and that without any marked change in engineering, the biofuel capability within transport could increase.

It will be seen in the Biofuels Modes 2 and Biofuels Mode 3 projects that the for the diesel fuelled vehicles that the aggregated fuel supplied by depot fuelled fleet vehicles was estimated to be 37.6%, with the majority, 62.4% of diesel being supplied from forecourts.[33]. This was calculated both using a bottom up methodology, considering each of the types of road vehicles individually, and a top down methodology using information from the Digest of UK Energy Statistics.

In addition to the percentage of the current, and of new models, that can use the individual blends, these data can be used, with the fuel usage data of Table 2.10, to calculate the amount of biofuel that each transport mode could use both presently, and in the future as the older vehicles, which can only use lower biofuel blends, are scrapped.

It is probable that in the near future, e.g. in five years time, the difference between gas oil and DERV will disappear. In this case from the table above the total fleet capability for using biodiesel would be 4,388 kt per year in the context of a total diesel usage of 26,310 (around 16.7%) and the total fleet capability for using bio-ethanol would be 1,267 kt per year in the context of a total petrol usage of 13,154 (9.6%). For all transport fuel excluding aviation, this would be a biofuel capability of 14.3% across the three modes.

Generally it was found that vehicle manufacturers are anticipating increased use of biofuels, and they are not fundamentally against this. They do have some concerns, and comments, which are detailed in section 2.5.5 because they are principally derived from comments from those connected with road transport. However, many of these views are applicable to all transport modes, especially those concerning the economics, infrastructure and fuel specifications.

[33] The derivation of this split is outside the scope of the Biofuel Mode 0 project, but is described fully in the Modes 3 report

3 Audit of existing capacity of the UK biofuel infrastructure

As discussed in Section 1.2, in addition to understanding the capability of the UK's vehicle fleet (across all transport modes) to use biofuels, the other key, and equally important aspect of this project is concerned with understanding the capacity of the UK's existing infrastructure with respect to the production, distribution, and delivery of biofuels and biofuel blends to end users. This will take into account all of the steps from production/import of fuels through to fuel dispensing to consumers and businesses. As with vehicle capability, a key issue for the infrastructure elements is the ability of the existing infrastructure to deal with multiple types of biofuel blends.

The key methodology employed within this task was to undertake an audit of the major stakeholders involved in each element of the existing infrastructure. This included investigating current dedicated biofuel facilities as well as determining the extent of any existing capacity within facilities not currently used for biofuel that could be migrated to biofuel use.

3.1 Developing the audit strategy

3.1.1 Identifying the key elements of the UK's biofuels infrastructure

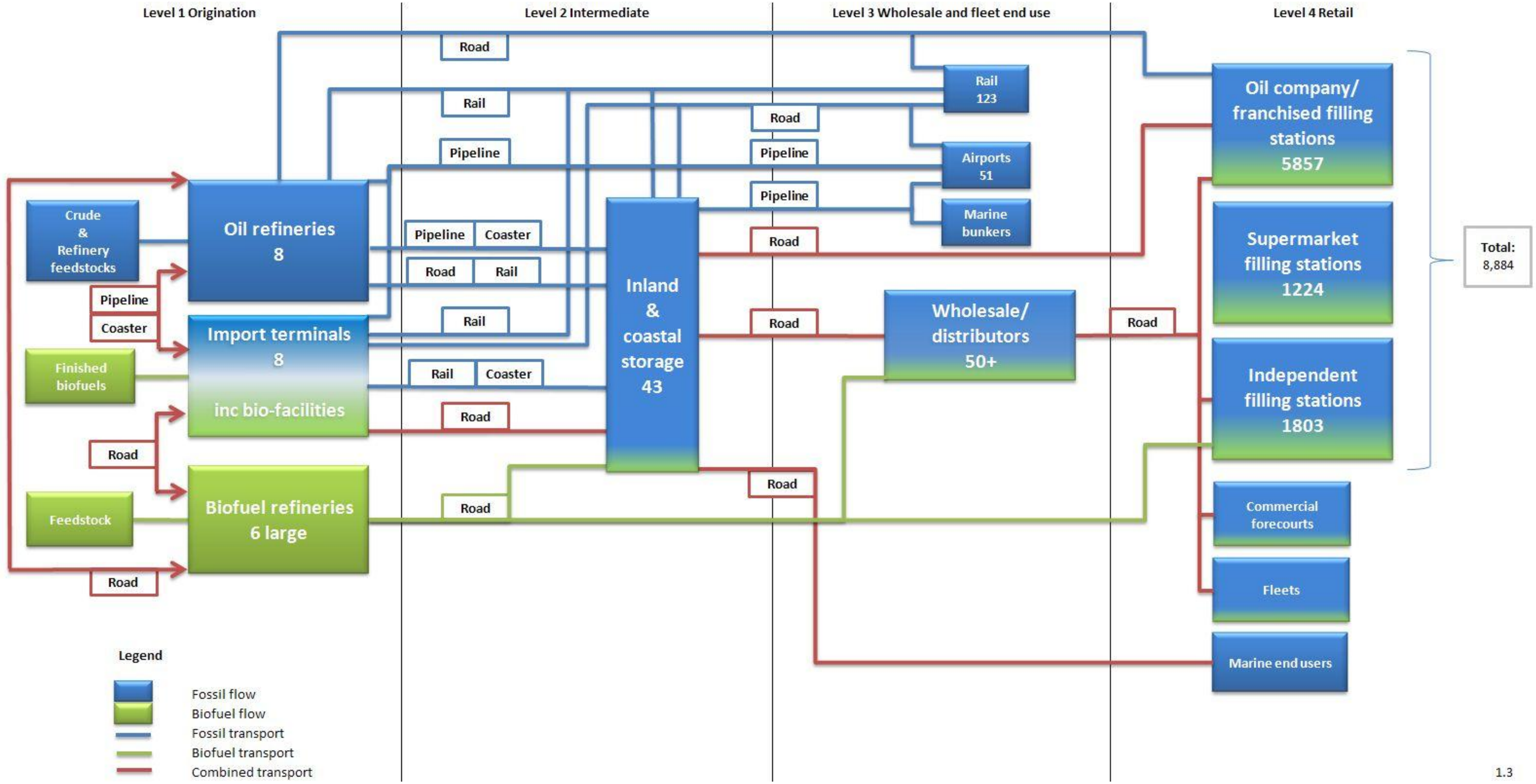
The existing fossil fuel infrastructure is likely to continue to represent a significant cornerstone to any future distribution of transport fuels, with adaptation to accommodate increased biofuel inclusion, rather than parallel development of dedicated biofuels infrastructure. In order to develop a robust sampling strategy, the first step was to identify each of the elements that together constitute the UK's current fossil fuel and biofuel infrastructure, and to collate information on the numbers of UK facilities associated with each element. This was then used to develop appropriate data sampling strategies for each of the key elements to assess the capacity of the existing fossil fuel and biofuel infrastructure. The main elements that make up this infrastructure are as follows:

- Refineries and production facilities (split into bioethanol refineries and biodiesel refineries, and biomethane production facilities)
- Import facilities
- Pipelines
- Tank storage
- Tankers for transport of products (using road, rail and coasters)
- Retail forecourts
- On-site fuel depots (road freight, bus/coach operators, aviation, rail and shipping)

To better understand the inter-relationships between these infrastructure components, the study team prepared a fuel production, distribution, and supply flow diagram (see Figure 3.1). This highlights the key elements of the UK's fossil fuel and biofuel infrastructure. This flow diagram has been further refined and updated during the course of the project.

In order to create compatibility with other DfT, and wider life cycle analysis work, one recommendation from this study is that additional "levels" are incorporated into the flowchart, prior to the existing "Level 1". This would allow consideration of biofuels raw material pathways and processing outside the UK.

Figure 3.1: Outline flow diagram of fossil fuel and biofuels production and supply infrastructure



3.1.2 The audit strategy

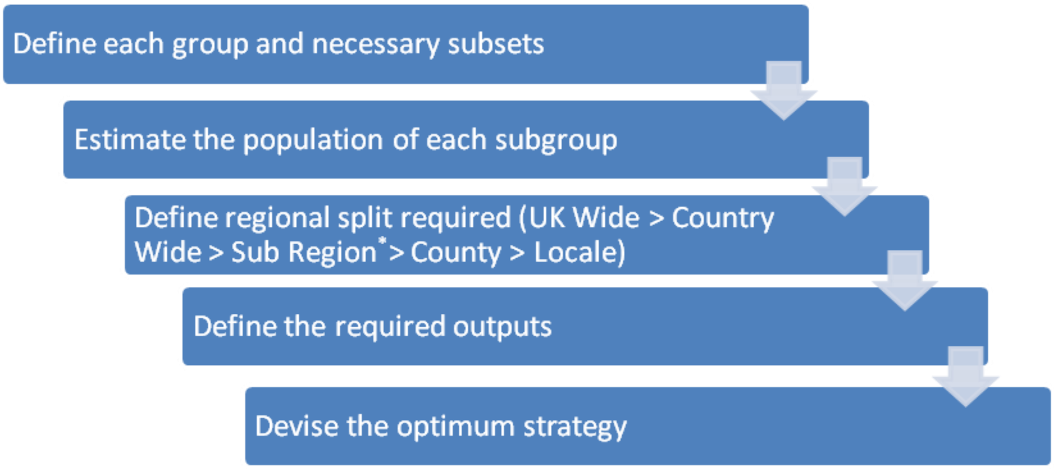
The audit strategy that was used for each core infrastructure element is detailed in Table 3.1. It was acknowledged that the audit strategy would vary depending on the particular elements of the infrastructure being investigated and was constrained by the resources available within the project. For example, for elements where there are a small number of facilities we have adopted a 100% sampling strategy; where the study team has extensive knowledge we have been able to rely on existing contacts within the industry sector; and for those elements where the numbers of facilities are large (e.g. retail forecourts and on-site, non-retail refuelling depots) a sampling approach of a sub-set of the whole was defined in order to ensure that audit data were collected from a statistically representative sample of the UK's infrastructure that can then be used as the basis for estimating capacity at the UK level.

Table 3.1: Audit strategy for each infrastructure element.

Infrastructure element	Level (as per Figure 3.1)	Primary audit strategy
Refineries and production facilities	Level 1 (Origination)	Review of existing literature, discussion with industry representatives
Import facilities	Level 1 (Origination)	Review of existing literature, discussion with industry representatives
Pipelines	Inter-level transfer	Review of existing literature, discussion with industry representatives
Tank storage	Level 2 (Intermediate)	Review of existing literature, discussion with industry representatives
On-site fuel depots (road freight, bus/coach operators, aviation, rail and shipping)	Level 3 (Wholesale and fleet end use)	Direct sampling of a representative sample of key stakeholders
Retail forecourts	Level 4 (Retail)	Direct sampling of a representative sample of key stakeholders
Tankers for transport of products (using road, rail and coasters)	Inter-level transfer	Direct sampling of a representative sample of key stakeholders

For the Level 1 and Level 2 infrastructure elements and pipeline transfer, information was primarily gathered from existing knowledge of the study team, discussion with key industry contacts and a review of the most relevant, up-to-date literature.

For the Level 3 and Level 4 infrastructure elements and tanker transfer a more intensive approach was required to obtain the required information. A common approach was applied to identify a sampling strategy for the various user groups within these sub-elements. This approach is summarised overleaf.



*Sub Region – Scotland, North East, North West, Central, South East, South West, Wales

The relevant survey candidates represent statistically significant samples, those with key roles in the distribution system, and those with specific experience of developing or adapting infrastructure for specific use of biofuels or biofuel blends. The surveying was undertaken principally via telephone but also using e-mail to maximise the information gleaned from each source and to ensure a high number of responses were obtained, in particular from key stakeholders. A large range of companies were approached as part of this sampling activity. Of these companies not all were approached successfully. Any gaps in the survey work are identified in subsequent sections.

The following sections detail each sector and discuss the audit approach that was taken in more detail.

3.2 Audit of biofuel refinery facilities and import facilities

With reference to Figure 3.2, this section presents an up-to-date and comprehensive picture of the current status of existing biofuel production (refineries) and import facilities. Information has been gathered from existing knowledge of the study team, discussion with industry and a review of the 2008 and 2009 DECC Renewable Energy Statistics (RESTATS) database. This is produced by the UK Department of Energy and Climate Change (DECC) following data collection activities undertaken by AEA on their behalf[34]. This includes a confidential annual survey on biofuels production from which a public domain summary report is produced annually (O'Brien, 2010[35]).   In this report some high level figures and information relevant to this study are provided.

Complementary data on biofuel production (refinery) is available from the RESTATS (Renewable Energy Statistics) database.

In 2009, DECC commissioned Wood Mackenzie, consultants in the oil industry, to analyse the market framework in the downstream oil sector which included the refineries, distribution terminals and filling stations[36]. The final report for this study provides a good overview of some of the key elements of the downstream fuel supply infrastructure, and the information from this report has been used as the starting point for our research in Section 3.2 and Section 3.3.

For this report we have considered two sources of bioethanol and biodiesel in the UK market: import of finished product; or processing of biofuel feedstocks, such as rapeseed oil, at UK based facilities to produce a finished product. Both sources are required to produce products that meet the EU biodiesel

[34] The home website for RESTATS is at: https://restats.decc.gov.uk/cms/welcome-to-the-restats-web-site
[35] UK Production of Biofuels for transport in 2009: Executive summary", O'Brien, July 2010, available from: https://restats.decc.gov.uk/cms/assets/Uploads/Results_2009/RestatsUKBiofuelsProduction2009Abstract27July10.pdf
[36] http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/resilience/downstream_oil/improving/improving.aspx

(EN 14214) and bioethanol (EN 15376) specifications. The processing of biofuel feedstocks is discussed in more detail below.

3.2.1 Biofuel refinery facilities

Major facilities

There are currently only a limited number of major biofuel refinery/production facilities in the UK. Figure 3.2 shows a map of the locations of biofuel refineries in the UK including those operating, under construction, proposed and cancelled. This is an up to date version of a map available from the Biofuelswatch website which was produced in 2007[37], and differs markedly from it. For example, the Biofuelswatch 2007 map listed eleven proposed biofuel production facilities, whereas the updated 2010 map has only two, noting six are postponed or cancelled. A key message from this map is that the biofuel production facility plans are very fluid and can change rapidly. This message was also obtained from the RESTATS survey, discussed later.

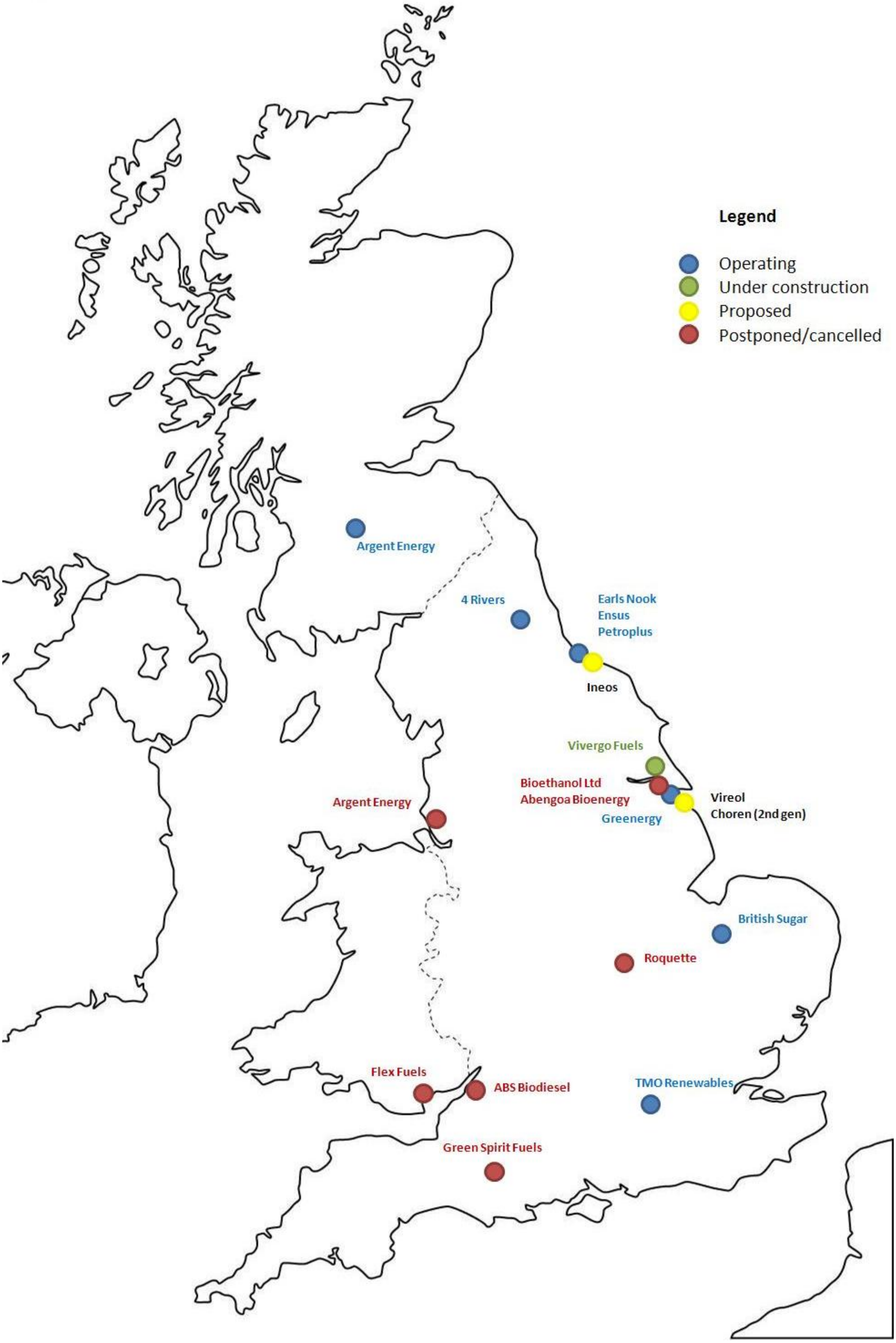
The map shows the location of seven operating biodiesel plants, and a single operating bioethanol plant. It also shows a bioethanol plant under construction and two proposed biodiesel plants.

The recent recession has meant that a number of biofuels producers have either stopped production or cancelled plans for new facilities that were due to come on line by 2010. Some of the key developments that have occurred more recently include the following:

- The Ensus wheat ethanol production plant in Wilton is now in operation;
- The previously proposed Abengoa and Bioethanol Ltd Ethanol plants in Immingham have now been cancelled as have those of Green Spirit Fuels, Henstridge and Roquette Freres at Corby. The plans for Biodiesel processing by Argent, Ellesmere Port by ABS, Bristol and by Flex Fuels Energy, Cardiff have also been cancelled. The Vivergo Fuels plant in Saltend is planned to go into operation later this year, and Vireol have now received key funding for their ethanol plant at Grimsby.
- The TMO Renewables operation in Guildford remains at the research and development stage rather than a production facility, while a lack of any news from Bio Driven, Agri Energy or Bioethanol Ltd suggests any plans are at best on hold.
- The former V fuels plant is now operating with a new investor as 4 Rivers, and Earls Nook Ltd (formerly Biofuels corporation) has itself gone into liquidation. The facility, largely owned by Simon Storage, has now been leased to Harvest Energy (a significant importer and distributor, who expect to have it back in operation this year).
- A number of small recycled vegetable oil (RVO) fed facilities have closed either due to lack of feedstock (which is limited to around 120kte in the UK) or environmental issues. The continued duty derogation for RVO has led a number of facilities to look at importing feedstock.
- "2nd Generation" biofuels have yet to make any impact, with the possible Choren plant at Immingham currently unlikely, and the Vivergo plant intending to commence ethanol production, with no date yet set for proposed butanol production. The most likely developments for 2nd Generation are the use of vegetable oils as a refinery feedstock with Total's Lindsay refinery due to deploy licensed Neste technology.

[37] http://www.biofuelwatch.org.uk/

Figure 3.2: Locations of biofuel refinery facilities (2010).



Small facilities

These are defined as biofuel production facilities whose capacity is less than 500,000 litres per year.

Complementary data on biofuel production (refinery) is available from the RESTATS (Renewable Energy Statistics) database (see Section 3.2). From the full report for 2009, a total of 77 companies were surveyed, consisting of current producers of biofuels and companies identified as possible new producers. Whilst it is not possible to present figures on capacity for individual facilities (because of commercial sensitivity) an overview of the work is provided.

Total biofuels consumption in the UK road transport sector can be obtained from figures published by HM Revenue and Customs (HMRC) (HMRC 2010) and by the Renewable Fuels Agency (RFA). HMRC figures for calendar year 2009 show that biofuels consumption in the UK has grown from 1092 million litres in 2008 to 1361 million litres in 2009. The RESTATS survey covers a sub-set of this, namely the UK production of biofuels (some of which is for use within the UK but some may be exported).

For biodiesel the RESTATs survey had 25 positive responses from producers, and presumed there were around five further, small producers in the non-respondents, suggesting there were at least 25 and possibly up to 30 biodiesel producers in 2008. By 2009, numbers were around 15 positive responses from producers but with 12 respondents indicating that they had stopped production during the last year. This supports the key message from the review of large producers that biofuel production facility plans are very fluid and can change rapidly.

The biodiesel production estimate therefore includes an estimate of production from non-respondents, small-scale commercial producers and people producing for personal use. Small-scale production is estimated to be low, about six million litres, but the contribution from non-respondents is possibly a very significant source of uncertainty in the results.

Table 3.2: Summary of UK biofuels production.

	Data for 2008 (millions of litres)	Data for 2009 (millions of litres)
UK road transport biofuel consumption (from RFA data)	1,092	1,361
Bioethanol		
UK road transport consumption	206	317
UK bioethanol production	70	76
Biodiesel		
UK road transport consumption	886	1,044
UK biodiesel production	Approx 190	223

One message from the data included in this table is that most road transport biofuel use in the UK in 2008 and 2009 was imported. For 2009 the RESTATS Executive Summary calculates the UK sourced fraction of biofuels as 21% and 24% for biodiesel and bioethanol, respectively.

Also of key interest to this study is that, in terms of volume, production levels are very unevenly distributed, with the three largest biodiesel producers making around 96% of all the UK produced biodiesel (just over 180 million litres in 2008[38]). Furthermore, only one company produced bioethanol at large scale in 2008 and 2009, and the production shown is based on their published capacity.

Bio-methane is not included in the table as only a small quantity of bio-methane for transport use was produced in 2009. However, to place it in the same context as the liquid biofuels, the sum of the UK production of liquid biofuels in 2009 was approximately 247 Mt, whereas the total production in the UK of bio-methane for transport use was 0.7 Mt.

[38] 2008 data is used because of a more complete level of response. A few non-respondents in 2009 were large producers, and this lead to large uncertainties in the data, though the pattern was the same: a few large producers dominate biodiesel production volumes.

There was not enough information provided in the RESTATs survey to provide quantitative estimates of the proportions of biofuels going into each end market. However, qualitatively, close to 100% of the biofuels were used in the road market, with a small quantity going to the UK heat and power market.

The most recent year's RESTATS survey identified one bioethanol plant starting production 2010, one planned for 2011 and two planned for 2012. The current estimate is that bioethanol production capacity would be 494 million litres in 2010, rising to 1,100 million litres in 2012 and possibly to 1,700 million litres after 2012. As discussed above, for biodiesel a significant number of companies, including some of the largest UK producers, have gone into administration or stopped production. This has affected biodiesel production capacity both currently and looking to the future. The RESTATS survey did not identify any new large-scale biodiesel production capacity, and estimated capacity for 2010 is now the current capacity of 464 million litres. The reasons for the reduced capacity included adverse general market conditions, uncertainty surrounding the value of Renewable Transport Fuel Certificates (RTFCs)[39] and possible changes to sustainability requirements when the Renewable Energy Directive is introduced.

Indications of future trends from the RESTATS report suggest that the production of bioethanol and biodiesel is likely to change rapidly over the next five years, and additional biofuels such as bio-methane may become a more significant part of the UK biofuels mix. Biofuels will also have to meet the sustainability and greenhouse gas (GHG) emissions savings targets in the Renewable Energy Directive and Fuel Quality Directive to count towards UK transport biofuel targets.

3.2.2 Capacity of UK biofuel refineries

Table 3.3 provides data on current biofuel capacity in the UK. Neither contact with the biofuel production facilities nor the 2009 RESTATS Executive Summary identified any new large-scale biodiesel production capacity that is likely to be available in the near future. Consequently, the RESTATS estimate for biodiesel production capacity in the UK remains at the 2009 figure of 464 millions of litres. It is also noted that this is for FAME, the biofuel currently specified for inclusion in "pump" diesel for road vehicles and gas oil.

Table 3.3: Summary of UK biofuels production capacity[40].

	Production volume for 2009 (millions of litres)	Production capacity in 2009 (millions of litres)
UK road transport biofuel consumption (from RFA data)	1361	1361
Bioethanol		
UK bioethanol production	76	84
Biodiesel		
UK biodiesel production	223	463

In contrast, there are several bioethanol production facilities, using wheat as a feedstock which are planned to start production in 2010, 2011 and 2012. If these plans go ahead there would be a huge increase in bioethanol production. RESTATS suggests this increase could be in excess of a factor of 20, with UK bioethanol production rising to possibly 1,700 million litres after 2012.

3.2.3 Biofuel import facilities

Table 3.4 summarises the major oil refineries in the UK and Table 3.5 summarises the major UK oil terminals. These tables are based on data available in the Wood Mackenzie report and the data have been supplemented by information obtained from UKPIA, Tank Storage Association, Linewatch, COMAH documents and existing knowledge of the project team. The information received from various enquiries suggests that, because any increase in biofuels usage will result in a roughly comparable fall in fossil fuel volume, total or excess capacity is not the most effective indicator of

[39] For further details regarding RTFCs see the RFA website: http://www.renewablefuelsagency.gov.uk/forfuelsuppliers/rtfctrading
[40] https://restats.decc.gov.uk/cms/national-renewables-statistics/#biofuels

biofuel capability. However, indications from discussions with the owning companies of these facilities suggested that modifications would need to be made. These changes are costly but if there is a demand for biofuels then the investment would not be a barrier to increase capacity. Instead the focus has been on whether a facility can currently handle either biodiesel or bioethanol. Actual throughputs for either biofuel would fluctuate on a weekly and monthly basis and are commercially sensitive information. For these reasons it could not be relied on for this report.

There are currently eight major oil refineries and eight major oil import terminals in the UK, some of these are jointly owned by a number of companies or located separately within a 1-2km area and therefore have been grouped together for simplicity. Many of these have capabilities for handling biofuels, both Table 3.4 and Table 3.5 highlight where biofuels are handled.

Table 3.4: Details of UK Oil Refineries.

Name	Owner	Connections	Biofuels handled*
Pembroke	Chevron	Sea, rail, road, pipeline	
Humber	ConocoPhillips	Sea, rail, road, pipeline	BD
Fawley	ExxonMobil	Sea, rail, road, pipeline	BD
Grangemouth	Ineos	Sea, rail, road, pipeline	BD
Milford Haven	Murco	Sea, rail, road, pipeline	BD
Coryton	Petroplus	Sea, rail, road, pipeline	BD
Stanlow	Shell	Sea, rail, road, pipeline	BD, BE
Lindsey	Total	Sea, rail, road, pipeline	BD

*BD refers to 100% biodiesel and BE refers to 100% bioethanol.

Table 3.5: Details of UK Import Terminals.

Name	Owner	Connections	Biofuels handled*	Fuels stored	Volume m^3	Number of tanks	Heated
Seal sands	ConocoPhillips	Sea, rail, road, pipeline	BD, BE				
	Seal Sands Storage	Sea, rail, road, pipeline	BD, BE	Oil products, veg oils, ethanol	219,995	111	35
	Vopak	Sea, rail, road, pipeline	BD, BE	Petroleum products, veg oils	287,000	168	
Milford Haven	Total	Sea, rail, road, pipeline	BD, BE				
	SEM Logistics *(Waterston Refinery)*	Sea, rail, road, pipeline		Petroleum, Jet fuel, ULSD	1,476,447	80	
Eastham	NuStar	Sea, road	BD	Petroleum, veg oils	346,500	163	94
	Kaneb	Sea, road	BD, BE				
West Thurrock	Vopak	Sea, road, pipeline	BD, BE	Petroleum, veg oils	393,000	125	
Grays	NuStar	Sea, road	BD, BE	Petroleum	311,000		53
	Kaneb	Sea, road					
Avonmouth	Westway	Sea, road	BD	Veg oils	24,542	41	
	Esso	Sea, road, pipeline					
	Bristol Oil Storage (Chevron) *(Royal Edward Dock)*	Sea, road					
Belfast	NuStar	Sea, road	BD				
Immingham	APT	Sea, rail, road, pipeline					
	Simon Storage	Sea, rail, road, pipeline	BD	Oil products, veg oils, ethanol	615,984	243	44

*BD refers to 100% biodiesel and BE refers to 100% bioethanol.

3.3 Audit of tank storage and pipelines

The Wood Mackenzie report indicates that the major oil companies dominate inland primary supply and oil terminal infrastructure through ownership of oil terminals and product pipelines. Appendix 3 provides details of the inland and marine storage facilities at around 60 locations in the UK together with the total volume of tank storage on-site. The information is summarised in Table 3.6. There are too many gaps in the data to be able to obtain a complete view of the total fuel storage capacity within the UK.

The large storage facilities receive and dispatch their fuel by pipelines, and tankers travelling on road, by rail and by sea. In terms of the importance of these different distribution connection options road dominates, with all storage facilities being connected by road. Around one half to two thirds are connected by sea and/or pipelines, but only six storage facilities are connected by rail.

The UK pipeline infrastructure has been extended and developed over many years. While this may offer some benefits in terms of flexibility in the system, it also means that there are potential operational constraints on the system that may reduce the effective capacity. For example, flow rates between different points on the system may vary quite significantly. This has resulted in the need for storage capacity in certain locations to regulate the flow of fuel. This makes determining the volume of product that can be transported from one location to another difficult to ascertain. Effective capacity is also impacted by the number of companies using a line and also the number of products being moved.

Table 3.6: Summary of UK tank storage.

		Types of connections			
Type of storage facility	**Number of this type of facility**	**Sea**	**Rail**	**Road**	**Pipeline**
Large storage facilities	36	23	5	36	14
Small storage facilities	9	8	0	9	2
Storage facilities for aviation	11	1	1	11	11
Storage facilities for marine	5	5	0	5	0
Total for all facilities	61	37	6	61	27

The Wood Mackenzie report discusses the key facilities. The oil refineries are supported by a dense network of product pipelines in the southern half of the UK. A summary of the information provided on UK privately owned pipelines is presented in Table 3.7 and Figure 3.3. Table 3.7 clearly highlights the dominance of the major oil companies in pipeline supply. Furthermore, most of the inland oil terminal storage facilities are owned or jointly owned by the major oil companies. In addition to the privately owned pipelines there is a network of Government owned pipelines (Government Pipeline and Storage System (GPSS)) which is primarily used for jet fuel supply (~90%). The GPSS network is presented in Figure 3.4.

Table 3.7: Key features of the UK pipeline infrastructure (source: Wood Mackenzie).

	Map Reference	**Ownership**	**Fuel**	**Detail**
1	Finaline	Total	Jet Fuel	Lindsey oil refinery to Buncefield
2	UKOP	Shell (47.8%), BP (33.24%), Chevron (15.16%), Total (3.8%)	Multiproduct	Coryton Refinery to Stanlow Refinery
3	UKOP		Multiproduct	Coryton Refinery to Stanlow Refinery
4	Exxon	ExxonMobil	Multi product	Fawley Refinery to West London oil terminal
5	Exxon	ExxonMobil	Jet fuel	Fawley Refinery to West London oil terminal
6	Exxon	ExxonMobil	Multiproduct	Midline – Fawley Refinery to Seisdon and Birmingham
7	Exxon	ExxonMobil	Multiproduct	Fawley to Thames estuary
8a	Mainline	ExxonMobil 65%, Chevron 20%, Total 10%, and Shell 5%	Multiproduct	Milford Haven/Pembroke Refineries via Midlands to Manchester
8b	Mainline		Multiproduct	Milford Haven/Pembroke Refineries via Midlands to Kingsbury and Nottingham
9	West London	West London Pipeline & Storage Limited – jointly owned by Shell, BP, Total and Chevron	Jet fuel	Buncefield to Heathrow and Gatwick
10	Walton - Gatwick	BP 60.7%, Shell 33.3% and Chevron 6%	Jet fuel	Walton-on-Thames storage facility to Gatwick
11	Manchester Airport	Manchester Jetline Ltd	Jet fuel	Stanlow to Manchester Airport
12	Finnart	INEOS	Multiproduct	Grangemouth Refinery to Finnart

Figure 3.3: Outline schematic showing the locations of privately run pipelines.

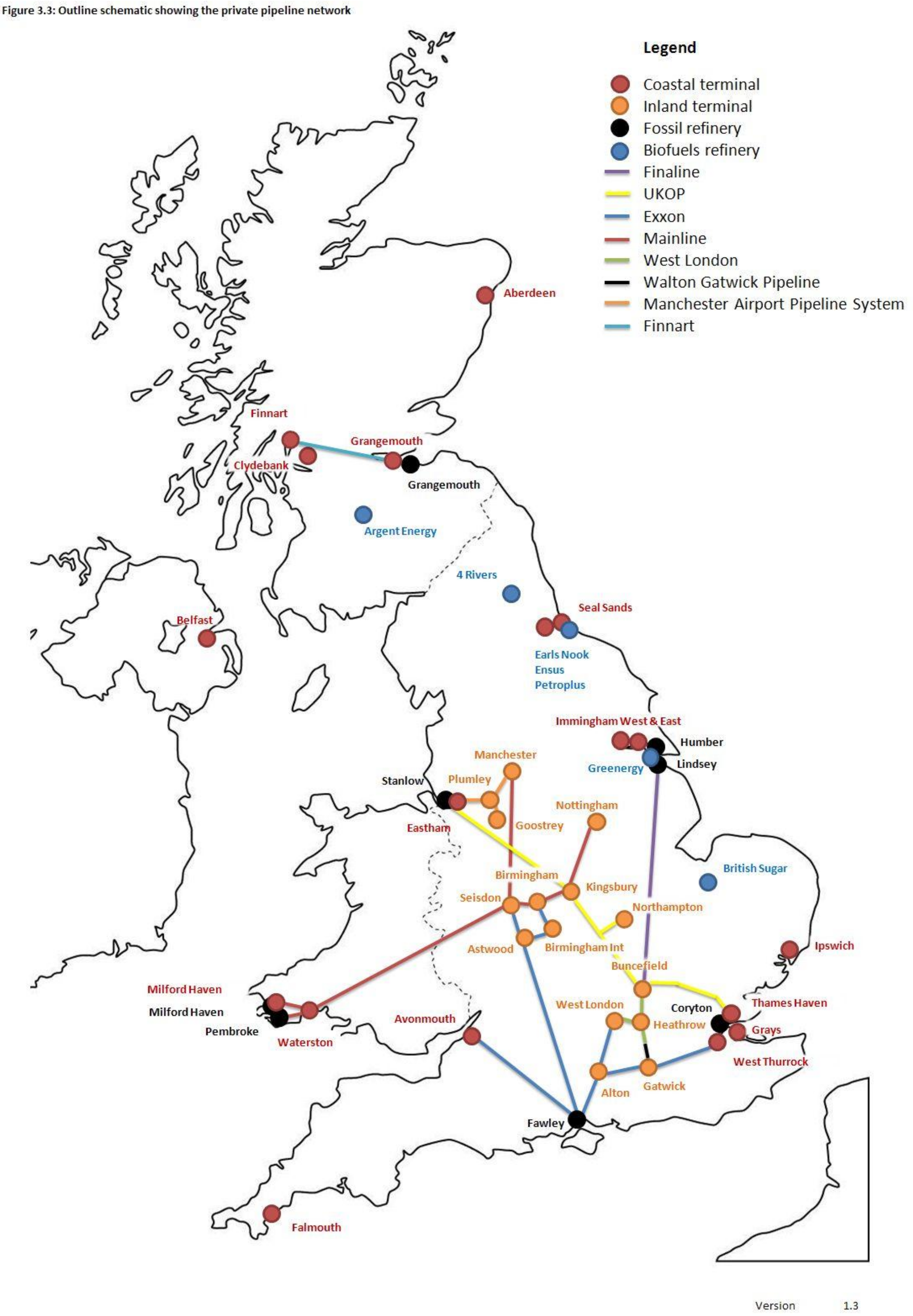
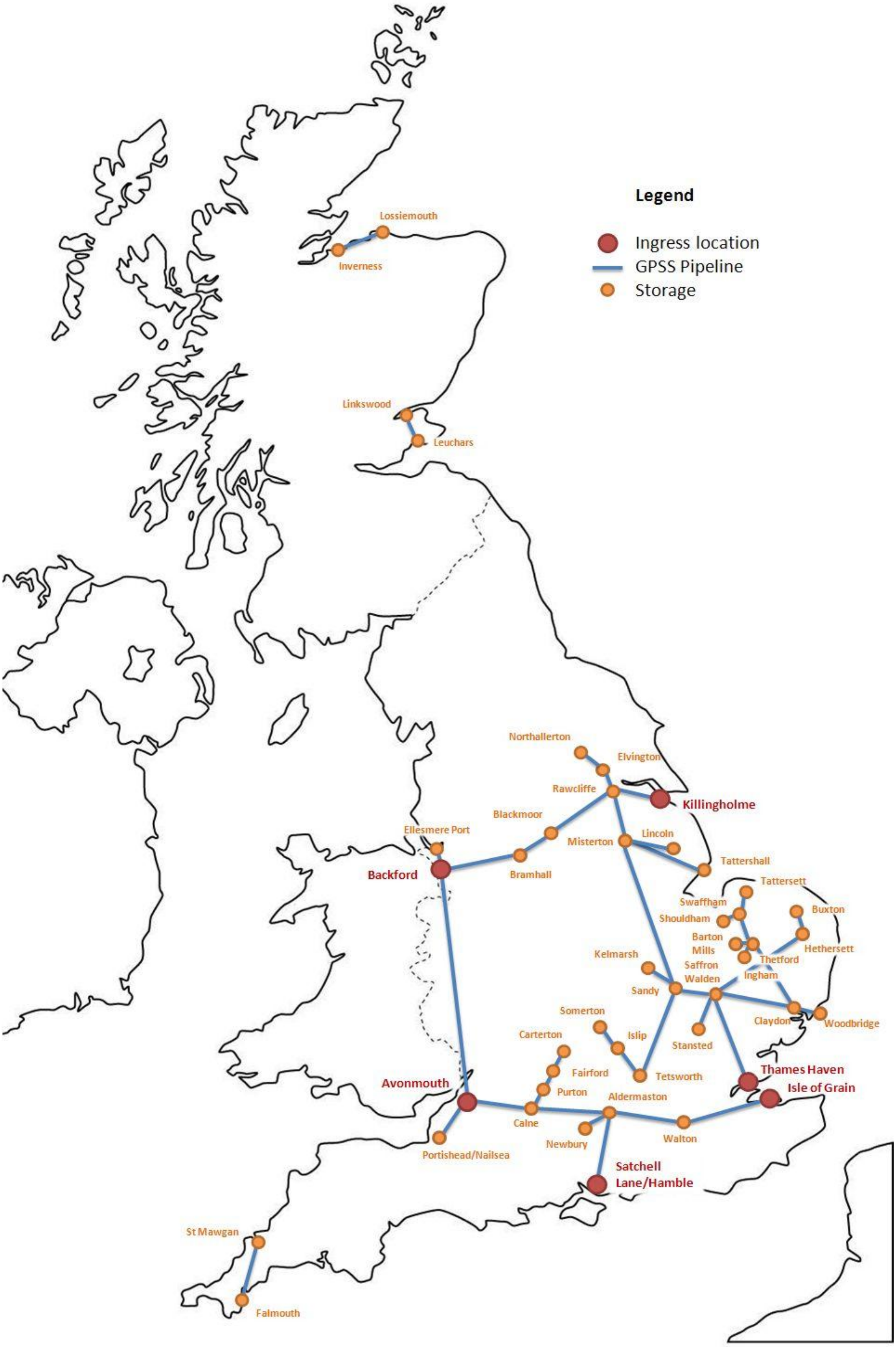


Figure 3.4: Outline schematic showing the locations of Government run pipelines.



No data were made available to Wood Mackenzie with regard to the effective capacity and volume throughputs of the various pipelines and therefore they found that it was not possible to quantify the historic or current utilisation of the pipeline systems. Based upon the information that was available to the study they concluded that all of the pipelines were generally highly utilised with the exception of the Mainline system. This pipeline, which runs from Milford Haven and Pembroke refineries to Manchester and the Midlands, was the only UK pipeline that appeared to have any significant spare capacity. There was no evidence of any biofuels being transported by pipeline.

The technical ability of the pipeline networks to carry biofuels is also unknown. Ethanol's corrosive nature and propensity to absorb water and impurities means pipeline transportation is problematic. Currently, only in the US are pipelines used to carry ethanol blends but they must be dedicated to this fuel and maintained to a much higher standard than oil product pipelines.

Transporting high strength blended biodiesel can also cause issues. The current limit on FAME contamination in Jet fuel is set at <5ppm which is the current detection limit. This has been set by the aircraft engine OEMs due to the following issues:

- At sufficiently high concentrations FAME impacts the thermal stability of the jet fuel leading to coke deposits in the fuel system
- Can also cause fuel gelling due to high pour point of FAME

These can lead to engine operability problems and possible flameout. 1m^3 of B5 in 10,000m^3 of Jet fuel equates to 5ppm.

Worst case scenario testing by a French pipeline company Trapil in 2007 suggested B10 followed directly by Jet A1 resulted in breaches of the current 5ppm limit up to 11ppm in head of jet batch but within limits in composite samples. They did not conduct testing with higher blends. The use of non-aviation buffers (e.g. gas oil) was not recommended as a long term measure due to the expected increase in FAME volumes. Simply increasing the interface volume to remove contaminated jet was not deemed economic or practical. However, UKPIA have indicated that the use of gas oil as a buffer volume is considered sufficient to mitigate this risk.

The Joint Inspection Group and Energy Institute are looking to gain approval for 100ppm FAME in jet fuel. Currently due to the difficulty in testing for FAME in jet fuel down to 5ppm very few laboratories are suitably equipped making it impossible to test each batch. Increasing the limit to 100ppm would allow the use of less sophisticated testing equipment which would not require laboratory facilities. According to the JIG, current supply chain systems will only limit inter grade contamination to 1 part in 200 whereas, for B5 this would need to be 1 part in 10,000. If this approval was granted, then the Trapil testing would suggest that B100 followed directly by Jet A1 would lead to a FAME contamination up to 110 ppm, which whilst still being above the potential new limit would be very close to being practical.

In summary, work is ongoing safety considerations/risk assessments means that a cautious approach is adopted when transporting aviation fuel.

The key gap in the Wood Mackenzie data is the lack of effective capacity and volume throughput and confirmation of the biofuel capability and capacity of the pipelines which they were unable to obtain from the pipeline operators. Within this project we have been unable to fill this gap using in-house expertise and therefore explored a number of options including a review of publicly available information (i.e. the Digest of UK Energy Statistics (DUKES)[41] and Office of National Statistics (ONS)[42]), third party reports[43] [44] and high level industry enquiries. However, despite this research we have been unable to obtain the information. As with the information on biofuel throughputs of storage facilities, examining capacity and throughputs of pipelines is not feasible due to the commercial sensitivity of the data. We have collected general data regarding biofuel transport across the entire network, which suggests that E5 and B7, i.e. current standard pump fuel, are currently transported throughout the system. Higher strength blends of either bioethanol or biodiesel are not currently transported throughout the system because of the risks described above.

Wood Mackenzie did consider biofuels within a list of future UK investment considerations for both pipelines and product storage capacity. The high capital expenditure involved and inflexible nature of oil pipelines mean there is typically a need for a high degree of long term confidence in future flows or

[41] The Digest of UK Energy Statistics is available online from: http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx
[42] The Office for National Statistics website is available online from: http://www.statistics.gov.uk/hub/index.html
[43] UK PIA: Statistical review 2009 http://www.ukpia.com/publications.aspx
[44] Linewatch – Pipeline advice ;Rev 6; Jan 2006

tariffs to weigh against the long payback times usually involved. Confidence that demand will be sustainable in the long term, with no cost competitive supply alternatives, are likely to be the key drivers determining investment. For biofuels, future increased ethanol use, especially if underpinned long term within legislation, could lead to consideration of segregated pipeline capacity to transport ethanol to inland depots. With regard to storage facilities the key drivers are commercial, determined by future expectations of future import/export trade, oil product demand and niche market opportunities (either regionally or product specific).

Increasing the number of grades distributed at a retail, and/or fleet level is likely to result in an increase in the number of small tanks at distribution terminals. The type of tank will depend on where the final grade is blended but will either require additional tankage for the blend feedstock or the finished product. In situations where the blend is carried out at refinery, such as the current trend for FAME, tanks for feedstock and finished product would be required at refinery with additional product tanks required at storage terminals despite there being no increase in overall product throughput. In the case of ethanol, blending can be carried out in tanker and therefore currently occurs further downstream at final distribution points. This requires separate tanks for storing pure ethanol on receipt from the origination point. These tanks are currently very small “additive” tanks and would not be suitable for higher percentage blends.

Consequently the replacement of current biofuel blends, e.g. E5/B7, with E10/B10 and the introduction of E85/B30, would require an increase in the number of smaller tanks.

3.4 Audit of road and rail distribution of fuels

3.4.1 Background and survey approach

In addition to distribution by pipeline, transport fuels are also distributed around the country via road transport (tankers) and via rail. As can be seen from the schematic diagram in Figure 3.1, unblended biofuels (marked in green) are predominantly transported from production facilities directly to end users or retail dispensing facilities via road or rail. The Transport Statistics Great Britain (DfT, 2009) includes statistics for the movement of petroleum products in the UK. This considers all movements both midstream and downstream. The values for 2008 are presented in Table 3.8. This shows that road transport accounts for just under 10% of all petroleum movements whilst rail accounts for less than 3%. Please note that these figures include the import of crude oil under the “Water” category. The Marine Statistics Report 2009[45] indicates that crude oil accounts for over 60% of the total crude oil and oil products transported via domestic shipping traffic. The remainder are “oil products” which includes any liquid product of crude oil and so refined fuels will be included in this category. Making the assumption that 40% of the water borne freight transport of petroleum goods is a liquid petroleum fuel, a new calculation has been derived in Table 3.8 to allow a better comparison between the transport modes.

Table 3.8: Domestic freight transport of petroleum products by mode, 2008.

Mode	Billion tonne kilometres	Derived billion tonne kilometres (assuming 40% of water borne freight is crude oil)
Road	6.5	6.5
Rail	1.5	1.5
Water	36.4	14.6
Pipeline	10.2	10.2
Total	*54.7*	*32.8*

Source: DfT Transport Statistics Great Britain 2009

This part of the study has identified companies that carry out road and rail distribution of fuels in order to survey a representative sample of operators, taking into account the need to adequately cover different geographical regions and different types of supply routes (e.g. supply from biofuel refineries directly to retail facilities vs. supply routes with intermediate steps via storage facilities and/or wholesale distribution facilities, etc). The survey work was undertaken primarily by phone and was sought to identify the numbers of tankers in operation for distributing transport fuels, the types of fuel these tankers are currently transporting, what blends of biofuel they are able to transport and the ability of these vehicles to deliver multiple types of fuels within one delivery. Importantly, information was also sought on the availability of any spare capacity, as this will be important in identifying the ability of the tanker network to handle multiple biofuel blends without the need for investing in additional/new tanker vehicles.

Rail

As presented in Table 3.8 the use of rail for the distribution of oil products accounts for less than 5% of the product miles covered when taking into account the derived calculation. At the outset of the study this was believed to be largely accounted for by two oil companies (Murco and Conoco-Phillips) and three rail companies (DB Schenker, Freightliner and First GB Railfreight). All five companies were successfully approached as part of the survey work except for the contact regarding the freight ownership and operation for Murco. In addition VTG Rail UK was identified as a key supplier of tankers to Conoco-Phillips and were also surveyed. Freightliner and First GB Railfreight were found to no longer transport fuel.

[45] http://www.dft.gov.uk/pgr/statistics/datatablespublications/maritime/compendium/maritimestatistics2009

The main routes for rail distribution are as a primary supply from refineries and import terminals, to storage terminals and wholesale distributors. There is sometimes supply to end-users (for example direct from refinery to airports and to industrial end-users) via rail, but this is minimal.

Currently no higher strength blended biofuels (above B7 and E5) are transported via rail. Issues were raised over the ability to transport higher blend biofuels due to their corrosive nature which acts on the seals and linings of the tankers. Varying estimates suggested that tankers without modification could transport blended diesel and petrol fuels with 10% to 15% biodiesel and bioethanol content respectively, with tankers requiring testing for the impact of higher blends on the seals and linings. The consensus from the rail freight companies was that no tankers in the UK are currently able to transport higher percentage blend biofuels. One company is currently working on a solution to this and hopes to have this ready by early 2011. The need to investigate and initiate modification is purely market driven as opposed to being a technical obstacle which could not be overcome although there would be costs and time implications associated with these modifications. A rough estimate given was £5,000 per tanker to modify linings and an estimate of 6 to 12 months as a maximum lead time to meet any new demand in transporting significant volumes of higher blends. It must be noted that in the current economic climate there would need to be significant customer demand to initiate any such changes.

VTG Rail UK hire out tankers to oil companies (for example, to Conoco-Phillips), and currently operate 600 wagons and are operating at 92% capacity. DB Schenker currently operates 900 wagons across the UK with an average capacity of 70 tonnes each. They are operating at full capacity – any increase in demand would require them to commission more wagons at a cost of approximately £150,000 each and a lead time of 12 to 18 months. Each wagon is a single compartment but a train can pull multiple wagons with different fuel grades in each wagon. There is therefore the capability to blend at the delivery point and indeed this is undertaken for some customers.

Road

This sector is diverse and complicated, relating to primary supply of smaller terminals and end user/retail site deliveries. The key players are respectively large logistics companies and oil companies (increasingly through third party haulage) and the captive fleets of small distributors/re-sellers. In the former category, we approached Conoco-Philips, Wincanton, Hoyer, Chevron-Texaco, TDG Exel, Greenergy, Harvest and Mabanaft. Responses were not forthcoming from a number of these contacts, primarily due to confidentiality issues or difficulties making contact with an appropriate person. Responses were received from Hoyer, Conoco-Philips (who contract to Wincanton, DHL and Suckling Transport), Harvest and Greenergy. Five smaller distributors were also contacted. No responses were received from these companies.

All of the road tankers currently transport B7 and E5. There was, however, some discrepancy in responses as to the ability of road tankers to transport higher percentage blended biofuels. Those companies which have not been involved in transporting higher blend biofuels were unsure as to the ability of the tankers to transport these fuels and the need for modifications. Those companies with experience of handling higher strength blends stated that there were no issues or barriers to the transport of these blends by road other than some minor modifications: for example, changes to tanker seals and vents to carry high blend ethanol products and, depending on the feedstock, improved insulation or heating for some high strength biodiesel blends.

Capacity was not considered an issue by any of the respondents. All companies were operating at or close to capacity but had the flexibility to expand. Companies operating their own fleets had the capability to hire in additional tankers whilst companies which use third party haulage are continually expanding and contracting the fleet depending on demand.

The road tankers have one, four or six compartments although the majority have six - one respondent stated that 90% of their fleet had six compartments. This would allow the transport of multiple blends. The tankers transport typically 38,000 to 40,000 litres (44 tonnes gross vehicle weight). One respondent worked on a basis of 2.5 deliveries per shift and two shifts per day with a fleet currently comprising 200 trucks. Another respondent detailed that the majority of their movements consisted of the transport of fuels from terminals to industrial sites (rail and bus depots, industrial sites) and to forecourt retail.

The RTFO standards were seen as generating an upper blend limit which has discouraged a movement toward the use of higher strength blends. As with all other sectors surveyed the removal of the duty incentive saw a cessation of almost all high strength blended biofuel usage. Some end user companies had invested in infrastructure and vehicles to allow them to utilise higher blend biofuels and take advantage of the duty incentive; this was coupled by development of the wider infrastructure to support them and meeting the demand. Greenergy and Harvest were both supplying this demand prior to the removal of the duty incentive. The removal of this incentive has reduced involvement in high strength blended biofuels across the industry to almost to zero.

Coastal Trading Ships
Coastal trading ships are used for trade between locations on the same island. ChevronTexaco was identified as having a disproportionate role in this activity and were surveyed. Standard pump biodiesel (B7) is blended at the refinery and then loaded onto the coastal tankers for transport to terminals. There is currently no transport of any higher blend biodiesels. Although there were no capacity barriers to increasing the proportion of biofuel blended and shipped, there would potentially be an issue with transporting blends above B15 or B20 as the coastal tankers do not currently have the ability to keep the fuel heated. There has been no investigation of this at present. Blended bioethanol is not transported via coastal tanker due to issues of separation in the presence of water. This is blended at the terminal prior to distribution by road. No information could be provided on the volume of fuel transported due to commercial confidentiality issues.

3.5 Audit of end user fuel dispensing facilities

3.5.1 Background and survey approach

Transport fuels are delivered to vehicle operators and consumers via a number of mechanisms including consumer-facing retail refuelling facilities and on-site depots. An audit of fuel dispensing facilities is required to understand how much capacity is currently available for delivering biofuels to final users (i.e. vehicle operators) covering all modes of transport. This is important as whilst currently, biofuels are predominantly delivered to final users in the form of low-percentage blended fuels (i.e. most petrol and diesel contains a minor biofuel element), in the future, in order to meet RED and FQD targets, it is likely that multiple types of biofuel blends will need to be available at retail fuel stations and possibly also at on-site depots. In particular, there may be a need for additional fuel grades to be available on retail service station forecourts to preserve availability of E5 petrol/ethanol blend for those older vehicles unable to use E10 or higher blends.

Given this situation, it is necessary to gather data on the capacity of dispensing facilities to accommodate multiple blends – i.e. gathering data on the numbers of tanks and dispensing pumps available at individual facilities in order to build up an understanding of the feasibility for dispensing facilities to provide multiple blends of biofuels. Our approach to gathering this information, for both retail forecourt facilities and other dispensing facilities is presented below.

Retail forecourts
Consumer-facing retail refuelling stations can be broken down into:

- Oil company/franchised refuelling stations
- Supermarket refuelling stations
- Independent refuelling stations

In total, there are around 9,000 retail forecourt facilities in the UK. A mixture of two approaches was utilised to gather data on the numbers of fuel grades that can be accommodated by these facilities. Firstly, DfT acquired for this study the Catalist data base which is produced by Experian. This holds detailed information on all UK retail refuelling stations, including data on number of fuel pumps, geographical location of each refuelling station and volume of fuel dispensed. To supplement the Catalist database additional survey work was undertaken on a subset of retail facilities to gather more detailed information specific to biofuel. The survey work aimed to collect information on the number of storage tanks, current and potential biofuel capability, and the degree of unused capacity which is important data not available from the Catalist database. The Catalist database was used to shortlist the companies approached during this survey.

The Catalist database listed a total of 2,776 companies involved in dispensing fuel at just over 9,000 retail outlets. The fifteen companies with the greatest number of retail outlets account for 47% of the total retail outlets whilst the ten companies with the greatest fuel volume throughput account for almost 75% of total volume throughput. The companies are listed in Table 3.9 and are primarily comprised of a mixture of supermarkets and oil companies. This table also highlights the domination of a small number of companies in this overall market. The cooperation of these companies with any policy to increase the volume of biofuel usage within the UK car private sector is therefore crucial. The converse of this, however, is the fact that 50% of the retail outlets are operated by over 2,700 different independent companies. Although these only equate to, approximately, 22% of the total volume of fuel sold in the UK, the ability of these companies to facilitate higher blend biofuel within their existing infrastructure is significant.

Table 3.9: Rank of companies by number of retail outlets and volume of fuel sold.

Company	Number of retail outlets	% of all companies in UK
Tesco Stores Ltd	643	8.32%
Total UK Ltd	453	5.86%
ROC UK Ltd	381	4.93%
Shell UK Ltd	304	3.93%
WM Morrisons Supermarkets Plc	293	3.79%
MRH (GB) Ltd	289	3.74%
J Sainsbury Plc	255	3.30%
BP Oil UK Ltd	230	2.97%
Murco Petroleum Ltd	182	2.35%
Asda Stores Plc	180	2.33%
Somerfield Stores Ltd	139	1.80%
Co-op Group	86	1.11%
Snax 24 Ltd	76	0.98%
Euro Garages Ltd	61	0.79%
MPK Garages Ltd	56	0.72%

Company	Litres of fuel per year ('000)	% of all companies in UK
Tesco Stores Ltd	6,474,591	18.14%
WM Morrisons Supermarkets Plc	3,300,550	9.25%
J Sainsbury Plc	3,150,500	8.83%
ROC UK Ltd	1,813,324	5.08%
Asda Stores Plc	1,752,000	4.91%
Shell UK Ltd	1,680,900	4.71%
Total UK Ltd	1,576,200	4.42%
BP Oil UK Ltd	1,552,000	4.35%
MRH (GB) Ltd	1,066,686	2.99%
Somerfield Stores Ltd	727,431	2.04%
Murco Petroleum Ltd	526,879	1.48%
Moto	416,717	1.17%
Welcome Break Group Ltd	392,450	1.10%
Snax 24 Ltd	366,300	1.03%
Co-op Group	309,155	0.87%

The Catalist database was also used to produce a shortlist of companies to contact for more detailed information. The 15 companies with the greatest number of retail outlets (as listed in the left-hand column in Table 3.9) were approached as were a random sample of 14 small, independent companies. From the companies listed in Table 3.9 responses were received from four companies, this was supplemented by additional on-line research. Contacting the smaller, independent companies proved extremely difficult; however a definitive overview of the sector was obtained via contacting the Petrol Retailers Association.

Survey results

The majority of the companies with the larger market share currently offer a minimum of three fuel grades at the majority of their outlets, one respondent quantified this with 95% of their stores selling three grades, diesel, gasoline and super unleaded, with two grades being sold at the remaining 5%. The companies with smaller scale operations and a small number of supermarkets only offer standard diesel and petrol at all of their sites. All respondents confirmed that they are currently operating at full storage capacity. No tanks are out of commission with some sites having three to four deliveries a day to meet demand. This was particularly the case with supermarkets which in general were found not to build large storage tanks but instead rely on an efficient delivery infrastructure which is more flexible and able to respond to fluctuations in demand.

The expansion into higher blended biofuels was not seen as economically viable by any respondents due to the small size of the market. Most respondents reported that they do not have the infrastructure capacity to extend to additional blends of biofuels on top of what is currently offered and significant investment would be needed. Additional costs were also cited for cleaning as well as the need for improved water management.

One respondent discussed a general period of disinvestment across the sector. They believed that the most effective way forward would be for legislation to increase the biofuel content of standard blends in a step change process (to potentially B10 and E10) across the board so that there is market consistency and to limit the amount of expenditure needed for new infrastructure.

Only one respondent had trialled the sale of both B30 and E85 at their filling stations. They ceased selling B30 in anticipation of the removal of the duty incentive in April 2010 and since then have also withdrawn their supply of E85 across their filling stations. Out of some 300 retail sites owned by the company, there were 144 which had the ability to sell B30 and 20 which had the ability to sell E85. Of the 20 sites selling E85, 10 sites were modified with the addition of a new tank and associated pipework at a cost of approximately £20,000 per site, the other 10 sites were located at new filling stations and the required infrastructure was built as part of the planned construction of these sites. For B30 no additional work was undertaken to facilitate the additional blend of fuel. The existing infrastructure consisted of 4 to 5 tanks (or tank compartments) with a fixed configuration of underground lines plumbed and carrying the two grades to each of the refuelling positions. Within this configuration B30 was offered at usually one pump utilising one of the storage tanks. This experience suggests that other companies could provide higher blend biofuels whilst maintain supply of the standard grade fuel within their existing infrastructure, but that there is currently a strong reluctance to reduce the volume of standard grades available for economic reasons.

One of the key challenges for the existing infrastructure was the additional maintenance costs (such as cleaning) associated with higher blend biofuels. The higher biofuel content increased the housekeeping required which increased expense and disruption. In particular E85 is much more corrosive and also separates in the presence of moisture, which is extremely difficult to remove from the underground storage tanks. A separate hurdle to overcome was that B30 was only available from one supplier and the supply infrastructure was therefore limited. In order to distribute the fuel a "milk–round" style delivery had to be undertaken which was expensive and time-inefficient. Finally, the cessation of the duty incentive made the sale of these biofuel economical unviable as well as removing the economic motivation to invest in further infrastructure changes.

The contact from the Petrol Retails Association provided a very similar summary to the contacts discussed above. These are summarised below:

- Smaller retailers are generally operating at full storage capacity and would not have tank capacity which would be unused. In some specific cases, filling stations have stated the opinion up that licensing authorities may have been over-zealous in decommissioning tanks which have fallen from use.
- Bioethanol has a tendency to separate if it is mixed with sufficient quantities of water, which means it has to be returned (uplifted) and disposed of as hazardous waste at the cost of the retailer. Water occurs naturally in underground storage due to condensation, exacerbated by fuel being supplied at high temperature. This also gives rise to potential microbial growth and subsequent corrosion of tanks. When quality problems occur, it is very difficult to prove who is at fault along the supply chain and usually the onus is on the retailer to prove negligence or errors.
- Moving to E10 in a step change process is preferred by retailers. A single tank commitment to biofuels could be updated with gradually higher blends. This would need to be driven by suppliers. There would also need to be the confidence that if there was a move to E10 that all cars would be able to use this blend as providing E5 widely in parallel would be expensive.

- Small retailers and rural communities in particular will only have the option to supply two blends - petrol and diesel. They will not have the infrastructure capacity or the demand to expand to high strength blended biofuels.
- At the moment, there is not a sufficient profit margin on higher strength blended biofuels for retailers to sell these in preference to the standard diesel and petrol blends.
- If smaller rural sites were to build additional capacity for higher strength blended biofuels, including both additional storage facilities and additional pumps, they may also be burdened with having to invest in Stage 2 petrol vapour recovery facilities. Stage 2 vapour recovery captures the evaporated petrol emissions of vehicles which escape into the atmosphere during the refuelling process at filling stations. Under UK legislation, sites with petrol sales above 3.5 million litres per annum were required to install petrol vapour recovery facilities before the 1st January 2010. By adding additional capacity to smaller sites, this may require them to spend between £30,000 and £60,000 installing these facilities to comply with this legislation.

Further analysis of the Experian database

We have attempted to provide some quantification of the qualitative comments using data from the Experian database, bought from Catalist UK, to define the numbers of fuelling stations able to handle high blend strengths. However, this was hampered by the Experian database not containing details on the number of storage tanks, and how many nozzles each multi-fuel pump has. However, the stakeholder consultation indicated that it was the smaller, rural, filling stations which do not have the tank or pump capacity to handle higher blends. Our survey indicated that all forecourts visited with four or more multi-fuel pumps offer at least three blends of road fuels. The Experian database indicates 65% of forecourts have four or more pumps, and these forecourts sell 85% of forecourt road fuel. Our survey revealed that some forecourts with three pumps also sell more than two blends, and therefore we believe this is a conservative estimate

The analysis of the database indicates that the average fuel sales for each pump per filling station increases with increasing numbers of pumps, as shown in the table below.

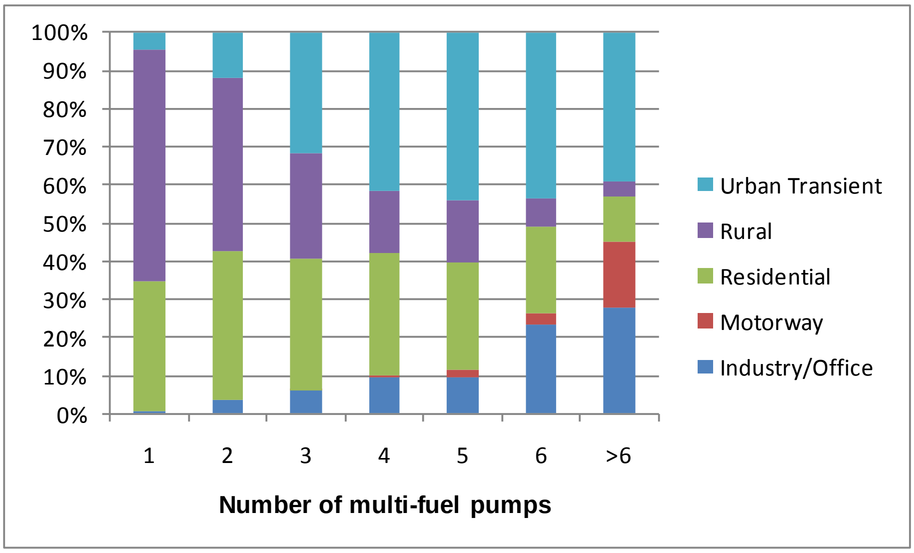
Table 3.10: Average volumes of fuel dispensed, and numbers of filling stations, for stations with different numbers of multi-fuel pumps.

Number of multi-fuel pumps	Average vol of fuel sold for each pump (1000s litres)	% of all fuel dispensed	Cumulative % of all fuel dispensed	% of all filling stations with this no of pumps	Cumulative % of all filling stations with this no of pumps
1	280	0.16	0.16	2.20	2.20
2	470	2.89	3.05	12.6	14.8
3	870	12.3	15.4	19.7	34.5
4	1,000	39.1	54.5	41.0	75.5
5	830	6.2	60.7	6.3	81.8
>5	>1,000	39.3	100.0	18.2	100.0

The table shows how the volume of fuel sold for each pump is around, usually above, 1,000,000 litres per pump for retailers with four or more pumps, and under half this for retailers with one or two pumps. Given that a retailer's income is the average sales per pump multiplied by the number of pumps, this means retailers with one or two pumps have, on average, less than a quarter of the income of those with four or more pumps. Consequently, retailers with small numbers of pumps will typically only choose to supply two blends, incurring the running costs for having two storage tanks, whereas retailers with four or more pumps **may** choose to supply three (or even more) blends.

The Experian database does contain a column entitled "location type" categorising each filling station location into urban transient, rural, residential, motorway and industry/office (plus a few further categories that comprise less than 0.1% of all retail locations). Figure 3.5 shows the breakdown of retailers with different numbers of multi-fuel pumps by location type. This figure shows that the vast majority (three quarters) of filling stations with fewer than four multi-fuel pumps are either in rural or residential areas.

Figure 3.5: Breakdown of retailers by location type for different numbers of multi-fuel pumps.



The Experian database also categorises filling stations by site type, describing 83.6% as “petrol stations”, 13.1% as “hypermarkets”, 2.7% as “service areas” and the remaining 0.6% as “kerbside”. For the filling stations with fewer than four multi-fuel pumps 97% are described as “petrol stations” whereas 98% of “hypermarkets” and 94% of “service areas” have more than four pumps.

It is emphasised that the Experian database does not specify the number of fuel streams available at filling stations and the analysis above is based on the premise that filling stations with fewer than four multi-fuel pumps are unlikely to have more than two fuel streams, whereas those with four or more pumps offer at least three fuel steams. There are no data to indicate how many filling stations can take four or more fuel streams.

Conclusions

The two options for retail filling stations looking to sell higher strength blended biofuels are in essence to either a) invest in new capacity or b) replace existing fuels with higher strength biofuel blends. The investment in new capacity is costly (and possibly logistically not viable at some locations) but even if no new capacity is required there are still costs associated with utilising existing tanks. These were estimated by PRA, based on their representation of 6000 retail filling stations across the UK, as below:

- Initial costs of preparing underground storage tanks includes around £2,000 for dewatering and up to £4000 for sludge removal. The costs for the removal of sludge can be as high as £4,000 as it may require man entry to clean badly contaminated tanks, due to uplift of fuel and making tanks safe to enter;
- Site visits, if necessary, to clear or replace filters can cost around £350 per site;
- Fuel polishing, where fuel becomes contaminated with microbial growth can incur costs of around £800 per tank.
- Disposal of contaminated waste costs approximately £120 per 1,000 litres;
- Cleaning and flushing of suction lines, where necessary, costs around £50 per suction line with an average site having around 10 lines;
- Older sites without access through tank lids may need specialist drilling, due to flammable substances which are stored, with costs around £750 per tank;
- Ongoing costs for checking the condition of tanks and quality of stored fuel costs approximately £500 per annum.

Following further conversations and clarification with the PRA the retail infrastructure costs that have been included in the Biofuels Modes 2 model, aggregating and augmenting information given above, are:

<u>Changing existing fuel tanks to B30 (for diesel tank) or E85 (for petrol tank)</u>
Capital costs £2,000 - £5,000
(where Higher figure is for older tanks which require specialist drilling and man entry into tank for water and sludge removal).
Operating costs £1,000 - £1,500 per annum

<u>Adding new B30 capacity</u>
Capital costs £75,000 - £100,000
Operating costs £500 - £750 per annum
(assuming the frequency isreduced by a half compared with repurposing existing capacity)

<u>Adding new E85 capacity</u>
Capital costs £95,000 - £120,000
Operating costs £500 - £750 per annum

On-site fuel depot dispensing facilities

For a number of applications, transport fuels are supplied to vehicle operators from on-site fuel depot dispensing facilities. The key sectors which utilise storage depots are airports, rail, road and ports. Each sector was surveyed directly via telephone and email. The sampling strategy employed and findings for each sector are discussed below.

Airports

Aviation fuel supply falls into two categories: major airports, predominantly fed by pipeline, and minor airports/airfields, largely road fed. The volume of fuel used by minor airfields will be dwarfed by the large commercial airports and so only the larger airports were considered.

At the larger airports the only fuel stored is for the use of airside ground vehicles which encompasses a large number of vehicle types. The diesel used is road grade with biodiesel fraction up to 7%. Some airport companies are interested in using higher strength blends of biodiesel, but there is concern that manufacturers' warranties would be invalidated. There is no envisaged barrier to utilising existing storage facilities to store a product with a higher biofuel content.

The fuel for the aeroplanes is supplied via pipeline. This is Jet A-1 fuel which is a jet fuel produced to a standardised international specification. In August 2009, the American Society for Testing and Materials International Committee on Petroleum Products and Lubricants approved the use of up to 50% blends of bio-derived Jet A-1[46] and the expectation is that the UK will follow this lead. In the event that the UK follows the US model, the fuel will be indistinguishable from crude-based Jet A-1 when it arrives at the airport. The airport will therefore be able to handle both types of fuel in exactly the same way, as it is a drop-in replacement fuel, and there are no issues with the end user.

Rail

This sector is by definition, return to base fuelling, with all light maintenance depots holding fuel stores for non electric rolling stock, in many cases, supplied by road. Communications with the rolling stock companies (ROSCOS) and with the Association of Train Operating Companies (ATOC) indicated that there are around 50 fuel depots in the UK. These are generally run by Network Rail, but in some cases are run by Passenger Train Operating Companies. The structure of a typical on-site rail fuel depot, and its fuel dispensing facilities, are that a tank (or a network of tanks) has a single pipe network from the tanks to the filling points. The importance of this structure is that all locomotives must run on the same fuel.

Where trials are being (or have been) conducted (for example by the Rail Safety Standards Board (RSSB) with First Great Western and South West Trains (RSSB, 2009)) a separate, dedicated, fuel

[46] http://www.astm.org/Standards/D7566.htm

tank and dispensing pump has been required, so that the locomotives in the trial can conveniently be fuelled with the biofuel blend.

Road

Road fuel storage has been split into three core sectors: road haulage; bus and coach operators and public service fleets (emergency services/refuse etc). All three have traditionally utilised high percentages of return to base fuelling, although in recent years there has been a significant migration, often driven by cost or health and safety concerns, to third party fuelling using fuel cards from commercial bunkering sites and from truckstops to retail forecourts. Buses and coaches remain almost exclusively return to base due to a combination of public safety and proximity to base. The fuelling facilities are usually of a fairly primitive one grade nature, but may offer a significant opportunity for the utilisation of “drop in fuels” with significantly greater fleet flexibility than exhibited in aviation. Each sector is considered below:

Haulage operators

Hauliers account for circa seven million tons of oil equivalent (Mtoe) per annum of road fuel which is seven times the amount used by buses and coaches. Operators range from one man owner operators to large national logistics companies. In 2008 there were 95,000 goods vehicle operators of whom it has been estimated between 2,000 and 3,000 had some form of on-site fuel storage. Following the sampling strategy outlined in Appendix 4, 17 haulage companies were approached. Of these, responses were received from three large and four small operators.

Fleet sizes of the respondents ranged from less than 3,000 to 33,000 vehicles. Of the answers given it was noted that the smaller operators tended to have vans as their predominant vehicle type. While for the larger operators the type ranged from mopeds to artic lorries.

Companies surveyed used either 100% fuel cards or a mixture of fuel cards and return to base (depot) refuelling. Where a mixture of fuel cards and return to base was used there was no consistent split across the companies with fuel card usage ranging from 25% to 75%. Where fuel cards were preferred this was generally stated to be due to issues with storage, handling and environmental issues associated with bunkering. The key reason cited for the continuation of depot refuelling was due to the presence of artic lorries in fleets. One respondent acknowledged that it would be possible to refuel this part of the fleet via fuel cards but it is unlikely to be cost effective to do so where a company operates a significant number of artic vehicles plus the size of the vehicles limits the number of refuelling sites that can be accessed. The Experian database includes the number of HDV pumps as a separate column. Analysis indicates only 19.6% of all the filling stations are listed as having any HGV pumps, and of these 64% have only a single pump. However, many of these filling stations whilst suitable for smaller rigid HGVs cannot accommodate large articulated trucks. No additional data were forthcoming to quantify the proportion of the fuel used by heavy goods vehicle obtained from depot storage as opposed to fuel cards.

Those companies with depot facilities are all currently storing standard diesel fuel (up to B7) only. The number of depots available to a company reflected the proportion of their fleet that was fuelled at base, the fleet size and the geographical coverage of the company. This ranged between 6 and 256 depot sites. The depots were reported to typically have one tank although where there is heavy use a small number of depots have up to three tanks.

When asked why higher blend biofuels were not being used, the key barriers put forward were a lack of commercial incentive (i.e. no duty incentive), no consistent supply of higher strength blends in the required volumes and concerns over the limited supply of fully certified sustainable biofuels. There was also the implication that widely providing more than one blend would be restrictive due to the depots primarily having one tank. Due to the lack of commercial incentive it was clear that respondents had not considered the feasibility of the installation of additional tanks across their depots to facilitate a concurrent use of a higher blend biofuel.

A number of respondents have trialled biofuels. The key issue was found to be fuel waxing, where waxes in the fuel precipitate out as very small crystals as the temperature drops. Continued low temperatures can cause these fine crystals to grow together into much larger crystals which can block fuel filters and pipelines, causing engines and heating plant to fail due to fuel starvation. This is not an impurity issue, that can be solved by changing filters more frequently, but a reversible phase change that occurs at low temperatures. It reflects some current limitations on the low temperature characteristics of biofuels relative to diesel fuel from fossil sources, and may be overcome in the future by further processing of the fuel, or the addition of additives.

Bus and Coach Operators
Bus and coach operation is less fragmented than road haulage, with five operators representing 65% of vehicles. These five companies were surveyed plus two smaller companies were included to establish if there were any significant differences in their infrastructure.

The majority of operators work to a return to base fuelling policy with the exception of one company operating on national routes which use fuel cards. The respondents from the other companies reported that the majority of the depots have one tank ranging in size from 25,000 to 100,000 litres, with a minority, mainly older depots, having two tanks. At the majority of depots, the move to higher blend strengths would therefore require all buses to use the same fuel or require depots to install additional storage facilities to cope with multiple blends. One respondent provided some particularly detailed information as to the estimated costs involved with both of these options:

- If the existing bulk storage was to be used the existing tank would require fully cleaning and additional electrics installed to keep the fuel warm. This would cost in the region of £20,000.
- If additional storage was required the level of investment would depend on the number of vehicles that were to be refuelled:
- If there were a small number of buses at a depot, say less than 20, a bulk tank of between 20,000 to 30,000 litres would probably be installed if space allowed. This size tank would minimise the number of deliveries from the fuel supplier. This would cost approximately £50,000 to install which would cover the installation of a concrete slab, the new tank, all the electrics and the bunding of the tank. Although installation of a small tank can be completed within 20 working days, the lead time for a new tank can be as much as six months, along with all the planning associated with such a design.

For larger depots where the standard bulk tank specification is 100,000 litres, the cost for a biofuel installation would be approximately £100,000. Changes of this scale are usually carried out in conjunction with other major refurbishments.

Public Service Fleets
Emergency services appear to be in wholesale retreat as far as return-to-base fuelling is concerned. The widespread removal of storage and refuelling facilities in favour of limited strategic/emergency stock, suggests that expansion of biofuel supply in this area will centre on third party supply. This, coupled with the insignificant market share held by any remaining return-to-base refuelling use and the tight budget, led to the decision that it was not necessary to survey these end-users.

To understand how local authorities may utilise biofuels, AEA had the opportunity to utilise a resource which is currently unpublished. During 2010, AEA assisted DECC (Department of Energy and Climate Change) in the collation of information for National Indicator 185 – “Percentage CO_2 reduction from local authority operations”[47]. As part of this exercise all English local authorities were asked questions about their fuel consumption. This was used to calculated CO_2 emissions for the financial year 2008/09. They were not explicitly asked a question about biofuel use but were asked what fuel they used in their fleet. AEA was able to analyse the submissions to investigate the frequency of biofuel use in the responses. Of the 327 Local Authority responses only 5 discussed the use of biofuels in their fleets. This approach may not have captured all local authorities which use biofuels but serves to demonstrate the low frequency of biofuel use in this sector.

To gather some further information each of the five Councils were approached. Responses were received from three. Two respondents had trialled biogas but had not continued with its use. The respondents were not able to supply information as to fuel storage capability. The third respondent reported that it was using B30 diesel and that this accounted for 13% of its total diesel usage per year. The fuel was stored in a single location with a separate storage tank for each grade they use.

[47] http://www.decc.gov.uk/en/content/cms/statistics/indicators/ni185/ni185.aspx

- Cambridge City Council trialled three vehicles on biogas in 2000. Since this was ten years ago the challenges they report do not reflect the "current capabilities" and are not detailed further. They currently do not use higher blend biofuels in their fleets and have no plans to do so in the near future.
- Oxford City Council are using 600,000 litres year of standard B5 diesel, 90,000 litres year of B30 diesel, 80,000 litres year unleaded petrol (which will contain some ethanol) and 25,000 litres year gas oil. Oxford City Council has a single location where the fuel is stored. They have separate storage tanks for these four fuels.
- Reading Borough Council currently utilise standard conventional diesel but trialled biogas last year. They are currently investigating options for taking forward the use of biogas. The ability to store other biofuels was not known by the respondent.

Marine

Marine supply falls into essentially two categories: large scale port based refuelling (often within refineries/major store, for export under bond); and smaller scale coastal/inland waterway refuelling. These facilities, even where co-located with major refining/storage assets, are often operated by separate divisions or independent bunkering companies. Our first contact made was with Fawley Refinery. This contact provided sufficient information to formulate a good overview on this sector.

The key issue with the use of biofuels, as discussed in Section 2.5, is that shipping can only use the permissible specifications.

With respect to the current infrastructure the majority of the depots consist of a single tank fed by pipeline. Although there was no perceived issue with storing biofuels there was no scope for storing both standard fuel and a biofuel blend due to it being cost can be prohibitive. An estimate was provided of $12 million construct one tank which does not include the need to provide an additional pipeline feed. The key barriers to using vegetable oil or Biomass to Liquid (BTL) fuels, other than the current UK guidelines, were deemed to be the absence of any obligation and a lack of sufficient supply.

4 Audit of biogas capacity

Biogas is a mixture of gases produced by anaerobic digestion (AD). Its major constituents are methane (chemical formula CH_4) at about 60% and carbon dioxide (CO_2) at around 30% to 40% with other gases in trace amounts (mostly hydrogen sulphide and ammonia). The composition of the biogas depends on the type of feedstock and the type of AD. Biogas can be 'upgraded' to biomethane by removing contaminants in the raw biogas stream leaving 98% methane per unit volume of gas. Four different elements are required for the use of biomethane as a vehicle fuel. They are:

- A source of biogas
- Cleanup equipment, to convert the biogas to biomethane
- Gas transportation, storage and dispensing infrastructure
- Vehicles able to use the gas

All four elements need to be developed in parallel. Below we offer a brief qualitative overview of each, and whether/how it is likely to limit biomethane use in transport.

4.1 Sources of biogas - current and potential UK production

The UK biogas resource is extremely large, consisting of landfill gas, sewage gas and an increasing supply of gas from anaerobic digestion plants. Taken together, these sources might not fuel the entire UK vehicle fleet, but they would certainly not be the limiting factor on the uptake of biomethane vehicles for the foreseeable future.

Table 4.1 has been constructed from the reported waste arisings and an estimate of the abandoned arable land that may be accessed for growing energy crops to make feed for AD plants[48] (Defra 2007; Defra 2005; WRAP 2010). To each waste stream, the biogas production potentials have been estimated. The figures in the table represent the ‘potential biomethane’ energy (in GWh and in ktonnes) and have been converted from biogas on ‘energy equivalent basis’. Any parasitic loads (i.e. energy uses on the AD plant or gas clean up and compression plant) have not been subtracted (these may typically represent between 15% and 25%).

In practice, only a fraction of the existing biogas supply is likely to be made available for transport under the current economic conditions and incentives. The default use of biogas is to burn it in a generator to generate electricity – this use attracts Renewable Obligation Certificates (ROCs)[49], and going forward smaller plants will be eligible for a Feed-In Tariff (FIT)[50].

AD plants can claim two ROCs per kWh of electricity generated and so the business case for most AD plants currently being planned is based on electricity generation. The incentives would have to alter very significantly for this to change.

[48] There will be some abandoned arable land and pasture land that will no longer be required for food production which by 2030 could be around 1.1 Mha (E4Tech, 2009). Given that total area of tillage land in the UK is around 4.7 Mha, with about 6.4 Mha of grass, we have taken 0.5 Mha of abandoned arable land that would be available for energy crops by 2030 with a maximum of 1 Mha in future. Both liquid biofuels and biogas will compete for this land. We have assumed that 50% of this abandoned arable land would be used for biogas due to its superior environmental credentials over liquid biofuels.
[49] A Renewables Obligation Certificate (ROC) is issued to an accredited generator for eligible renewable electricity generated and supplied to customers. Where suppliers do not have sufficient ROCs to meet their obligations, they must pay an equivalent amount into a fund, the proceeds of which are paid back on a pro-rated basis to those suppliers that have presented ROCs.
[50] Under this scheme energy suppliers have to (compulsory for big six suppliers) make regular payments to householders and communities who generate their own electricity from renewable or low carbon sources.

Table 4.1: Breakdown of biogas (to biomethane) resource by waste type for the UK as a whole.

Waste/feed category	Biogas (biomethane) potential (GWh/y)		Biomethane potential (ktonnes/y)	
Food waste - household	7,370		**475**	
Food waste - commercial	6,600		**425**	
Food waste - industrial-PPC returns	2,860		**184**	
Food waste - agro-industrial/other	2,970		**191**	
Total from food waste		19,800		**1,276**
Dairy cattle	2,430		**157**	
Other cattle excl. calves	816		**53**	
Dry sows	171		**11**	
Sows plus litters	90		**6**	
Fatteners 20-130 kg	714		**46**	
Weaners (<20 kg)	257		**17**	
Poultry (only egg laying)	2,438		**157**	
		6,900		**446**
Other (e.g. waste feed)		2,800		**180**
Abandoned arable land (not used for food)		18,000		**1,160**
Total from all resources		47,500		**3,060**

Sewage treatment works can claim half a ROC and landfill sites quarter of a ROC and so these are much more likely to favour upgrading biogas to biomethane. Most sites do already have on-site generators but a significant number are limited in their electricity generating capacity by the size of their grid connection. Anecdotal evidence suggests that a significant number of sites are currently flaring excess gas. This implies that there is likely to be sufficient resource for the expansion of biomethane production in the UK.

GasRec is currently the only commercial producer of biomethane which is used in the road transport sector in the UK. It operates from a landfill site owned by Sita at Albury in Surrey. As with other similar sites electricity generation was effectively limited by the capacity of the grid connection, and as installing a new substation was found to be uneconomic, a significant proportion of gas was being flared. GasRec set up their biomethane plant at the site to use this excess gas, with a grant from the Infrastructure Grants Programme. GasRec production capacity is 5,000 tonnes per annum (tpa) of liquefied biomethane (LBM), approximately enough to fuel 500 light commercial vehicles (LCVs) or 150 heavy goods vehicles (HGVs). However, it is operating at a production level below full capacity. Comparing its production capacity with the estimated potential in Table 4.1 highlights the fact that only a fraction of the full potential of biomethane production is currently being harnessed. Much of the gas produced by GasRec is currently exported, with the remainder supplying all of the biomethane vehicle trial projects currently underway in the UK.

4.2 Gas cleanup equipment

The main barrier to wider use of gas cleanup equipment is its capital cost vs the rate of return that it can generate. Although there are well established technologies for biogas cleanup, there is considerable ongoing work to improve them and reduce their cost. Much of this work is also focused on developing technologies that make it economical to clean smaller flows of gas – allowing the ‘excess’ gas from sewage and landfill sites identified above to be upgraded economically.

In the case of sewage plants and landfill sites, the site owners are generally water companies and refuse companies who have significant vehicle fleets of their own. Many of these companies are attracted by the prospect of using their own waste gas to fuel their vehicles, and clearly this kind of closed loop arrangement is more financially attractive than selling biomethane on the open market – the market is guaranteed, and there are lower transaction costs.

4.3 Gas storage, distribution and dispensing infrastructure

Storage and distribution is possibly the main limiting factor on the use of biomethane as a transport fuel. There are two possible routes for the distribution of biomethane (or natural gas) for use in vehicles, either liquefied or compressed, and it is unclear which of these approaches will become the standard.

The current refuelling infrastructure is based on Liquified Biomethane (LBM). This is operated solely by Chive Fuels in the UK and consists of nine LBM dispensing stations situated on the two key North-South motorway corridors. All of its LBM is sourced from GasRec, and it currently has around 20 times the capacity needed to serve the small number of vehicles that make use of the network.

LBM has the advantage of being more dense than CBM, and is therefore easier and cheaper to transport, and vehicles running on LBM can carry enough to give a range similar to diesel. However, it takes a significant amount of energy to liquefy the gas, which negates some of the benefit of the fuel, and if the fuel is left in the vehicle for more than a few days it will start to evaporate.

The alternative, compressed biomethane (CBM), uses less energy to produce than liquefaction, and does not evaporate. However, it is more costly and energy intensive to transport than LBM, as it requires heavy tanks. The cost of storage and refuelling facilities for CBM can be costly. Costs to install a permanent facility servicing commercial vehicles were quoted by stakeholders to cost a minimum of £150,000. A large station which can service dozens of vehicles and fill each in around the same time as it takes to fill with diesel can cost upwards of £500,000. However, the cost of filling infrastructure does benefit from economies of scale, so a shared infrastructure is financially beneficial.

As mentioned above, trials of biomethane-to-grid injection are currently under way. Proponents of CBM advocate the distribution of the gas through the gas grid and suggest that biomethane ‘green gas’ should be injected into the gas grid in the same way as ‘green electricity’ is put into the electricity grid. Gas consumers can then choose to buy the ‘green’ gas, and companies are prohibited from selling more than they actually produce. From an energy and carbon saving point of view, this is extremely attractive. Fleet operators could install a compressor at any site with a suitable gas grid connection, and run their gas powered vehicles on CNG, or choose to pay more for CBM (depending on its availability).

4.4 Vehicles that can use biomethane

Vehicles running on methane are already widely deployed around the world. As with conventional vehicles there are essentially two different vehicle technologies:

- Spark ignition petrol engine - these will run on natural gas with only minimal modifications, and this is usually referred to as a ‘dedicated’ gas engine. Some vehicles with this type of engine retain a small petrol tank, and can switch to running on petrol if they run out of gas – these are referred to as ‘bi-fuel’ engines.

- Compression ignition diesel engines – these are more efficient than spark ignition engines, but will not work with only gas in the cylinders. One way around this problem is to introduce both diesel and gas into the cylinders, which allows the diesel to ignite under compression, thus also igniting the gas. These are referred to as ‘dual fuel’ engines.

Of the 11 million or so vehicles running on natural gas around the world, most run on a conventional petrol engine that has been re-tuned. No manufacturers in Europe offer dedicated gas variants of the largest goods vehicles, because they still cannot compete with modern diesel engines for efficiency. Dedicated gas engines are more frequently used in buses, as they are not as heavily loaded as HGV engines.

Dual fuel engines have been used in industrial applications since the 1930s, but their development for use in vehicles is relatively recent. They retain the benefits of diesel engines over spark ignition engines – higher efficiency, greater power density and lower maintenance – while offering the cost savings, emissions and noise reduction of using gas. They can also switch seamlessly to running on 100% diesel if the gas tanks are exhausted. The technical challenge of dual fuel is to introduce as much gas as possible into the fuel mix while maintaining the required level of engine performance. While the vehicle is in use, the engine control unit will adjust the balance of diesel and gas to deliver the required power.

5 Conclusions

5.1 Audit of current UK fleet biofuel capability

The project covered four transport modes, namely road transport, rail, marine, and air travel. For each mode the biofuel capability of the current fleet was identified from a combination of the team's existing knowledge, recent information in the public domain and engaging with key stakeholders. These activities combined to provide:

- The current biofuel usage, in the context of current fuel specifications (Table 2.10).
- The current biofuel capability of the current fleet, taking into account its age profile and the differing biofuel capabilities of equipment of different ages.
- The biofuel capability of the fleet in, for example around 2020, when older, possibly less biofuel compatible equipment has been replaced by current models.

The fleet averaged vehicle capabilities for all four transport modes are summarised in Table 5.1.

Table 5.1: The current biofuel capability across all transport modes, for both the current fleet and new vehicles (current models only)

Mode	Fuel	Biofuel blends				
Current fleet capability						
Road transport		Bioethanol				
		E0	E5	E10	E85	
Passenger cars	Petrol	100%	100%	84.0%	0.0025%	
Light commercial vehicles	Petrol	100%	100%	84.0%	0.0%	
Mopeds and motor cycles	Petrol	100%	100%	0%	0%	
		Biodiesel				
		B0	B7	B20	B30	B100
Passenger cars	Diesel	100%	100%	6.8%	6.8%	0%
Light commercial vehicles	Diesel	100%	100%	11.0%	11.0%	0%
Rigid trucks (Note 1)	Diesel	100%	100%	31.0%	11.7%	8.2%
Articulated trucks (Note 2)	Diesel	100%	100%	61.6%	61.6%	43.3%
Buses and coaches (Note 1)	Diesel	100%	100%	31.0%	11.7%	8.2%
Other transport modes						
Domestic Ships	Gas oil	100%	0%	0%	0%	0%
Trains	Gas oil	100%	100%	100%	0%	0%
Domestic Aviation	Jet A1	100%	0%	0%	0%	0%
Capability of current models weighted by sales volume						
Road transport			Bioethanol			
		E0	E5	E10	E85	
Passenger cars	Petrol	100%	100%	93.9%	0.008%	
Light commercial vehicles	Petrol	100%	100%	93.9%	0.008%	
Mopeds and motor cycles	Petrol	100%	100%	0%	0%	
		Biodiesel	Biodiesel			
		B0	B7	B20	B30	B100
Passenger cars	Diesel	100%	100%	9.1%	9.1%	0%
Light commercial vehicles	Diesel	100%	100%	20.4%	20.4%	0%
Rigid trucks (Note 1)	Diesel	100%	100%	45.9%	17.3%	12.1%
Articulated trucks (Note 2)	Diesel	100%	100%	91.2%	91.2%	64.3%
Buses and coaches (Note 1)	Diesel	100%	100%	45.9%	17.3%	12.1%
Other transport modes						
Domestic Ships	Gas oil	100%	0%	0%	0%	0%
Trains	Gas oil	100%	100%	100%	0%	0%
Domestic Aviation	Jet A1	100%	0%	0%	0%	0%

Notes to table

1 The survey expressed HDV capability in terms of engines fitted with unit injectors and those using common rail fuelling systems. The assumption made here is that rigid trucks, buses and coaches do not use unit injectors.
2 See Note 1. The assumption made here is that articulated trucks all use unit injectors.

The discussions with the principal stakeholders for each of the modes of transport indicated that vehicles are warranted to use, or can use, five different biodiesel strengths (0%, 7%, 20%, 30% and 100%) which can be considered for all four transport modes, and four different bioethanol strengths (0%, 5%, 10% and 85%) which are only used in road transport. The vehicle capabilities given in Table 5.1 summarises the fraction of the fleets for the different transport modes that can use these different blend strengths.

Generally it was found that vehicle manufacturers are anticipating increased use of biofuels, and they are not fundamentally against this. They do have some concerns, and comments, which are detailed in section 2.5.5 because they are principally derived from comments from those connected with road transport. However, many of these views are applicable to all transport modes, especially those concerning the economics, infrastructure and fuel specifications.

Some commonly expressed themes and concerns from the consultants are:

- The users of biofuels are not willing to pay a significant premium for this, i.e. the economics of using higher biofuel blends needs to commercially attractive.
- Vehicle manufacturers require a long term plan/policy that is adhered to because of the time required to design, develop and then have a production run of a new vehicle (or engine).
- Because vehicles are manufactured for European and global markets there should be a harmonised approach across Europe rather than bespoke country specific biofuel strategies.
- Each vehicle's development cycle requires significant development, and so vehicle manufacturers do not want a gradual creeping up of the permitted biofuel limit, rather bold, technologically viable steps, that last for at least a decade.
- Fuel specifications need to be revised and developed to reduce variability of fuels permitted.
- FAME and bioethanol fuels lead to engineering and practicality challenges relative to their petroleum derived counterparts, whereas it is anticipated that second generation biofuels will be more compatible with current transport equipment.
- In addition to the economics and engineering being favourable, increased biofuel usage also requires users to be able to buy the fuel, i.e. the biofuel infrastructure needs to be in place.

5.2 Infrastructure Capability

The key elements of the biofuel infrastructure have been identified and expressed as a flow diagram (Figure 3.1). These are:

- the origination of fuel (import terminals, oil refineries and biofuel production plant)
- the intermediate storage (both coastal and inland)
- the wholesale and fleet end use (where the fleet use is for all rail, airports, marine and road use)
- and the retail of fuel.

Connecting these is the transportation of fuel by pipeline, sea, road and rail.

Main elements of infrastructure	Numbers of such infrastructure facilities
Origination	8 oil refineries, 8 import terminals and 6 large biofuel refineries
Intermediate storage	43 Inland and coastal storage facilities
Wholesale and fleet end use	50+ wholesale distributors, 51 airports, 123 rail, marine bunkers
Retail	8,884 forecourts with a range of ownership, commercial forecourts and fleets & marine end users

The import terminals have a combined volume capacity of 3,675 million litres.

The audit of tank storage contained too many gaps in the data to be able to obtain a complete view of the total fuel storage capacity. The sum of the known capacities of the large and small facilities was just in excess of 1,000 million litres. If the average size of the two thirds of facilities whose storage capacity was not know followed this average size, then the overall storage capacity would be around 3,000 million litres.

We have attempted to define the numbers of fuelling stations able to handle high blend strengths. This was hampered by the Experian database, bought from Catalist UK, not containing details on the number of storage tanks, and how many nozzles each multi-fuel pump has. However, the stakeholder consultation indicated that it was the smaller, rural, filling stations which do not have the tank or pump capacity to handle higher blends. Our survey indicated that all forecourts visited with four or more multi-fuel pumps offer at least three blends of road fuels. The Experian database indicates 65% of forecourts have four or more pumps, and these forecourts sell 85% of forecourt road fuel. Our survey revealed some forecourts with three pumps also sell more than two blends, and therefore we believe this is a conservative estimate.

Information regarding all these infrastructure aspects, auditing the current practices and how the biofuel elements of transport fuel supply fit in to the overall infrastructure capability was undertaken using the knowledge of the team, information in the public domain, and engaging with stakeholders. From all this information some common themes regarding the current infrastructure capability were found. These are given below.

Prior to the removal of the duty incentive there was significant investment in certain sectors to allow the utilisation of higher blend biofuels. Higher strength blended biofuels (primarily B30, B50 and E85) were successfully being produced, transferred and utilised by a small number of dedicated fleets and retail forecourts. The cessation of the duty incentive stopped the investment and halted the movement that was being seen towards an expansion in the use of higher blend biofuel. However, what this demonstrated was that the use of higher blends within the UK infrastructure was possible.

Refinery and import facilities

The current production of biofuels in the UK from feedstocks is not sufficient to meet the demand and consequently a large proportion of transport biofuels are imported. There was an intention within the industry to increase the UKs production of biofuel and a number of biofuel production facility construction projects had been planned for the UK. Research has found that a number of these construction projects have been cancelled for primarily financial reasons and a number of small facilities have closed due to a lack of feedstock. The ability for the UK to increase its use of biofuels without requiring an increase in importation is therefore limited at present.

The import of biofuels was considered with respect to available capacity and capabilities to handle biofuels. Enquiries highlighted that the issue of potential spare capacity to handle increased biofuels was not deemed problematic as an increase in biofuel usage was envisaged to be accompanied by a reduction in fossil fuel usage. As such significant excess capacity to supply the market is not required. The majority of the UK oil refineries and import terminals have the ability to handle biofuels and so this is not seen as a significant barrier to expansion.

Distribution

The primary distribution routes are via pipeline, rail or road. There was no evidence of any higher strength blended biofuels being transported via pipeline. With respect to future utilisation there are concerns over the higher ethanol blends corroding the pipelines and a risk that higher blend biodiesel fuels will contaminate jet fuel. Currently only the US uses pipelines to carry ethanol blends but they must be dedicated to this fuel and maintained to a much higher standard than oil product pipelines. Discussion with a representative from Heathrow suggested that the UK may introduce higher biofuel content in jet fuel following a lead from the US.

The transport of fuels via road and rail was not found to be a barrier to distribution. Both modes have the flexibility to transport a mixture of blends and to meet any increase in overall fuel capacity demanded with the UK. The only limitations were the need to modify the tankers. If high blend bioethanol is to be transported the seals and linings require modification due to the corrosive properties of ethanol and for the transport of biodiesel there is sometimes the need to improve the insulation or heat tankers. All companies surveyed were either already equipped with tankers which had these modifications or did not see these modifications as any barrier to increasing biofuel distribution providing these changes were demanded by their customers and therefore were economically viable.

End-user dispensing capability

End-users were split into retail forecourt refuelling and on-site depot refuelling.

The retail forecourts are an important link in the chain due to this sector supplying fuel to a large proportion of the end user market. This includes private individuals and increasingly haulage companies and public service vehicles which are moving towards fuel card use. The key findings from the survey of this sector are as follows:

- There is no spare storage capacity available either at small or large retail sites;
- Smaller and rural retailers have the tank capacity to supply one blend of petrol and diesel only;
- Larger retailers are not prepared to allocate storage space to higher blend fuels at the expense of more profitable and higher demand standard products;
- Installation of additional tank space is costly and logistically difficult at most sites;
- The costs associated with additional tank cleaning and improved water management when storing higher blend biofuels is another barrier to uptake. There is evidence of a need for these costs already with the B7 and E5 blends.
- There was a desire to move to higher blends via slowly increasing the volume in standard pump fuel in step changes. This would eliminate any economic disadvantage that would be incurred by any one company attempting to make a change to higher blends.

The ability for on-site depots to handle multiple blends was variable. The majority of respondents from all sectors stated that the standard set up at a depot is one fuel tank, although there were some exceptions. The use of this one tank to store higher blend biofuels was not generally thought to be an issue but the ability to store two or more blends of biofuel was restricted to a small number of sites where more than one tank would be available. The cost of installing additional tank capacity was quoted by one respondent as being anything from £50,000 to £100,000 depending on the size of the installation.

Those respondents who had experience of trialling biofuels had incurred additional cleaning costs with higher blend biodiesels as well as requirements to install electric heating within the tanks. Furthermore, some general feedback suggested that even with the current B7 blend additional cleaning costs were being incurred. There was also concern over the increase in the volume of fuel used for the same energy output when moving to higher blends which would result in higher costs incurred to fuel the same vehicle fleet.

Therefore for all end-user supply there is a restriction to the potential to supply multiple blends of biofuel – both in terms of infrastructure and economic viability. The dispensing of higher blend within the standard pump fuel also is not without financial outlay but is feasible within the current infrastructure.

Common themes

Finally, the common feedback across all of the survey work undertaken was that without an economic incentive which feeds throughout the supply chain there will be no move towards higher blend biofuels. A number of companies had started to supply and utilise biofuels when there was a tax incentive to do so and without this the uptake has become economically unviable.

Similarly, without warranties from vehicle manufacturers to approve the use of higher blend biofuels there is no confidence within the haulage and public service sector, or the private sector to move towards higher biofuel blends.

5.3 Audit of biogas capacity currently used for electricity and gas grid injection that could be migrated to road transport fuel use

The production and use of biomethane as a fuel for road transport is an option that is being investigated by the UK Government. DfT has commissioned separate research in this area, with a study entitled “Feasibility study for a road vehicle biomethane demonstration project” and this research draws on these findings. Whilst the production of biomethane from organic wastes via anaerobic digestion is well developed, most of this is used for electricity or for injection into the gas grid for commercial and domestic use.

The study found that the biomethane potential production capacity of the UK from waste (using anaerobic digestion) is 3,060 ktonnes per year. At present the sole source of biomethane for road transport is from a landfill site, whose capacity is 5 ktonnes per year, a small fraction of the biomethane potential production capacity of the UK from waste. However, the RFA record that only 0.4 ktonnes were used in the 12 months ending 14th April 2009, and only 0.2 ktonnes were used in the 12 months ending 14th April 2010.

There are a number of reasons for the very low usage of biomethane in road vehicles in the UK. These include:

- the need for gas cleanup equipment to convert from biogas (which is not compatible with vehicles) to biomethane (which is),
- the gas storage, distribution and dispensing infrastructure,
- and vehicle technologies that can use (bio)methane.

All three are important, though it was found that challenges with the gas storage, distribution and dispensing infrastructure is the main limiting factor. However, alongside this is the economics of using (bio)methane fuelled vehicles.

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Appendices

Appendix 1

Stakeholder consultation for heavy duty vehicles

The principal activities undertaken to determine the biofuel capability of heavy duty vehicles were:

1. The identification of the principal stakeholder
2. Obtaining a view on the biofuel compatibility of their current vehicles from the Biofuel Cities and LowCVP reports
3. Communicating with them to confirm/amend the biofuel compatibility of their current vehicles
4. Collect statistics on the manufacturers HDV sales profile, e.g. regarding sales <16 tonnes GVW and >16 tonnes GVW.
5. Build a simple model that enables the **weighted biofuel compatibility** of HDVs to be calculated.

Identification of principal stakeholders, and their UK market share

For Step 1, some ACEA statistics on the production of new commercial vehicles less than, and greater than 16 tonnes GVW, and of new buses and coaches, for 2009 are shown in Figures A1.1 to A1.3. These indicate that the principal HDV manufacturers are, in alphabetical order:

- DAF
- Daimler (badged Mercedes Benz)
- Fiat (badged Iveco)
- MAN
- Renault
- Scania, and
- Volvo

We approached all seven of these companies.

Figure A1.1: The % of new commercial vehicle (3.5t – 16t GVW) registrations in the EU27 (plus Iceland and Norway) by manufacturer in 2009, ACEA (2010)

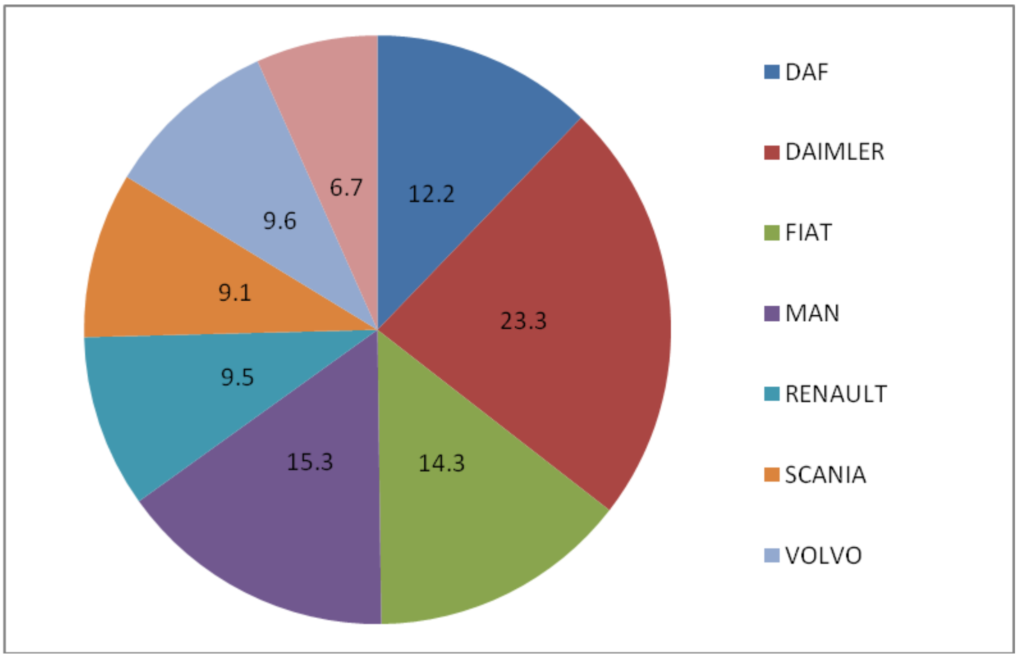


Figure A1.2: The % share of commercial vehicles - Bus and Coach manufacturers, 3.5t to 16t GVW, in the EU27 in 2009, ACEA (2010)

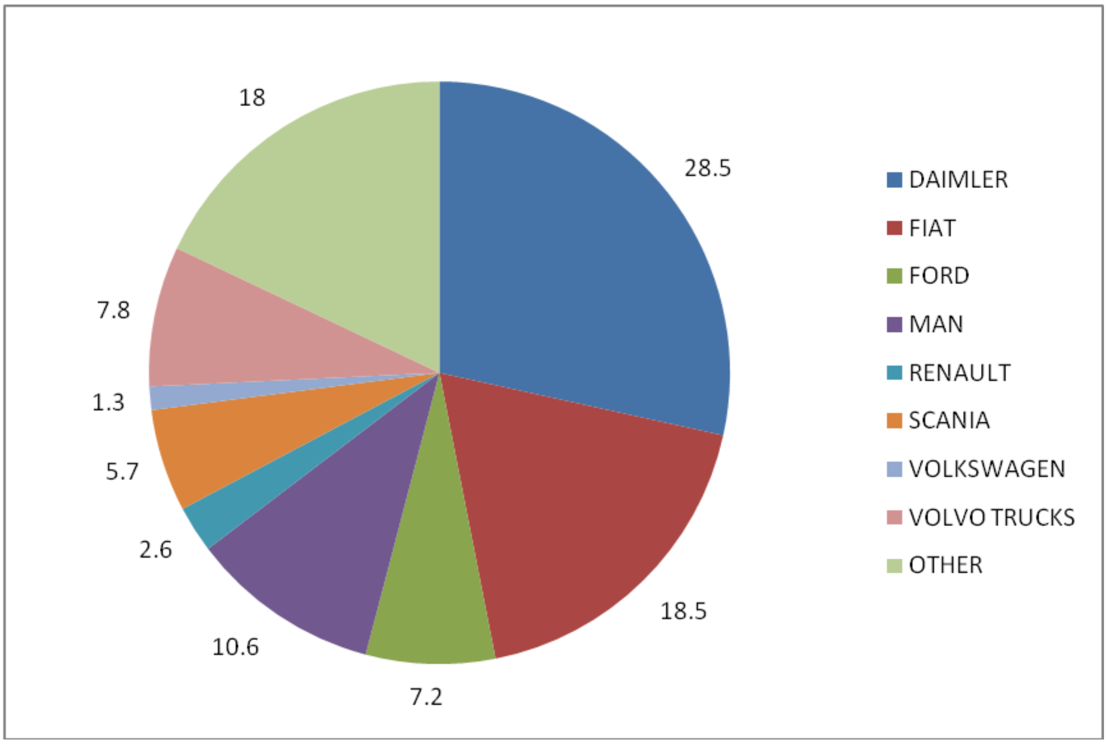
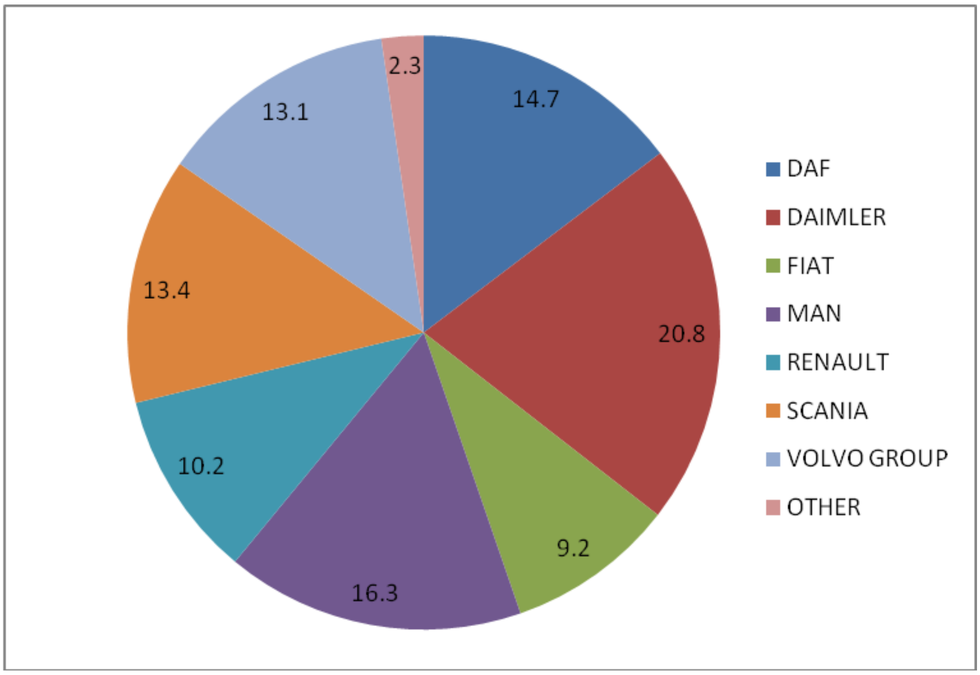


Figure A1.3: The % of new commercial vehicle (> 16t GVW) registrations in the EU27 (plus Iceland and Norway) by manufacturer in 2009, ACEA (2010)



A breakdown of the manufacturers' sales volume in Europe in 2009 is given in Table A1.1.

Table A1.1: Total estimates sales volume by manufacturer in 2009

Manufacturer	% share	Estimated sales volume
DAF	14.7	24,062
Daimler	20.8	34,046
Fiat	9.2	15,058
MAN	16.3	26,680
Renault	10.2	16,696
Scania	13.4	21,934
Volvo	13.1	21,443
Other	2.3	3,765

For the UK fleet the share of the market for the heavy duty engine manufacturers was taken from a published study[51]. This provides data for market shares of heavy duty vehicles registered in the UK in 2004, split into two weight groups, 3.5 – 16 tonnes GVW and >16 tonnes GVW. These data are given in Table A1.2.

Table A1.2 The UK market share of different HDV manufacturers

Weight range	DAF	Iveco	MAN	D/C	Renault	Scania	Volvo	Others
< 16 tonnes	28.6	31.2	12.1	16.1	5.2	0	1.7	5.1
> 16 tonnes	23	5.7	7.5	16.6	4.8	17.2	16.4	8.8

Establishing the biodiesel capability of the current models

All seven heavy duty vehicle engine manufacturers were contacted, principally by telephone, which was followed up with e-mails as appropriate. All seven kindly provided valuable information about the biofuel compatibility of both their current vehicles and their historic fleets. A summary of these findings is given in Table A1.3.

Table A1.3 Summary of biodiesel compatibility of engines/HDVs for the seven principal stakeholders

Company In alphabetical order	Capability of their engines to use biodiesel fuels
DAF	• All engines compatible with current pump diesel (B7) • Euro III and later LF & CF65 models can use B20 (EN14214) without modification of the vehicle or change to service requirements • All DAF CF75, CF85 & XF95 & XF105 vehicles produced from spring 2001 can operate on EN590 and subject to certain specifications & service limitations[1] can be operated on blends up to B100
Daimler	• All engines compatible with current pump diesel (B7) • All Euro III, IV and V engines fitted with unit injectors can be operated on B100 biodiesel (specified only as FAME, EN14214), given a range of precautions and increased service frequency.
Iveco	• All engines compatible with current pump diesel (B7) • This is the upper biofuel limit for common rail engines. • But engines with unit injectors, Cursor engine, can use B30 (but not warranted to use B100) • The capabilities of Iveco trucks using bio-methane was also emphasised (see section on Bio-methane)
MAN	• All engines compatible with current pump diesel (B7)

[51] The influence of recent legislation for heavy vehicles on the risk of under-run collisions, A Malczyk, available from http://www.udv.de/uploads/media/manuskript_vdi_vortrag_malczyk_gdv.pdf

Company In alphabetical order	Capability of their engines to use biodiesel fuels
	• All Euro III, IV and V engines can also be operated on B100 biodiesel (specified only as FAME, EN14214) but an additional warranty would need to be purchased, and currently MAN only provide this for vehicles that are on contract. (Currently low demand for this option).
Renault Trucks	• All engines compatible with current pump diesel (B7) • Also, 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 III, IV and V, i.e. manufactured after Oct 2001). 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.
Scania	• All engines compatible with current pump diesel (B7) • All Euro III, IV engines with unit injectors can also be operated on B100 biodiesel (specified only as FAME, EN14214) but there are additional servicing requirements. • For Euro V trucks, all can be B100 compatible, but this should be specified at the time of ordering so that vehicle is built with appropriate gaskets and hoses, etc. Again there are additional servicing requirements.
Volvo	• All engines compatible with current pump diesel (B7) • This is the upper limit of biodiesel compatibility for the common rail Volvo engines (e.g. < 7 litre capacity). • Volvo permit the use of permit the use of B30 in Euro III, IV and V engines using Unit Injectors. PLUS there are other servicing requirements[2].

Notes to table

1. The specification items include fuel line water separator, replacement fuel hoses - the majority of existing vehicles have **not** had these items fitted during production. Service requirements include half the normal oil drain intervals, fuel filter replacement and fuel tank checks- this can significantly increase annual operating costs. Warranty on the SCR catalyst fitted to Euro 4/5 vehicles is limited to 12 months instead of 24 months
2. The additional servicing requirements specified by Volvo are more frequent servicing including changing fuel filters, plus a clean of the fuel tank once a year.

Key points from these communications are:

- The frequent divide between engines with common rail fuelling and unit injectors, with common rail systems often being limited to B7, i.e. current pump diesel, and unit injectors being permitted to use up to B100.
- The use of biodiesel blends above B20 for engines with unit injectors is usually accompanied by increases in service intervals often with additional activities (e.g. a clean of the fuel tank).
- For some manufacturers their current low levels of direct experience of having vehicles running on B100, combined with the need for commercial prudence, means that whilst all of a specific engine model with unit injectors could, they believe, use B100, they are only agreeing to a sub-set of these engines "trialling" the fuel under conditions were they are able to continually monitor performance.

These biodiesel compatibility data can be combined with the manufacturer's share of the 3.5 – 16 tonnes market, and greater than 16 tonnes GVW market, to obtain a weighted biodiesel overall capability for current sales. This gives the maximum biodiesel capacity that would occur if every vehicle used the maximum biodiesel blend that it could, with all additional extended warranties etc. being applied for and accepted. The results are summarised in Table A1.4.

Table A1.4 The maximum biodiesel capability of heavy duty engines/HDVs

Vehicle group	Weighted Biodiesel capability	Fraction of overall HDV sales corresponding to this vehicle group
For HDVs 3.5 – 16 tonnes	13.4%	44.37%
For HDV > 16 tonnes	50.4%	55.63%
All HDV currently on the market	34.0%	100%

Therefore, it is concluded that the **biofuel capability of current heavy duty vehicles** is that they can use up to a maximum of 34% biodiesel. This can also be taken as the biodiesel compatibility of the fleet as a whole that would exist by 2020 based on current sales.

Establishing the biodiesel capability of the current fleet

The figure above is the biofuel capability of **currently available** heavy duty vehicles, **not** the biofuel capability of the current heavy duty vehicle fleet. The fleet contains vehicles with a range of ages. The data in Table A1.3 often indicates that vehicles meeting Euro III emissions standards can use higher biofuel blends whereas older vehicles cannot. All vehicles sold after 1st October 2001 were required to meet Euro III standards.

The age profile of the heavy duty vehicle fleet was obtained from DfT Vehicle Licensing Statistics (2009)[52] (Table 40). This contains the data, for the 2009 fleet, is given in Table A1.5.

Table A1.5 The numbers of heavy duty registered in 2009 by years since first registration

Age	Numbers of vehicles registered since first registration (thousands)
0 – 1 years	30
1 – 2 years	50
2 – 3 years	44
3 – 4 years	48
4 – 6 years	89
6-13 years	164
Older than 13 years	65

From these data 53.3% of vehicles are up to 6 years old, with a further 33.3% aged between 6 and 13 years old. At the end of 2009 the youngest pre-Euro III HDV would be 8 ¼ years old. It is estimated from the above data that 67% of vehicles were registered after Euro III became mandatory, with 33% being older than this milestone. From the data in Table A1.3, none of the pre-Euro III vehicles are viewed by their manufacturers as being compatible with blends greater than B7.

When this age profile is combined with the biofuel capabilities for vehicles of different ages then the overall biodiesel capability for the current heavy duty vehicle fleet is calculated to be 25.1%, i.e. the fleet could use up to a maximum of 25.1%. As noted in the previous section, this would rise to 34% by 2020.

Experience of specific HDV operators when using biodiesel in their fleets

These snippets of information were gleaned when discussing the infrastructure arrangements with, in particular fleet operators. They provide hands on **raw** evidence from trials, supporting the generalities discussed in the main body of the report. Because they are direct evidence, within an appendix, no attempt has been made to further assess or critique them here, although this does occur in the main body of the report where common themes and experience are drawn out.

52 Reference to DfT Vehicle Licensing Statistics

Bus and Coach Operators

All of the companies have trialled or are trialling biofuels. A number of conclusions have been drawn from these trails:

- Engines had to be run for five minutes with conventional fuel before using B100.
- Engines had to be modified with a special fuel tank with a heater coil.
- The benefits of using biodiesel were deemed not to outweigh the risk to the sustainability of food crop sources.
- Warranties are not available for higher blend biofuel use from the vehicle manufacturers.
- A lack of incentive to branch into biofuels following the removal of the tax incentives.

Concerns were also raised over the current use of B7, the standard pump diesel. First Group reported a need to increase the volume of fuel usage for the same energy output when moving to biodiesel blends.

Heavy duty vehicles operating on biomethane (or methane)

One local authority running diesel Refuse Collection Vehicles is achieving fuel consumption of around 3.3 miles per gallon (mpg) or 1.17 km/litre. They introduced a dedicated CNG variant of the same vehicle, which achieved 1.32 km/kg gas, which equates to a financial saving of around 20p per km. On the basis of the vehicle mileage this translates to an approximate saving of just under £4,000 pa. The cost differential on this vehicle is £21,000 - £23,000 compared to the diesel equivalent. However, from an energy use point of view the gas powered vehicle was less efficient than its diesel equivalent. In this case the drop in efficiency was 27%, which is largely due to the fact that spark ignition engines are inherently less efficient than compression ignition engines.

One operator interviewed in a previous study is running 44t dual-fuel HGVs for a mixture of long and short haul journeys, and achieving an average of 60% substitution of gas for diesel. This translates to a fuel saving of 11p per mile as compared to identical diesel-only vehicles running on the same routes. Given that the vehicles are in constant use and travel around 130,000 miles per annum, this gives an annual saving in the region of £14,000.

The conversion cost for regular diesel HGVs to dual-fuel HGVs is approximately £25,000, with a payback for the vehicle alone under two years. However, the operator also spent £300,000 on a filling station, and plans to expand both its dual-fuel fleet and its filling station network. In terms of energy use per mile [or per km], the vehicles were actually around 4% less efficient (although they still save CO_2).

In conclusion, a variety of gas-powered vehicles are available in the UK, and if used in the right applications they are economically viable. Gas vehicles have a range of benefits as well as cost and GHG emissions reduction – they are very clean from an air quality perspective and they are very quiet. However, they do currently have a significant price premium over conventional vehicles, and some uncertainty over their residual value. It seems likely that if refuelling infrastructure were more widely/cheaply available, that a significant number of operators would be willing to add these vehicles to their fleets.

Appendix 2

Stakeholder consultation for light duty vehicles

This task has parallels with the stakeholder consultation for the heavy duty vehicles. However, there are two major differences:

- for light duty vehicles there are a much larger number of engine/vehicle manufacturers that the seven dominant manufacturers for HDV engines, and
- for light duty vehicles there are two biofuels to be considered, both bio-ethanol (or biofuels to be added to petrol) and biodiesel.

Despite these differences the key steps in the stakeholder consultation process remain:

1. The identification of the principal stakeholder
2. Obtaining a view on the biofuel compatibility of their current vehicles from the Biofuel Cities and LowCVP reports
3. Communicating with them to confirm/amend the biofuel compatibility of their current vehicles
4. Collect statistics on the manufacturers HDV sales profile, e.g. regarding sales <16 tonnes GVW and >16 tonnes GVW.
5. Build a simple model that enables the **weighted biofuel compatibility** of HDVs to be calculated.

Identification of principal stakeholders, and their UK market share

For Step 1, the Polk database of vehicle sales in 2008, indicated there are 66 different manufacturers of light duty vehicles. Contacting 13 of these with the highest sales volumes will cover 87.3% of sales because some manufacturers make engines for several different companies (e.g. Volkswagen Audy Group make engines for VW, Audi, Skoda and Seat). Table A2.1 contains all these manufacturers, and their share of the total light duty vehicle market. The manufacturers are sorted in order of decreasing market share.

In addition, light duty vehicles can be categorised by their fuel (petrol or diesel) and whether the vehicles are passenger cars or light commercial vehicles. Table A2.1 also contains these details with each percentage being the portion of a particular manufacturer- vehicle type- fuel combination of the whole light duty vehicle sales. Hence these four columns add up to 100%.

Table A2.1 Analysis of light duty vehicle sales database, listing the companies in order of decreasing share of the light duty vehicle market, as a whole.

	Passenger cars		Vans		Total LDV market share for manufacturer	Cumulative share
Manufacturer	Petrol	Diesel	Petrol	Diesel		
Ford	8.00%	5.32%	0.01%	3.32%	16.66%	16.66%
Vauxhall	8.45%	3.90%	0.01%	2.05%	14.41%	31.06%
VW	2.63%	4.77%	0.00%	1.07%	8.48%	39.54%
Peugeot	3.00%	1.90%	0.00%	0.64%	5.55%	45.09%
Toyota	2.93%	1.43%	0.00%	0.35%	4.72%	49.81%
BMW	1.57%	3.11%	0.00%	0.00%	4.67%	54.48%
Renault	2.53%	1.17%	0.00%	0.73%	4.44%	58.92%
Citroen	1.78%	1.58%	0.05%	0.83%	4.23%	63.15%
Audi	1.23%	2.93%	0.00%	0.00%	4.17%	67.31%
Mercedes	1.30%	1.79%	0.00%	1.02%	4.11%	71.42%
Honda	2.40%	1.06%	0.00%	0.00%	3.46%	74.88%
Nissan	2.08%	0.66%	0.00%	0.41%	3.15%	78.04%
Fiat	1.73%	0.55%	0.00%	0.39%	2.68%	80.71%

Manufacturer	Passenger cars Petrol	Passenger cars Diesel	Vans Petrol	Vans Diesel	Total LDV market share for manufacturer	Cumulative share
Mazda	1.62%	0.44%	0.00%	0.02%	2.08%	82.79%
Mini	1.37%	0.31%	0.00%	0.00%	1.68%	84.48%
Skoda	0.53%	1.00%	0.00%	0.00%	1.53%	86.01%
Land Rover	0.02%	1.33%	0.00%	0.17%	1.52%	87.53%
Volvo	0.40%	0.98%	0.00%	0.00%	1.38%	88.91%
Kia	0.61%	0.68%	0.00%	0.00%	1.30%	90.20%
Seat	0.60%	0.62%	0.00%	0.00%	1.21%	91.42%
Hyundai	0.90%	0.26%	0.00%	0.00%	1.16%	92.58%
Suzuki	0.94%	0.14%	0.00%	0.00%	1.08%	93.65%
Mitsubishi	0.39%	0.25%	0.00%	0.29%	0.93%	94.58%
Jaguar/Daimler	0.14%	0.70%	0.00%	0.00%	0.84%	95.43%
Chevrolet	0.65%	0.11%	0.00%	0.00%	0.76%	96.19%
Saab	0.17%	0.49%	0.00%	0.00%	0.66%	96.85%
Lexus	0.29%	0.13%	0.00%	0.00%	0.42%	97.27%
Smart	0.31%	0.00%	0.00%	0.00%	0.31%	97.58%
Alfa Romeo	0.09%	0.16%	0.00%	0.00%	0.25%	97.82%
Porsche	0.24%	0.00%	0.00%	0.00%	0.24%	98.07%
Iveco	0.00%	0.00%	0.00%	0.24%	0.24%	98.31%
Chrysler	0.05%	0.18%	0.00%	0.00%	0.23%	98.54%
Daihatsu	0.20%	0.00%	0.00%	0.00%	0.20%	98.74%
Subaru	0.15%	0.05%	0.00%	0.00%	0.19%	98.93%
LDV	0.00%	0.00%	0.00%	0.19%	0.19%	99.12%
Jeep	0.03%	0.14%	0.00%	0.00%	0.17%	99.29%
Dodge	0.07%	0.09%	0.00%	0.00%	0.16%	99.45%
Other	0.02%	0.00%	0.00%	0.06%	0.09%	99.54%
Aston Martin	0.06%	0.00%	0.00%	0.00%	0.06%	99.60%
Bentley	0.06%	0.00%	0.00%	0.00%	0.06%	99.67%
Proton	0.06%	0.00%	0.00%	0.00%	0.06%	99.73%
Isuzu	0.00%	0.00%	0.00%	0.06%	0.06%	99.79%
Maserati	0.03%	0.00%	0.00%	0.00%	0.03%	99.82%
Lotus	0.03%	0.00%	0.00%	0.00%	0.03%	99.84%
Ferrari	0.03%	0.00%	0.00%	0.00%	0.03%	99.87%
Ssangyong	0.00%	0.03%	0.00%	0.00%	0.03%	99.89%
Perodua	0.03%	0.00%	0.00%	0.00%	0.03%	99.92%
Piaggio	0.00%	0.00%	0.01%	0.00%	0.01%	99.93%
Morgan	0.01%	0.00%	0.00%	0.00%	0.01%	99.94%
Microcar	0.01%	0.00%	0.00%	0.00%	0.01%	99.95%
Rolls-Royce	0.01%	0.00%	0.00%	0.00%	0.01%	99.96%
Mega	0.00%	0.00%	0.00%	0.00%	0.00%	99.96%
Hummer	0.01%	0.00%	0.00%	0.00%	0.01%	99.97%
Cadillac	0.00%	0.00%	0.00%	0.00%	0.01%	99.98%
Lamborghini	0.01%	0.00%	0.00%	0.00%	0.01%	99.98%
MG	0.01%	0.00%	0.00%	0.00%	0.01%	99.99%
Aixam	0.00%	0.00%	0.00%	0.00%	0.01%	100.00%
Renault Trucks	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Reva Electric Car Comp. (RECC)	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Tata	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
NICE Car Company	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%

	Passenger cars		Vans		Total LDV market share for manufacturer	Cumulative share
Manufacturer	Petrol	Diesel	Petrol	Diesel		
Corvette	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
KTM	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Maybach	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Rover	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Santana	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Grand Total	49.78%	38.27%	0.09%	11.86%	100.00%	

For all stakeholder engagements the strategy was to try to minimise the time required by stakeholders to provide the information we sought. This was achieved by building on current practice and knowledge obtained from the recent reviews. Consequently, prior to contacting organisations a bespoke questionnaire was prepared which:

- took the use of current pump fuel as a starting point,
- used the information within the LowCVP and Biofuel cities reports pertinent to the organisation as a reference point, and asking if this was correct.
- If it was not correct the information sought was the exceptions to this starting point.

The manufacturers of 15 of the 66 vehicle manufacturers listed in Table A2.1 were approached for details about the biofuel capability of their vehicles. (In practice this amounted to only eleven separate companies. A summary of the findings from this stakeholder consultation is given in Tables A2.2 (for bio-ethanol use) and A2.3 (for biodiesel use).

Although this sample is only a sub-set of the manufacturers' marques (around 23%) the manucturers contacted included the companies with high volume sales. The accounted for around 72% of total light duty vehicle sales.

It should be remembered that the principal objective of this evidence collection is to establish what is the biofuel capability of the current models and the current fleet. It will be seen in the next section that whilst the vast majority of vehicles are E10 and B7 compatible, there are some models available that can use higher blends, e.g. E85 and B30. However, for bioethanol capability, sales of these options have been extremely low. (In 2008 flex fuel vehicle sales were around 0.008% of all petrol fuelled passenger car sales[53].) Consequently confirming that manufacturer X offers this option does not materially affect the biofuel capability of the current fleet. However, what it does do is demonstrate the range of companies offering vehicles capable of using blends containing more than 10% ethanol. Therefore this study did not extend its surveying of companies beyond those listed. Instead a list of vehicle available in the UK offering flex fuel (and E85) compatible vehicles was compiled. This is given in Table A2.4.

A list for the whole of Europe, and the countries where the E85 vehicles are sold, is given in Table A2.2.

[53] Data obtained from analysing Polk LDV database for UK, kindly made available for this project by DfT.

Table A2.2 The results of the consultation with light duty vehicle engine manufacturers regarding the capability of their engines to use bio-ethanol

Company In order of market share	**Capability of their engines to use bioethanol petrol blends**
Ford	All Ford vehicles have been E10 compatible since 1992, with the exception of the GDI Mondeo Sci model which was on sale between 2004 and 2006. There are E85 Flex-fuel versions of the 1.8 and 2.0 Duratec engines available, though sales of this option are currently low.
Vauxhall	All Vauxhall vehicles have been E10 compatible since 1993, with the exception of a small number of 2.2 litre GDI engined models (Signum, Vectra and Zafira. Vauxhall have no E85 Flex-fuel models available in the UK.
Volkswagen Audi Group (VW, Audi, Seat & Skoda)	All models except: Vehicles with first generation FSI engines (Polo, Golf, Bora, Touran, Audi A2, Audi A3 and Audi A4 models built in 2000 – 2004, and in some cases upto 2006). And 77 kW Lupo, Audi A4 Limousine with auxiliary heater (2001-2008) and Audi A4 Avant with auxiliary heater (2002-2008). Volkswagen Audi Group have no E85 Flex-fuel models available in the UK
PSA (Peugeot and Citroen)	All PSA's current petrol fuelled LDVs are compatible with E10 from the introduction of the Euro 3 emissions standard (Jan 2000). PSA make one model that can use E85, Peugeot 407 flex fuel.
BMW	No reply The Biofuel Cities report indicates No BMW vehicles are compatible with E10, and the are no E85 flex fuel models available in the UK.
Toyota	All models manufactured since 1998 are E10 compatible. Toyota have no E85 Flex-fuel models available in the UK
Renault (cars)	All Renaults models manufactured since 2000 are E10 compatible except those with >2.0 litre direct injection and 2.0 litre turbo engines built between 2000 and 2002. The Megan is the only car offered for sale in the UK which can run on E85, but sales have been slow.
Honda	Awaiting reply
Mercedes	Virtually all Mercedes cars can use E10 except some very old ones. None can use E85. But contact added that he was more knowledge-able regarding diesel fuelled vehicles. The above view is in agreement with the details given in the Biofuel Cities report (which does specify a few older, low production volume models as requiring super plus fuel, and not being E10 compatible.
Nissan	All Nissan's current models are E10 compatible. However, the date of this compatibility ranges from 2000 (for the Micra, Almera, Almera Tino, Primera, Terano II and Pathfinder). The Biofuel Cities report comments that some models have only been E10 compatible for a shorter time, e.g. Note since 2006 and Qashqai since 2007. This is because these are the years these models were introduced, not because there were previous E10 incompatible version. Nissan have no E85 Flex-fuel models available in the UK
Lotus	All Lotus models are compatible with E10. In addition the Exige 265E is available compatible with E85 (flex fuel) but this is not available in the UK. Also, there is the Lotus 270E, a tri-fuel research vehicle, which I have been driven in, which it is claimed, can run on any mixture of petrol, ethanol and methanol.

Table A2.3 The results of the consultation with light duty vehicle engine manufacturers regarding the capability of their engines to use biodiesel

Company In order of market share	**Capability of their engines to use bioethanol petrol blends**
Ford	All Fords current models are B7 compatible, as too are their older vehicles (there appear to be no models that can not use current pump diesel meeting EN 590:2009) No Ford models are warranted to use blends above B7.
Vauxhall	All Vauxhall light duty vehicles are B7 compatible (both current models and older models). No Vauxhall passenger cars are compatible with higher blends, but from 2007 onwards Vivaro and Movano vans operating within fleet controlled conditions, are warranted to use B30.
Volkswagen Audi Group (VW, Audi, Seat & Skoda)	For the Volkswagen Audi Group all diesel engined vehicles are compatible with the EN590:2009, i.e. compatible with B7. No current models are warranted to use higher biofuel concentrations, i.e. blends above B7. However, 100% RME can be used on non-PD and CRD engines, circa pre 2005.
PSA (Peugeot and Citroen)	All PSA's current diesel fuelled LDVs are B7 compatible. In addition, all common rail, turbo diesel engined vehicles manufacturered since around 1998 – 2000 (this is the HDI engine series) are warranted to run using B30 fuel. Searching through the VCA new car CO2 database, this is all of Peugeot's and Citroen's diesel engined passenger cars and vans. (Although this does require an increased service frequency, and use of specified engine oils). No PSA light duty vehicles are warranted to use blends higher than B30.
BMW	No reply The Biofuel Cities report indicates No BMW vehicles (along with the vast majority of other LDV manufacturers) are compatible with "biodiesel". This is interpreted as blends beyond the B7 as specified in EN590:2009.
Toyota	All current models are B7 compatible. It is believed all older models are B7 compatible (but as warranties have lapsed there was some uncertainty regarding this). Currently Toyota warrant no new models to use blends containing more biodiesel than 7%.
Renault (cars)	All current models are B7 compatible. As for Toyota, it is believed all older models are B7 compatible (but as warranties have lapsed there was some uncertainty regarding this). Currently Renault warrant no new models to use blends containing more biodiesel than 7%. However, Renault engines do make B30 compatible engines which are fitted in Vauxhall vans. But currently Renault vans do not warrant their vans (containing these engines) to use B30.
Honda	Awaiting reply. The Biofuel Cities report indicates No Honda vehicles (along with the vast majority of other LDV manufacturers) are compatible with "biodiesel", interpreted as blends beyond B7.
Mercedes	It was reported that all Mercedes cars can use B7 as specified for current pump diesel (EN590:2009), both current and past models. None are warranted to use blends containing more biodiesel than B7.
Nissan	All Nissan's current models are B7 compatible. It is believed none of Nissan's older diesel LDVs are incompatible with B7 (EN590:2009) either. None of Nissan's vehicles are warranted to use blends containing more biodiesel than B7.
Lotus	Lotus do not make any diesel fuelled vehicles.

Table A2.4 Vehicle manufacturers who make E85 compatible vehicles for sale in UK[54].

Manufacturer	Number of models listed in VCA database	Number of different engine sizes
Bentley Motors	1	1
Cadillac	4	1
Ford	11	2
Peugeot	2	1
Saab	24	2
Volvo	9	3 (1 Euro 5)

Table A2.5 Vehicle manufacturers (in addition to those listed in Table A2.4) who make E85 compatible vehicles for sale in Europe.

Manufacturer	Countries where E85 models are sold
Audi	Sweden
Chevrolet	Sweden
Chrysler	Sweden and Netherlands
Citroen	Sweden
Dacia	Sweden
Dodge	Sweden + 5 other European countries
Hummer	France and Netherlands
Lotus	France
Mitsubishi	Sweden and Netherlands
Renault	Sweden + 2 other European countries
Seat	Sweden
Skoda	Sweden
Volkswagen	Sweden

When added to the 6 manufacturers selling E85 compatible vehicles in the UK, the list extends to 19 manufacturers. 17 of these manufacturers sell in Sweden (with Hummer and Lotus being the only exceptions according to the Biofuel Cities report).

By way of some interesting background, at the time of writing the recommended price of fuel at the pumps in Sweden on 21st September 2010 was:

for standard 95 octane unleaded petrol	12.58 SeK per litre (£1.1304)
for E85	9.14 SeK per litre (£0.8489)[55]

In terms of infrastructure, E85 was available at over 1,200 filling stations in Sweden by early 2008, 30% of the national total, and this total is increasing[56].

Key points concerning the bioethanol capability from the communications with vehicle manufacturers, and from the information already in the public domain from the Biofuel Cities and LowCVP reports are, for spark ignition (petrol-bioethanol fuelled vehicles):

- The vast majority of current models can run using E10. (This is twice the current maximum bioethanol level permitted, which is 5%, but may become a new standard pump fuel in a few years.)
- A very small proportion of current models, but a larger proportion of older spark ignition light duty vehicle can not use E10, but require a protection grade (E5) petrol.
- Six vehicle manufacturers do offer E85 compatible vehicles for sale in the UK.
- However, from 2008 vehicle sales figures uptake is small (around 0.008% of the petrol light duty vehicles sold are capable of using E85 fuel).
- Following the removal of the 20p a litre duty rebate for biofuels from 1st April 2010, manufacturers report the market for E85 vehicles has slumped.

54 Taken from the VCA New Car CO2 database, May 2010 version (available from http://www.vcacarfueldata.org.uk/)
55 Data taken from Statoil website: http://www.statoil.se/FrontServlet?s=sdh&state=sdh_dynamic&viewid=1882197&showMenu=0_2
56 Data taken from C40 Cities, http://www.c40cities.org/bestpractices/transport/sweden_fuels.jsp

- Across Europe the number of manufacturers offering E85 compatible light duty vehicles is 19, with the country with the largest number of sales being Sweden.
- However, for Sweden the fraction of all passenger cars that were E85 compatible for the 24 months from January 2008 to December 2009, (i.e. including diesel vehicles) was around 60%. (This is more than 10,000 times the market share in the UK.)

Key points concerning the biodiesel capability of the current fleet, from the communications with vehicle manufacturers, and from the information already in the public domain from the Biofuel Cities and LowCVP reports are:

- All current CI models can run using B7 (which is what is permitted in current pump diesel complying with EN590:2009).
- A small proportion of older compression ignition light duty vehicles can not use B7, but require a protection grade (E5) petrol.

Appendix 3
Details of Inland and Coastal Storage Facilities

Location	Owner	Connections	Biofuels handled*	Fuels stored	Volume (m^3)	Number of tanks	No of heated tanks
Large Storage Facilities							
Riverside Terminal, Middlesborough	Simon Riverside	Sea, rail, road, pipeline	BD, BE	Oil products	65,150	22	
Aberdeen	ASCO	Sea, rail, road			26,880	31	
Canvey Island	Oikos Storage	Sea, road, pipeline	BD, BE		300,000	100	62
Cardiff Docks	HCB Storage	Sea, road					
Inver	Greenergy	Sea, road	BD				
Buncefield	BP	Road, pipeline					
Kingsbury	BP	Road, pipeline					
	Warwickshire Oil Storage	Road, pipeline					
	Texaco	Road, pipeline					
Grangemouth	NuStar	Sea, road	BD	Petroleum products	86,000	47	6
	Westway	Sea, road	BD	Veg oils	18,604	29	
Coryton	BP	Sea, road					
Poole	Texaco	Sea, road	BE				
West London	Esso	Sea, road, pipeline					
Roath Dock	Chevron (SM)	Sea, road	BD, BE				
Purfleet	Esso	Sea, road, pipeline					
Ellesmere Port	Shell	Sea, road					
Hamble	BP	Sea, road					
Plymouth	Greenergy	Sea, road	BD, BE	Kero	50,085	13	
Ipswich	Vopak	Sea, road		Petroleum products, veg oils	57,000	20	
Tyne Terminal	Simon Storage	Sea, road		Oil products, veg oils, ethanol	56,815	64	11
Dagenham	TDG	Sea, road		Distillates, FAME, ethanol	135,000	200	50
Derry	LSS	Sea, road			86,000		
Portslade, Hove	Simon Management	Sea, road					
Tranmere	Shell	Sea, road					
Clydebank	NuStar	Sea, road	BD	Petroleum products	55,000	16	
Bedworth	Murco	Rail, road					
Theale	Murco	Rail, road					
Westerleigh	Murco	Rail, road					

Location	Owner	Connections	Biofuels handled*	Fuels stored	Volume (m^3)	Number of tanks	No of heated tanks
Trafford Park	Esso	Road, pipeline					
Birmingham Erdington	Esso	Road, pipeline					
Astwood	Esso	Road, pipeline					
Dalston	BP	Road only					
Nottingham	Total Fina Elf	Road, pipeline					
Small Storage Facilities							
Port of Workington	Cumbrian Storage	Sea, road					
East Cowes	BP	Sea, road					
Hull	Westway	Sea, road	BD	Veg oils	25,100	21	
Liverpool - Sandhills	Westway	Sea, road		Veg oils	60,000	44	39
Liverpool - Regent Rd	Westway	Sea, road	BD	Veg oils, fuel oils	19,860	25	
Great Yarmouth	ASCO	Sea, road		Kero, ULSD	10,374	33	
Peterhead	ASCO	Sea, road		Kero, ULSD	35,139	19	
Northampton	BP	Road, pipeline					
Finnart	Ineos	Sea, road, pipeline					
Aviation							
Luton	Shell	Road, pipeline		Primarily jet fuel			
Gatwick Fuel Farm	Shell	Road, pipeline		Primarily jet fuel			
	Esso	Road, pipeline		Primarily jet fuel			
Manchester Airport	Esso	Road, pipeline		Primarily jet fuel			
Stansted	Stansted Fuelling Co	Road, pipeline		Primarily jet fuel			
Sandringham Road Tank Farm	Heathrow HOC	Road, pipeline		Primarily jet fuel			
Heathrow Perry Oaks	Heathrow HOC	Road, pipeline		Primarily jet fuel			
Isle of Grain	BP	Sea, road, pipeline		Primarily jet fuel			
Walton-on-Thames Storage	BP	Road, pipeline		Primarily jet fuel			
Birmingham Int	Esso	Road, pipeline		Primarily jet fuel			
Colnbrook	No data	Rail, road, pipeline		Primarily jet fuel			
Marine							
Falmouth	Falmouth Oil Services	Sea, road		Primarily marine fuel	70,000		
Plymouth	SGS Strath Services	Sea, road		Primarily marine fuel			
Port of Sunderland	Sunderland Oil Storage	Sea, road		Primarily marine fuel			
Portland Port	Portland Bunkers Int	Sea, road		Primarily marine fuel			
Holyhead	Henty Oil	Sea, road		Primarily marine fuel			

*BD refers to 100% biodiesel and BE refers to 100% bioethanol.

Appendix 4

UK Infrastructure Sampling Strategy

Wholesale Storage (Level 3)

	Rail	Airports	Wholesale/distributors	Dedicated Fleet Storage
Define	Depots holding fuel for rail transport	Depots holding fuel for civilian air transport	Depots holding road transport fuel for distribution to the retail market	Depots holding road transport fuel for dedicated fleet refuelling
Population	123	51	250+	3000+
Questions raised/information sought	Ownership Coverage Storage Capacity - Tank #, Type, Volume & Flexibility Unutilised capacity Recent or future change	Ownership Coverage Storage Capacity - Tank #, Type, Volume & Flexibility Unutilised capacity Recent or future change	Ownership Coverage Storage Capacity - Tank #, Type, Volume & Flexibility Unutilised Recent or future change capacity	Ownership Coverage Storage Capacity - Tank #, Type, Volume & Flexibility Unutilised capacity Import – Mode, Volume Recent or future change
Companies approached	Direct contact with rolling stock companies (ROSCOS) and with the Associate of Train Operating Companies (ATOC)	Heathrow Airports Limited	<u>Nationwide operators</u> DCC Watson <u>Small operators</u> Swan petroleum Countrywide Evesons	<u>Haulage</u> Large: Tesco, Sainsburys, Ford, BT Fleet, Royal Mail, Veolia, DHL Supply Chain, TNT, Kuehne + Nagel Small: Tenens Environmental, Samworth Bros, BskyB, Gasrec Ltd, Robert Wiseman Dairies, Great Bear, Thames Water <u>Bus and Coach</u> Arriva, First Group, Go Ahead (Oxford bus company), Stagecoach, National Express, Comfort Delgro (Metroline), Transdev plc, Rotala plc

Inter – Level Transfer

	Coaster	**Rail**	**Road**	**Pipeline**
Define	A coastal vessel capable of moving transport fuel around the UK Coast.	A rail tanker capable of moving transport fuel by rail	A road tanker capable of moving transport fuel by road	A pipeline capable of distributing transport fuel
Population	Unknown	Unknown	Unknown	8
Questions raised/information sought	Ownership Capacity Configuration, volume, flexibility Recent or future change	Ownership of tankers Capacity Tanker #, volume, flexibility Fleet numbers Fuels transported Recent or future change	Ownership of tankers Capacity Tanker #, volume, flexibility Fleet numbers Fuels transported Recent or future change	Ownership Route Capacity Flexibility Recent or future change
Sampling Strategy	Entire Population at Corporate Level	Entire Population at Corporate Level	Entire Population at Corporate Level	Entire Population at Corporate Level
Updated	Greenergy ChevronTexaco	All 3 operators at corporate level plus Murco/Conoco-Phillips.	Corporate to hauliers (Hoyer, TDG, Exel and Wincanton), Oil companies BP, ChevTex, and Greenergy. Distributors - 2 large(DCC, Watson) 4 small (per distributor review)	

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