Scenarios and opportunities for reducing greenhouse gases and pollutant emissions from bus fleets in PTE areas

Prepared for

pteg

by

ttr

Transport & Travel Research Ltd

Study Report

Final

Version 1.4 - March 2009

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Version	1.4 Final
Date	March 2009
File location	\\Ttdc01\company\TTR Projects\Current Projects\pteg bus emissions\Technical\Reporting\PTEG_busttrreport v1.4 final.doc

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ISO 9001
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GB2000157

CONTENTS

Key findings

On city region bus fleets and the environment:

- Reductions in regulated pollutants are taking place across all main transport sectors as Euro standards for toxic emissions have taken effect;
- Trend comparisons indicate that on an average per passenger kilometer traveled basis, bus travel appears to have been more polluting in terms of toxic emissions than car travel over the last 10 years;
- Bus travel now appears to be now less polluting that car travel for Particulate matter, and will get increasingly clean as fewer of the oldest buses remain in the fleet. Car travel may still have the advantage for oxides of nitrogen (NO_x) emissions;
- The historic advantage bus travel has over car travel for greenhouse gas emissions appears to be narrowing as smaller and fuel-efficient cars become more popular and car manufacturers react to EC pressure on CO2 emissions;
- The analysis shows the importance of modernising the bus fleet if the bus is to be promoted as a reduced pollution option compared to the car;
- Increasing the passenger loading can only go so far if older buses are kept in the fleet.

On technologies to improve bus fleets environmental performance:

- The most modern conventional diesel buses are hard to beat for reducing pollutants when compared with current alternative technologies;
- In addition, current (business as usual) rates of fleet replacement could substantially reduce emissions from city region bus fleets if the oldest vehicles are replaced with the newest;
- However, there is a continued risk that old buses are operated in areas with dense populations as a significant proportion of old buses remain in the PTE fleet – 25% of buses in PTE areas could be Euro II standard even in 2012;
- In addition, modern conventional diesel buses will not reduce greenhouse gas (GHG) emissions - the least cost-effective way to reduce GHG is to channel investment into conventional diesel buses;
- The key to high levels of GHG emission reduction is high blend and gaseous biofuel and/or diesel-electric hybrid buses;
- However, the comparable cost of biofuel/hybrid buses against conventional diesel technology is currently a considerable barrier and requires a change in one or more of the following: the bus subsidy regime; fuel and vehicle costs; and/or the framework in which the bus sector is regulated and planned;
- Retrofit of pollution abatement equipment to older buses can be very cost effective for reducing key pollutants, and are suitable for vehicles that have considerable useful life remaining;
- Training and then ongoing encouragement of safe and efficient driving can be a very cost effective complementary measure to reduce emissions;
- The most effective way to green PTE/SPT area bus fleets, in terms of absolute costs and emission reduction, is a planned approach with high-blend biofuel and/or hybrid vehicles introduced when the technology is robust and duty rates / BSOG make them commercially attractive, together with a replacement of the oldest diesel buses with their modern low-pollution versions or targeted emission abatement via retrofit technology.

0 SUMMARY

0.1 Study aims

This report has been produced by Transport & Travel Research Ltd (TTR) on behalf of ***pteg*** as part of a study to investigate scenarios and opportunities for reducing emissions of greenhouse gases and toxic pollutants from bus fleets in the PTE areas.

The aims of this study are to provide ***pteg*** with:

- Information on the policy and political drivers for reducing greenhouse gases and toxic pollutants from the bus fleet;
- Information on the strengths and weaknesses of the various emerging technology/fuel options for new buses;
- A set of broadly costed scenarios for renewing bus fleets in the metropolitan areas to a range of environmental standards, with details of the benefits each would bring and the methods by which they could be implemented; and
- An assessment of how possible reforms of the BSOG subsidy regime could impact on the scenarios.

0.2 City region bus fleets and the environment

EU legislation has regulated vehicle emissions through the application of "Euro" standards for vehicle type approval, with limit values for a range of regulated pollutants becoming tighter over the years. Emissions of the various regulated pollutants have fallen by between 20 and 50% on average since 1995. This has contributed to major public health benefits from cleaner air. A further decrease is expected, bringing levels down to 25-50% of the 2000 level by 2020.[1]

However, take up of cleaner engine technologies by vehicle type has proceeded at different speeds, as fleet replacement rates vary across the sectors. Various low emission zone studies have shown the most cost-effective emission reductions can be achieved with Heavy Duty Vehicles, because of their high emission levels per vehicle compared to Light Duty Vehicles. This seems to apply to buses in particular, because of their high average age compared to all other heavy duty vehicles.

Estimates for bus fleet composition up to 2015 predict that around 10% of the UK bus mileage travelled will be done by vehicles of Euro II standard or lower (manufactured in 1996 or earlier).[2] For particulate matter (PM) such vehicles are over 40 times more polluting than the Euro IV equivalent (manufactured from 2005 onwards). The problems of local air quality are exacerbated by the disproportionate amount of pollution produced from the few oldest vehicles.

[1] CAFE - Clean Air For Europe (2005).
[2] Projections from 1999 NAEI road transport emissions inventory, Netcen (1999).

Trend comparisons, based on national statistics,[3] indicate that on average, per passenger kilometre travelled, bus travel appears to have been more polluting in terms of toxic emission than car travel over the last 10 years. This is at odds with the majority of public perception and marketing messages that bus travel is cleaner. Clearly, adding one passenger that previously drove alone to a bus that is already scheduled is going to reduce their contribution to total emissions, but analysis shows there is only so far increasing patronage could help if the fleet profile is based on a high average age.

Estimates are that bus emissions will fall faster than car emissions in the future, so that on average bus travel will become less polluting for PM emissions compared to car (on a passenger km basis). However, bus travel may remain, on average, more polluting for oxides of nitrogen (NO_x) emissions. This analysis shows the importance of modernising the bus fleet if the bus is to be promoted as a reduced pollution option compared to the car, and indicates that increasing the passenger loading can only go so far to achieve emission parity with car travel if older buses are kept in the fleet.

For greenhouse gas (GHG) emissions such as carbon dioxide (CO_2) national figures for bus and car travel, plus analysis of PTE/SPT area specific data in a parallel *pteg* study[4] seems to show the advantage of bus travel over private transport could be narrowing, particularly as new, smaller and/or fuel-efficient car sales increase the proportion of these vehicles in the total car fleet.

0.3 Technologies to improve bus fleets environmental performance

0.3.1 Euro standards role in improving environmental performance

Euro standards describe the emissions criteria that vehicle manufacturers must type-approve their vehicles to in order to supply for general sale in the EU. The first, Euro I vehicles began to be produced for an EC-specific type-approval standard that came into force in 1993. Euro standards apply to all vehicles whatever their technology basis or fuel type.

Each successive Euro standard has reduced the amount of toxic pollutants allowed to be produced, as measured in testing over prescribed drive cycles. The significant impact of this policy on total road transport emissions is highlighted in section 3.1 of this report.

0.3.2 Diesel fuelled vehicles

For Heavy Duty Vehicles (HDV) such as bus, coach and Heavy Goods Vehicles (HGV) the most common technology is a compression ignition engine fuelled by diesel. Combustion in a diesel engine provides one of most energy efficient power-plants among all types of internal combustion engines. This high efficiency translates

[3] Transport Statistics Great Britain 2007, DfT (2008).
[4] Carbon Footprinting of PTE Policies, Programmes and Projects, AEA E&E for *pteg*.

to good fuel economy and low greenhouse gas emissions (compared to petrol). Other positive features include durability, reliability, and fuel safety. The downsides of diesel engines include high noise, low specific power output, NO_x and PM emissions, and relatively high engine cost (compared to petrol).

Conventional diesel vehicles are the standard HDV technology, with the widest range and number of suppliers. Due to the imposition of Euro standards diesel vehicles have increasingly low levels of NO_x and PM. Huge investments in latest engine design by manufacturers have been required to meet Euro standards reliably. In the past there has been a small, and generally temporary, CO_2 penalty from increased fuel consumption in period immediately after a new Euro standard.

The objective of engine manufacturers is to meet increasingly stringent emission limits, while maintaining durability, fuel efficiency and cost effectiveness as far as possible. The adoption of ever more stringent Euro standards has led to improvements in combustion technology, a need for exhaust after-treatment and even the use of additives to help the removal of toxic pollutants.

There will be a small increase in maintenance required for Euro V diesel vehicles that use Selective Catalytic Reduction (SCR) for reducing oxides of nitrogen emissions (NO_x). Exhaust Gas Re-circulation (EGR) is an alternative method for reducing NO_x levels that does not require additives, but is somewhat less efficient than SCR at reducing NO_x.

0.3.3 Retrofit technology for emission abatement

Retrofitting older heavy duty vehicles, such as buses, with exhaust abatement technology can significantly reduce emissions and bring them up to the standard of much newer vehicles that will have benefited from more stringent application of Euro standards at the type approval stage.

To reduce particulate emissions from buses, diesel particulate filters (DPF) are used. When operating effectively DPF can reduce emissions of particulate by 90 - 95%. These are fine mesh filters that collect carbon particles. These devices generally have some means of self-regeneration, such as a fuel-borne catalyst or embedded catalyst within the filter. For DPF to work effectively the vehicle must include in its duties a phase of medium-high speed operation, in order to raise exhaust temperatures and regenerate the filters. Some manufacturers do not recommend fitting their DPF to the very oldest vehicles (pre-Euro and Euro I), whereas others are more flexible. The cost to purchase and fit a DPF is around £4000. DPF require regular maintenance to empty out the ash from combustion of collected particles which could cost about £200 each time, required once or twice a year. Some early DPF increased fuel consumption (by 0.5 - 1%), but newer models have a negligible effect if the filter is maintained properly. There is however a potential issue of increased NO_2 as some evidence links DPF to increased amounts of NO_2 emissions.

Diesel Oxidisation Catalyst (DOC) technology is an alternative option for removing PM emissions. DOCs are effective at removing larger particulate matter, reducing total PM by some 20-50%. The equipment is lower cost (than DPF) at around £1,000 per vehicle. DOCs require minimal maintenance, and are more likely to be suitable (i.e. remain effective) for the very oldest vehicles and those with only low speed duties.

To reduce emissions of NO_x a selective catalytic reduction (SCR) device can be fitted. SCR engines inject urea (ammonia) and water into exhaust gasses, producing nitrogen and water. An SCR can reduce emissions of NO_x by around 50-90%, depending on the duty cycle. SCR is best suited to depot-based vehicles as the system needs topping up with AdBlue (the mix of urea and water used in the SCR system).

Exhaust Gas Re-circulation (EGR) is an alternative approach to reducing NO_x levels, and works by recycling exhaust gases to lower combustion temperatures and emit less NO_x. EGR is somewhat less efficient than SCR at reducing NO_x (at around 40-50%), but does not require additives.

The available retrofit options are not universally favoured (or adopted) by bus operators in the UK. However, the cost-effectiveness of this option for dealing with key regulated pollutants means it should be of considerable interest for a PTE-wide strategy to reduce emissions. Retrofit technology could be very relevant for early low-floor buses that increasingly will be seen as the more polluting sub-section of the bus fleet.

0.3.4 Diesel-electric hybrid

A diesel-electric hybrid is powered by both an internal combustion (diesel) engine and electric motor from battery stored electricity. Regenerative braking is used to recharge the on-board batteries, and because the battery is charged by the operation of the bus no extra charging in the depot is required. As a result a smaller internal combustion engine than normal is required and aided by the electric motor this leads to improved fuel efficiency compared to a conventional vehicle.

Hybrid buses use the same diesel fuel as a conventional bus, and therefore no new infrastructure is required in order to operate a hybrid bus. Maintenance costs for hybrid buses are higher than those for conventional diesel buses due to the additional technology and the need for battery maintenance and replacement in time. Fuel costs are lower due to their fuel efficiency.

Hybrid buses are available in Europe from a small, yet growing, number of manufacturers. Up until this point there has been a limited choice of vehicles produced in small volumes for the UK market. The available technology currently has not had much operational ‘in-use’ testing or experience compared with conventional diesel vehicles. A number of trials to date have experienced reliability problems in diesel-electric hybrid operation.

Revisiting earlier analysis for TfL on the economics of diesel-electric hybrids it can be seen that if diesel prices are high there is a case for operating such vehicles based on fuel savings alone, over a 10-year operating life. This would require reliable and robust diesel-electric hybrids on which to base this long-term financial decision. The current TfL purchasing commitment to hybrids (combined with cost savings due to rising diesel oil prices) should mean much more experience of what is a suitable diesel-electric hybrid, and therefore increase commercial acceptance by some operators in the medium term.

0.3.5 Compressed Natural Gas and Liquefied Natural Gas

Natural gas can be stored as a vehicle fuel either as compressed natural gas (CNG) or liquefied natural gas (LNG). CNG vehicles can be designed to run either solely on gas using dedicated gas engines (mono-fuel), on gas and diesel in the same modified diesel engine (dual-fuel) or by switching between petrol and gas (bi-fuel), with petrol used as a back up fuel and to extend range. Mono-fuel and dual-fuel are the most common designs for heavy duty vehicles such as bus, while bi-fuel designs tend to be used in light duty vehicles and are based on petrol engines.

Natural gas is made up of a mix of propane and butane and is derived from natural gas fields or from oil refining and is therefore not a renewable fuel. Life cycle CO_2 emissions are approximately the same as for diesel (perhaps 10-15% lower) but NO_2 emissions are significantly lower (80 per cent lower) and particulate matter is virtually non-existent. These natural advantages are being eroded as diesel engine exhaust abatement technology improves in response to successive Euro standards, although the very best gas engines can still outperform the best diesel engines on most relevant emissions. Noise levels are lower than for equivalent diesel engines.

Gas vehicles can be purchased new, or converted from existing diesel vehicles to run as dual-fuel. The best emissions performance tends to comes from dedicated gas engines. Fuel storage tanks on the vehicle add weight can reduce the overall payload for certain types of vehicle (such as buses). The additional fuel storage requirements and specialist engine modifications/design mean higher costs for a new vehicle. Maintenance costs for gas buses have tended to be higher than for conventional diesel buses due to higher parts costs and increased maintenance requirements, although there is some experience of this being dealt with through negotiation at the procurement stage. Fuel costs are lower so it is possible for high-mileage fleets to benefit financially from this fuel, particularly when covering high mileages. The best financial case for CNG tends to be for use in long-distance freight haulage operations in the UK (for quickest payback of the capital costs).

There have been some trials of CNG buses in the UK. Early trials did not produce convincing results, with initial problems over reliability and maintenance costs. The variable quality/specification of gas used may have been a factor. In addition, the configuration of the Fuel Duty Rebate (FDR) and its replacement, Bus Service Operators' Grant (BSOG), meant that fuel costs were higher overall than for diesel vehicles. Experience with the technology has improved performance, but there are few CNG buses operating in the UK at this time.

0.3.6 Biomethane

Biomethane is the term used for upgraded and cleaned biogas (the raw gas) produced from anaerobic digestion of organic matter, or decomposition in land-fill sites. Biomethane is chemically very similar to natural gas, and therefore can be stored in the same way and used in the same vehicles. Biomethane is available in compressed and liquid forms (as per natural gas).The use of biomethane in vehicles has many of the same benefits, and barriers, as using natural gas.

A major advantage compared to natural gas (and many other road transport fuels) is that biomethane is a renewable fuel produced from waste materials and therefore the life cycle carbon emissions are significantly reduced. Using biomethane in vehicles can give a reduction in life-cycle CO_2 emissions of around 80-90% compared to conventional diesel. If the waste material is animal manure, that would otherwise decompose and release methane into the atmosphere, then capturing this via the AD process and using it as a fuel actually produces a negative CO_2 balance.

0.3.7 Biodiesel

Biodiesel is produced from the vegetable oils from crops such as rapeseed or soy, or can be reclaimed from recycled waste cooking oil. Biodiesel can be blended with conventional diesel at varying proportions. At low-blends diesel vehicles can be refuelled in the same way as conventional diesel vehicles and therefore major new infrastructure is not required, although care is required during storage of the fuel to prevent water absorption.

Low-blend fuels containing 5% biodiesel (B5) are widely available and can generally be used in the same way as conventional diesel. Higher blends (e.g. B10, 20, 30, 50 and B100) are available to varying specifications, but their suitability depends on the vehicle requirements. Reliable use will depend on the specification (and blend limit) the vehicle manufacturer has defined as acceptable.

Biodiesel has been known to break down deposits of residue in the fuel lines where mineral diesel has been used. As a result, fuel filters may initially need changing due to clogging with particulates if a quick transition to high-blend biodiesel is made.

Life cycle CO_2 emissions vary depending on the source of the biodiesel. If land use change is not considered and assuming today's production methods, 100% biodiesel from rapeseed and sunflower oil produce 45%-65% lower greenhouse gas emissions than normal diesel. Lower blend biodiesel produces proportionately lower GHG savings.

0.3.8 Bioethanol

Bioethanol is produced from the fermentation of plant-based materials, such as corn, wheat and sugar cane.

Bioethanol can be used in compression ignition engines, suitable for heavy duty vehicles such as buses, designed or modified to handle the different characteristics of ethanol as a vehicle fuel. Bioethanol as a bus fuel is generally 95% biofuel with the remainder comprised of ignition improvement additives. Etamax-D and Greenergy E95 are examples of fuel produced for bioethanol specific compression ignition engines such as those found in Scania buses. The most experience of bus fleet operation in Europe is found in Sweden, using Scania-manufactured vehicles.

For high-blend bioethanol special transport, storage and refuelling infrastructure is needed, because ethanol can corrode equipment designed for diesel or petrol. Ethanol and water can dissolve into one another, degrading the properties of the fuel, which requires precautions in fuel storage and handling.

The fuel costs per litre of bioethanol are slightly lower then diesel (<5%) but fuel consumption on a volumetric basis is higher than gasoline by about 50-60% for pure ethanol (about 40% for E85) due to the lower energy density. For this reason, fuel consumption of bioethanol buses will tend to be higher than their diesel counterparts.

Estimates of the GHG savings of bioethanol vary widely, mainly depending on the type of feedstock and manufacturing process. Depending on the production method and source, the best-performing bioethanol gives a 70% carbon dioxide reduction, with UK-sourced bioethanol providing around a 25 to 50% reduction, from either wheat or the more effective sugar beet.

0.3.9 Hydrogen fuel cell

Hydrogen is produced by the electrolysis of water or by the breakdown of a hydrocarbon source (e.g. natural gas, fossil fuels or ethanol). In some cases it is also produced as an industrial by-product.

When used as a fuel the only by-product of hydrogen combustion is water, leading to zero tailpipe emissions. Life cycle CO_2 emissions vary depending on the source of electricity used to produce the fuel. Where renewable electricity is used, the life cycle emissions can be lower.

Production of hydrogen-fuelled vehicles has been limited to a small number of demonstration fuel cell projects made by a few vehicle manufacturers. Currently such vehicles can cost up to 10-20 times more to produce than their conventional fuelled equivalents (e.g. £1m+ per bus). At the present stage of development the cost of the vehicles and associated refuelling infrastructure is extremely high.

Therefore hydrogen fuel cells and hydrogen combustion engines are considered to still be at a prototype stage, with only small-scale demonstrations having been carried out (e.g. in London). While useful, these should be viewed as steps in a longer-term process. It is very unlikely that this technology will become commercially attractive to bus operators within the 10-year time horizon of this study.

0.3.10 Driver training for fuel efficiency

Driver behaviour can significantly affect fuel consumption and therefore is a potential non-technology route to achieving reduced emissions (of both regulated and GHG). HGV operators who implement fuel management programmes (of which vehicle and driver performance monitoring and incentive schemes are component elements) achieve a minimum of 5% fuel savings within the first year.[5] Actual savings depend on the exact nature of the fuel management programme or the individual initiative implemented.

[5] SAFED for HGVs - A Guide to Safe and Fuel Efficient Driving for HGVs. DfT. (2006)

Much work has been done in the field of fuel efficiency in the HGV industry, but it has been much more slowly adopted in the public transport industry. Information from the major bus operators suggests they wish to do more in this area and there is certainly much potential for improvement and cost/emissions savings.

0.3.11 Conclusions on current and emerging technologies / fuels

For new vehicle purchasing decisions, the latest Euro standard conventional diesel buses are very attractive for reducing the environmental impact of PM and NO_x, given their reliability, tested design and bus operators existing experience in refuelling, operation and maintenance of such vehicles. As new vehicles they are a very cost effective option.

Retrofitting older vehicles with exhaust after-treatment for NO_x, PM or a combination of both (with a dual system) is extremely cost effective, but has not been attractive to bus operators in the current regulatory regime where there are few commercial benefits to reducing pollution further than the business as usual trends.

A number of technology/fuel options are available that can reduce emission levels to lower than current Euro standards and more significantly reduce GHG emissions. Low-blend biofuel such 5% biodiesel (B5) are becoming standard and on a national basis will contribute to a noticeable reduction in GHG emissions from road transport. However, the key to more significant levels of GHG emission reduction from bus fleets is in the use medium to high-blend and gaseous biofuels and/or hybrid drive-trains. Biodiesel at a high-blend could deliver the GHG benefits of renewable fuels at a lower additional cost, as engine design and refuelling infrastructure are quite similar to standard diesel. For the same reason diesel-electric hybrid technology has the practical benefit of using a standard diesel fuel, and potentially in the future medium to high-blend biodiesel.

In the UK the key sustained take-up of high-blend biofuel will be an effective reform to BSOG and a favourable fuel duty differential on biofuel for buses beyond 2010, in order to overcome the price disincentive to bus operators.

A complementary option for reducing fuel use (and associated emissions) is for bus operators to introduce fuel management systems and safe/efficient driving training and incentive schemes for bus drivers.

Table 0.1 below summarises the current status of the technologies and fuels for use in bus fleets, together with their current advantages and drawbacks.[6] The biofuel options are for high-blend fuels (>10% by volume).

It should be acknowledged that experience of alternative technologies and fuels to date has included problems with performance and reliability. The maintenance cost of a new technology, introduced in small numbers, is generally higher than the existing and accepted option. Capital costs for supply and storage of alternative fuels tend to fall more heavily on the initial users, making the upfront costs needed to use biofuel much less likely to be offset by the potential for lower fuel costs. The

[6] Update of a summary table from EST Transport Energy 'The Route to Cleaner Buses'(2003)

current system of BSOG has up until now actively discouraged take-up of alternatives to diesel fuel, and any capital investment in order to reduce fuel consumption (e.g. diesel-electric hybrids).

The use of diesel-electric hybrids, high-blend bioethanol and biodiesel or gaseous fuels such as biomethane will require an investment in one or more of the following: depot fuelling equipment; training and maintenance regimes; and more expensive vehicles. The kinds of issues that will need to be addressed in order to make cleaner, low carbon technologies and fuels more viable include: improving vehicle reliability; reducing absolute costs; and/or enabling the factoring the value of saved emissions into purchase and/or operating costs.

One aim of this study is to attempt to forecast forward when these issues might be addressed. If a sufficient number of current policy drivers, support mechanisms and initiatives ensure momentum behind low emission technology/fuel options then a potential pathway to cleaner fleets over the next 10 years could initially be based on diesel-electric hybrids, followed by high-blend and gaseous biofuels and ultimately biofuel-electric hybrids. This study makes some predictions about when low emission technologies and fuels could be commercially attractive to bus companies, and uses this as a basis for some of the future scenarios for greening PTE/SPT fleets, which are described in chapter 4.

Table 0.1: Summary of current technologies and fuels

Fuel / vehicle type	Pros	Cons
Diesel	Standard technology and therefore of widest availability and number of vehicle and fuel suppliers; increasingly low levels of air pollutants (PM and NO_x) from advancing engine design and exhaust treatments; current BSOG arrangements refund 80% of duty on diesel used making it cost-effective compared to alternative fuels with lower duty levels.	New Euro standards sometimes herald slight rise in fuel consumption; some increase in maintenance required for Euro V SCR engines.
Natural gas (CNG or LNG)	Slightly lower CO_2 emissions compared to diesel; low levels of air pollutants; low levels of engine noise; low fuel duty compared to diesel. Vehicles quite widely available in mainland Europe.	Currently limited public refuelling infrastructures; dedicated refuelling infrastructure more costly than diesel; loss of some load space due to weight of gas tanks; vehicles are more expensive to buy and maintain than diesel vehicles; reliability/cost issues in early UK bus trials.
Biomethane (CBG or LBG)	Considerably lower CO_2 emissions. Remainder as per natural gas.	Currently not available via the natural gas grid, so requires dedicated transport as well as refuelling (unless depot located with production site).
Bioethanol	Lower CO_2 emissions compared to diesel; low levels of air pollutants; low fuel duty compared to diesel.	Dedicated refuelling infrastructure slightly more costly than diesel; fuel efficiency considerably lower at high-blends. Choice of fuel source can impact on sustainability.
Liquefied petroleum gas (LPG)	CO_2 emission similar to diesel, generally low levels of air pollutants; lower engine noise; low fuel duty compared to diesel	Limited but expanding public refuelling infrastructures (1200); loss of some load space due to weight of gas tanks; vehicles are more expensive to buy than diesel vehicles, but maintenance cost now largely similar to diesel; reliability/cost issues in early UK bus trials
Diesel-electric hybrid	Lower CO_2 and other pollutants compared to equivalent diesel; requires only diesel fuel; better fuel economy.	Vehicles are more expensive than diesel counterparts and require more specialist maintenance; earlier stage of development compared to diesel mean reliability yet to reach that level.
Biodiesel	Lower CO_2 and reduction in PM; low blends need no modification needed to engine.	Low blends provide more limited benefits (although on a national scale these are significant); higher blends often not acceptable under manufacturers warranty; slight increase in NOx emissions

		compared to ULSD. Choice of fuel source can impact on sustainability.
Battery electric	Zero emissions at point of use; low cost fuel; silent operation.	Batteries and vehicles have tended to be more expensive than diesel vehicles; pollution still created (at power station) unless created from renewable sources; vehicle size currently limited; range can be limited between charges; battery durability can be limited.
Hydrogen fuel cell	Zero emissions at point of use; low noise operation. Potential for low CO_2 emissions if based on renewable sources.	Experimental/pilot stages of technology mean extremely high purchase and operation costs; requires specialised/ dedicated refuelling infrastructure.
Exhaust abatement technology (retrofit)		
Diesel Particulate Filter (DPF)	Highly effective at reduction particulate matter including ultra-fine particles (by up to 95%); can quality vehicle for reduced pollution certificate (RPC) and lower Vehicle Excise Duty (VED).	Choice of DPF needs matching to age of vehicle, and duty cycle of vehicle to ensure optimum operation; annual/bi-annual maintenance required; early or poorly maintained DPF increased fuel consumption; may be some evidence of increased NO_2 production.
Diesel Oxidisation Catalyst (DOC)	Effective at removing larger particulate matters (20-50%); Lower cost (than DPF); more likely to be suitable for very oldest vehicles and any duty cycle; minimal maintenance.	Cannot reach potential emission reduction of DPF.
Exhaust Gas Recirculation (EGR)	Has potential to reduce NO_x emissions by 40 – 50%, depending on duty cycle; can be retrofitted to a range of HDV; no maintenance.	Cannot reach potential emission reduction of SCR.
Selective Catalytic Reduction (SCR)	Has potential to reduce NO_x emissions by 30 – 70%, depending on duty cycle; can be retrofitted to a range of HDV.	Requires topping up with urea when refuelling (approx 5% by volume). Will become the norm for modern Euro V HDV that use SCR. Retrofit to older vehicles only benefits NO_x levels.

0.4 PTE policy context

PTE responsibilities and powers to influence commercial bus services in their area have been limited. Regulations from the recent Local Transport Act 2008 will enhance the existing mechanisms of VPA, SQP and QC to provide more effective methods of improving network, timetable and vehicle quality through the co-ordinating role of the PTE (or Transport Authority in non-Metropolitan areas).

DfT has extended Traffic Commissioner powers to enable actions to be taken on grounds of improving air quality via Traffic Regulation Conditions (TRC). TRC have been taken up in Bath and more recently and extensively in Norwich, as the basis for a Low Emission Zone.

Overall, PTEs have been hindered in their efforts to introduce cleaner, low-carbon vehicles, as bus operators understandably resist any increase in costs or risk to their operations (from non-conventional vehicle technology). The arrangements for Bus Service Operators' Grant (BSOG), previously called Fuel Duty Rebate, only hindered the economic case further against investing in fuel-efficient vehicles or renewable fuels. Support for low-carbon buses through changes to BSOG was announced in the November 2008 pre-budget report.

Overall, there are significant policy steps to encourage low emission and low carbon vehicles in the UK, but until very recently there have been some sector-specific barriers to their introduction for bus services in the deregulated environment outside London.

0.5 Fleet improvement scenarios, impact and costs

A range of scenarios for the renewal of the Metropolitan area bus fleets was determined, based on the review of policy drivers, policy tools, current/emerging initiatives and trends in technology/fuels.

Scenarios were produced based on a combination of different vehicle replacement rates and varying ambition (and appetite) for alternative technology/fuels. The technology/fuel component of each scenario is based on different proportions of current conventional combined with fuel-efficiency technology (i.e. hybrids) and GHG reducing technologies (hybrid plus biofuel powered vehicles).

Three study years were chosen, from the current situation (2007/8) to the future years of 2012/13 and 2015/16. The future years are the business as usual (BAU) outcomes expected if rates of fleet renewal continue at current levels of 5.5% p.a. A more optimistic 2012/13 BAU scenario was generated based on a higher than current fleet replacement rate of 7.5% p.a. The business as usual (BAU) estimates provide the baseline years against which 'do-something' scenarios were generated and then measured. Five do-something 2012/13 scenarios were generated and four 2015/16 scenarios. The scenarios resulting from the combination of replacement rate and ambition for alternative fuels/technologies are illustrated in Table 0.2 below.

Table 0.2: Summary of fleet renewal scenarios

		Level of ambition and Fleet renewal policy			
Year		**BAU**	**1. Low**	**2. Medium**	**3. High**
2012/13	**Fuel / Technology mix**	a) Conventional diesel	a) Fuel efficiency	a) Fuel efficiency	a) Fuel efficiency
				b) Fuel efficiency & biofuels	b) Fuel efficiency & biofuels
2015/16	**Fuel/ technology mix**	b) Conventional diesel	b) Fuel efficiency	c) Fuel efficiency & biofuels	c) Fuel efficiency & biofuels
					d) Conventional diesel
Fleet replacement rate (p.a.)		a) 5.5% current b) 7.5% optimistic	5.5%	10%	16.5%

In an effort to make the scenarios more realistic the numbers of vehicles that could be 'replaced' with more fuel efficient or renewable (bio) fuelled vehicles was carefully estimated based on the actual composition of various PTE bus fleets and the selected fleet replacement rates. The availability of future technologies at a reliability and cost likely to enable commercial take up was built into the estimates. For example it was predicted that diesel-electric hybrids do not start entering the future PTE fleets until after 2012, and high-blend biofuel vehicles a year or two later than that. This means that the 2012/13 year scenarios include somewhat limited numbers of non-conventional vehicles, which limits their impacts, but is a more realistic forecast.

For each of the scenarios developed, a broad assessment of the costs and environmental impacts has been carried out. To estimate the impacts of the scenarios actual sample fleet data from the PTE/SPT areas has been used as inputs to a spreadsheet tool. This tool has been used to assess for each scenario the environmental impacts relative to a future business as usual baseline. Vehicle replacement numbers have been used in tandem with data gathered during the background stages to estimate broad capital costs of each scenario. In this manner, estimates were made of the amounts of regulated and GHG emissions for each scenario and of investment costs in each PTE/SPT area.

Figures 0.1 and 0.2 below show the total NO_x and PM tailpipe emissions for each scenario. Emission estimates have been compiled separately for each PTE area, but presented together in these figures to show the impact of the scenarios across the total PTE/SPT area bus fleet.

To aid understanding, the percentage decrease between the current 2007/08 situation (5.5% replacement rate) and the 2012/13 baseline business as usual (BAU) scenario is annotated in orange. This shows a 29% reduction for NO_x and a 49% reduction for PM. These reductions are due to anticipated improvements in average bus fleet emissions as a result of progression through the Euro standards. The green annotation then shows the percentage decrease in emissions for each of the 2012/13 scenarios compared to the current BAU 2012/13 scenario. The blue annotation highlights the percentage decrease in emissions for each of the 2015/16 scenarios compared to the BAU 2015/16 scenario.

Figure 0.1: NO_x emissions by scenario

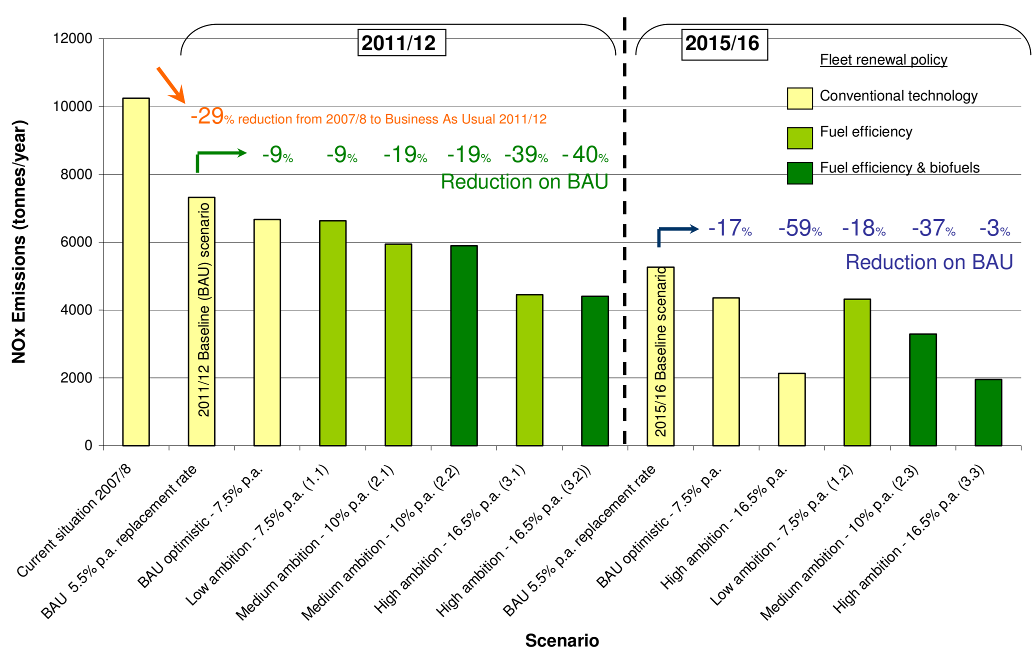
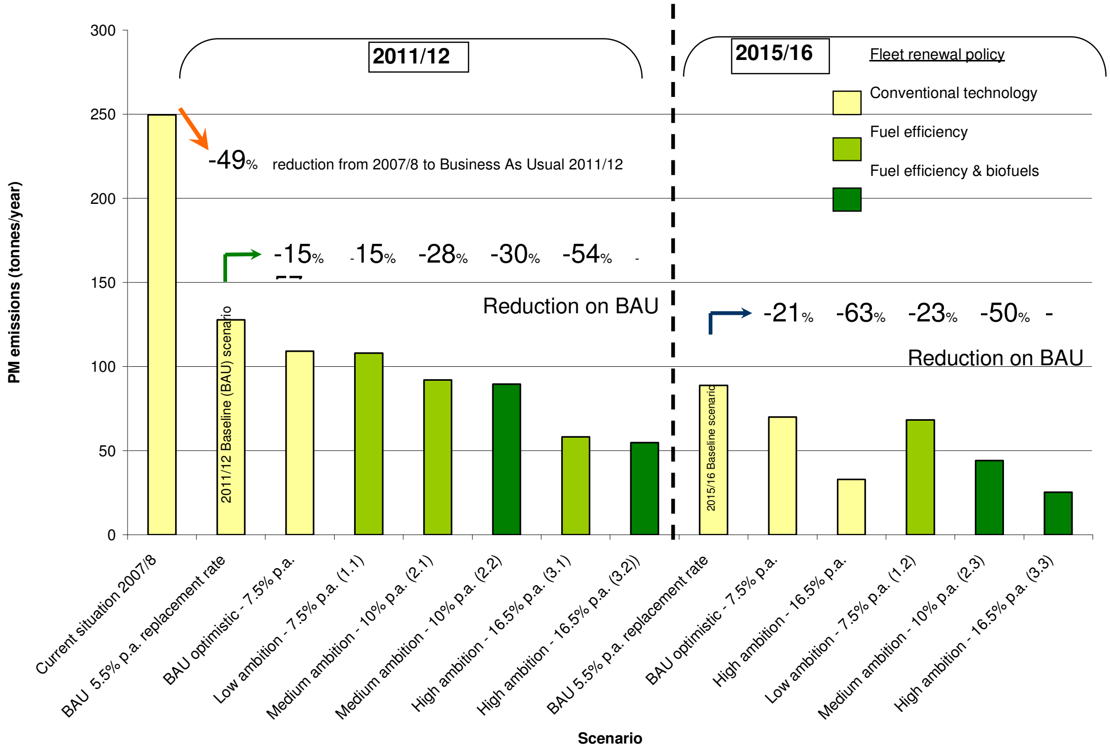


Figure 0.2: PM emissions by scenario



The analysis of absolute emission reductions shows that for toxic pollutants the most important tool to reduce emissions is to ensure (and hopefully accelerate) the vehicle replacement rates to remove the oldest, most polluting vehicles from the bus fleet. Older vehicles are disproportionately polluting, and even taking the national (average) view some very polluting vehicles are predicted to remain in the fleet for some years to come.

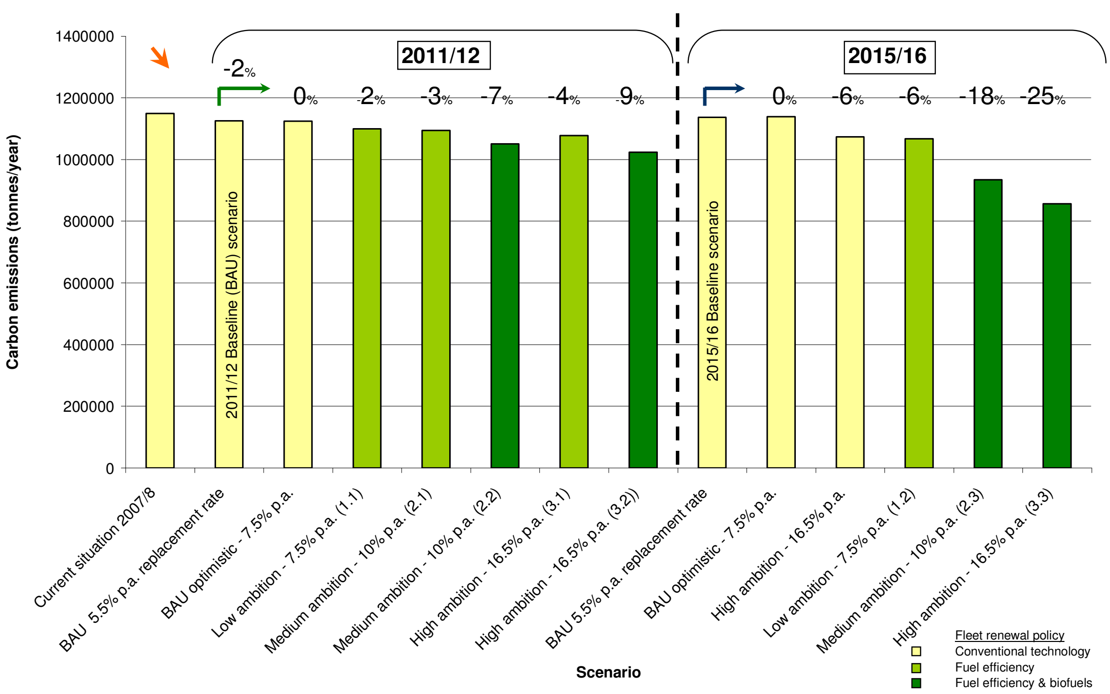
The analysis suggests that new technologies (diesel-electric hybrid and renewable fuels) can reduce toxic emissions further, but conventional diesel vehicles will become increasingly ‘clean’ and difficult to beat on regulated pollutant emissions. The latest conventional diesel vehicles are predicted to achieve nearly as much of a reduction in regulated pollutants as if some of this investment in new vehicles was allocated to diesel-electric and biofuel vehicles. Therefore, realising the additional benefits of alternative technologies and fuels can only be done by deploying significant numbers, rather than small scale demonstrations on single routes.

The study has also undertaken a similar analysis of scenarios based on the life-cycle emissions of producing, distributing and using a particular fuel in a given technology. The estimates use comparatively conservative figures for the potential benefits of renewable fuels. Overall, the analysis emphasises that, in contrast to the toxic emissions, fleet renewal with solely conventional diesel vehicles does not have an impact on life-cycle carbon emissions and is not a cost-effective way to achieve reductions in greenhouse gases. If vehicle kilometres travelled and driver behaviour remains the same, then carbon reduction is only possible with greater fuel efficiency and/or renewable fuels.

The analysis illustrates that the largest reductions cannot be realised until further into the future (2015/16). This is largely because more wide-spread commercial take-up of diesel-electric hybrids and medium to high-blend biofuel are not anticipated in PTE/SPT areas before 2012.

The more ambitious scenarios in 2015/16 assume the when new vehicles are purchased they include reasonable numbers of hybrid and high-blend biofuel vehicles (around 60%) to complement the conventional diesel vehicles, and that about half of the diesel vehicles operate with B20 (20% biodiesel) blend. With such scenarios the analysis shows it could be possible to achieve significant GHG reductions (of 18 - 25%), noting this is based on rather conservative estimation figures.

Figure 0.3: Life-cycle carbon emissions by scenario



It is important to understand the levels of investment that would be required to achieve a given emission reduction scenario. The study has therefore built on the cost-assessment of various technology/fuel options presented in Chapter 3 to estimate a total capital cost for each scenario in each PTE/SPT area. It is clear that increasing the fleet replacement rates from the current 5.5% to the scenarios representing 7.5%, 10% or 16.5% would have a very significant cost, whatever the technologies chosen in the mix of new vehicles. Based on current experience, biofuel and hybrid vehicles are estimated to require additional capital investment costs in the future compared to conventional diesel technology. Biomethane is estimated towards the upper end of the range of capital costs, diesel-electric hybrids around the middle and biodiesel towards the lower end of the range.

A complementary action for reducing fuel use (and associated emissions) whatever the technology used is for bus fleets to introduce fuel management and safe/efficient driving training and incentive schemes for bus drivers. In addition retrofit with DPF, and potentially SCR/EGR, could play a significant role in cleaning up older vehicles which otherwise are serviceable and Disability Discrimination Act (DDA) compliant.

From the analysis undertaken the best overall strategy to ensure a significant reduction in regulated and GHG pollutants is to share new vehicle purchases between latest conventional diesel technology, diesel-electric hybrid and biofuel vehicles in order to achieve a reasonable scale of reduction while combining the relative cost-effectiveness each technology brings to these different emissions.

However, as noted earlier in this chapter the additional cost of hybrid and some types of high-blend biofuel buses over conventional diesel operation is a considerable barrier to overcome and requires a change in one or more of the following: the bus subsidy regime; fuel and vehicle costs; and the framework in which the bus sector outside London is regulated.

0.6 Conclusions

The study has considered what mechanisms would be important to realising the scenarios proposed for greening PTE bus fleets. The various scenarios modelled in this study are made up of two components: a fleet replacement rate and a policy for certain technology/fuel characteristics (supporting diesel fuel efficiency and biofuels, or just diesel efficiency).

It is possible that the 'low-ambition' scenarios with replacement rates of 7.5% may be achieved by operators alone, under influence of external factors such as:

- operators increasing their fleet replacement rates in response to the upcoming DDA compliance dates;
- the historically high price of diesel (and in parallel an improving economic and reliability case for hybrids).

In order that high-blend biofuels and fuel-efficient vehicles can be considered in a strategy for greening PTE fleets in more than pilot/demonstration numbers, effective changes to the relationship between fuel duty and BSOG are required. An announcement on incentives for low-carbon buses was made in the November 2009 pre-budget report, with details to follow, but the current favourable duty differential of 20ppl for biofuels is due to be reviewed in 2009/10.

There is an argument for supporting demonstration of biofuel technologies in the UK now that there are some large bus fleets operating in a few mainland European cities using dedicated bioethanol, biodiesel and biomethane vehicles. Demonstrations can be useful to help overcome some understandably negative perceptions held by UK bus operators based on earlier vehicle trials, which will otherwise be a barrier to introducing many of the GHG reducing technologies into PTE bus fleets.

Changes to the current arrangements for the organisation of bus services in PTE areas are required in order to achieve a shift sufficient to reach the medium and high-ambition scenarios proposed in this study. These are now dependent on regulations for SQP and QC derived from the recent Local Transport Act. It is hoped that the stability and removal of damaging competitive practices can enable long-term investment plan to be to properly costed, decisions made and then implemented. Work has begun at some PTEs on the opportunities that SQP and QC would provide, and this information and experience should be shared as a matter of priority as a basis for a strategy to green bus fleets.

1 INTRODUCTION

1.1 Background

This report has been produced by Transport & Travel Research Ltd (TTR) on behalf of ***pteg*** as part of a study to investigate scenarios and opportunities for reducing emissions of greenhouse gases and toxic pollutants from bus fleets in the PTE areas.

pteg's main tasks are facilitating the exchange of knowledge and good practice within the PTE network, and raising awareness nationally about the key transport challenges which face the city regions, and the public transport solutions which PTEs are implementing. ***pteg*** represents the six English PTEs, with Strathclyde Partnership for Transport and Transport for London as associate members. The study has been being co-funded by the six English PTEs and Strathclyde Partnership for Transport.

The aims of this study are to provide ***pteg*** with:

- Information on the policy and political drivers for reducing greenhouse gases and toxic pollutants from the bus fleet;
- Information on the strengths and weaknesses of the various emerging technology/fuel options for new buses;
- A set of broadly costed scenarios for renewing bus fleets in the metropolitan areas to a range of environmental standards, with details of the benefits each would bring and the methods by which they could be implemented; and
- An assessment of how possible reforms of the BSOG subsidy regime could impact on the scenarios.

1.2 Context

A number of recent developments have meant that the focus on reducing emissions from bus fleets is likely to intensify over the next few years. These include:

- London’s work on introducing a LEZ and greening the bus fleet;
- Potential EU legislation;
- Public interest in the environmental performance of public transport and a possible change in balance of green credentials as car fleets continue to improve;
- Stakeholders’ assumption that Statutory Quality Contracts and Statutory Quality Partnerships are partly being promoted for environmental reasons; and
- Likely reform of BSOG, with options that include re-directing subsidy to incentivise reducing emissions and GHG from the bus fleet.

In the past, PTEs/SPT have promoted cleaner vehicle technology through piloting new vehicle types (particularly on high profile city centre services) and through specific grants (such as for particulate traps or other retrofit technology). However, the reduction in the availability of government grant aid for the introduction of greener buses has hampered PTE/SPT's work in this area.

Research recently carried out by Merseytravel[7] has suggested that without significant intervention the environmental advantages of the bus will continue to be eroded as the environmental standard of the car fleet steadily improves.

The PTEs/SPT could manage bus emissions by the specification of tendered bus contracts. However, the PTEs/SPT have raised some concerns due to a number of issues:

- Different technology and fuel combinations have different strengths and weaknesses in the relative emissions of greenhouse gas and toxic pollutants;
- Vehicle technology and developments in alternative fuels are developing rapidly, making it hard to judge how the various competing claims made for the different options will work out in practice (including on costs, reliability, performance and 'well to wheel' CO_2/toxic emissions); and
- Passenger loadings can make a big difference to environmental performance.

The six English PTEs, together with Strathclyde Partnership for Transport, have commissioned this study in order to investigate these concerns and to identify scenarios and opportunities for reducing emissions of greenhouse gases and toxic pollutants from bus fleets in the PTE metropolitan areas.

1.3 Contents of this report

After this brief introduction, we set out the policy and political drivers in Chapter 2. In Chapter 3 we provide a review of technology and fuels relevant to the UK bus industry. Chapter 4 contains the description and analysis of the scenarios for greening PTE fleets, and commentary on the practicability of achieving them. Conclusions are drawn together in Chapter 5.

[7] http://www.pteg.net/NR/rdonlyres/423DC5B6-1ED4-47DC-B20B-B2F06288B892/0/MTComparisonBusCarEmissionsAL1.pdf

2 POLICY AND POLITICAL DRIVERS

2.1 Introduction

A literature review has been carried out in order to provide background information and context to the study. Here we summarise and analyse the drivers for improving the environmental profile of the bus fleets that are likely to develop over the next ten years.

2.2 Government policy and legislative framework

Existing and forthcoming policy drivers include those from legislation, regulations and consultations arising from the European Commission and UK Government sources.

2.2.1 Greenhouse gases

The Stern Review [8] on the Economics of Climate Change, released on October 30, 2006 by economist Lord Stern of Brentford for the UK Treasury, discusses the effect of climate change and global warming on the world economy. Its main conclusions are that one percent of global gross domestic product (GDP) per annum is required to be invested in order to avoid the worst effects of climate change, and that failure to do so could risk global GDP being up to twenty percent lower than it otherwise might be. Stern's report suggests that climate change threatens to be the greatest and widest-ranging market failure ever seen, and it provides prescriptions including environmental taxes to minimise the economic and social disruptions. In June 2008 Stern increased the estimate of investment required to offset climate change to 2% of GNP to account for faster than expected climate change.

The European Union "Biofuels Directive" (Directive 2003/30/EC) requires Member States to set and achieve targets for increased biofuel use. From this, the UK's Renewable Transport Fuel Obligation (RTFO) Programme places an obligation on fuel suppliers to ensure that a certain percentage of their aggregate sales is made up of biofuels[9]. The effect of this is that from April 2008 up to 5% of all UK fuel sold on UK forecourts will come from a renewable source with a target to achieve this by 2010. Since the Gallagher Review of biofuel sustainability the Government's intention is to consult on the proposal to delay the introduction of the requirement for biofuels to comprise 5% of road transport fuel from 2010/11 to 2013/14. The 5% by volume target represents the maximum biofuel content allowed by European Specifications to be sold on the forecourts as standard petrol or diesel. It is intended to deliver reductions in carbon dioxide emissions from the road transport sector of 2.6 - 3.0 million tonnes per annum (equivalent to carbon savings of 700,000 - 800,000 tonnes) by 2010, by encouraging the supply of renewable fuels.

The European Commission has communicated its intention to propose demanding, mandatory carbon emission standards for new cars, with a specific target of 130g

[8] Nicholas Stern (2006) - The Economics of Climate Change - The Stern Review
[9] DfT (2008) - Carbon and Sustainability Reporting Within the Renewable Transport Fuel Obligation

CO_2/km from vehicle technology averaged across the new vehicle fleet to be achieved by 2012. In 2006 the UK fleet average for new cars was 167.7g CO_2/km.

UK Government is also significantly expanding the scope of its policies in this area. The May 2007 Low Carbon Transport Innovation Strategy [10]sets out a wide range of measures that the Government is taking to transform the market for lower carbon vehicles. These include:

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

- low carbon vehicle procurement programme that has an initial £20m of funding, to support the public procurement and demonstration of innovative lower carbon vehicles in fleets of public organisation. Initially targeted at vans, a second potential phase and which type of vehicle fleets to support are still being agreed.

In parallel the Low Carbon Vehicle Innovation Platform (LCVIP) launched by the Technology Strategy Board and the Department for Transport (DfT), is allocating up to £20m of funding to support low carbon vehicle research, development and demonstration projects.[11] This is the first competition under the Low Carbon Vehicles Innovation Platform, which seeks to position the UK's automotive sector to benefit from growing public and private sector demand for lower carbon vehicles.

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

The Climate Change Bill was introduced in Parliament in November 2007. The aim is to receive Royal Assent by summer 2008. The Bill aims to create a new approach to managing and responding to climate change in the UK through: setting ambitious targets, taking powers to help achieve them, strengthening the institutional framework, enhancing the UK's ability to adapt to the impact of climate change and establishing clear and regular accountability to the UK, Parliament and devolved legislatures. There is proposed legislation in the Climate Change Bill to set binding legal commitments to reduce UK CO_2 emissions. A review of the target to reduce the UK's CO_2 emissions by at least 60% by 2050 will become a statutory duty under the Climate Change Bill.

The Chancellor commissioned Professor Julia King to undertake an independent review to examine the vehicle and fuel technologies which over the next 25 years could help to decarbonise road transport, particularly cars. Part I of the Review, published on 9th October 2007, set out the potential for reducing CO_2 emissions

[10] DfT (2007) - Low Carbon Transport Innovation Strategy.
[11] Technology Strategy Board (2007) - Low Carbon Vehicles Innovation Platform First Technology Competition.

from road transport.[12] The report had a positive message: that there is significant potential to reduce CO_2 from cars, both in the next few years and in the medium and longer term, and that this could bring considerable benefits for the UK. It set out the role that more efficient vehicles, cleaner fuels and smarter consumer choices need to play in reducing emissions. The key findings on the potential for CO_2 reduction were that:

- almost complete de-carbonisation of road transport is a realistic long-term objective, through electric or hydrogen-powered vehicles. This will require major technological breakthroughs as well as substantial progress towards de-carbonising the power sector.
- at low cost and by 2030, per kilometre emissions could be reduced by 50 per cent - equivalent to a 30 per cent reduction in the absolute level of emissions.
- fuels must be considered on the basis of their life-cycle CO_2 emissions. Biofuels can occupy a segment of the UK fuel market but care must be taken not to expand demand too quickly, before crop breakthroughs and robust environmental safeguards are in place.

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

The King Review Part II, published on 12th March 2008, picked up on these challenges and made a series of recommendations aimed at ensuring that government, industry, the research community and consumers all contribute to realising this potential for reducing CO_2 emissions.[13] A key recommendation was for Government to set a long-term direction for policy that has CO_2 reduction at its heart, rather than any one method of achieving it. Different technologies are likely to offer the most potential to reduce CO_2 emissions in the short, medium and long term. Good policy should target CO_2 reduction in recognition that the most efficient methods are likely to change over time.

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

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

[12] HM Treasury (2007) – The King Review of Low Carbon Cars (Part 1).
[13] HM Treasury (2007) – The King Review of Low Carbon Cars (Part 2).

2.2.2 Toxic emissions from transport

Health impacts

The pollutants commonly associated with road traffic emissions are nitrogen dioxide (NO2), fine particulates (PM10), carbon monoxide (CO), 1,3-butadiene and benzene, as well as carbon dioxide (CO2), which is of importance on a regional and global scale with respect to its global warming potential. Further details of these pollutants can be found below:

Oxides of Nitrogen

Nitrogen dioxide (NO_2) and nitric oxide (NO) are both oxides of nitrogen and together are referred to as NO_x. All combustion processes in the air produce NOx through the colourless gas NO. The conversion of NO to the red-brown NO_2 takes place in the atmosphere via the reaction of chemically active species such as ozone. It is NO_2 that is associated with adverse effects upon human health, particularly with respect to the exacerbation of symptoms associated with respiratory illness.

Exposure to NO_2 can bring about reversible effects on lung function and airway responsiveness. It may also increase reactivity to natural allergens and exposure to NO_2 puts children at increased risk of respiratory infection and may lead to poorer lung function in later life.

Current estimates of national emissions show that road transport accounts for 46.5% of the total UK emissions of NO_x. The electricity supply industry accounts for approximately 23%, whilst the industrial and commercial sectors account for 20% of the total annual emissions.

Particulate matter (PM)

Unlike the individual gaseous pollutants discussed above and below, which are single, well-defined substances, particulate matter in the atmosphere is composed of a wide range of materials arising from a variety of sources. Examples of man-made sources are carbon particles from incomplete combustion, ash, re-condensed metallic vapours and so-called secondary particles (or aerosols) formed by chemical reactions in the atmosphere. As well as being emitted directly from combustion sources, man-made particles can arise from mining, quarrying, and construction operations, from brake and tyre wear in motor vehicles and from road dust re-suspension from moving traffic or strong winds. Natural sources of particles include wind-blown dust and sea salt, and biological particles such as pollen and fungal spores. Of the man-made sources road transport remains the dominant contributor to particle levels in the air in most towns and cities.

Particles smaller than 10µm in diameter, referred to as PM_{10}, are more likely to reach the lung and cause adverse health effects. The material is solely defined on physical characteristics rather than chemical composition, and enables a uniform method of measurement and comparison with air quality standards.

Particulate matter is responsible for harmful effects on health, even in the absence of other air pollutants. Both fine and coarse particles have been shown to affect health, in particular the respiratory system.

Long-term exposure to current ambient particulate matter concentrations may affect the lungs of both children and adults and may reduce life expectancy by a few months, mainly in subjects with pre-existing heart and lung diseases.

Certain groups of people are more likely to suffer health effects due to ambient particulate matter. These include elderly people, children, people with a pre-existing heart and lung disease and asthmatics.

Because some people are vulnerable even at low concentrations of ambient particular matter, no threshold has been identified below which nobody's health is affected.

Carbon Monoxide (CO)

The majority of carbon monoxide emitted in the UK is from road transport. It is readily absorbed through the lungs and reduces the oxygen carrying capability of the blood.

Hydrocarbons (HC)

The term 'hydrocarbons' is used to include all organic compounds emitted from vehicles both in the exhaust and by evaporation from the fuel system, and covers many hundreds of different compounds. About one third of the UK hydrocarbon emissions are produced by road transport. Hydrocarbons are important precursors of photochemical smog and oxidising compounds. Hydrocarbons include benzene and 1.3-butadiene, which are both genotoxic carcinogens and exposure to them is associated with certain types of leukaemia.

Relevant legislation and responsibilities for air quality

Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe came into force on June 11th 2008. The New Directive merges four existing Directives and one Council Decision into a single Directive on air quality. It also sets new standards and target dates for reducing concentrations of fine particles, which together with coarser particles known as PM_{10} already subject to legislation, are among the most dangerous pollutants for human health.

Under the Directive, Member States are required to reduce exposure to $PM_{2.5}$ in urban areas by an average of 20% by 2020 based on 2010 levels. It obliges them to bring exposure levels below 20 micrograms/m^3 by 2015 in these areas. Throughout their territory, Member States will need to respect the $PM_{2.5}$ limit value set at 25 micrograms/m^3. This value must be achieved by 2015 or, where possible, already by 2010.

EU legislation has regulated vehicle emissions through the so called "Euro" standards, with limit values becoming tighter over the years. The current standard implemented is the Euro 4 standard for passenger cars and Light Duty Vehicles, as from January 2005. Euro 5 for passenger cars and Light Duty Vehicles will come into force in 2009, and Euro 6 in 2014. For Heavy Duty Vehicles, Euro IV standards are in force from October 2005, Euro V will enter into force in 2008, and a proposal for a new Euro VI standard is being prepared by the Commission. The effect of the measures on pollution levels from transport has been significant. Emissions of the various regulated pollutants have fallen by between 20 and 50% on average since 1995. A further decrease is expected, bringing levels down to 25-50% of the 2000 level by 2020.[14]

However, in many places ambient air quality still does not meet the legal requirements set by EU Directives. Many larger towns and cities are having difficulty meeting the requirements of the Air Quality Directive (Directive 96/62/EC on air quality and Directive 1999/30/EC on limit values of pollutants in ambient air). Limit values for particulates, which came into force from January 2005, pose problems and the same may also be expected in future with nitrous oxide when their limit values are lowered from January 2010.[15]

The Commission's 2001 White Paper on the European transport policy for 2010 [COM(2001) 370: "European Transport policy for 2010: time to decide"] noted the need for further measures to combat emissions from transport and stated that the Commission would encourage the development of a market for "clean vehicles". The mid-term review [COM(2006) 314: "Keep Europe moving – Sustainable mobility for our continent"] announced that the EU will stimulate environmentally friendly innovation, by successive Euro norms and by the promotion of clean vehicles on the basis of public procurement.

A revised EC proposal on green public procurement of road transport vehicles was put forward in the Green Paper on Urban Transport [COM(2007) 551: "Towards a new culture for urban mobility"]. The Commission proposal would require all public procurers to consider not only the purchase price of vehicles but also their environmental impacts. Lifetime costs for fuel, CO_2 emissions and air pollution should be considered and used as a criterion for purchase. It introduces "a harmonised and monetised method for clean and energy-efficient vehicle procurement for public transport". In addition, public procurement could give preference to new Euro standards.

The proposal on green public procurement of vehicles was backed by the Committee on Environment, Public Health and Food Safety in June 2008. MEPs want the "green award" environmental criteria, including fuel costs, to become mandatory as soon as 2010, but also to exclude certain vehicles from the proposal. The committee proposes that local, regional and national authorities that procure clean and energy-efficient vehicles accounting for at least 75% of their annual specific procurement needs should be allowed to use the label "clean and energy-efficient urban road transport". Finally, the Commission is asked to develop a "European Climate

[14] CAFE - Clean Air For Europe (2005) – Modeling.

[15] European Commission (2007) - Directive of the European Parliament and of the Council on the promotion of clean and energy efficient road transport vehicles.

Protection Fund" to encourage the purchase of clean and energy-efficient road transport vehicles.

Defra works to control and manage air quality across the UK. The UK Government and the devolved administrations published the latest Air Quality Strategy for England, Scotland, Wales and Northern Ireland in July 2007 - setting out a way forward for work and planning on air quality issues and the air quality standards and objectives to be achieved; introducing new policy framework for tackling fine particles similar to the approach being proposed in the latest European air quality directive (which was at the time still under negotiation). It also identifies potential new national policy measures which modelling suggests could help achieve significant health benefits and move us closer towards meeting the air quality objectives.

Air quality in the UK has generally improved since 1997 when the first Air Quality Strategy was adopted. The Evaluation of the Air Quality Strategy, published in 2005, indicated that, between 1990 and 2001, policies have resulted in a marked decline in concentrations of air pollutants. However, for some pollutants and at certain locations, levels are not declining as fast as expected and trends are flattening or even reversing. Even though further emission reductions are expected (e.g. as new vehicles and fuels become cleaner and older more polluting vehicles are replaced), experience shows there has been exceedences of the objectives for PM, NO_2 and PAHs well after the target achievement dates of end of 2005. Projections suggest the same will occur again by 2010 in some of our major urban areas and alongside busy roads.[16]

A CBA was undertaken on possible specific national strategies, in addition to the baseline of existing or agreed measures, and the key messages relevant to road transport were that the analysis favoured:

- Incentivising the early uptake of new tighter Euro standards;
- Increased uptake of low emission vehicles;

A number of measures were analysed and the conclusion reached that they required further work. Defra are keeping them under review as they require additional development work prior to implementation and/or coordination with other policy measures which are yet to be implemented. As the measures have been modelled, these measures are unlikely to generate positive net benefits at the present time, however they may have potential to produce significant health benefits to society and may therefore be recommended if and when the situation changes and/or more detailed and fuller assessments indicate that the measures become cost beneficial and/or more feasible:

- A national road pricing scheme;
- London and other low emission zones; and
- Retrofitting catalyst-based diesel particulate filters to HGVs.

At the local authority level, there exist statutory duties for local air quality management (LAQM) under the Environment Act 1995. Local authorities are required to carry out regular reviews and assessments of air quality in their area against standards and objectives in the national Air Quality Strategy and which have

[16] Defra (2007) - The Air Quality Strategy for England, Scotland, Wales and Northern Ireland.

been prescribed in regulations for the purpose of LAQM. Where it is found these are unlikely to be met, authorities must designate air quality management areas (AQMAs) and prepare and implement remedial action plans to tackle the problem. Over 100 AQMAs have been declared to date, with over 90% of these due to road traffic pollution.

2.2.3 Biofuel policy and support

The European Union has developed a number of policy instruments of importance to the increased supply of biofuels. The most important is the "Biofuels Directive" (Directive 2003/30/EC) which requires Member States to set and achieve targets for increased biofuel use. Indicative targets were set at 2 percent for December 2005 and 5.75 percent for December 2010 (on an energy basis). Amendments in 2003 to the Energy Taxation Directive (Directive 2003/96/EC) allow Member States to provide financial support for biofuels in the form of reduced fuel excise duty (subject to State Aid control) which the majority now do. In addition, the European Common Agricultural Policy provides subsides for energy crops (including wheat but excluding sugar beet) grown on set-aside land.

Government support for biofuels in the UK comes in the form of reduced fuel excise duty as allowed by the European Union. A reduction in fuel excise duty of 20 pence per litre (ppl) has applied for biodiesel since July 2002 and for bioethanol since January 2005.

More recently, the Renewable Transport Fuel Obligation (RTFO) forms one of the Government's main policies for reducing greenhouse gas emissions from road transport, placing a legal obligation on fuel suppliers in the UK to supply a certain percentage of their fuel from renewable sources. It is intended to deliver reductions in carbon dioxide emissions from the road transport sector of 2.6 - 3.0 million tonnes per annum (equivalent to carbon savings of 700,000 - 800,000 tonnes) by 2010, by encouraging the supply of renewable fuels. The RTFO commenced on 15 April 2008, with obligations set at 2.5% in 2008-09, 3.75 % in 2009-10 and 5 % in 2010-11 (by volume). The RTFO can be met by supplying biodiesel and bioethanol in a variety of blends and also with biomethane.[17] However, the main focus is on the provision of a large volume of low-blend liquid biofuel, given the composition of the existing road transport fleet.

There are other technical and regulatory obstacles however that inhibit take-up of high-blend liquid and gaseous biofuels. The duty differential of 20ppl for ethanol does not compensate users for the higher fuel consumption they would achieve with E85 (85% ethanol) given the lower energy value of ethanol per litre compared to gasoline.

Under the RTFO, fuel suppliers have the option of either supplying the required amount of biofuel, purchasing tradable certificates from another supplier or paying a 'buy-out' fee. The buy-out fee, which the government has set at 15 pence per litre, will have an effect broadly similar to that of a fuel excise duty rebate. Initially the RTFO will run alongside the existing fuel duty incentives bringing the total effective support to 35 pence per litre. From 2010-11 the fuel duty incentives will gradually be phased out, and the buy-out price increased.

[17] DfT (2008) - Carbon and Sustainability Reporting Within the Renewable Transport Fuel Obligation

A report by E4Tech for TfL concludes that the introduction of the RTFO is likely to lead to a more fluid market for biofuels in the UK, which could lead to greater opportunities for their introduction in public transport. However, the phase-out of the fuel duty reductions means that the economic viability of biofuel use in buses may depend even more in the future on the Bus Services Operators Grant.

It is acknowledged that while there are potentially significant GHG savings to be made via biofuels (particularly those from waste streams) the amount of GHG savings and sustainability impacts of different biofuels varies significantly. The GHG benefits of biofuels depend, among other things, on the system of cultivation, processing and transportation of feedstock. The introduction of biofuels can also lead to unintended negative environmental and social impacts.

To support this, Government commissioned in 2007 a review of work on the environmental sustainability of international biofuel production and use. The 'Gallagher Review' by the Renewable Fuels Agency was published in early July 2008, and it expresses concern about the impacts of biofuels' growth and advocates a slowdown in the rate of their introduction. The government subsequently announced proposals to slow down the rate of introduction of biofuels through the Renewable Transport Fuels Obligation (RTFO).

The Transport Secretary, Ruth Kelly, said that she intends to consult on the proposal to delay the introduction of the requirement for biofuels to comprise 5% of road transport fuel from 2010/11 to 2013/14. The Transport Secretary also called for a further review of the UK's progress on the sustainability of biofuels in 2011/12. The government believes that the overall EU target of 10% renewable transport fuels by 2020 can remain an overall objective but only subject to clear conditions on sustainability and taking into account indirect, as well as direct, effects on land use.

The Gallagher Review, which was completed by the independent Renewable Fuels Agency (RFA) at the request of the government, concluded that there is a future for a sustainable biofuels industry but that feedstock production must avoid agricultural land that would otherwise be used for food production.

The report says that biofuel growth has contributed to rising food prices for some commodities - such as oil seeds - where there is competition between food and fuel uses. It says that biofuel demand is displacing some existing agricultural production and, if left unchecked, will reduce biodiversity and may even cause an increase in greenhouse gas emissions rather than savings.

The report calls for a significant slowdown in the rate of introduction of biofuels until adequate controls to address displacement effects are implemented and are shown to be effective. It proposes that biofuel production must be focused on idle and marginal land and increasingly use wastes and residues.

In a wide-ranging set of recommendations, The Gallagher Review says that the optimum policy approach would be to base incentives and targets for biofuels on the greenhouse gas savings they produce. The report emphasises the importance of ensuring consistency in European and global policy approaches. It also proposes that carbon and sustainability certification used for biofuels should be extended to all agricultural activities over time.

2.3 Fuel duty and BSOG

Fuel duty is payable on a range of road transport fuels at varying rates. Through this mechanism Government aims to incentivise take-up of fuels that are considered to have an environmental advantage over more conventional road fuels.

Table 2.1: Current hydrocarbon oil duty rates (July 2008)

Fuel	Duty rate
Ultra low sulphur diesel (ULSD)	48.35 ppl
Biodiesel	28.35 ppl
Bioethanol	28.35 ppl
Natural Gas (NG)	10.81 ppkg
Road fuel gas other than natural gas e.g. liquefied petroleum gas (LPG)	12.21 ppkg

Road fuel gases such as biomethane, CNG and LPG attract the lowest fuel duty, currently 10.81 and 12.21 ppkg. Biodiesel and bioethanol also incur a reduced fuel duty at 28.1ppl (a 20ppl duty differential). The fuel duty rate provides an economic incentive for these 'alternative' road fuels. In addition, the duty rate for road fuel gases is roughly equivalent to two thirds their fuel duty rate on an equivalent energy basis (i.e. approximately 8 ppkg), compared with ULSD which incurs the full fuel duty of 48.35 ppl. Gaseous and bio fuels, whatever their GHG potential, have a duty advantage over ULSD.

The current duty differential of 20ppl for biofuels will be extended until 2009/10, in line with the alternative fuels framework. Decisions on duty rates for these fuels in future years will be taken following consideration of the scope for simplifying the duty rate structure. The Treasury has indicated it intends, over time, to reduce the duty differential for biofuels, which would reduce the stimulus for high blends.

Bus Service Operators Grant (BSOG) is a payment made to bus operators by DfT that offsets a high proportion of the fuel duty paid on fuel consumed. BSOG represents the largest proportion of direct funding (outside concessionary fares). Its effect is to allow bus operators to run a wider network of services than would otherwise be the case, and so arguably it does incentivise patronage increases. However, it is directly related to the amount of fuel used, and so is poorly linked to environmental objectives, particularly climate change.

Based on figures available from October 2007, for diesel, BSOG is paid at a rate of 41.21 ppl in comparison to fuel duty of 50.35 ppl, therefore at 82% of the duty paid. Bioethanol and biodiesel attract 100% duty repayment via BSOG, but the duty payable is lower and their base cost is generally higher. Therefore, for the UK bus sector BSOG effectively neutralises the preferential duty arrangements given to gaseous and biofuels.

DfT has allowed the full 'diesel' duty to be recouped on a 5% biodiesel blend, which is enough to make this product financially preferable to bus operators. However, higher biodiesel blends still suffer from a financial disincentive through the application of proportional rebates as the biodiesel content increases.

At present the Bus Service Operators Grant (BSOG) serves as a disincentive for the use of alternative fuels within the commercial UK bus sector. The cost of producing and supplying biofuel is in most cases higher than for fossil fuels, although recent rises in oil price are eroding this difference.

Consultation on BSOG, initiated by DfT in April 2008, outlines the following short-medium term options for reform, some of which could be implemented in parallel to one another:

- Proposal 1: BSOG rate capped at a minimum fuel efficiency level;
- Proposal 2: New arrangements for Low Carbon Buses (to be determined, following consultation feedback);
- Proposal 3: Devolve BSOG payments to areas undertaking Quality Contracts including London;
- Proposal 4: A longer-term proposal for tiered rates of BSOG based on emissions or other quality criteria, e.g. smartcard readers;
- Proposal 5: Payment of BSOG in arrears and e-submission of claims;
- Proposal 6: Safe and Fuel-Efficient Driving demonstration.

The consultation paper sets out a number of short-term options for modest reform to the BSOG system, but it is also raises some fundamental questions about bus service support. Subsequently, it was announced thre would be reform of BSOG to incentivise low-carbon buses the November 2008 Pre-Budget Report, with details to follow.

2.4 PTE policy tools

The Transport Act 2000 included powers aimed to provide PTE (and other Transport Authorities) with a wider range of options for engaging with and influence commercial bus operations in their area.

The recent Local Transport Act (2008) will update and extend many of these powers. The aim of the Local Transport Act was to enhance the existing mechanisms of VPA, SQP and QC so that they can be applied in a cost-effective manner to significantly improve network, timetable and vehicle quality through the co-ordinating role of the PTE (or Transport Authority in non-Metropolitan areas). The approaches discussed here will be dependent on the final regulations and guidance derived from the recent Local Transport Act issued over the next year or so.

With the widening of powers there are variety of routes under which improved fleet emissions might be sought:

- Voluntary Partnership Agreement (VPA);
- Tendered services;
- Statutory Quality Partnership (SQP);
- Quality Contract (QC); and
- Traffic Regulation Condition (TRC).

Note that DfT use the terms Quality Bus Partnership Agreement and Quality Partnership Scheme in their guidance, rather than the terms more commonly used in practice by the PTE (and therefore used in this report).

The Local Transport Act (LTA 2008) aims to strengthen the powers and strategic role of existing locally accountable Passenger Transport Authorities (to be re-named Integrated Transport Authorities). It will also allow for boundary extensions to existing ITAs, and the creation of new ITAs in areas not currently served. The Bill also reforms the bus sector – with a new process for the introduction of the franchising of networks of bus services, and new measures designed to make effective voluntary and statutory partnerships easier to introduce and maintain. *pteg* has supported the overall objectives of the Bill and much of the detail.

The deregulated bus environment in England (outside of London) has been the backdrop to poor integration of public transport, declining patronage in PTE areas, service cuts and patchy quality. The Act aims to tackle this by:

- making changes to the way in which voluntary and statutory partnerships can be introduced and operated;
- bringing in a new process for franchising networks of services ('Quality Contracts');
- strengthening the role of the Traffic Commissioners in enforcing better punctuality;
- making provision for a new passenger watchdog.

2.4.1 Voluntary Partnership Agreement

Voluntary partnership agreements involve local transport authorities and private operators work together to bring about improvements in local bus services. This could include cooperating on the marketing and promotion of services or a local transport authority improving the infrastructure in return for an operator investing in new vehicles.

Voluntary partnerships can be encoded in a document signed by both parties, or may just be a descriptive term for ways of working between the LTA and operators with no binding documentation.

VPA are the focus of a considerable amount of time and investment by PTE/SPT as a method to channel spending on bus infrastructure and priority. For example, GMPTE's Quality Bus Corridor (QBC) programme which will deliver a 280-kilometre, 24-corridor, £80 million bus priority network that will improve the reliability and quality of the Greater Manchester bus network.

From discussions with operators it is clear that voluntary agreement on an ambitious emissions reduction programme will be much easier to achieve if complementary measures are also introduced that significantly improve the commercial environment for bus operations.

Some VPA operate by both parties investing in the improvement to services, so there can be considerable capital and revenue costs for the PTE/Local Transport Authority.

Overall, due to their voluntary nature, they are can sometimes be a slow and unreliable method for a PTE to push forward significant and long-lasting emission improvements.

2.4.2 Tendered services

PTEs spend more than £80 million a year supporting nearly 100 million kilometres of bus services that can't be run commercially. These are mainly 'lifeline' off-peak services or those extending the network to isolated rural communities or council estates.[18]

Tendered services provide a service for:
- Subsidised public services;
- Education department (i.e. school buses); and
- Other contracts (e.g. Park and Ride buses).

PTEs have the power to regulate the emissions performance of tendered services including subsidised services, educational contracts and other specialised contracts.

A variety of initiatives exist across the PTE/SPT for encouraging improved emission performance:

- QuayLink bus service using diesel-electric hybrids along the Newcastle and Gateshead quaysides is operated by Stagecoach North East under contract for Newcastle and Gateshead Councils and the Tyne and Wear Passenger Transport Executive (NEXUS);
- Park and Ride – a number of examples in PTE areas that specify latest vehicle and engine technology;
- Free or low-cost city centre shuttle services using latest low-floor midi-buses, in Bristol, Liverpool, Leeds and Manchester (which have included trials of hybrid vehicles).

In an example from Oxfordshire, the County does not currently specify emissions criteria in its contracts but a pricing preference scheme has the effect of encouraging the use of brand new vehicles on subsidised bus routes when their contracts are renewed.

Experience in Merseyside has shown that raising vehicle standards for tendered services could lead to higher contract prices and fewer bidders. This could in turn result in a reduction in the size of the tendered service network – which brings with it significant social inclusion implications

If directing spending by PTE to secure reduced transport emissions is acceptable, then tendered services do provide a potential route to directly influence up to 13% of the PTE area bus fleets.

[18] A Fresh Start for the Urban Bus - pteg's initial response to the Government's bus policy review.

2.4.3 Statutory Quality Partnership

An SQP in effect represents a commitment on the part of the authority to provide certain facilities to improve local bus services, and to maintain them throughout the life of the scheme; and an obligation on the part of participating bus operators to meet the quality standards prescribed in the scheme when using the facilities in question. The cost of the scheme to the authority will largely be comprised of any investment in roadside infrastructure, bus priority etc.

SQP are intended to address the potential problem found in voluntary approaches that operators who do not agree to raise their standards cannot be excluded from using the new facilities. Bus operators might be reluctant to enter partnerships and spend money if they can be undercut by low cost, low quality rivals.

Under a statutory Quality Partnership Scheme (SQP), the local authority - for these purposes, county councils, unitary authorities and Passenger Transport Authorities - draws up a scheme, aimed at implementing the policies in its local bus strategy. Up until the Local Transport Act the bus strategy formed part of the local transport policies required under section 108 of the Transport Act 2000.

Such schemes have statutory force and would be registered with the Traffic Commissioner, who can prevent non-compliant operations from using corridor facilities. In this respect, a SQP varies from a Quality Bus Partnership Agreement, the latter being entirely voluntary.

Draft DfT guidance notes that the specified standard of services should be one which can be reasonably met by any operator, unless the standard is higher but the benefits derived from its application outweigh the costs of compliance. For instance, a requirement to operate buses with facilities to give a high standard of accessibility for disabled people will probably be considered reasonable, as the benefit to the travelling public would justify any operator investment. However a requirement to operate vehicles built by a particular manufacturer or to a particular design is likely to be unreasonable.[19]

A key question is what is the standard of service the main bus operators and smaller bus operators would find reasonable to offer in return for incentives by the Authority? The SQP is still a partnership between the Authority and one or more operators, so finding grounds for an agreement is fundamental to its operation.

The participating bus operators are obliged to meet the quality standards prescribed in the scheme when using these facilities, and must give a written undertaking to the traffic commissioners to provide the service to the specified standard. Quality standards can relate to the vehicles to be used, and this can include the percentage of vehicles that meet a given Euro standard either due to vehicle replacement or due to retrofitting abatement equipment.

Operators that choose to continue to operate along a route subject to a SQP but which are not participating in the Scheme, will need to give thought to what, if any,

[19] DfT (2006) - Guidance on Quality Partnership Schemes in England.

stopping points they observe. They will need to satisfy the Traffic Commissioner that they are neither using the facilities included in the Scheme, nor are they planning to stop in places that will create adverse traffic congestion or safety impacts.

The Transport Act 2000 specifically excludes the Authority from specifying timetables and fares as part of the scheme. In this respect, a SQP scheme differs from the provisions of a Quality Contract (discussed later in this guidance), and SQP represents something of a half-way house between a voluntary Quality Bus Partnership agreement and a Quality Contract Scheme.

The Local Transport Act 2008 will make significant changes to SQP while retaining its essential nature. In particular, it would allow Authorities to specify frequencies, timings and maximum fares in a scheme, subject to safeguards to give existing operators in the area the opportunity to object to such a proposal, and to ensure that all relevant operators are involved in subsequent fare reviews. However, operators would not have a similar right to object to provisions about vehicle standards.

2.4.4 Quality Contracts

The powers of the Transport Act 2000 enable local authorities to bring forward schemes in which they can determine what local bus services should be provided in their area, and to what standards, and can let contracts with bus operators giving them exclusive rights to provide services to the Authority's specification. The Authority may determine the routes, timetables, fares and ticketing arrangements for the bus services, and any other matters relating to their standards including the emissions standards of the vehicles used.[20]

Under the Transport Act legislation a QC scheme must relate to the implementation of a bus strategy, and the making of a scheme must be 'the only practicable way' of implementing the bus strategy. This is a difficult hurdle to clear. Schemes require Ministerial approval. As with SQP, statutory Quality Contracts Schemes (QC) apply only to “local services” (bus services where passengers may travel at “separate fares” for distances less than 15 miles).

There are no QC schemes currently in operation. Nexus and SYPTE undertook a joint market testing of the QC process with a number of bus operators in order to investigate the costs and risks to all parties involved during 2006/7. Responses on all issues raised were broadly in line with expectations and the finance data supplied would enable SYPTE to assess the cost of ‘buying in’ the network. The exercise gave confidence that QC for the area could bring major benefits (addressing some to the problems highlighted with the deregulated environment). In summary, operators were making a better overall offer for a comparable amount of subsidy, including a newer fleet of low floor buses. Work continues in South Yorkshire to develop a programme of work related to a QC option.

The Local Transport Act 2008 includes a number of changes to the legislation aimed at making QC (and SQP) more realistic options for Authorities with a good case for using it. In particular, the Bill would replace the “only practicable way” criterion with

[20] Dft (2005) - Quality contracts for bus services: Guidance for English local authorities.

new, more objective public interest criteria based on increasing bus use and improving service quality. With the Local Transport Act 2008 the approval process for Quality Contracts is locally determined with a consultation board and Tribunal allowing for a degree of external scrutiny and a hearing for operator objections.

As a result of planned changes to regulations via the Local Transport Act 2008 some PTE are currently working up potential plans for future QCs, and working with DfT on the progress of the Bill.

The chief advantage of a QC for vehicle emissions is that under a QC an LTA is free to specify whatever type of vehicle it sees fit. However, clearly the higher the standard of vehicle specified the higher the potential cost (although at the same time large orders for higher spec vehicles could bring unit costs down).

2.4.5 Traffic Regulation Condition

Since November 2004, local authorities have been able to apply to the Traffic Commissioner for a Traffic Regulation Condition (TRC) to regulate vehicle emissions (and / or noise). Under section 7 of the Transport Act 1985, a local authority outside London with responsibility for traffic may ask the Traffic Commissioner to attach a Traffic Regulation Condition (TRC) to an operator's Public Service Vehicle (PSV) Operator's Licence - provided he/she is satisfied that this is required in order to reduce or limit noise or air pollution.

DfT have produced guidance for the Traffic Commissioners in England and Wales to consider when responding to requests from a local authority to attach TRCs to an operator's Public Service Vehicle Operator's Licence to reduce or limit air pollution.[21] The guidance notes that buses can be a significant factor in contributing to air quality problems caused by traffic emissions, and that further controls granted by the Traffic Commissioner to reduce emissions from buses would have a positive effect in reducing air pollution, particularly in Air Quality Management Areas.

A TRC has been used in Bath to set minimum standards for city tour buses, in order to raise overall standards and in particular vehicle emissions and noise. This had a direct impact on the businesses willing to operate such services, leaving only higher quality operators in situ. More recently, in 2008, a TRC has been used in Norwich to formalise emission improvement programme for all local bus services entering the Castle Meadows area over a given frequency each week. Defined proportions of the fleet must comply with emission standards by set dates.

From a meeting between TTR and the now Head Traffic Commissioner (during 2007) to discuss an Air Quality Action Plan for a small historic city, the following information was shared:

- The Traffic Commissioner was positive in principle about the concept of using a TRC for Air Quality objectives;

[21] DfT (2004) - Information and advice for Traffic Commissioners regarding Traffic Regulation Conditions required to reduce or limit air pollution.

- In principle a TRC could apply to all local buses in the city, or to those operating over a certain frequency;
- The Traffic Commissioner advised the Authority to try to encourage bus operators to agree to improved standards in advance of any formal application for a TRC. This suggests working initially via SBQP against clear objectives, evidence base and a timetable (for achieving results);
- The Traffic Commissioner advised that a TRC might also be used to direct the frequency of vehicles serving an area;
- A TRC can be varied in light of operational experience.

It is useful to note that DfT guidance suggests flexibility over application of the TRC by the Traffic Commissioner and that the Traffic Commissioner will strive to reach a solution that best suits all parties. To get the greatest benefit from taking this approach, a strong case needs to be made by the Authority, with good evidence and arguments to support raised emission standards.

Taking forward a bus emission reduction strategy based on a TRC could include the following four stages:

a) Preparation

Local transport authority to prepare evidence base, scenario(s) and preferred outcome for future bus fleet profiles for all local commercial service providers, including:

- target emission reduction;
- target for carbon reduction.

b) Negotiation and decision on TRC

The Authority might enter into negotiations with bus operators for raising emissions standards through voluntary means, within a timetable for achieving the preferred (or next best) outcome and commitment to move to a TRC approach (fallback statutory means).

The Authority should evaluate the proposals of the bus operators if they fall short of the preferred scenario, quantify the shortfall, and make a decision as to whether the bus operator's proposals are acceptable. The assessment should include evaluation of emissions and any requests for additional expenditure on highways or roadside infrastructure.

c) Application for a TRC

If the Authority decides a TRC is required in order to meet emission levels within the necessary timescale, they should inform the TC of their wish for a TRC and provide the evidence base, scenarios and proposals for future fleet profile and timescales to reduce vehicle emissions over business as usual expectations.

The TC is guided by DfT to:

- request verification of a profile of bus fleets (which TC may do in addition to Council(s)' data gathering); and
- request a plan from the operators about how to reduce emissions further (which TC may do in addition to outcome of Council(s)' negotiations) and assess the outcomes.

d) Agreement on a TRC

The following steps are interpreted from reading of the DfT guidance to the TC:

- TC may make suggestions to the bus operators about further improvements to their fleet emissions. These suggestions may vary, depending on service characteristics (e.g. frequency of service);
- TC to hold an inquiry into the Council(s)' request, if asked by the Operators or Council(s);
- TC to reject, uphold or recommend a variation on the Council(s)' request for a TRC and if successful will move to formalise it by appending the new conditions to relevant bus operator's PSV license;
- TC to enforce TRC by monitoring bus service operations in the city. Council(s) may offer to undertake monitoring. TC can withdraw operating licenses from those infringing the TRC conditions.

Although in principle a local transport authority is not obliged to provide investment in infrastructure (as per a VPA or a SQP) the reality is that if an extensive and stretching TRC is imposed on operators in a PTE area there could be some withdrawal of commercial services. Similarly, while ongoing operation and enforcement of a TRC is for the Traffic Commissioner to fund, they would realistically need support from the transport authority for monitoring and reporting of non-compliant vehicles.

Overall, therefore, a TRC is unlikely to give a quick and cheap solution in PTE areas. What it might offer is a way in which to provide VPA-negotiated arrangements a greater degree of permanence and enforcement, something akin to a SQP.

2.5 Bus company initiatives and CSR statements

Bus companies have, on many occasions, participated in demonstrations and pilots of new technology. Sometimes this has been in partnership with a Local Authority and PTE, with the objective of sharing costs/risk, and sometimes under their own initiative.

Examining the Corporate and Social Responsibility (CSR) Reports for statements of intent and a strategy for greening their fleets we can summarise the position of the largest five operators as follows:

First Group have committed to converting the entire UK Bus fleet to sulphur-free 5% biodiesel where supply is available. They wish to closely follow the development of hybrid technology. They are committed to improving fuel efficiency by improvements in engineering, driver training and operational efficiency. When buying new vehicles they will opt for Euro IV engines which they think are 10-15% more fuel-efficient than Euro III.

Arriva seem quite open to exploring alternative technologies, by working with a vehicle systems management company on the feasibility of monitoring energy usage and helping operate vehicles as efficiently as possible. Arriva state they are working with bus manufacturers Mercedes Benz, Volvo, MAN, VDL, Van Hool and Wright Bus to explore new engine technology, such as hybrid and hydrogen combustion. They are trialling low-emission vehicles which exceed Euro IV and V standards, and investigating alternative fuels: ultra-low sulphur diesel, compressed natural gas and palm oil biodiesel. Arriva state they are actively seeking to identify and implement viable low emission and renewable fuels.

National Express CSR reporting suggests they believe improving the performance of modern diesel engines is the answer in the short term at least, running on conventional fuel. This means buying conventional diesel vehicles for fleet replacement. The company does have ongoing experience of liquefied petroleum gas (LPG) buses and compressed natural gas (CNG) buses in the West Midlands. Their commitment is to continue to keep abreast of new fuel alternatives as they come onto the market and in the future they will be looking to participate in trial diesel-electric hybrid buses when these are available.

Stagecoach group runs 60% of the fleet on 5% biodiesel. Investments are being made in more efficient vehicles and bioethanol-fuelled buses, and they are involved in one of the current UK trials of bioethanol-fuelled buses.

Go Ahead have trialled electric and LPG vehicles in the past, and are now involved in trials of diesel-electric hybrid technology.

In summary, we see a commitment to low blend biodiesel from some of the operators, and some experience of alternative technologies. The level of commitment to trialling alternative technologies varies, but will be important for gaining experience and giving direct feedback to manufactures of such vehicles about the performance required for use in a commercial environment. There are no firm statements about moving beyond testing and small scale trial activities in the short term.

2.6 Current and emerging initiatives

A number of other recent and ongoing initiatives are relevant to improving the environmental performance of the UK bus fleet.

Low Emission Zone schemes are operating in several UK and overseas cities such as London and cities in Sweden and Germany. The most significant existing scheme in the UK is the London LEZ scheme which from July 2008 requires that all heavy duty vehicles achieve at least a Euro III emission standard for PM_{10}. London Buses have been working for some time on vehicle replacement and retrofit schemes, which means all bus fleets will comply. In 2008 the scheme is expected to reduce the area of Greater London that exceeds the daily PM_{10} limit by 7% and by 15% by

2012. By 2010 the scheme is expected to reduce the area of Greater London that exceeds the annual mean NO_2 limit by 4% and by 16% by 2012. Health benefits associated with these changes are estimated to be £170-250 million due to predicted reduction in illness and premature death.

A number of Low Emissions Strategies (LES) studies have been undertaken across the UK, particularly in light of the decision to proceed with implementation of the London LEZ. Studies have been carried out to investigate LEZ and LES in Bristol, Sheffield and others. A key conclusion from each of these studies, when examining cost-effectiveness of pollutant reduction, was that targeting HDV was more cost-effective and that from this sector bus fleets were the most cost-effective. This is due to the high level of pollutants from heavy duty vehicles in general, combined with the older age profile of typical city bus fleets.

The current TfL initiative of signalling intent to purchase hybrid buses is significant. TfL has a fleet of just over 8,000 buses to run contracted services in London and the operators involved buy approximately 500 new buses each year. The plan for diesel-electric hybrids is for:

- 40 to 50 trial buses in operation by end of 2008;
- Up to 100 new buses in operation by end of year 2009 / 2010;
- Up to 200 new buses in operation by end of year 2010 / 2011;
- Up to 500 new buses in operation by end of year 2011 / 2012; with
- All new buses entering service to be hybrid-powered after 2012

In addition, TfL has trials underway during 2008 which will produce a specification for low-carbon diesel-electric hybrid buses, as a basis for future purchasing rounds.

As previously noted, the low carbon vehicle procurement programme (administered on behalf of DfT by CENEX) has an initial £20m of funding, to support the public procurement and demonstration of innovative lower carbon vehicles. Initially targeted at vans, a second potential phase of the programme and a decision on which type of vehicle fleets to support are still being agreed. Clearly there is scope (and value) in lobbying for a second phase of support of similar value and for this to be targeted at buses if possible.

An initiative by the Low Carbon Vehicle Partnership (LowCVP) is aimed at facilitating large-scale introduction of low-carbon bus technology, by proposing local transport authorities use innovative procurement commitments to support research and development phase investment by bus manufacturers. The objective is to get volume orders that will bring existing and near-to-market technologies into the market at a faster rate.

From 2007, DfT extended tax incentives to encourage goods hauliers and bus operators to buy vehicles that meet the latest European standard for air pollutant emissions, known as 'Euro V', before it becomes mandatory. The incentive aims to encourage the early uptake of more environmentally friendly, low emission buses and lorries. The Reduced Pollution Certificate (RPC) scheme will be extended so that goods hauliers and bus operators first registering a Euro V compliant vehicle before 1 October 2009 can claim a discount of up to £500 a year on Vehicle Excise Duty (VED).

2.6.1 Wider environmental and policy concerns

Although the study primarily reflects the potential impact of technology developments and solutions and their influence on the environmental performance of the vehicle itself, it should not be forgotten that environmental performance is increasingly being measured on a per passenger carried, per seat and per passenger kilometre basis. The basis for the comparison between other modes can then depend upon the degree to which a vehicle is fully laden and much of the data which appears to question the environmental effectiveness of public transport is based on comparisons with cars which are carrying more than just their driver.

Much of the increasing scrutiny of this issue is based around perceptions that public transport, and particularly buses, is not maximising its passenger carrying and hence environmental potential. The primary manifestation of this is where buses are seen to be moving around urban areas with low passenger loadings – i.e. with a large number of unoccupied seats. Whether data backs this up or not is to a certain degree irrelevant. What is needed is a change in perception of the fleet and its performance both from a ridership and also environmental perspective. A contributing factor to this is that renewal of the bus fleet is, on average, significantly slower than the other major elements of the vehicle stock. This, combined with the high visibility of buses and sometimes poor presentation, can lead to a poor image of the product that PTEs and operators are trying to sell.

2.7 Conclusions

Overall, there is significant interest and policy support for greening PTE area bus fleets, but currently few direct options for managing the process to achieve this outcome. The enactment of the Local Transport Act should provide real scope for PTE to introduce SQP and QC that are fit-for-purpose. These are probably the most promising of policy areas as they will fall within PTE control as a method of changing the fundamental basis for organisation of bus services in PTE areas.

The operating environment for local government bodies such as PTEs is heavily influenced by EC and UK Government policy. This is increasingly focussing on developing low carbon transport with reduced toxic pollutants as continued development of proposals takes place under the relevant EC Papers and Directives, and UK Air Quality Strategies. In the UK context sufficient powers and adequate funding are required for PTE to support these policies.

UK-led reviews of policy and priority setting, such as the Stern and King reviews, have added weight to the argument for concrete actions that are likely to change the current provision of transport services to variants with increasing weight paid to sustainability. It is acknowledged however that transport may be an area that is more costly in which to make significant reductions.

One of the options for reducing GHG emissions could be the use of biofuels. While there are potentially significant GHG savings to be made via biofuels (particularly those from waste streams) the amount of GHG savings and sustainability impacts of different biofuels varies significantly. The EC's 'Biofuel Directive' and UK's implementation of the RTFO is already having the effect of stimulating large amounts of low-blend biofuel to be used in the UK vehicle fleet, but there is a risk this could stall. The ultimate shape of the RTFO, given the recent Gallagher Review, and a clearer understanding of the commercial viability of high-blend biofuels given rising oil prices and potential changes in fuel duty rates, are both key milestones on a route of biofuel growth into UK fuel markets.

BSOG has been acknowledged as a barrier to the sector taking up low-emission vehicle technology. It is likely that the negative experience of early vehicle trials has also been an important factor. Reform of BSOG to incentivise low-carbon buses was announced in the November 2008 Pre-Budget Report, with details to follow. However, it is clear that there are also significant risks and drawbacks from some of the options presented in the current consultation document, if it leads to a reduction in BSOG support for some services which currently rely on the subsidy.

Initiatives in London on fleet renewal, retrofitting, hydrogen trials and commitment to purchase diesel-electric hybrid buses generate both interest and momentum in the UK for adopting cleaner bus technologies as there are increases in both experience and market size for suppliers. On a practical level for PTE areas, increased bus purchasing levels for London have led to a cascading of vehicles to areas outside of London, and this is likely to continue.

Government support for low-carbon vehicles through research and procurement programmes can provide some of the capital required to invest in higher cost (but higher benefit) technologies. Increases in energy and fuel prices are anticipated to stimulate only greater development of second generation and advanced biofuels (produced from non-food crops).

3 TECHNOLOGY AND FUELS

3.1 Current trends in vehicle pollution

3.1.1 Emissions standards

Euro standards describe the emissions criteria that vehicle manufacturers must type-approve their vehicles to in order to supply for general sale in the EU.

Euro I vehicles began to be produced for an EC-specific type-approval standard that came into force in 1993, with pre-Euro vehicles generally being those registered before this date. The dates at which these standards came into force for the type approach of Heavy Duty vehicle types are shown in Table 3.1. These apply to buses in PSV M2 and M3. The entry into service date is generally one year later, so all vehicles entering service after October 2009 should be of Euro V standard, although an amount of overlap is allowed to enable old stock to be sold.

Table 3.1: Introduction dates and mass emissions standards (g/kWh[1]) for HDV

Tier[2]	Type-approval date[3]	NO_x	PM	HC	CO
Euro I[4]	Oct. 1992[5]	8.0	0.36	1.1	4.5
Euro II[4]	Oct. 1996	7.0	0.25	1.1	4.0
	Oct. 1998	7.0	0.15	1.1	4.0
Euro III	Oct. 2000	5.0	0.16	0.78	5.45
Euro IV	Oct. 2005	3.5	0.03	0.55	4.0
Euro V	Oct. 2008	2.0	0.03	0.55	4.0
Euro VI[6]	Potentially Oct 2014	1.0-0.2	0.025-0.01	0.55-0.16	4.0
EEV[7]	Oct. 1999	2.0	0.02	0.4	3.0

Notes:

1 The rates have to be complied with during the approved test cycle. The emission rates in the table are in terms of mass per power rating rather than mass per distance travelled (e.g. g/km). Detailed established methods are used to convert between the two sets of units when necessary.
2 There is a roman numeral naming convention for heavy-duty vehicles.
3 The dates refer to new type approvals. A second date usually a year later applies for entry into service (i.e. all vehicles whose first registration was after October 2009 would need to be at least of Euro V standard).
4 The approval of Euro I and II was based on a different test cycle (ECE R-49) compared to the other values in this table (ETC test cycle). This explains the observed discontinuity among values in the table.
5 For vehicles with greater than 85kW power rating.
6 Euro VI standards are still being negotiated hence values are representative of the range of proposals under consideration.
7 Enhanced Environmentally-friendly Vehicle.

Each successive Euro standard has reduced the amount of toxic pollutants produced, as measured in bench-testing over given cycles. The significant impact of this policy on total road transport emissions is highlighted in section 3.2 below.

Euro standards apply to all vehicles whatever their technology basis or fuel type. For Heavy Duty Vehicles the most common technology is a compression ignition engine fuelled by diesel. The adoption of ever more stringent Euro standards has led to improvements in combustion technology and an increasing need for exhaust after-treatment, and even use of additives to help the removal of toxic pollutants. The objective of engine manufactures is to meet increasingly stringent emission limits, while maintaining durability, fuel efficiency and cost characteristics as far as possible.

In addition to this conventional approach to Heavy Duty Vehicle propulsion there are a range of other engine technologies and fuels available. The specific characteristics of different alternative fuels can also be utilised to reach more stringent emission standards.

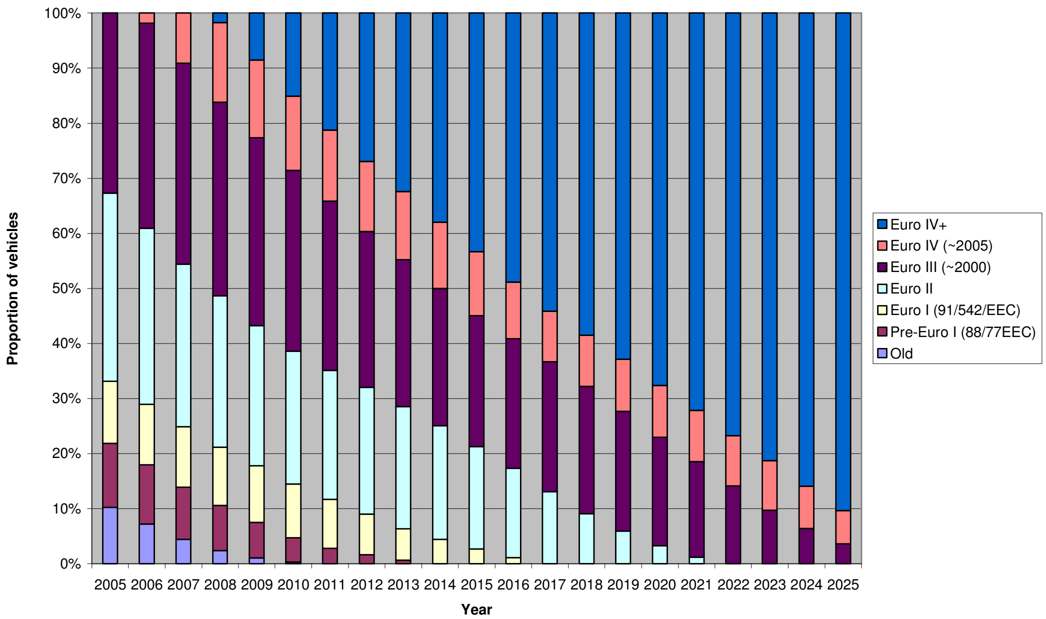
3.1.2 Impact of improving emission performance

All forms of road transport are predicted to become cleaner over time, as newer vehicles enter use which are manufactured to more stringent standards than those in the past.

The National Atmospheric Emissions Inventory (NAEI) compiles estimates of emissions to the atmosphere from UK sources such as cars, trucks, power stations and industrial plants. The NAEI is funded by Defra, The National Assembly for Wales, The Scottish Executive and The Department of Environment, Northern Ireland. The NAEI datasets include projections for how the composition of the UK bus fleet (and that of other vehicle types) is predicted to develop up to 2025.[22] The NAEI projections of bus numbers and activity by Euro standard type are shown in the graphs below.

[22] Projections from 1999 NAEI road transport emissions inventory, Netcen. (UK FLEET PROJECTIONS BASE99_3.XLS).

Figure 3.1: Bus fleet composition projections[23]



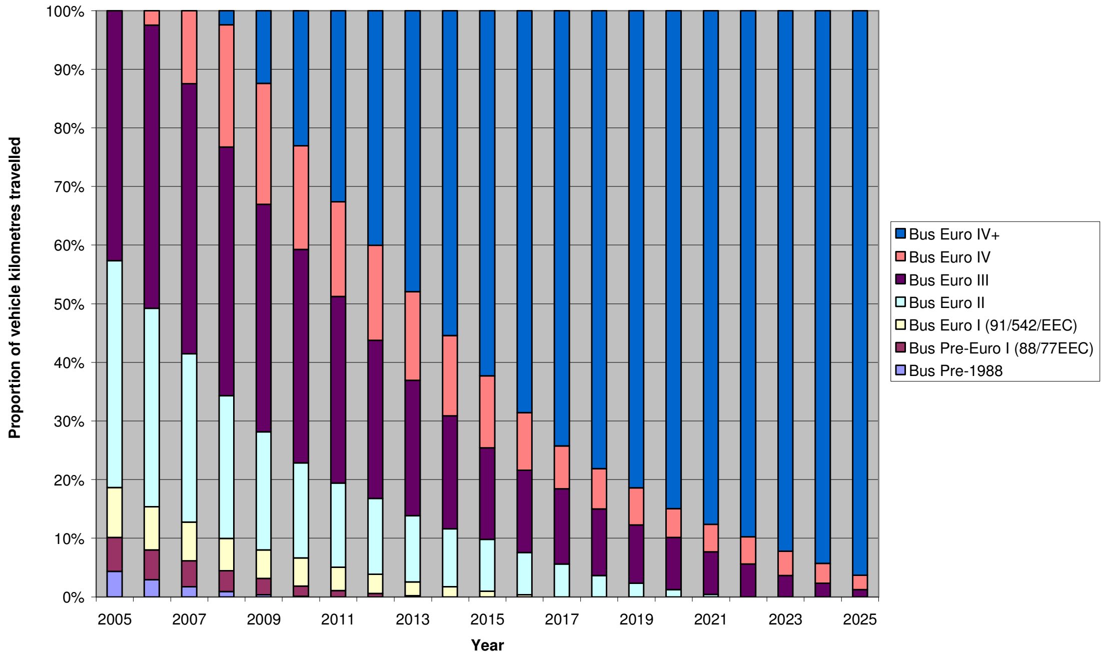
The graph shows a trend of the oldest buses in the fleet being displaced as newer vehicles enter the fleet. It is worth noting that these predictions show a small number of pre-Euro vehicles remaining in the fleet until 2013 and Euro 1 vehicles remaining in the fleet until 2016.

The NAEI projections also include predictions for how the proportions of vehicle kilometres travelled by the UK bus fleet are predicted to develop. This takes into account decreasing annual mileage with increasing age of vehicle. These projections of vehicle kilometres are shown in the graph below.

It can be seen that even in 2015 up to 10% of the bus fleet km travelled will be done by vehicles of Euro II or lower. Table 3.3 later in this chapter will show that for PM such vehicles are over 40 times more polluting than the Euro IV equivalent (based on the g/kWh metric). The problems of local air quality are exacerbated by the disproportionate amount of pollution from the few oldest vehicles.

[23] These projections contain a category 'Euro IV+' to represent a catch all for all categories such as Euro V and Euro VI, whether already specified or not, which come after Euro IV.

Figure 3.2: Bus vehicle kilometres travelled fleet projections



NAEI is a good source of data for this study, and is used as a basis for comparing the relative contribution of vehicle sectors to toxic pollutants and GHG.

Fleet data for each of the PTE areas has been collected during this study for 2007/08, and the future 'business as usual' fleet composition for each PTE has been forecast using the trends shown in the NAEI. More information on this process is given in Annex A. Two alternative 'business as usual' scenarios have been used: the current scenario, where buses are replaced at a conservative rate of 5.5% per year (BAUc) and an optimistic scenario, where buses are replaced at a rate of 7.5% per year (BAUo).

Table 3.2 shows a comparison between the projected vehicle kilometres travelled by each vehicle class derived using NAEI data (for the whole of the UK), and derived using data collected from the PTEs under each of the BAU cases.

Table 3.2: Forecast bus fleet compositions (%) for the PTE areas compared to the NAEI national forecasts

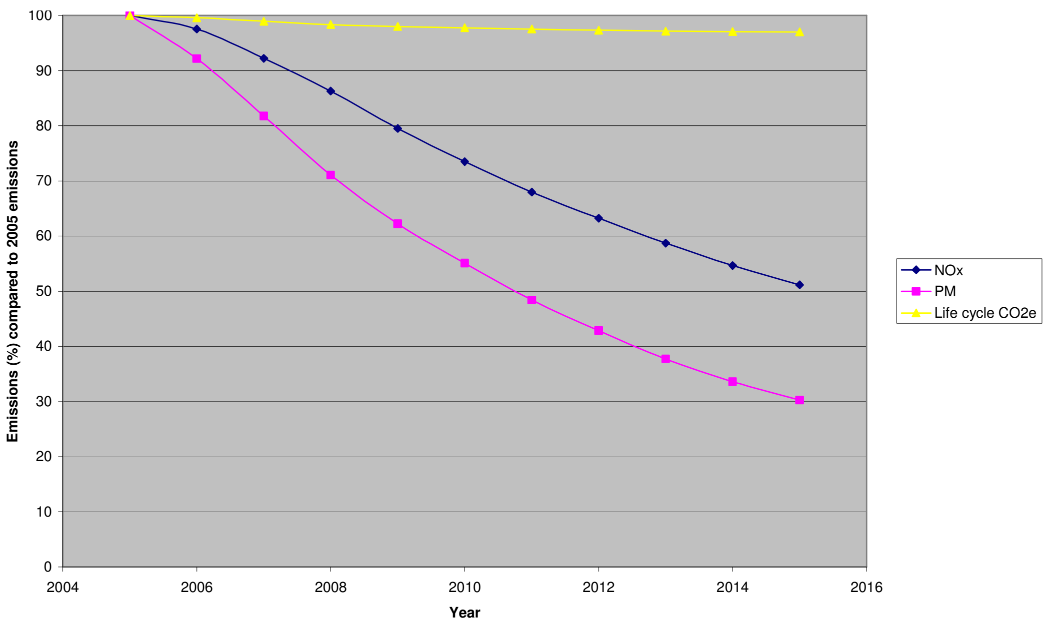
	NAEI 2007	PTE 2007/08	NAEI 2008	NAEI 2012	PTE 2012/13 BAUc	PTE 2012/13 BAUo	NAEI 2013	NAEI 2015	PTE 2015/16 BAUc	PTE 2015/16 BAUo	NAEI 2016
Pre-Euro I	6	7	4	1	0	0	0	0	0	0	0
Euro I	7	7	6	3	2	0	2	1	0	0	0
Euro II	29	37	24	13	23	17	11	9	12	3	7
Euro III	46	43	42	27	29	27	23	16	22	19	14
Euro IV	12	6	21	16	11	13	15	12	10	12	10
Euro IV+	0	0	2	40	35	43	48	62	56	66	69

Comparing the national NAEI and PTE specific figures for 2007/08 shows that a larger number of Euro II buses remain in the PTE fleets than is predicted nationally in the NAEI data, and that the uptake of Euro IV buses in the PTE fleets is lower than predicted in the NAEI data.

Projecting the fleet forwards using the fleet replacement rate of 5.5% (BAUc) gives a PTE fleet profile with higher proportions of Euro II and Euro III vehicles (i.e. an older fleet) in 2012/13 and 2015/16 than predicted in the NAEI. Projecting the fleet forwards using the fleet replacement rate of 7.5% (BAUo) gives a PTE fleet profile in 2012/13 and 2015/16 broadly in line with that predicted in the NAEI. Therefore, it seems sensible and valid to present both business as usual forecasts within this study.

Using the NAEI fleet forecasts, the relative emissions from the bus fleet for each year up to 2015 have been estimated and are shown in Figure 3.3.

Figure 3.3: Emissions trends for the bus fleet based on NAEI fleet forecasts



The graph clearly shows that the concentrations of the toxic pollutants PM and NO_x are predicted to fall in the future, as newer, less polluting vehicles displace older vehicles within the fleet. This is due to the impact of progressive introduction of Euro standards for type approval, which include emission limits (introduced in section 3.1). However, Euro standards do not include limits on Greenhouse Gas emissions and as a result we see that the decrease in life cycle CO_2-equivalent emissions is predicted to be limited.

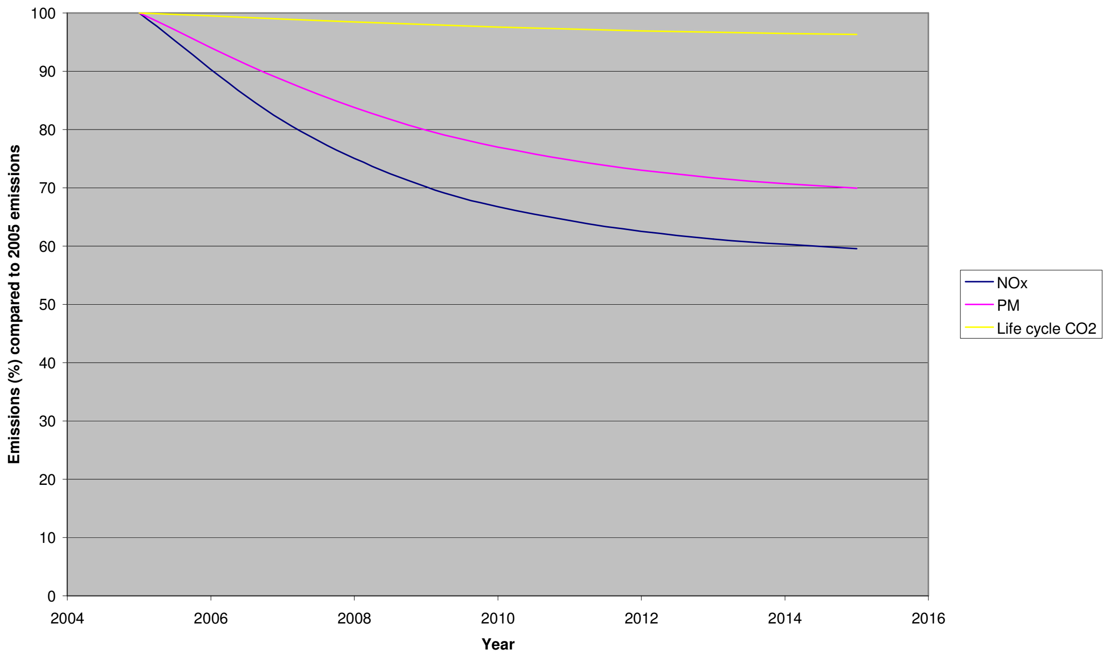
The reduction in emissions in the PTE areas under the business as usual scenarios has been calculated, and the percentages are shown in table 3.3.

Table 3.3: Business as usual emissions trends in the PTE areas

Pollutant	Percentage of emissions relative to 2007/2008 emissions				
	2007/8	2012/13 BAUc	2012/13 BAUo	2015/16 BAUc	2015/16 BAUo
NO_x	100	71	65	51	42
PM	100	51	44	36	28
Life cycle CO_2	100	98	98	99	99

Using the NAEI fleet forecasts the relative emissions from the car fleet for the years up to 2015 have been estimated using the JET model and are shown in the figures below. This assumes vehicle km stay the same, so this is showing the relative 'cleanliness' of the fleet over time, rather than total transport emissions.

Figure 3.4: Emissions trends for the car fleet based on NAEI fleet forecasts



It is informative to compare bus and car emissions. The respective graphs show that, NO_x, emissions from the bus fleet are predicted to fall to 42% of their 2005 values by 2015, whereas car emissions will be reduced to 60% of their 2005 values. For PM, emissions from the bus fleet are predicted to fall to 28% of their 2005 values by 2015, whereas car emissions will be reduced to 70% of their 2005 values. Notably, the trend for the bus fleet shows continual emissions improvement for both NO_x and PM, whereas the emissions levels of the car fleet begin to level off. This is likely to be due to the higher turnover of the car fleet, meaning that the emissions benefits of new vehicles have already been realised within the car fleet, i.e. earlier than within the bus fleet.

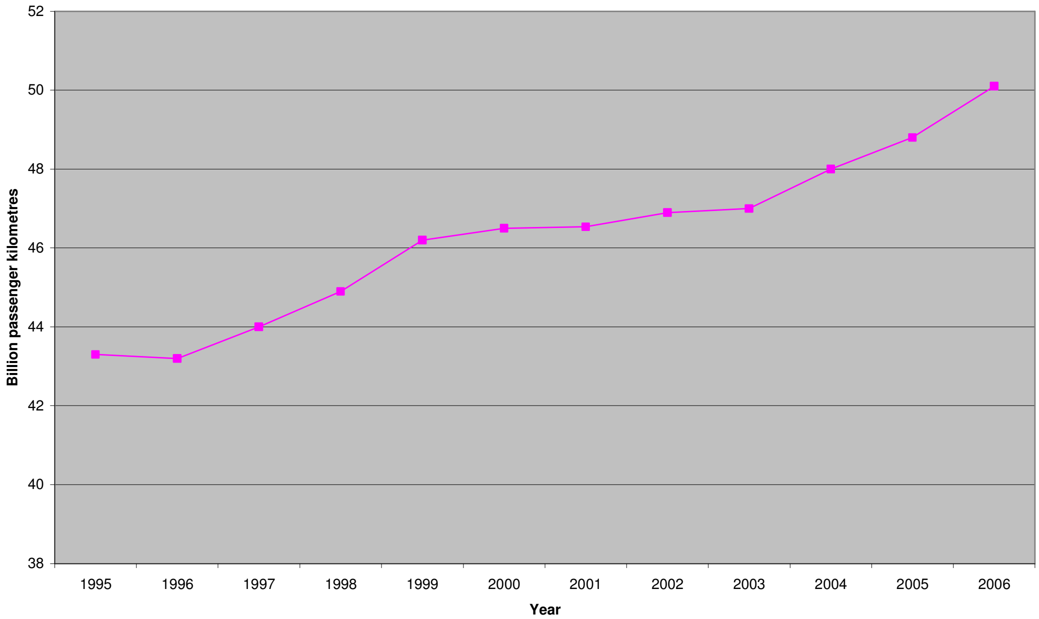
The difference in predicted reduction in life-cycle CO_2 emissions is less significant, with bus emissions predicted to fall by 4% to 96% of 2005 levels and car fleet emissions predicted to fall just 1% to 99% of 2005 levels.

3.1.3 Trends in passenger kilometres travelled

Information from the DfT[24] shows that the overall number of passenger kilometres travelled by bus in the UK is increasing, as shown in figure 3.5.

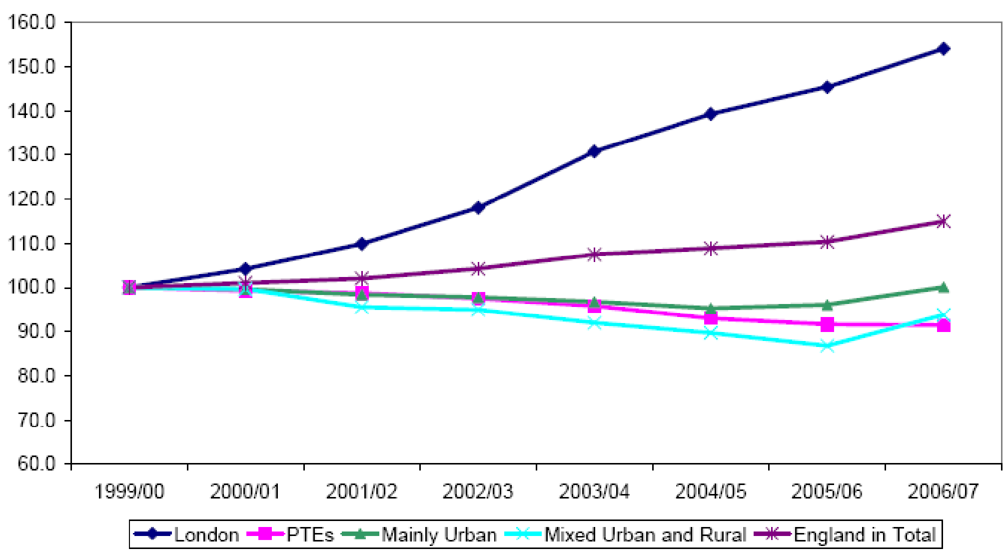
[24] Transport Statistics Great Britain 2007, Department for Transport (2008) http://www.dft.gov.uk/pgr/statistics

Figure 3.5: UK bus passenger kilometre trends



However, this growth has not been evenly distributed across the country or by type of area, as shown in Figure 3.6 below. Patronage in London has grown by over 50% in 10 years, and this has been the key reason for the overall growth in England overall to 14% higher than in 1999/2000. In contrast, in PTE areas there has been a downward trend.

Figure 3.6: Bus patronage in England (1999/2000 = 100)



3.1.4 Emissions per passenger kilometre

For a national perspective, DfT figures have been used to combine the total emissions of PM and NO_x with the total passenger kilometres travelled by different passenger modes over time.[25]

Figure 3.7: NO_x emissions by passenger kilometre travelled for each mode

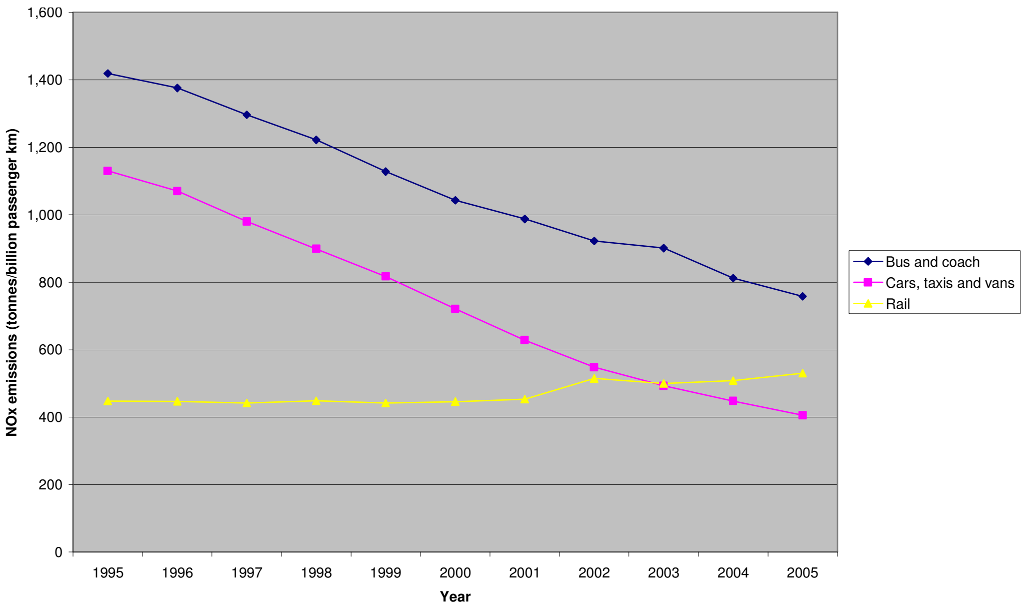
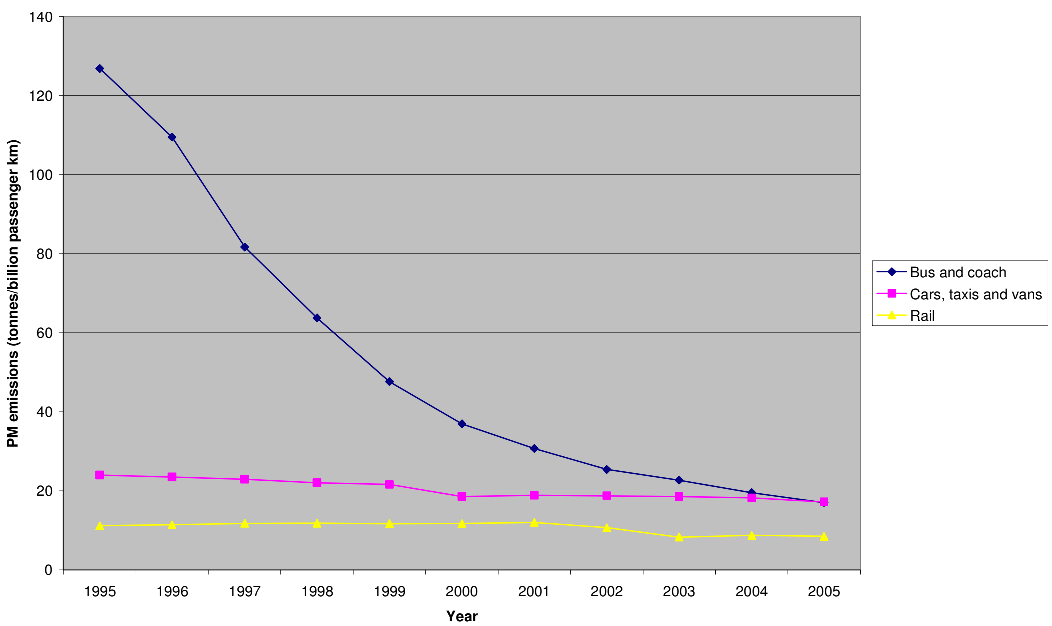


Figure 3.8: PM emissions by passenger kilometre travelled for each mode



[25] Transport Statistics Great Britain 2007, Department for Transport (2008)

The analysis shows that nationally NO_x emissions per passenger kilometre have been steadily declining for bus transport, but that the total emissions for travel by car (divided by km travelled) have been declining along a similar trajectory and remain lower. Emissions of NO_x per train passenger km have been historically low, but are at risk of being overtaken by car.

The picture for PM emissions is different, showing that in 1995 the bus represented by far the most polluting option per passenger km. However, since then a steady decline in emissions per passenger kilometre shows that the level of emissions for the car and bus are now approximately equal, and approaching that of the historically low levels of train. This view does include the London data on passenger growth, and removing this may set back some of the improvements made by bus (vs. car and rail).

Some simple analysis has been conducted to try and extend the trend lines shown in Figures 3.7 and Figures 3.8 from their present end point of 2005 based on the information in Figures 3.3 and 3.4, which predict forward to 2015. The latter show that the speed of emission reduction from the bus fleet will accelerate in future years. This is anticipated as the average aged bus takes advantage of subsequent Euro standard technology and engine/exhaust design after the average car has done so some years before (because of a faster fleet replacement rate, hence lower average age).

The analysis has been conducted using national figures but assuming passenger numbers are static. The respective figures for bus and car for PM are 5 and 18 tonnes per passenger km, showing bus improvements over car, but for NO_x 317 tonnes (bus) and 243 tonnes (car). This shows that for PM emissions the national bus fleet closes the gap on the car fleet and becomes cleaner (per passenger km), but for NO_x bus still remains more polluting. Sensitivity testing based on increasing passenger growth for bus and / or car has been done, but the relative performance does not alter, as changes in emissions per passenger km per mode are only in the order of 10-20%.

The analysis above takes an aggregate view based on national figures for the whole bus, car and train fleet. A report has been produced by Merseytravel[26] comparing bus with car in terms of total emissions per passenger investigate the potential impact of passenger loading. This does so by comparing a given Euro standard bus with the same Euro standard car, both in petrol and diesel versions. The report uses an average passenger loading of 9 passengers per bus, and assumes that if each of these passengers chose to drive cars instead they would require 7.5 cars (using a passenger loading of 1.2). Using these assumptions the report shows that it would not be beneficial to replace a Euro 3 bus with Euro 3 diesel cars, but that the bus emissions compared to petrol cars are similar for NO_x and far higher for PM. This is a natural outcome from comparing a diesel engine HDV, which produces larger amounts of pollutants than light duty vehicles, in particular petrol cars. The same conclusion follows for the comparison of Euro 4 buses and cars – i.e. that driving 7.5 Euro 4 petrol cars would produce lower PM emissions than one Euro 4 bus. In

[26] A Comparison of Bus and Car Emissions in the Urban Environment, Report of the Environmental Information Officer, Management Team, 8th January 2006

reality, the car fleet tends to turn over more quickly than the bus fleet, and therefore the same comparisons have been carried out for a Euro I bus and a Euro 3 car. This comparison also shows that it would not be beneficial to replace one Euro I bus with 7.5 Euro 3 diesel cars, but that it would be beneficial to replace one Euro 1 bus with 7.5 Euro 3 petrol cars.

The investigation into passenger loading shows that for a Euro III bus to have the same NO_x emissions per passenger as a Euro 3 petrol car, bus passenger loading would need to be increased to 77. For PM_{10} the passenger loading would need to be 733.

For CO_2 emissions we draw on two main sources for comparing bus to car travel. For a national view on cars[27] and buses[28] we can use the DEFRA guidelines and for a PTE specific view on buses we can draw on calculations done by AEA in a parallel study for *pteg* on Carbon Footprinting of PTE Policies, Programmes and Projects.

For bus travel DEFRA guidelines for GHG Company Reporting give a figure of 115.8g per passenger km. Calculations done by AEA have estimated for the PTE/SPT areas CO_2 emissions per passenger km for bus travel in the range 102.9 to 111.8 g, which are somewhat lower than the latest Defra guidelines. However, AEA undertook further sensitivity analysis of the PTE bus data and illustrated a closer match to the DEFRA figures, with certain assumptions applied.

A simple comparison of CO_2 emissions per passenger km for public and private transport using DEFRA sourced data is provided in Table 3.4. For private vehicles (car) the figures are for both diesel and petrol, noting that diesel vehicles have lower CO_2 emissions than petrol. National average car occupancy figures (of 1.6 persons) were used to estimate grams per passenger kilometre from grams per vehicle kilometre. An uplift factor of 15% applied to represent real-world driving conditions over the emission factors obtained from testing under a legislative drive cycle.

Table 3.4: CO_2 per passenger km (private and public transport)

Mode of transport	**Example of vehicle**	**CO_2 per passenger km (g)**
Public transport		
Bus		115.8
Private transport (car)		**Diesel / petrol**
Mini size	Smart City Coupe, Vauxhall Agila	84.81 / 101.38
Super-mini	Vauxhall Corsa, Renault Clio	92.3 / 110.4
Lower medium	Vauxhall Astra, VW Golf	107.9 / 125.6
Upper medium size	Ford Mondeo, Audi A4	120.13 / 136.56
MPV size	VW Touran, Ford Galaxy	132.50 / 151.37
Executive size	BMW 5 Series, Mercedes CLK	144.6 / 165.8
Dual purpose / 4x4	Land Rover Discovery, Toyota RAV4	166.5 / 190.9

[27] DEFRA Guidelines to DEFRA GHG Conversion Factors – Annexes(2008)
[28] DEFRA guidelines for GHG Company Reporting (2007)

The comparative figures indicate that on average bus travel produces lower carbon emissions per passenger kilometre than many types of car. However, the smaller 'mini' and super-mini class of cars (e.g. a Smart City Coupe, Vauxhall Corsa etc) could be outperforming the bus, as may diesel versions of lower medium class cars (e.g. Vauxhall Astra).

This direct comparison does not take into account the variation in vehicle occupancy that occurs by time of day. For example, for a commuter trip (at peak travel times) bus occupancy will be higher than average. CO_2 emissions per passenger km will therefore be lower for buses than indicated by the average of 115 g/ppkm.

3.1.5 Conclusions

These comparisons, based on national statistics, indicate that on an average per passenger per kilometre basis bus travel has been producing more local air pollution than car travel in the previous 10 years. Car travel overall produces more pollution due to greater numbers and distances travelled, but the result of this per passenger km estimate is at odds with public perception and marketing messages that bus travel is cleaner. Clearly, adding one passenger that previously drove alone to a bus that is already scheduled is going to reduce their contribution to total emissions, but the analysis shows there is only so far increasing patronage could help if the fleet profile is based on a high average age. Estimates are that bus emissions will fall faster than car emissions in the future, so that on average bus travel will become less polluting for PM emissions compared to car (on a passenger km basis). However, bus travel may remain, on average, more polluting for NO_x emissions. This analysis shows the importance of modernising the bus fleet if the bus is to be promoted as a reduced pollution option compared to the car, and show that simply increasing the passenger loading is not an option to achieve parity with car travel on all pollutants if older buses are kept in the fleet.

For carbon emissions travel by bus has an advantage over travel by most sizes of car. The only exception is when compared with the smallest size cars available (particularly if it uses diesel). These vehicles do not make up the largest share of the car market, however they are increasing their share and car manufactures are increasingly offering lower-carbon models across their range as demand for fuel-efficiency grows. This might lead to an increase in the number of cars that can compete with the bus on this environmental metric unless buses start to reduce their fuel consumption or move to lower-carbon fuels.

3.2 Current and emerging vehicle technologies and fuels

This chapter draws on existing literature to summarise the state of play on the range of current and emerging vehicle technologies and fuels available over the next ten years for bus fleet renewal.

This chapter does not aim to provide a full review and assessment of past experience of alternative fuels and vehicle technologies. It is acknowledged that operations of alternative-fuelled vehicles, often at prototype or small-series production volumes, have often been more costly or less reliable than their conventional diesel counterparts. A key report giving detailed consideration of cleaner technologies and fuels for the bus industry was the EST (Transport Energy) report 'The Route to Cleaner Buses – a guide to operating cleaner, low carbon buses' (2003)[29]. The EST published report gathered and presented the experience and available data from UK trials up to that point, much of which is still valid today.

Some of the information in this chapter has previously been compiled for three relevant technology/fuel options by the TfL-commissioned report 'Economic and Environmental Evaluation of Bioethanol, Biomethane and Diesel-Electric Hybrid Buses[30]'. Where relevant this chapter builds on this earlier report, which contains further detail on these three technologies.

3.2.1 Diesel-electric hybrid (series and parallel)

A diesel-electric hybrid is powered by both an internal combustion (diesel) engine and electric motor from battery stored electricity. As a result a smaller internal combustion engine is required and due to the use of regenerative braking to recharge the on-board batteries there should be improved fuel efficiency compared to a conventional vehicle. The battery is charged by the operation of the bus and therefore no extra charging of the battery is required.

Hybrid buses use the same diesel fuel as a conventional bus, and therefore no new infrastructure is required in order to operate a hybrid bus. Maintenance costs for hybrid buses are higher than those for conventional diesel buses due to the additional technology and the need for battery maintenance and replacement, however fuel costs are lower due to the reduction in the amount of fuel used.

The economic case for using diesel-electric hybrids should be more favourable if oil prices are higher, due to their improved fuel efficiency. The 2006 TfL report comparing diesel-electric hybrid, bioethanol and biomethane buses included an assessment of the economics of each technology with current duty rebates and BSOG payments. The analysis showed that the break-even results confirmed that diesel-electric hybrid buses were economically the most attractive option of the three considered. Under the baseline assumptions it would be cost-effective to operate diesel-hybrids if the average net price of diesel (paid by the operator after BSOG) was 55 pence per litre over the 10 year operating life. Diesel prices net to operators have generally been higher than this during 2008, given the BSOG rebate of 41.21 ppl. The key question is what will the average price of diesel be over the lifetime of the bus.

Hybrid buses are already in commercial use in parts of the USA. In Europe and the UK there have been a number of small-scale demonstrations of hybrid buses, and operation under contract to local authorities, but they have not been adopted by the bus industry for commercial operations.

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[29] EST Transport Energy, The Route to Cleaner Buses (2003) http://www.cleanaccessibletransport.com/Revised/Reports%20for%20publication/CleanBusGuide.pdf

[30] An economic and environmental evaluation of bioethanol, biomethane and diesel-electric hybrid buses, TfL (2006) http://www.pteg.net/NR/rdonlyres/DD227CAE-A9A2-4EC6-8895-84866C91D853/0/TfL_economic_and_environmental_evaluation_of_hybrid_buses.pdf

Hybrid buses are available in Europe from a small, yet growing, number of manufacturers. This has tended to limit the choice of vehicles and the small volumes produced for the UK market and means the technology has not been subject to the level of 'in-use' testing and operational experience anywhere close to that of conventional diesel vehicles.

For example, in June 2002 Newcastle and Gateshead councils and Nexus invited tenders for operation of a proposed Tyne Quayside Link, and for manufacture of 8 alternatively fuelled buses for a Quayside Transit System. The vehicles used on the QuayLink services are hybrid diesel-electric vehicles from Designline Olympic, from New Zealand and in current operation. As well as new buses, the project involved the construction of a bus lane and improvements to some bus stops, making them fully accessible. Ridership levels have increased and the Quayside Link scheme expanded. However, there have been issues over the reliability of the vehicles.

London Buses is the subsidiary of Transport for London (TfL) that manages bus services within Greater London. Contracts are placed with private bus operators, which gives London Buses control over a fleet of over 8,000 buses in London. This fleet is maintained with the purchase of approximately 500 new buses each year.

TfL London Buses is currently trialling the use of hybrid buses, with plans that by 2012 all new buses will be hybrids, as follows:

- 40 to 50 trial buses in operation by end of 2008;
- Up to 100 new buses in operation by end of year 2009/2010;
- Up to 200 new buses in operation by end of year 2010/2011;
- Up to 500 new buses in operation by end of year 2011/2012; with
- All new buses entering service to be hybrid powered after 2012.

As part of the current trials, a London Buses diesel hybrid bus specification will be developed, that will set operational and environmental performance standards for future purchases. It is thought likely that the London Buses hybrid purchasing initiative will have a major impact on the amount of operational experience, feed-back into designs and therefore the ultimate suitability of diesel-electric hybrid vehicles for the UK market.

3.2.2 Liquefied petroleum gas (LPG)

Liquefied petroleum gas (LPG) is a mixture of propane and butane (in the UK over 90% propane by weight). LPG is a by-product of oil refining and found as a liquid gas in natural gas fields. LPG has been used an alternative road fuel for many years across the world and there are large numbers in the UK (over 100,000 vehicles), mainly comprising cars and light vans. Serving these private and fleet vehicles is a limited but expanding public refuelling infrastructure at some 1200 locations.

Power, acceleration, payload, and speed are similar to diesel buses, but propane buses are less fuel efficient than diesel buses, and hence their driving range is somewhat lower than for comparable vehicles. LPG engines are spark-ignited the same as CNG engines and similarly heavy goods vehicles and buses for use with gas tend to cost around 15 – 25% more than conventional diesel-fuelled vehicles of the same size. LPG is slightly heavier than air which means that LPG-gas coming out from a leakage may collect in areas where the gas is highly explosive, so particular safety systems need adopting.

Very low duty on LPG means it can cost considerably less than petrol/diesel, and can be cost effective for those doing high mileages and can pay back the additional cost of the engine and fuel system modifications required. LPG is usually stored in moderately pressured tanks, which cost and weigh more than equivalent petrol/diesel storage. On large vehicles, such as buses, the weight of the tanks can reduce the overall payload and therefore passenger numbers by a small amount.

CO_2 emissions are similar to diesel. Regulated pollutants (PM and NO_x are considerably lower). This advantage is being somewhat eroded by cleaner diesel engines.

Past UK experience of LPG buses has included a fleet of 17 LPG buses at Gatwick Airport (operated by BAA), operating since 2000. An earlier demonstration (from 1998 to 2000) for a Park & Ride in Chester was technically successful, but with high capital costs for vehicles and refuelling.[31]

3.2.3 Natural gas

Natural gas can be stored as a vehicle fuel either as compressed natural gas (CNG) or liquefied natural gas (LNG). CNG vehicles can be designed to run either solely on gas using dedicated gas engines (mono-fuel), on gas and diesel in the same modified diesel engine (dual-fuel) or by switching between petrol and gas (bi-fuel), with petrol used as a back up fuel and to extend range. Mono-fuel and dual-fuel are the most common designs for heavy duty vehicles such as bus, while bi-fuel designs tend to be used in light duty vehicles and are based on petrol engines.

Natural gas is made up of a mix of propane and butane and is derived from natural gas fields or from oil refining and is therefore not a renewable fuel. Life cycle CO_2 emissions are approximately the same as for diesel (perhaps 10-15% lower) but NO_2 emissions are significantly lower (80 per cent lower) and particulate matter is virtually non-existent. These natural advantages are being eroded as diesel engine exhaust abatement technology improves in response to successive Euro standards, although the very best gas engines can still outperform the best diesel engines on most relevant emissions. Noise levels are lower than for equivalent diesel engines.

Gas vehicles can be purchased new, or converted from existing diesel vehicles to run as dual-fuel. The best emissions performance tends to comes from dedicated gas engines. Fuel storage tanks on the vehicle add weight can reduce the overall payload for certain types of vehicle (such as buses). The additional fuel storage requirements and specialist engine modifications/design mean higher costs for a new vehicle. Maintenance costs for gas buses have tended to be higher than for conventional diesel buses due to higher parts costs and increased maintenance requirements, although there is some experience of this being dealt with through negotiation at the procurement stage. Fuel costs are lower so it is possible for high-mileage fleets to benefit financially from this fuel, particularly when covering high

[31] EST Transport Action ‘The Route to Cleaner Buses’ (2003)

mileages. The best financial case for CNG tends to be for use in long-distance freight haulage operations in the UK (for quickest payback of the capital costs).

There have been some trials of CNG buses in the UK. Early trials did not produce convincing results, with initial problems over reliability and maintenance costs. The variable quality/specification of gas used may have been a factor. In addition, the configuration of the Fuel Duty Rebate (FDR) and its replacement, Bus Service Operators' Grant (BSOG), meant that fuel costs were higher overall than for diesel vehicles. Experience with the technology has improved performance, but there are few CNG buses operating in the UK at this time.

In the UK, gas for fuelling is available through the existing natural gas infrastructure. However, operation of gas vehicles requires dedicated refuelling infrastructure. There are a very limited number of public refuelling stations for CNG and LNG in the UK (about 20 stations) so it is currently best suited to refuelling depot-based fleets such as buses, where a refuelling facility can be installed at the depot. Only about 500 vehicles in the UK are capable of running on methane or methane / diesel mix (dual fuel), and that number has been fairly constant for some time. However, there are a number of UK companies active in this market, undertaking vehicle conversions, and producing/supplying equipment for distribution, storage and refuelling of CNG and LNG. The potential for production of biomethane and use in gas vehicles has increased interest in gas vehicles.

Gas buses are widely used elsewhere in the world, particularly in India and throughout France, but also in Italy (Rome), Spain (Barcelona), Australia (Sydney), and China (Beijing) and new models are offered by manufacturers for mainland Europe markets.

3.2.4 Biomethane

Biomethane is chemically very similar to natural gas, and therefore can be stored in the same way and used in the same vehicles. The use of biomethane in vehicles has many of the same benefits, and barriers, as using natural gas.

Biogas is produced from the decomposition of organic matter, and can be produced from a number of waste sources such as sewage, animal slurry, municipal waste and food waste using anaerobic digestion (AD). Biogas can be processed into biomethane and then used in vehicles in the same way as natural gas, as the engines combust the methane (CH4).

A major benefit over natural gas, and other fuels, is that biomethane is a renewable fuel and therefore the life cycle carbon emissions are significantly lower for biomethane than for natural gas (and most if not all other biofuels). Using biomethane in vehicles can give a reduction in life-cycle CO_2 emissions of around 80-90% compared to conventional diesel. If the waste material is animal manure, that would otherwise decompose and release methane into the atmosphere, then capturing this via the AD process and using it as a fuel actually produces a negative CO_2 balance.

There is currently renewed interest in methane from renewable sources as a transport fuel, and in increasing the amount of AD generally in the UK to capture more of this renewal energy source.[32] Biomethane fits with the recommendations of the Gallagher Review that proposes that biofuel production must be focused on idle and marginal land and increasingly use wastes and residues. The sustainability credentials of biomethane are extremely good.

There are the same barriers for using biomethane as a road fuel in the UK as exist for natural gas: the availability of suitable vehicles and the need for a dedicated refueling infrastructure. Fuel costs depend on the production and distribution methods, but the price of biomethane often mirrors the price for natural gas which is generally lower than diesel, so offsetting some of the extra capital costs associated with setting up a gas-fuelled fleet.

Biomethane-powered light duty vehicles are widely used in Sweden, and heavy duty vehicles, such as buses, are in operation in the same regions. Lille in France has operated 127 of the region's bus fleet on biomethane (in gas vehicles) proving the reliability and cost-effectiveness, and aim to move 100% of their bus fleet to biomethane by 2011.

3.2.5 Biodiesel

Biodiesel is produced from biomass (from the oil of crops such as rapeseed) or from recycled waste cooking oil. Biodiesel can be blended with conventional diesel to varying proportions. Vehicles can be refuelled in the same way as conventional diesel vehicles and therefore major new infrastructure is not required, although care is required during storage of the fuel to prevent water absorption.

Diesel containing 5% biodiesel (B5) is widely available and can generally be used in the same way as conventional diesel. Higher blends (e.g. B10, 20, 30, 50 and B100) are available to varying specifications, but their suitability depends on the vehicle specification. Reliable use will depend on the specification (and blend limit) the vehicle manufacturer has defined as acceptable.

Life cycle CO_2 emissions vary depending on the source of the biodiesel. If land use change is not considered and assuming today's production methods, biodiesel from rapeseed and sunflower oil produce 45%-65% lower greenhouse gas emissions than petrodiesel.[33] [34] [35] [36] However, there is ongoing research to improve the efficiency of

[32] Defra (June 2008) - Renewable Energy Strategy Consultation Document

[33] Mortimer, N. D.; P. Cormack, M. A. Elsayed, R. E. Horne (January 2003). Evaluation of the comparative energy, global warming and socio-economic costs and benefits of biodiesel. Sheffield Hallam University. (DEFRA).

[34] Summary: Biodiesel Life Cycle Assessment. Well-to-Wheels analysis of future automotive fuels and powertrains in the European context. Joint Research Centre (European Commission), EUCAR & CONCAWE (March 2007).

[35] (2006) Transport and environment : facing a dilemma : TERM 2005: indicators tracking transport and environment in the European Union (PDF 3.87 MB), Copenhagen: European Environment Agency ; Luxembourg : Office for Official Publications of the European Communities. ISBN 92-9167-811-2. Retrieved on 2008-05-01.

the production process. Biodiesel produced from used cooking oil or other waste fat could reduce CO_2 emissions by as much as 85%, and would have better sustainability credentials. Toxic emissions (NO_2, PM_{10}) are broadly the same as for conventional diesel. A 2002 EPA summary analysis of existing data suggests vehicles using biodiesel may emit slightly more nitrogen oxide (NO_x) (about 2% for B20 and 10% for B100). Subsequent studies have yielded mixed results, with some showing small increases and others showing small decreases.[37]

There are some specific issues over using higher blends of biodiesel that are of concern to vehicle manufacturers:

- High viscosity stresses the high pressure fuel pump;
- Oxidation degradation with time;
- Moisture content leading to microbial growth;
- Solvency of biodiesel on seals.

Biodiesel has been known to break down deposits of residue in the fuel lines where petro-diesel has been used. As a result, fuel filters may become clogged with particulates if a quick transition to pure biodiesel is made.

The specific properties of biodiesel mean vehicle manufacturers are careful to state what blends can be used without invalidating vehicle warranties. Ensuring fuel quality and meeting any required certification levels is therefore important.

At the time of writing Morrison's has been supplying B30 biodiesel via selected forecourts to support a trial with BSkyB-operated Vauxhall vans. Much work has been done on the blending process behind this fuel to obtain the best performance.

To encourage biodiesel use and production, tax on biodiesel was reduced by 20p/litre in 2002. Because biodiesel has a similar calorific value and density to normal diesel, the impact of the fuel duty differential means that the biodiesel price was roughly equivalent to conventional diesel before 2008. The spike in diesel prices in the first half of 2008 put some biodiesel supplies at a price advantage, although the parallel rise in the prices of vegetable oils somewhat negated this.

Take up of 5% biodiesel by some bus operators has been dependent on whether or not it is lower cost than conventional diesel. Production costs of biodiesel are not strongly linked to the oil price, but are dependant on prices of vegetable oils. The economic case for both low and high blend biodiesel is more favourable if oil prices are historically high, as was the case during parts of 2007/2008.

3.2.6 Bioethanol

Bioethanol is produced from the fermentation of plant-based materials, such as corn, wheat and sugar cane.

Bioethanol can be blended with petrol in varying proportions for use in spark-ignition engines. The more common blends are E5 (5% ethanol, 95% petrol) and E85 (85%

[36] Biodiesel. Energy Saving Trust. Retrieved on 2008-05-01. "[B]iodiesel is considered a renewable fuel. It gives a 60 per cent reduction in CO2 well to wheel"
[37] EPA420-F-06-044, October 2006.

ethanol, 15% petrol). E5 can be used in all petrol-fuelled engines without any modifications to engines or refuelling infrastructure. Current European specification petrol (EN228) can contain up to 5% ethanol, and some petrol sold in the UK already has 5% ethanol in it, for example Tesco standard unleaded as supplied to forecourts in the South East of England from April 2006. Higher blends require modified engine designs, known as 'flex-fuel' vehicles.

Bioethanol can also be used in compression ignition engines, suitable for heavy duty vehicles such as buses, designed or modified to handle the different characteristics of ethanol as a vehicle fuel. Bioethanol as a bus fuel requires some ignition improvement additives to complement the normal 95% ethanol proportion. Etamax-D and Greenergy's E95 are examples of fuel produced for dedicated compression ignition engines, such as those manufactured by Scania.

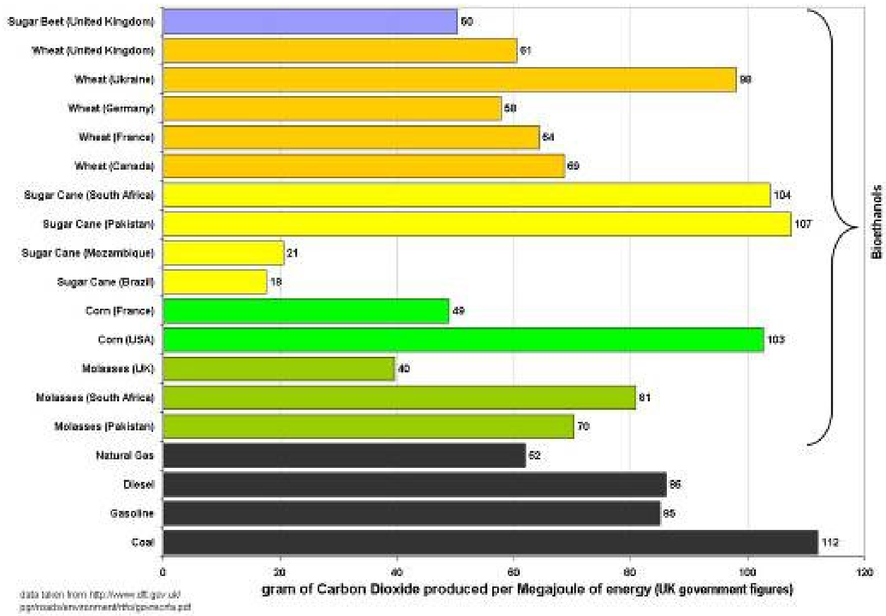
For higher blends of bioethanol special transport, storage and refuelling infrastructure is needed, because ethanol can corrode equipment designed for diesel or petrol. Ethanol and water can dissolve into one another, degrading the properties of the fuel, which requires precautions in fuel storage and handling not needed for diesel.

The fuel costs per litre of bioethanol is slightly lower then diesel (<5%) but fuel consumption on a volumetric basis is higher than gasoline by about 50-60% for pure ethanol (about 40% for E85) due to the lower energy density. For this reason, fuel consumption of bioethanol buses will tend to be higher than their diesel counterparts.

Estimates of the GHG savings of bioethanol vary widely, mainly depending on the type of feedstock and manufacturing process. Depending on the production method and source, the best-performing bioethanol gives a 70 per cent carbon dioxide reduction, which means 3.5 per cent in a 5 per cent blend or 50 per cent in an E85 blend.[38] UK-sourced bioethanol gives around a 25 to 50% reduction, depending on whether the feedstock is wheat or the more effective sugar beet. The graph below is based on figures calculated by the UK government for the purposes of the Renewable Transport Fuel Obligation (assuming the bioethanol is burnt in their country of origin and that previously existing cropland is used to grow the feedstock).[39]

[38] Energy Savings Trust – Alternative Fuels web-page viewed July 2008.
[39] Defra (2008) - Carbon and Sustainability Reporting Within the Renewable Transport Fuel Obligation.

Figure 3.9: Carbon intensity of bioethanol and fossil fuels



Regarding regulated emissions, for high petrol-bioethanol blends, carbon monoxide, particulate emissions and tailpipe hydrocarbons are generally reduced. In theory, bioethanol vehicles should emit fewer nitrogen oxides (as alcohol fuels burn at a lower temperature than petrol). In practice the compression ratio is often increased to improve engine efficiency, which raises the combustion temperature and offsets any NO_x emission benefit.

Worldwide, Brazil, the USA, India and China are the largest producers and consumers of bioethanol. In Europe, France is one of the bigger producers and the consumption of bioethanol is largest in Germany, Sweden, France and Spain. By 2007 in Sweden there were 792 E85 filling stations and in France 131 E85 service stations with 550 more under construction.

In terms of bus fleet operations most experience in Europe is found in Sweden, using Scania-manufactured vehicles. Ethanol buses are widely used in Sweden, particularly in Stockholm where the fleet numbers in the hundreds. However, ethanol buses are also in operation on a smaller scale in Spain, Italy and Poland.

While the situation is changing, the high-blend use of bioethanol in the UK HDV fleets can be considered to be in the demonstration phase. Recent UK initiatives include:

- British Sugar, trading as British Bio-ethanol, began production of bioethanol in the UK in September 2007 in Wissington in Norfolk. British Bio-ethanol report a 71% reduction in life-cycle carbon emissions compared to conventional fuel.
- The UK's first 95% bioethanol bus route, Ecolink 30, was launched in Nottingham in April 2008 with 3 Scania buses (using wood-based fuel from Sweden) which exceed the emissions standards for Euro 5 and meet the higher EEV in-service vehicle standards;

- Reading Borough Council started taking delivery of the first of 13 bioethanol buses in spring 2008, for use by Reading Buses on the number 17 major bus route;
- British Sugar has also entered into a joint venture, Vivergo Fuels Limited, with BP and DuPont to build and operate a world-scale bioethanol plant at Saltend, Hull. Expected to come on stream in 2009, this plant will produce 420 million litres of bioethanol each year from UK-grown wheat.

Figure 3.10: Nottingham Ecolink

3.2.7 Hydrogen fuel cells

Hydrogen is produced by the electrolysis of water or by the breakdown of a hydrocarbon source (e.g. natural gas, fossil fuels or ethanol). In some cases it is also produced as an industrial by-product.

When used as a fuel the only by-product of hydrogen combustion is water, leading to zero tailpipe emissions. Life cycle CO_2 emissions vary depending on the source of electricity used to produce the fuel. Where renewable electricity is used, the life cycle emissions can be lower.

Production of hydrogen-fuelled vehicles has been limited to a small number of demonstration fuel cell projects made by a few vehicle manufacturers. Currently such vehicles can cost up to 10-20 times more to produce than their conventional fuelled equivalents (e.g. £1m+ per bus). At the present stage of development the cost of the vehicles and associated refuelling infrastructure is high, and little information is available about how much the fuel would cost.

Therefore hydrogen fuel cells and hydrogen combustion engines are considered to still be at a prototype stage, with only small-scale demonstrations having been carried out (e.g. in London). While useful, these should be viewed as steps on a longer-term process and it seems unlikely that this technology will become commercially attractive to bus operators within the 10-year time horizon of this study.

3.2.8 Electric vehicles

Vehicles can be powered by electricity either by using an onboard rechargeable battery to supply power to an electric motor, or by using rails to supply power to a trolleybus (catenary). The infrastructure needs associated with catenary technology makes it a subject for a wider study, and they are not considered further here.

Vehicles run on electricity produce no tailpipe emissions. Life cycle CO_2 emissions vary depending on the source of electricity used to produce the fuel, but where renewable electricity is used the life cycle emissions are lower.

Refuelling is low-cost compared to diesel, so running costs are reduced once the vehicle has been purchased. Battery durability and longevity can be an important barrier to realising cost savings over the lifetime of the vehicle. Engine noise is minimal.

Current commercial battery technology can only at present supply electric buses with enough power for shorter-range and low capacity vehicles. This severely limits the size / range of applications. Therefore, electric vehicles are not considered further in for the scenarios developed as part of this study.

3.2.9 Biofuel-electric hybrids

A biofuel-electric hybrid would be configured on the same principle as a diesel-electric hybrid, but the combustion engine would be powered by a biofuel, such as biodiesel, biomethane or bioethanol. A diesel-electric hybrid running on biodiesel is probably the simplest technological path to such a concept in the UK setting. However, some hybrid buses are manufactured with gas turbines (e.g. Designline New Zealand), which would be suitable for 100% biomethane. Saab have recently produced a 100% bioethanol-electric hybrid car as a concept vehicle, showing the technology in a light duty vehicle.

3.2.10 Other biofuel variants

The problem that second generation biofuel processes are addressing is how to extract useful feedstock from woody or fibrous biomass, where the useful sugars are locked in by lignin and cellulose. The goal of second generation biofuel processes is to extend the amount of biofuel that can be produced sustainably by using biomass comprised of the residual non-food parts of current crops, such as stems, leaves and husks that are left behind once the food crop has been extracted. The option is to use other crops that are not also used for food purposes, such as switch grass and cereals that bear little grain, and also industry waste such as wood chips, skins and pulp from fruit pressing etc.

Second generation biofuels include biomass-to-liquid technologies, such as cellulosic ethanol and Fischer-Tropsch gasification, which can derive fuel from lignocellulosic biomass. These technologies are not yet commercially used to provide vehicle fuels, but are attracting considerable research monies.

3.2.11 Retrofit technologies for older vehicles

Retrofitting pollution abatement devices to older vehicles can reduce the levels of emissions from these vehicles without the need to re-engine or replace the entire vehicle. This should be a potentially attractive option for greening fleets.

To reduce particulate emissions from buses, diesel particulate filters (DPF) are used. These are fine mesh filters that collect carbon particles. These devices generally have some means of self-regeneration, such as a fuel-borne catalyst or embedded catalyst within the filter. DPF can reduce emissions of particulate by 90- 95%. The cost to fit a DPF is around £4000. DPF require regular maintenance to empty out the ash from combustion of collected particles at about £200 each time, required once or twice a year.

Some earlier particulate traps increased fuel consumption (0.5 to 1%), although newer models have a negligible effect if the filter is maintained properly. There is however a potential issue of increased NO_2, as some evidence shows DPF increase the amount of NO_2 emitted directly.

Diesel Oxidisation Catalyst (DOC) technology is an alternative option for removing PM emissions. It is effective at removing larger particulate matters, reducing total PM by some 30-50%. The equipment is lower cost (than DPF) at around £1,000 per HDV, and is more likely to be suitable for very oldest vehicles and on any duty cycle. They require minimal maintenance.

To reduce emissions of NO_x a selective catalytic reduction (SCR) device can be fitted. SCR engines inject urea (ammonia) and water into exhaust gasses, producing nitrogen and water. An SCR can reduce emissions of NO_x by around 30-70%. SCR is best suited to depot-based vehicles due to the need for an ammonia supply infrastructure.

Exhaust Gas Re-circulation (EGR) is an alternative approach to reducing NO_x levels, by recycling exhaust gases to lower combustion temperatures and emit less NO_x. Manufacturers acknowledge that it is less efficient than SCR (at 40 – 50%), but the benefit is no need to top up with AdBlue (the mix of urea and water used in the SCR system).

EGR or SCR will be required for manufacturers of new HDV (including bus) to meet Euro V standard emission limits for NO_x. Manufacturers are divided between two leading emission-reducing technologies. Companies such as Daf, Iveco, Mercedes and Renault will feature selective catalytic reduction (SCR) technology, while MAN and Isuzu are set to employ exhaust gas recirculation (EGR).

The retrofit of NO_x abatement is possible for HDV (including buses) and suppliers of such equipment exist in the UK. Bus fleets in Belgium and Germany are trialling these technologies. In the UK such technology is being applied London taxi fleet requirements for NO_x reduction.

The cost to fit and maintain an SCR/EGR device is estimated at around £7000, although the variety of approaches and relatively small size of the market means this estimate may have a large margin of uncertainty either side.

Some combined SCR/DPF systems are now available, and in the early stages of trial and adoption by some mainland European bus operators.

Retrofitting can significantly reduce emissions from older vehicles. However, while some bus operators took up past grants to fit DPF in other areas bus operators could not be encouraged to fit DPF even with a local scheme that topped up those grants. Money spent on retrofitting and ongoing maintenance does not bring any cost benefits to bus operators. Therefore operators seem in general to favour fleet renewal as the route to cleaner vehicles.

3.2.12 Driver training for fuel efficiency

Driver behaviour can significantly affect fuel consumption and therefore is a potential non-technology route to achieving reduced emissions (of both regulated and GHG).

HGV operators who implement fuel management programmes (of which vehicle and driver performance monitoring and incentive schemes are component elements) achieve a minimum of 5% fuel savings within the first year.[40] Actual savings depend on the exact nature of the fuel management programme or the individual initiative implemented.

Fuel efficient driving practices can be supported by monitoring and in-cab equipment to inform drivers when they are driving most fuel efficiently. When using in-cab data loggers it is likely that fuel consumption savings of 5-10% are achievable even with fairly basic equipment.[41] Basic data logger units cost approximately £1,000 or less), or can be leased for a weekly rate that could include analysis and management support, providing specific data on individual vehicles and drivers.

Much work has been done in the field of fuel efficiency in the HGV industry, but it has been much more slowly adopted in the public transport industry. Information from the major bus fleets suggest they wish to do more in this area and there is certainly much potential for improvement and cost/emissions savings.

3.2.13 Summary of technologies and fuels

It is acknowledged that experience of alternative technologies and fuels has included problems with performance and reliability. The maintenance cost of a new technology, introduced in small numbers, is generally higher than the existing and accepted option. Capital costs for supply and storage of alternative fuels tend to fall more heavily on the initial users, making some of the upfront costs of using a biofuel less likely to be offset by lower fuel costs. Such issues will need to be addressed in order to make low emission and low carbon technologies and fuels viable, by improving vehicle reliability, either reducing cost and/or enabling the benefits of reduced emissions to be fully factored into purchase and / or operating costs.

[40] SAFED for HGVs - A Guide to Safe and Fuel Efficient Driving for HGVs. DfT. (2006)
[41] Telematics for Efficient Road Freight Operations. DfT Freight Best Practice Programme (2007)

A complementary option for reducing fuel use (and associated emissions) is for bus fleets to introduce fuel management and safe/efficient driving training and incentive schemes for bus drivers.

The following table summarises the current status of the technologies and fuels for use in bus fleets. The biofuel options are for high-blend fuels, rather than the 5% blends which are becoming standard. The table also includes some indication about future viability of some technology/fuel options, in a bid to forecast the relevance for this study's scenario development.

Table 3.5: Summary of technologies and fuels

Technology /Fuel	Availability and experience	Environmental impacts – compared to conventional diesel.	Reliability, operation and costs - compared to conventional diesel.
Conventional diesel (Euro IV, Euro V and Euro VI diesel)	The standard technology and therefore of widest availability and number of suppliers. Reliable and certified emission benefits.	Increasingly low levels of NO_x and PM. May be some small CO_2 penalty from increased fuel consumption in period immediately after a new Euro standard.	Standard technology, so known and understood. Huge investments in latest engine design required to meet Euro standards reliably. Some increase in maintaining expected for SCR Euro V vehicles. BSOG rebate of around 80% of duty makes diesel very cost effective (vs. lower duty rated alternative fuels)
Natural Gas (CNG/LNG) and Biomethane (CBG/LBG)	Vehicles available and use in numbers on mainland Europe. No or few CNG buses being supplied to UK. Past experience of reliability problems and higher costs. Relatively little fuelling infrastructure. Some conversion technologies available. Market for technology may grow on back of expanding biomethane production	Slightly lower CO_2 than diesel, significantly lower NO_x and very low particulates. Dedicated (mono-fuel) engine has lower noise than diesel engine. Biomethane has major reduction in CO2 if feedstock is waste organic matter, and is very sustainable.	Vehicles: increased cost. Maintenance: some increase. Fuel: cheaper than diesel, higher fuel consumption that diesel however, natural gas available from Grid. Biomethane requires dedicated distribution networks at present. Depot: investment in new equipment needed.
Liquefied Petroleum Gas	Vehicles available and use in numbers on mainland Europe. Few/no vehicles being supplied or used in UK. Limited but expanding public refuelling infrastructures (1200); loss of some load space due to weight of gas tanks; reliability/cost issues in early UK bus trials.	CO2 emission similar to diesel, generally low levels of air pollutants; lower engine noise;	Vehicles are more expensive to buy and maintain than diesel vehicles; low fuel duty compared to diesel, but higher fuel consumption; dedicated refuelling infrastructure more costly than diesel.
Bioethanol	European experience mainly based on extensive Swedish operation. Only one European vehicle supplier, but can supply bus to UK spec. Two current demonstrations on supported UK services. Expect increasing viability if BSOG reformed and further demos/trials supported by UK Gov or LA's.	Particulate matter reduced, NO_x often similar, CO_2 emissions reduced by up to 50% on life-cycle basis (E85 blend). Some biofuel raises sustainability issues.	Vehicles: more costly. Maintenance: costs are higher. Fuel consumption higher therefore fuel cost is higher (in UK). Depot: investment in new equipment needed.
Biodiesel	Increasing use of low-blend fuels in UK bus fleets (from 5 to 20%). Some demonstrations of high-blend biodiesel in buses. No manufacturer offering warranty for high-blend (>30%) as standard for UK use. Expect increasing viability for high-blend fuels, if BSOG reformed and demos/trials supported by UK Gov, LA's and bus operators.	Lower particulates, some potential for rise in NO_x, low sulphur, low CO_2 when using sustainable feedstock sources. Some biofuel raises sustainability issues.	Vehicles: no major differences from conventional diesel. Maintenance: some increase filter changes and oil seal checks. Fuel: similar to conventional diesel. Depot: additional storage for a different fuel may be required.
Diesel-electric hybrid	Technology well-developed and in use in USA. Small-scale demonstrations in Europe/UK, with various problems over reliability and durability. Currently small number of vehicle suppliers, but major manufacturers starting to enter market. Could anticipate commercial viability in short to medium term. Future scope for operating with biodiesel.	Low levels of NO_x and PM. Should exceed conventional diesel of same year age. Key benefit arises from reduced fuel consumption therefore reduced CO_2 emissions. Biofuel hybrids provide scope for further emission reductions.	Capital higher than conventional bus. Fuel costs lower. Maintenance costs will be higher, but should reduce with experience (as shown by US fleets) TfL trials, specification and purchase anticipated to reduce costs and increase reliability of available vehicles.
Battery electric	Technology available for small and low-range vehicles. Some demonstrations/pilots in UK. Do not expect technology advances to transfer to full size buses sufficiently to compete with other fuels. Vehicle range restricted	Zero emissions at point of use. Life cycle emissions will vary depending on electricity production methods.	Vehicles: most costly. Maintenance: generally more costly due to reliability issues. Fuel: less costly (although battery replacement costly). Depot: some changes and costs.
Hydrogen	Technology available in concept vehicles and for pilots. Bus trials in European cities, including London. Do not expect technology to become commercially viable in study time-horizon.	Point of use emissions are zero. Life cycle emissions vary depending on production methods. Potentially very low toxic and GHG emissions if renewable sources used.	Currently vehicles, maintenance and fuel costs are all considerably higher than conventional fuels and first generation biofuels.
Exhaust abatement (retrofit)	Diesel Particulate Filter widely available and many units fitted and in use. Diesel Oxidisation Catalyst a less effective PM reduction option, but may suit a wider range of duty cycles and age of vehicle. Selective Catalytic Reduction & Exhaust Gas Recirculation available and being trialled, and used in some fleets.	DPF removed 90-95 of PM from old HDV, DOC removes 20-50% of PM. SCR removes 30-70% of NOx, partly depending on duty cycle. EGR removes 40-50% of NOx.	DPF requires maintenance (annual filter clean). SCR requires urea additive (AdBlue) with each refuelling of diesel (as per some modern Euro V HDV that will use SCR as standard).

3.3 Forecasting options for greening PTE fleets

3.3.1 Selection of technology and fuel options

A consideration of options for reducing emissions for UK bus fleets in PTE areas needs to take into account the policy and regulatory setting, as well as the technology options, their costs and supporting initiatives. The objective of this study is to look up to 10 years ahead, but this means a considerable degree of uncertainty arises. As an example, during the short timescale of this study, the release of the Gallagher Review for the RFA has led to a possible change in the UK government's timetable for the RTFO.

We have also considered when such vehicles may become commercially available and attractive. We have considered the availability of vehicles and technology, and the operational experience that exists for each technology/fuel type at this time. For future technology/fuel options we have predicted when these will be attractive for bus operations.

Predicting forward, with some optimism in order to contrast with business-as-usual, we suggested the most attractive and likely technology innovations for reducing emissions from bus fleets to be, in the following order:

1. Conventional diesel technology (using EGR/SCR to reach Euro V in a cost-effective manner);
2. Hybrid diesel-electric – in response to rising fuel prices and improvement in technology;
3. Renewable fuels (biodiesel, bioethanol or biomethane) – in response to carbon reduction requirements; and
4. Use of second generation biofuel(s) in hybrid vehicles – combining the best of renewable fuel and hybrid technology for reducing regulated and GHG emissions.

For biofuels, we consider it possible there will be an increased use of medium-blend biodiesel by bus fleets in the future, and that at some point after 2010 government policy, oil prices, fuel standards and engine design will move forward sufficiently so that B20 can be used as one of a number of standard diesel blends, much in the way B5 is becoming standard in 2008.

However, this outcome is at risk as Treasury has indicated it intends, over time, to reduce the duty differential for biofuels, which would reduce the stimulus for high blends.

In developing the scenarios for greening the PTE bus fleets, the background evidence, corroborated by feedback from study stakeholders, suggests that hydrogen and electric vehicles will not be sufficiently developed to compete with the other technology/fuel options available. In addition, it is likely that CNG/LNG vehicles will not prove attractive without the additional benefits of biomethane as a vehicle fuel. Therefore, the option of biomethane-fuelled vehicles is the one to take forward.

Finally, while exhaust abatement technologies can be very effective methods, the evidence to date shows they are not popular with bus operators. With the greater powers to be available under the Local Transport Act, the use of retrofit in a wider bus emissions strategy should be seriously considered for older vehicles that may otherwise remain in the fleet.

In the tables below, the timing of future availability of technology/fuel options is indicated by the Euro standards likely to be in force, which by date corresponds to:

- Euro IV – current standard for new vehicles type approved for sale up to October 2009;
- Euro V – for sale from October 2009 until October 2014; and
- Euro VI – for sale potentially from October 2014 onwards.

3.3.2 Comparative emissions performance

The table below shows the typical anticipated emissions of each pollutant for each bus technology/fuel option within TTR's JET model, as used in subsequent study modelling. The background data for speed-emission curves are derived largely from COPERT IV data, supplemented where necessary with CONCAWE updates and recent experience of biomethane, bioethanol, biodiesel and diesel-electric hybrids.

Life cycle CO_2 equivalent (CO_2e) emissions are taken from DfT's recommendation to the Renewable Fuel Agency on how carbon and sustainability reporting should operate under the RTFO,[42] and extend only as far as fuel production, transport and use. They do not include vehicle manufacture and disposal. The estimates tend to be based on the 'worst-case' assumptions, which could be improved by specific data on feedstock source, processing and transport factors.

Assumptions have had to be applied to derive figures for future emissions from vehicles powered by non-conventional diesel technology, where this information was not present in COPERT IV. For biofuel buses manufactured during the period when Euro V standards will be required we have assumed better performance than the limit, and applied EEV in-service emission rates (which are part-way between Euro V and Euro VI). For comparative purposes we have included emission abatement retrofit technologies for particulate matter and NO_x

Assumptions, based on previous experience, have been applied to show a small increase in fuel consumption in the period immediately after a new Euro standard comes into force. Generally vehicle manufacturers need to stretch their engine design capability to meet the next emission standard, which comes at some dis-benefit to fuel consumption. Although over time they are able to re-address fuel consumption. This fuel penalty could be compensated for by lightweight chassis and body designs, but there is little past evidence to support the assumption this will happen in future. This situation is reflected in small increases in overall life-cycle CO_2e against future Euro standards.

[42] DfT (2008) - Carbon and Sustainability Reporting Within the RTFO, Requirements and Reporting.

Table 3.6: Pollutant emissions for new bus technologies

Vehicle type	NO_x		PM		Life-cycle CO_2e emissions	
	(g/km)	% improvement vs. Euro IV	(g/km)	% improvement vs. Euro IV	(g/km)	% improvement vs. Euro IV
Euro IV diesel (base case)	7.7	-	0.066	-	1512	-
Euro V diesel	4.9	36%	0.066	0%	1549	-2%
Euro V diesel-electric hybrid	4.3	44%	0.047	29%	1084	28%
Euro V Bioethanol[1]	4.0	48%	0.024	65%	1134	25%
Euro V Biodiesel[1]	4.7	39%	0.025	62%	946	37%
Euro V Biomethane[1]	2.5	68%	0.005	93%	841	44%
Euro V B20	5.0	35%	0.060	9%	1429	5%
Euro VI diesel	1.2	84%	0.034	49%	1611	-7%
Euro VI diesel-electric hybrid	1.1	86%	0.024	65%	1127	25%
Euro VI Bioethanol	1.1	86%	0.018	73%	1156	24%
Euro VI Biodiesel	1.3	83%	0.019	72%	946	37%
Euro VI Biomethane	0.6	92%	0.003	95%	841	44%
Euro VI B20	1.2	84%	0.030	55%	1486	2%
Euro VI bioethanol-electric hybrid	1.0	87%	0.012	82%	1134	25%
Euro VI biodiesel-electric hybrid	1.2	85%	0.013	80%	675	55%
Euro VI biomethane-electric hybrid	0.6	93%	0.002	97%	589	61%
Retrofit technologies						
Euro II DPF	-		0.014	79%	-	
Euro III DPF	-		0.013	80%	-	
Euro II SCR	2.2	72%	-		-	
Euro III SCR	2.0	74%	-		-	

[1] EEV in-service emission rates are assumed

Note that emission rates in the table are in terms of mass per distance travelled (e.g. g/km) rather than mass per power rating (as shown in the emission limits for Euro standards.

For vehicles manufactured from October 2008 to October 2014 (corresponding to Euro V) we can see rather similar reductions in NO_x from many of the technologies/fuels compared to Euro IV conventional diesel. The outlying figure comes from biomethane, a gaseous fuel, with a 68% predicted reduction over Euro IV diesel. Diesel-electric hybrid is forecast to perform better (with 44% reduction in NO_x) than conventional diesel, B20 and B100-fuelled vehicles, and about as well as an E85 bioethanol bus.

For PM emissions, a range of emission reductions are predicted, ranging from just 9% for B20 all the way up to 93% for biomethane. No emission reduction for PM is predicted for conventional diesel as the Euro standard is the same for Euro IV and Euro V.

For life-cycle CO_2e we see that a Euro V B20 bus is predicted to offset the fuel penalty predicted, but that the relatively low blend level produces a small GHG saving. A regular diesel-electric hybrid is estimated to perform similarly to a high-blend bioethanol bus (based on UK wheat feedstock). 100% biodiesel is estimated to provide significant GHG savings over an equivalent petro-diesel Euro V bus of 37%. Biomethane, with the virtual assurance of using waste materials as feedstock, performs best on life-cycle CO_2e based on the study input data.

For vehicles corresponding to the timescale of Euro VI type approval standards, the comparison of NO_x emissions shows very large and similar proportioned reductions against the Euro IV standard for all of the conventional and alternative technology/fuel options. Biomethane stands out as the technology/fuel predicted to achieve the lowest emission levels.

For particulate matter the use of biofuel (mono-fuel) and hybridisation are both predicted to lead to such a reduction in pollutants that they will be significantly lower than that of a future Euro VI diesel-fuelled bus.

For life-cycle CO_2e emissions post-2014 the Euro VI conventional diesel is anticipated to make little impact, and may even increase GHG emissions by a marginal amount (compared to the best current Euro IV technology.) The high-blend mono biofuel vehicles (bioethanol, biodiesel and biomethane) show the same percentage savings over the conventional diesel bus as they did in Euro V mode, of 24%, 37% and 44% respectively.

In the post-2014 forecasts, a new range of vehicles are predicted to be available, combining hybrid drive trains with biofuel combustion engines. These may provide an additional GHG saving over mono-fuel variations, for example a 37% reduction for biodiesel bus over the standard Euro VI vehicle, but an even larger 55% reduction with a biodiesel-electric bus.

The table illustrates that they study data assumes the overall lowest emissions of NO_x, PM and life cycle CO_2 would be possible from the Euro VI biomethane-electric hybrid.

This analysis also includes the comparative options of exhaust retrofit technologies for abatement of NO_x (via SCR) and separately abatement of PM (via DPF). The emission reductions these typically provide for older buses manufactured between 1996 and 2005 (at Euro II and Euro III standard) are very significant for the respective pollutant and take the emission levels beyond that which will be required for Euro V vehicles manufactured after October 2008. These technologies are therefore very effective at rejuvenating older buses if the focus is on one regulated pollutant only. No impacts should arise on GHG emission from modern and well maintained retrofit equipment.

3.3.3 Costs effectiveness

Cost-effectiveness is the ratio of the total costs of the option to the emission benefit obtained (i.e. £ per tonne abated). In this study we have estimated a simplified cost-effectiveness figure, based on additional costs and benefits over a baseline vehicle (in this case a Euro IV conventional diesel). In affect, we combine the emissions performance data in the section above with cost data, to examine if this changes conclusions on 'winning' technology/fuel options.

Given the natural choice for a bus operator when buying a new bus is to buy a conventional diesel bus it is interesting to reflect on the cost implications of doing something different when the objective is to reduce regulated and GHG emissions.

It should be noted that this assessment only includes capital costs and not running costs. It is very difficult to make any estimates of future fuel costs, given the uncertainty of fluctuations in oil prices, future tax regimes and the policy uncertainty surrounding biofuel. The complexity of fuel and maintenance costs for the range of technology options considered by this study, and the fact they are predictions of future vehicles, means the range of operating costs by technology have not been considered. It should be borne in mind that the lack of operating cost data is likely to skew the results, negatively against hybrids (which will not show any benefit from fuel savings) and positively in favour of biofuel options that might require additional maintenance.

Cost-effectiveness is a parameter by which options can be prioritised (for example from most to least cost-effective). This is important as most Government guidance suggests that options should be implemented cost-effectively. It should be noted that cost-effectiveness does not indicate how far an option will contribute in progress towards achieving the air quality objectives. That is, an option may be very cost-effective but only have a very small potential to reduce total emissions.

Table 3.7 below shows the cost of vehicles and fuelling infrastructure for each of the vehicle technologies, moving forward from Euro IV vehicles. An estimate has been made about capital costs based on the TfL report by E4Tech, verified with other sources and updated where necessary. Capital costs have been averaged over a typical 12 year lifetime. Emission savings, based on the rates of g/km from table 3.5, are quantified by combining them with an average PTE bus mileage from study input data of 61,551 km p.a. Emission reductions are based on the cost of emission reduction in £/tonnes, per annum and are estimated for $NO_{x,}$ PM and CO_{2e} (carbon dioxide equivalent).

The costs for retrofit technology have not been included for comparison because there is considered to be no capital cost for the vehicle (beyond the retrofit technology), so the calculation returns a negative cost compared to a new Euro IV vehicle. It is very cost-effective to retrofit DPF (for PM) or SCR/EGR (for NO_x), if the objective is to reduce the one or two regulated pollutants of most concern.

The most cost effective option for reduced emissions from a new vehicle is to buy the latest Euro standard vehicle. There is no additional cost, but the emissions savings are considerable when moving from Euro IV to Euro V for NO_x. No further emissions savings for PM are predicted however, nor for GHG. Further reductions in PM are anticipated from Euro VI emission standards expected in 2014.

The comparison of a Euro IV bus to a Euro V bus for NO_x and PM shows no cost increase, as the vehicle is anticipated to cost the same. It should be noted that the Euro V standard reduces NO_x emissions over a Euro IV, but does not reduce PM emissions.

Table 3.7: Vehicle capital cost (capex) vs. emission reduction over Euro IV diesel

Technology	Vehicle cost (£)	Fuelling Infrastructure Cost (£) per veh.	Avg. extra Capex p.v.p.yr (£)	Cost of emissions reduction (£/tonne)[1] Per annum		
				NO_x	PM	Life cycle CO_2e
Euro IV diesel (base case)	120,000	0	10,000			
Euro V diesel	120,000	0	0	0	0	0
Euro V diesel-electric hybrid	180,000	0	5,000	24,007	4,251,379	190
Euro V Bioethanol	140,000	1700	1,808	7,905	689,918	78
Euro V Biodiesel	120,000	750	63	341	24,666	2
Euro V Biomethane	150,000	14500	3,708	11,562	984,414	90
Euro V B20	120,000	750	63	373	169,065	12
Euro VI diesel	120,000	0	0	0	0	0
Euro VI diesel-electric hybrid	180,000	0	5,000	12,254	1,904,439	211
Euro VI Bioethanol	140,000	1700	1,808	4,451	605,795	83
Euro VI Biodiesel	120,000	750	63	159	21,406	2
Euro VI Biomethane	150,000	14500	3,708	8,503	958,266	90
Euro VI B20	120,000	750	63	157	28,125	39
Euro VI bioethanol-electric hybrid	180,000	1700	5,142	12,404	1,552,444	221
Euro VI biodiesel-electric hybrid	180,000	750	5,063	12,548	1,549,960	98
Euro VI biomethane-electric hybrid	180,000	14500	6,208	14,086	1,579,196	109

[1] Relative to a Euro IV diesel vehicle

Examining the biofuel options illustrates the assessment that high-blend biodiesel offers the most cost effective option per tonne of NO_x, PM *and* GHG emissions. The assumption underpinning this is that vehicle manufacturers will design engines able to run on high or pure biodiesel blends within the next five years, without a significant price premium. Some allowance has been made for a separate storage and re-fuelling equipment at the depot, but this is very low-cost on a per vehicle basis and on an annual cost basis.

It should be noted that Treasury has indicated it intends, over time, to reduce the duty differential for biofuels. If this does take place then it would increase the operating costs of using high-blend biofuels.

From the emissions comparison in the previous section (see Table 3.6) we can note that a biomethane bus will have lower regulated and GHG emissions than bioethanol. However, it is interesting to note that in the cost-effectiveness analysis below the situation is reversed. This is due to the greater capital expenditure required for biomethane fuelling compared to bioethanol. Taking into account operating costs may change this order once again, but what is interesting to note is the costs are many times greater than biodiesel. This illustrates that it is necessary to obtain comparably low fuel costs for bioethanol and biomethane operation, or consider a significantly longer payback period, in order to justify the relatively high upfront capital costs when comparing to biodiesel (and petro-diesel).

As noted already, the focus on capital costs only means that hybrid vehicles will perform relatively poorly in this particular analysis. Whole-life cost analysis for TfL has previously indicated that the reduced fuel costs of such vehicles partly off-set the increased vehicle and maintenance costs. This showed diesel electric hybrids as quite cost effective for GHG reductions, and markedly better than bioethanol or biomethane vehicles. In E4Tech's analysis a 10m diesel electric hybrid incurred a 9% increase in total cost per km compared to a standard diesel Euro III bus (66 pence per km vs. 60.7 pence). Bioethanol and biomethane buses were available in 12m length so they were compared to a 12 m Euro III conventional diesel bus with total costs of 72.3 pence per kilometre (ppkm). The bioethanol bus was estimated to have a total cost of 98.2 ppkm (+ 36%) and the biomethane bus to have a total cost of 96.9 ppkm (+ 34%).

The combined analysis suggests that diesel-electric hybrids will fall somewhere between high-blend biodiesel and bioethanol/biomethane vehicles for cost effectiveness of emission reduction.

Finally, we consider the option of combining a hybrid drive-train with a biofuel combustion engine. These offer the potential for extremely low emissions, perhaps the lowest emissions of any technology in advance of hydrogen. Again, bioethanol and biomethane in hybrid configuration do not perform well in this particular method of analysis because of high capital costs which is not offset by any operating savings. However, from previous analysis there seems to be a strong case for suggesting biodiesel-electric hybrids would be the most cost-effective option if the aim is to achieve very low emissions per vehicle (and therefore from total fleet activity).

4 RENEWAL OF PTE FLEETS

4.1 Introduction and overview

The objective of the study has been to determine a range of representative alternative scenarios for the renewal of PTE/SPT area bus fleets using a range of vehicle technologies and fuels. These different scenarios are based on different levels of ambition for a 'greening' of the bus fleet and are related to the policy tools which might be used to achieve them.

To understand the implications of adopting newer technologies and fuels, the study has estimated broad costs and implications for GHG/pollutants of these scenarios.

4.2 Scenarios

4.2.1 Introduction

A range of scenarios for the renewal of the Metropolitan area bus fleets was determined, based on the review of policy drivers, policy tools, current/emerging initiatives and trends in technology/fuels. Inputs to this analysis included the outcomes of the literature review and analysis exercise described above, and data describing the current and future PTE/SPT fleets.

4.2.2 Scenario development

The scenarios have been developed using a three-stage process:

1. A technical assessment was made of the potential options. The literature review and discussion with ***pteg*** members has identified the pros and cons for each technology/fuel type. This has been used to identify the technologies that could feasibly be used to renew the fleets, and give information about the likely costs and impacts of the different options. Using this information a range of potential options for 'greening the fleet' was developed.

2. Consultation with ***pteg*** and the ***pteg*** Sustainability Group was carried out to identify the approach for designing the scenarios, and decide the level of ambition that would be taken forward for the detailed analysis. A final selection of scenarios was made.

3. An analytical tool was developed to enable comparison between different options and determine the likely levels of emissions improvement over a business as usual outcome. This tool allowed the different options selected in step 2 to be refined based on fleet data for the PTE/SPT areas and an assessment made of the benefits and costs for the seven PTE/SPT areas both separately and on a combined basis.

The analytical tool was developed by modifying TTR's existing JET model to fit the purposes of this study. The JET model has previously been used as a basis for similar assessment of low emissions strategies, for example in the Bristol Low Emissions Strategy and Merseyside Bus Emissions Strategy projects.

Data to describe the current and future PTE/SPT fleet has been gathered for input to the tool. The PTE data for the bus emissions study would ideally include:

- the current profile of all the bus fleets in the PTE/SPT areas, by age or Euro standard, including information about any retrofit equipment;
- the mileage driven within the PTE/SPT areas; and
- a projection for how these fleets are expected to change in the future.

Where this data has not been available the study consultants have produced estimates based on PTE data and national / public data sets.

The future scenarios were constructed using the BAU (business as usual) as a baseline. Data for the 2007/2008 fleet in each PTE area was gathered and the fleets for each scenario estimated, based on a fleet replacement rate for determining the number of new vehicles in each future year. A key assumption when predicting the future fleets is that when new vehicles are introduced they displace the same number of the oldest vehicles. In the short term and for a local area viewpoint this is a simplistic approach, but is logical at the global level and over the long term.

The study has also made use of information about the proportion of the mileage or proportion of services operated by each sub-set of vehicles (because older buses are likely to be used less). The modelled scenarios are summarised in the table below.

Table 4.1: Modelled fleet scenarios

Year	Scenario name and year	Ambition	Fleet replacement rate (%)	Scenario description
2007/08	BAU 2007/8	-	-	Current fleet
2012/13	BAUc 2012/13	Current BAU	5.5	Conventional diesel; no policy reform
2012/13	BAUo 2012/13	Optimistic BAU	7.5	Conventional diesel; no policy reform
2012/13	1.1 2012/13	Low	7.5	Policy promotes diesel economy
2012/13	2.1 2012/13	Medium	10	Policy promotes diesel economy
2012/13	2.2 2012/13	Medium	10	Policy promotes diesel economy and renewable fuels
2012/13	3.1 2012/13	High	16.5	Policy promotes diesel fuel economy
2012/13	3.2 2012/13	High	16.5	Policy promotes fuel economy and renewable fuels
2015/16	BAUc 2015/16	Current BAU	5.5	Conventional diesel; no policy reform
2015/16	BAUo 2015/16	Optimistic BAU	7.5	Conventional diesel; no policy reform
2015/16	3.3 2015/16	High	16.5	Conventional diesel, high replacement
2015/16	1.2 2015/16	Low	7.5	Diesel economy paramount
2015/16	2.3 2015/16	Medium	10	Fuel economy and renewable fuels supported
2015/16	3.4 2015/16	High	16.5	Fuel economy and renewable fuels supported

Scenario Descriptions

- Current 'Business as Usual' (BAUc). This is based on conventional diesel technology. Without policy reform the incentive of fuel saving makes higher-cost hybrids unattractive. The current fleet replacement rate in the UK is 5.5% and this was used as a basis for the BAUc scenario.

- Optimistic 'Business as Usual' (BAUo). This is based on conventional diesel technology. Without policy reform the incentive of fuel saving makes higher-cost hybrids unattractive. A replacement rate of 7.5%, modelled around the replacement rate needed to achieve DDA compliance, represents a potential best case and this was used to derive an alternative 'optimistic' business as usual scenario.

- Low ambition scenarios. The fleet includes some hybrids, but only a few as they are predicted to be only recently commercially attractive in PTE areas. Therefore, the fleet is mostly conventional diesel as there is low turnover bringing in newer vehicles. Policy reform does not give much scope or appetite for introducing renewable fuels.

- Medium ambition scenarios (10% replacement p.a.):
    - Scenario 2.1 (2012/13). Policy reform has incentivised diesel fuel economy. PTEs are ambitious, so diesel-electric hybrids are taken up at a high proportion of the fleet replacement rate
    - Scenario 2.2 (2012/13). This is a second variation on scenario 2.1, where policy changes rapidly incentivise renewable fuels, in addition to fuel efficiency. However, there are still commercial availability constraints in 2012. The few biofuel vehicles are assumed to be shared between biomethane, biodiesel and bioethanol.
    - Scenario 2.3 (2015/6). Policy and economics have a stronger influence by 2015 for GHG reduction from transport. Technology development suggests biofuel hybrids are feasible and becoming commercially attractive. The mono-fuel biofuel vehicles are shared equally between biodiesel, bioethanol and biomethane, rather than picking one winner. Biodiesel medium-blend (B20) is considered to be standard in this scenario for all remaining conventional diesel vehicles.

- High ambition scenarios – the same factors apply as for the medium ambition scenarios, but the higher fleet turnover of 16.5% p.a. means a greater number of vehicles are replaced and modelled for each of the study years. In addition, one high ambition scenario is based on conventional diesel technology but with a high ambition replacement rate of 16.5%.

Three study years were chosen, covering the current situation (2007/8) and the future years of 2012/13 and 2015/16. The future years are the business as usual (BAU) outcomes expected if fleet renewal rates continue on broadly current levels. A more optimistic 2012/13 BAU scenario was generated based on a slightly higher than current fleet replacement rate (of 7.5% p.a. vs current 5.5%). The business as usual (BAU) estimates provide the baseline years against which 'do-something' scenarios were measured. Five further 2012/13 scenarios were generated and four

2015/16 scenarios, as per the levels of ambition and fleet replacement policy described in the table above. A summary of these scenarios is shown in Table 4.2 below.

Table 4.2: Summary of fleet renewal scenarios

		Level of ambition and Fleet renewal policy			
Year		**BAU**	**1. Low**	**2. Medium**	**3. High**
2012/13	**Fuel / Technology mix**	a) Conventional diesel	a) Fuel efficiency	a) Fuel efficiency	a) Fuel efficiency
				b) Fuel efficiency & biofuels	b) Fuel efficiency & biofuels
2015/16	**Fuel/ technology mix**	b) Conventional diesel	b) Fuel efficiency	c) Fuel efficiency & biofuels	c) Fuel efficiency & biofuels
					d) Conventional diesel
Fleet replacement rate (p.a.)		a) 5.5% current b) 7.5% optimistic	5.5%	10%	16.5%

In an effort to make the scenarios more realistic the numbers of vehicles that could be 'replaced' with more fuel efficient or renewable (bio) fuelled vehicles was carefully estimated based on the actual composition of various PTE bus fleets, and the potential fleet replacement rates for the future. The availability of future technologies at a robustness and cost likely to stimulate commercial take up was built into the estimates, so that diesel-electric hybrids do not start entering the future scenario fleets until after 2012, and high-blend biofuel vehicles a year or two later than that. This means that the 2012/13 scenarios include limited numbers of non-conventional vehicles, which limits their impacts, but forms a more realistic forecast.

Details of the calculated fleet compositions for each PTE and each scenario (i.e. number of vehicles), and the assumptions used in estimating fleet data and forecasting scenarios forwards to future years, are given in Annex A.

4.3 Scenario impacts

For each of the scenarios developed, a broad assessment of the costs and environmental impacts has been carried out. The JET model is designed to calculate the environmental impacts for each scenario, in terms of both emissions of greenhouse gases (tail-pipe and LCA) and of toxic pollutants.

Given PTE-supplied data about the current fleet and NAEI projections about how fleet turnover is likely to progress in the future, a 'business as usual' baseline fleet profile has been developed for each of two representative future years (2012/13 and

2015/16). The environmental impacts of each scenario have been calculated relative to this ‘business as usual’ future baseline. This has been done for each PTE/SPT area, as well as the total impacts across all of them.

In summary, the approach has been to use actual sample fleet data from the PTE/SPT areas as inputs to a spreadsheet tool, to assess for each scenario the environmental impacts relative to a business as usual future baseline. This has been used in tandem with data gathered during the background stages to estimate broad capital costs of each scenario.

4.3.1 Toxic pollutant emissions

The figures below show the total NO_x and PM tailpipe emissions for each scenario. Emission estimates have been compiled separately for each PTE area, but presented together in these figures to show the impact of the scenarios across the total PTE/SPT area bus fleets.

To aid understanding, the percentage decrease between the current 2007/08 situation (5.5% replacement rate) and the 2012/13 baseline business as usual (BAU) scenario is annotated in orange. This shows a 29% reduction for NO_x and a 49% reduction for PM. These reductions are due to anticipated improvements in average bus fleet emissions as a result of progression through the Euro standards. The green annotation then shows the percentage decrease in emissions for each of the 2012/13 scenarios compared to the current BAU 2012/13 scenario. The blue annotation highlights the percentage decrease in emissions for each of the 2015/16 scenarios compared to the BAU 2015/16 scenario.

The figures above show that for toxic pollutants the most important tool to reduce emissions is to accelerate the vehicle replacement rates so as to remove the oldest, more polluting vehicles from the fleet. This can be seen clearly by comparing the two BAU scenarios for each year. For 2012/13, the optimistic BAU scenario represents a 9% reduction in NO_x emissions and a 15% reduction in PM emissions over and above the current BAU scenario. For 2015/16 the optimistic BAU scenario represents a 17% reduction in NO_x emissions and a 21% reduction in PM emissions over and above the current BAU scenario. The same message can also be seen clearly from the scenario 3.3, when comparing with scenario 3.4 (which has the same replacement rate): the latest conventional diesel vehicles achieve nearly as much as introducing numbers of diesel-electric and biofuel vehicles, for regulated pollutants.

The analysis suggests that new technologies (diesel-electric hybrid, and renewable fuels) can reduce toxic emissions further, but they need to be deployed in significant numbers in order to generate large emissions savings. This is because conventional diesel vehicles will become increasingly ‘clean’ and harder to exceed on regulated pollutant emissions.

Figure 4.1: NO_x emissions by scenario

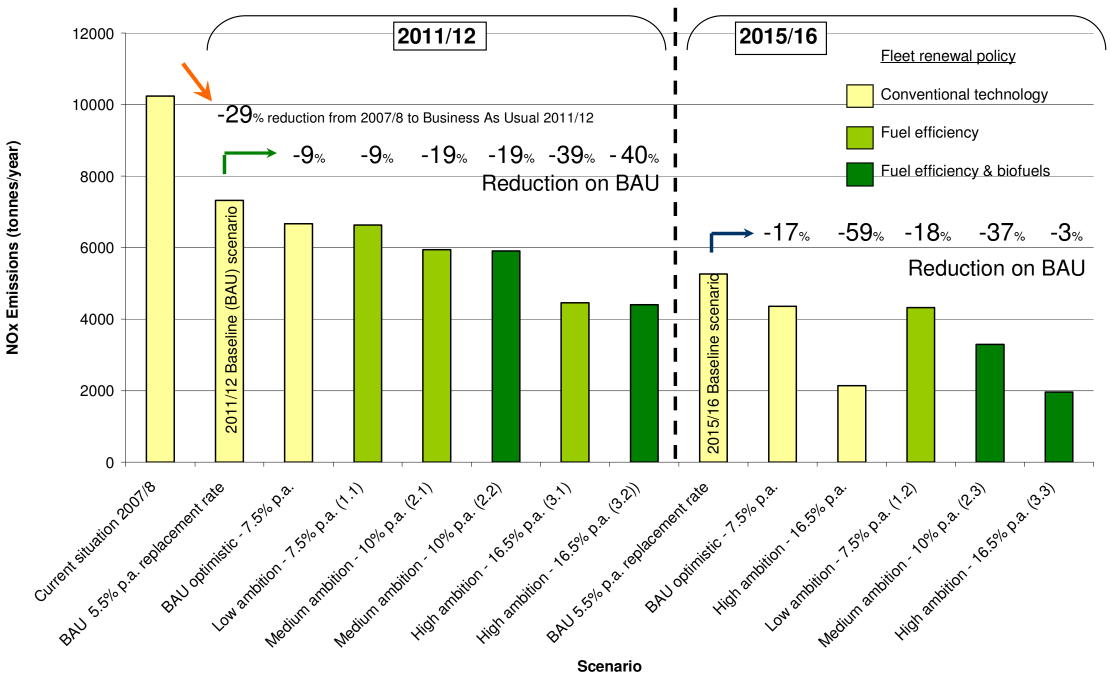
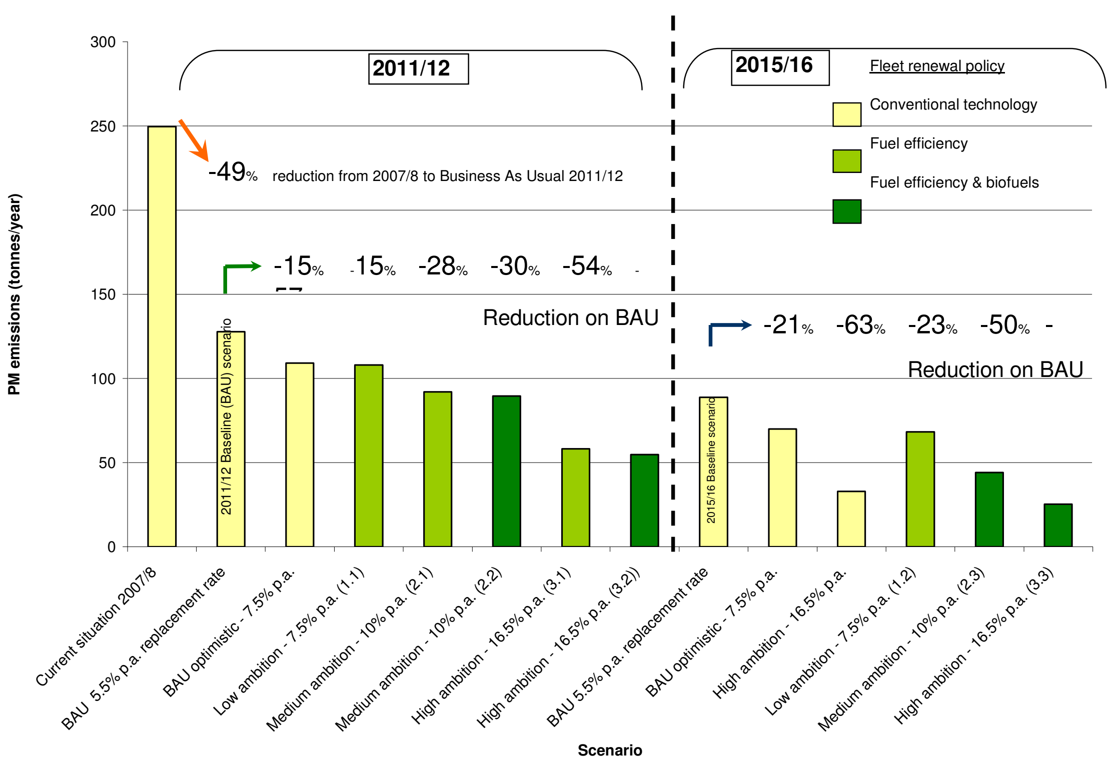


Figure 4.2: PM emissions by scenario

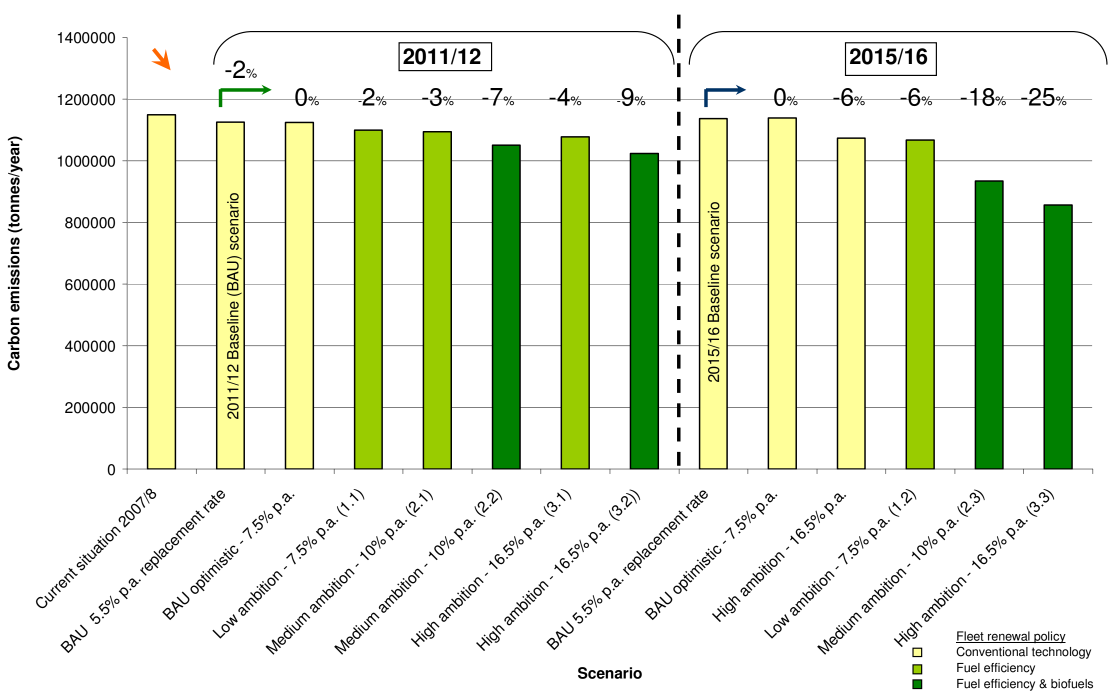


4.3.2 Greenhouse Gas emissions

The figure below shows the total life-cycle carbon emissions for each scenario. The percentage reduction from the BAU 2007/08 scenario and the predicted BAUc 2012/13 scenario is indicated by orange notation (2%). The percentage change in emissions for each of the 2012/13 scenarios compared to the current BAU 2012/13 scenario is annotated in green. The annotation in blue highlights the percentage change in emissions for each of the 2015/16 scenarios compared to the current BAU 2015/16 scenario.

The data used is based on the life-cycle emissions of producing, distributing and using a particular fuel in a particular technology and not the full-life cycle emissions of the vehicle production and ultimate disposal. This approach is considered appropriate, given the vast majority of life-cycle impacts of a vehicle are during the 'in use' phase, and primarily based on the amount of fuel used. The results are based on slightly conservative estimates of potential benefits, as we have used the 'worst-case' end of the range of estimates available from the Renewable Fuels Agency methodology.

Figure 4.3: Life-cycle carbon emissions by scenario



The analysis shows that, in contrast to the toxic emissions, fleet renewal of conventional diesel vehicles does not have any great impact on life-cycle carbon emissions. This can be seen by comparing scenarios BAU 5.5% replacement rate with BAU optimistic, which results in no change for GHG emissions.

Some reductions are shown in scenarios where diesel-electric hybrids are present, for example scenario 2.1 in 2012/13 (4% reduction), and a slightly greater benefit when the policy environment encourages some biofuel vehicles too, shown in scenarios 2.2 in 2012/13 (7% reduction). For 2012/13, scenario 2.2 is of particular interest, as a 10% fleet replacement rate to enable the introduction of a relatively small number of diesel-electric hybrids and biofuel vehicles is predicted to reduce GHG emissions by 7%.
The analysis shows that much greater reductions could be achieved further into the future (2015/16). This is because wide-spread commercial take-up of diesel-electric hybrids and medium to high-blend biofuels is not anticipated in PTE/SPT areas before 2012, and because even with high replacement rates it requires time for such impacts to work through the fleet profile.

It should be noted that for the 2015/16 assessment year the modelling assumes B20 becomes standard for up to half of the conventional diesel vehicles. The impact of this is illustrated in scenario 3.3, with a 6% reduction in GHG from use of this fuel alone. The use of biodiesel blends (B5, B10 or B20) clearly remains an option to reduce the CO_2 impact of using conventional diesel engines in the future.

However, to produce significant GHG reductions, hybrid and biofuel vehicles are required in significant numbers. Scenario 3.4 produces the maximum reduction in carbon emissions of 25% compared to the BAU scenarios. Due to the very high turnover rate going forward from 2008 (at 16.5% p.a.) and the assumptions around take-up of hybrids and biofuel vehicles, the fleet profile for scenario 3.4 includes only 37% conventional vehicles. Around half of these are modelled as running on B20. The majority of the fleet in this scenario comprises diesel-electric hybrids, biofuel vehicles and a small number of biofuel-electric hybrids.

For significant GHG savings, scenario 3.2 is potentially the most practicable approach, as it assumes a 'medium' replacement rate of 10% p.a. but still returns a GHG reduction over BAU of 18%.

4.3.3 Cost of emission reductions scenarios

It is important to understand the levels of investment that would be required to achieve a given emission reduction scenario. The study has therefore built on the cost-assessment of various technology/fuel options presented in Chapter 3 to estimate a total capital cost for each scenario in each PTE/SPT area.

Table 4.2 shows the broad cost estimates for each of the modelled scenarios, shown on an individual PTE basis. The estimates focus on capital costs only, taking account of the vehicle purchase price and the costs of the refuelling infrastructure. The number of new vehicles purchased under each scenario is included, noting that scenarios 3.3 and 3.4 involve full replacement of the current 2008 fleet by the end of 2015.

It is clear that increasing the fleet replacement rates from the current 5.5% to the scenarios representing 7.5% (BAUo), 10% (2.1, to 2.3) and 16.5% (3.1 to 3.4) would have significant cost implications. This runs into many millions of pounds. This is shown in table 4.3, both as a total investment cost and as the additional cost over the current business as usual (BAUc). The number of new vehicles required to support these replacement rates in each PTE/SPT area is shown.

In most of the scenarios the majority of new vehicles are conventional diesel, with varying numbers of hybrid and biofuel vehicles, depending on the scenario. This approach fits with the earlier analysis (of emissions savings) and cost-effectiveness which showed that for regulated pollutants the most cost-effective new vehicle investment was the latest conventional diesel. It is also realistic, given it is not practicable to change 100% of a fleet to a different technology/fuel in one year, but rather introduced at a rate that the replacement rate allows. It is only for scenario 3.4 that conventional diesel vehicles are in the minority (37%) and then around half were modelled as running on B20. This reflects a strong ambition to introduce hybrid and biofuel technology with a high replacement rate that gives scope to do so. However, even in this scenario the cost per vehicle rises by only a small percentage, to around £125,00 - £128,000 (in comparison with £120,000 for a conventional diesel bus).

The analysis has also examined the emission benefits of each scenario over the BAUc option, and combined these with the costs (over the cost of the BAUc option). In line with the other assessment of scenarios, this assessment is simplified to account only for one year of emission benefits. Costs are averaged to an annual capital cost, before combining with the emission reduction forecast for year 1 of the option. Emission benefits will continue in future years, but this will be at a reducing rate compared to the BAU, as the fleet will become cleaner over time based on the take-up of conventional technology. Therefore, the assessment of cost per tonne of emissions reduced should be used as an indicator of relative cost-effectiveness of one scenario against another.

Overall, in terms of cost per additional tonne abated (over the BAU) we see a range of costs for NO_x, PM and CO_2e across the PTEs. However, the pattern of scenario costs is similar from PTE to PTE. There will be some variation based on the starting point for the analysis: the current profile of a PTE fleet. A larger variable factor, and the reason for absolute figures varying between the PTE, is due to the input data on total vehicle km travelled (by number of vehicles). For example, input data for GMPTE total bus km travelled were lower than for other PTE areas, and this is reflected in a higher cost per tonne of emissions abated. Essentially, the same number of vehicles are travelling fewer km (compared to the next PTE) and hence any investment in new vehicles will lead to higher costs for the same amount of emission reduction.

Examining the relative costs for regulated pollutants, for one example PTE such as Merseytravel, we see that for NO_x the cost per tonne of additional pollutant abated is rather similar across the scenarios except in one case (scenario 1.2). However, putting aside this scenario, what is important to note is that the BAU optimistic scenario and scenarios 3.3 (based on conventional diesel technology) perform better than the scenarios with hybrids and biofuels, but only by about 10% on a cost per tonne abated basis.

Returning now to scenario 1.2 for study year 2015/16 the table shows a cost per tonne abated double that of the other scenarios, and a similar differential is seen across all of the PTEs. Scenario 1.2 also performs worst for PM abatement, when the cost of investment is taken into account. Scenario 1.2 is defined as having 25% of additional new vehicles being diesel-electric hybrid by the end of 2015, and it is likely that the additional emission savings are not sufficiently offset to balance the extra capital costs differential anticipated to still exist between this and conventional diesel technology. Narrowing the future cost differential between conventional and hybrid technologies and/or taking into account reduced fuel costs would reduce the cost-effectiveness differential illustrated by this analysis.

Examining the relative costs for GHG reductions (over the BAU emissions), a much greater variation in costs can be seen. Again, the absence of cost-savings in the operation phase for diesel-electric hybrids should be borne in mind. This will particularly affect scenario 3.1, where there is a high replacement rate and encouragement of diesel-electric hybrids rather than biofuel vehicles.

We can see that the least cost-effective way in which to reduce GHG is to channel investment into new vehicles of conventional diesel technology. BAUo in both study years show high (or negative) costs per tonne of CO_2e abated over the BAUc scenario emissions/costs. All scenarios with hybrid or biofuel vehicles show comparatively much lower costs per tonne of additional GHG abated.

To emphasise this point, the scenario 3.3 is useful to compare with scenario 3.4. The replacement rate is the same, which means that for scenario 3.4 there is a reasonably high proportion of hybrid and biofuel vehicles (with associated investment costs). In contrast, scenario 3.3 assumes investment only in conventional diesel technology, although it is assumed that a high proportion of these will run on B20 (around 80% of the new vehicles) which comes at no or very low additional cost per vehicle. The cost per tonne of C02e abated from this scenario is generally three to four times higher than one which includes a range of hybrid and biofuel technologies.

The cost-effectiveness analysis normalises the slightly larger total emission reduction, and contribution to air quality, that we see for scenario 3.4 compared to scenario 3.3. Returning to regulated pollutants, however, the cost comparison shows a premium of about 4% per tonne of emissions abated for scenario 3.4 over scenario 3.3. From this analysis there appears to be only small trade-off in cost-effectiveness for regulated pollutants by using hybrid and biofuel vehicles in order to achieve much better cost-effectiveness for GHG abatement.

This analysis supplements the earlier conclusion, from the analysis of total GHG emissions and emissions per technology, that if investment is to be made in new vehicles then it is most effective, in absolute emission and cost terms, to include some high-blend biofuel and / or hybrid vehicle technology rather than rely solely on low-blend biofuel vehicles.

Table 4.3: Emission impact and cost of scenarios by PTE area

PTE	Year	Scenario	Emissions (t/yr)			No. new veh.	Total cost (£)	Add. Cost over BAUc	Annual average cost over BAUc	Cost per additional tonne reduced p.a. (£/t)		
			NO_x	PM	Life Cycle CO_2e					NO_x	PM	LC CO_2e
GMPTE	2012/13	BAUc	1061	16	163404	945	113,367,600		0			
		BAUo	964	14	163281	1312	157,455,000	44,087,400	3,673,950	38227	1988668	29913
		1.1	960	14	159571	1312	168,476,850	55,109,250	4,592,438	45551	2286396	1198
		2.1	858	11	158785	1750	224,635,800	111,268,200	9,272,350	45879	2205078	2008
		2.2	853	11	152510	1750	222,160,841	108,793,241	9,066,103	43693	1989934	832
		3.1	646	8	156443	2887	370,649,070	257,281,470	21,440,123	51689	2691196	3080
		3.2	638	7	148576	2887	366,565,387	253,197,787	21,099,816	49924	2494317	1423
	2015/16	BAUc	760	11	165029	1522	182,647,800					
		BAUo	630	9	165351	2099	251,928,000	69,280,200	5,773,350	44275	2328848	-17910
		3.3	310	5	155622	3499	419,880,000	237,232,200	19,769,350	43874	3105319	2102
		1.2	623	8	154345	2099	286,568,100	173,200,500	14,433,375	105482	5195283	1351
		2.3	477	6	135612	2799	348,145,252	165,497,452	13,791,454	48695	2576420	469
		3.4	283	4	124119	3499	440,078,065	257,430,265	21,452,522	44980	2876737	524
Merseytravel	2012/13	BAUc	740	13	113141	339	40,629,600					
		BAUo	679	10	112901	470	56,430,000	15,800,400	1,316,700	21618	547602	5477
		1.1	676	10	110303	470	60,380,100	19,750,500	1,645,875	25634	653809	580
		2.1	607	9	109709	627	80,506,800	39,877,200	3,323,100	24934	867873	968
		2.2	603	9	105356	627	79,619,804	38,990,204	3,249,184	23690	797115	417
		3.1	455	6	108117	1035	132,836,220	92,206,620	7,683,885	26904	1092754	1529
		3.2	449	5	102599	1035	131,372,677	90,743,077	7,561,923	25966	1024685	717
	2015/16	BAUc	536	9	113963	545	65,458,800		0			
		BAUo	444	7	114254	752	90,288,000	24,829,200	2,069,100	22429	1111219	-7116

		3.3	215	3	107920	1254	150,480,000	85,021,200	7,085,100	22036	1356480	1172
		1.2	440	6	106555	752	102,702,600	62,073,000	5,172,750	53541	2499105	698
		2.3	334	4	93484	1003	124,771,119	59,312,319	4,942,693	24451	1146404	241
		3.4	197	3	86233	1254	157,718,746	92,259,946	7,688,329	22651	1286317	277
Metro	2012/13	BAUc	875	16	138000	415	49,798,800	-				
		BAUo	803	13	137765	576	69,165,000	19,366,200	1,613,850	22503	521059	6885
		1.1	799	13	134648	576	74,006,550	24,207,750	2,017,313	26657	624035	602
		2.1	715	11	134017	769	98,675,400	48,876,600	4,073,050	25496	778387	1023
		2.2	711	11	128760	769	97,588,229	47,789,429	3,982,452	24222	720265	431
		3.1	537	7	132177	1268	162,814,410	113,015,610	9,417,968	27860	993007	1617
		3.2	531	7	125570	1268	161,020,577	111,221,777	9,268,481	26901	936561	746
	2015/16	BAUc	634	11	139274	669	80,231,400					
		BAUo	526	9	139596	922	110,664,000	30,432,600	2,536,050	23553	1112169	-7876
		3.3	262	4	131702	1537	184,440,000	104,208,600	8,684,050	23354	1275105	1147
		1.2	521	8	130382	922	125,880,300	76,081,500	6,340,125	56158	2506928	713
		2.3	398	5	114746	1230	152,929,195	72,697,795	6,058,150	25646	1093911	247
		3.4	240	3	105034	1537	193,312,371	113,080,971	9,423,414	23909	1218541	275
Nexus	2012/13	BAUc	829	14	128524	386	46,364,400					
		BAUo	755	13	128522	537	64,395,000	18,030,600	1,502,550	20096	835474	861337
		1.1	751	13	125684	537	68,902,650	22,538,250	1,878,188	23965	977329	661
		2.1	674	11	125081	716	91,870,200	45,505,800	3,792,150	24340	1007017	1101
		2.2	669	10	120220	716	90,858,006	44,493,606	3,707,801	23155	917970	446
		3.1	502	7	123100	1181	151,585,830	105,221,430	8,768,453	26786	1114688	1617
		3.2	496	6	116942	1181	149,915,710	103,551,310	8,629,276	25880	1045904	745
	2015/16	BAUc	597	10	129868	622	74,698,200					
		BAUo	497	8	130143	859	103,032,000	28,333,800	2,361,150	23540	1111177	-8577
		3.3	244	4	122622	1431	171,720,000	97,021,800	8,085,150	22882	1239917	1116
		1.2	492	8	121668	859	117,198,900	70,834,500	5,902,875	56166	2508098	720
		2.3	372	5	106852	1145	142,382,354	67,684,154	5,640,346	25011	1068564	245
		3.4	223	3	97844	1431	179,980,483	105,282,283	8,773,524	23456	1189155	274
SPT	2012/13	BAUc	1555	28	240119	708	84,920,400	-				
		BAUo	1417	24	239956	983	117,945,000	33,024,600	2,752,050	19826	628853	16909

		1.1	1409	24	234455	983	126,201,150	41,280,750	3,440,063	23506	743411	607
		2.1	1260	20	233374	1311	168,268,200	83,347,800	6,945,650	23538	848723	1030
		2.2	1252	20	224089	1311	166,414,279	81,493,879	6,791,157	22378	779520	424
		3.1	949	13	230311	2162	277,642,530	192,722,130	16,060,178	26504	1027535	1637
		3.2	938	12	218729	2162	274,583,561	189,663,161	15,805,263	25583	965973	739
	2015/16	BAUc	1116	19	242633	1140	136,816,200	-				
		BAUo	923	15	243186	1573	188,712,000	51,895,800	4,324,650	22443	1048615	-7819
		3.3	456	7	229300	2621	314,520,000	177,703,800	14,808,650	22454	1190498	1111
		1.2	914	15	226917	1573	214,659,900	129,739,500	10,811,625	53467	2365545	688
		2.3	702	10	199694	2097	260,785,569	123,969,369	10,330,781	24930	1055333	241
		3.4	417	5	182863	2621	329,649,788	192,833,588	16,069,466	23003	1143796	269
SYPTE	2012/13	BAUc	796	14	123909	256	30,715,200	-				
		BAUo	725	12	123906	356	42,660,000	11,944,800	995,400	13945	579021	385351
		1.1	721	12	121160	356	45,646,200	14,931,000	1,244,250	16619	676807	453
		2.1	647	10	120613	474	60,861,600	30,146,400	2,512,200	16832	696591	762
		2.2	643	10	115929	474	60,191,048	29,475,848	2,456,321	16018	634974	308
		3.1	482	6	118697	782	100,421,640	69,706,440	5,808,870	18506	770969	1115
		3.2	476	6	112728	782	99,315,229	68,600,029	5,716,669	17845	721853	511
	2015/16	BAUc	574	10	125200	412	49,485,600	-				
		BAUo	478	8	125466	569	68,256,000	18,770,400	1,564,200	16300	770067	-5888
		3.3	235	4	118245	948	113,760,000	64,274,400	5,356,200	15808	863661	770
		1.2	474	8	117342	569	77,641,200	46,926,000	3,910,500	38881	1737338	498
		2.3	357	5	103005	758	94,324,578	44,838,978	3,736,582	17171	735032	168
		3.4	215	3	94325	948	119,232,354	69,746,754	5,812,229	16196	826667	188
Centro	2012/13	BAUc	1461	26	218478	540	64,800,000	0				
		BAUo	1323	23	218441	750	90,000,000	25,200,000	2,100,000	15284	622849	56098
		1.1	1317	23	213483	750	96,300,000	31,500,000	2,625,000	18267	731814	526
		2.1	1178	19	212368	1000	128,400,000	63,600,000	5,300,000	18736	763142	867
		2.2	1169	19	203960	1000	126,985,333	62,185,333	5,182,111	17782	696149	357
		3.1	884	12	209297	1650	211,860,000	147,060,000	12,255,000	21251	871884	1335
		3.2	873	12	198706	1650	209,525,800	144,725,800	12,060,483	20538	819354	610
	2015/16	BAUc	1040	19	220873	870	104,400,000	0	0			

		BAUo	860	15	221289	1200	144,000,000	39,600,000	3,300,000	18305	837543	-7925
		3.3	414	6	208145	2000	240,000,000	135,600,000	11,300,000	18035	909700	888
		1.2	859	15	210408	1200	163,800,000	99,000,000	8,250,000	45421	1993626	788
		2.3	651	9	181174	1600	198,997,000	94,597,000	7,883,083	20277	847408	199
		3.4	379	5	166011	2000	251,545,050	147,145,050	12,262,088	18544	883689	224

4.4 Potential impacts of reform of BSOG

As noted in Chapter 2, BSOG provides an important form of subsidy support to bus services in PTE areas. However, in its current form it effectively negates the preferential fuel duty differential for alternative fuels and does not reward fuel economy.

The 2008 consultation on BSOG outlined a number of options for reform which are particularly relevant to the scenarios examined in this study:

- Proposal 1: BSOG rate capped at a minimum fuel efficiency level.
- Proposal 2: New arrangements for Low Carbon Buses (LCB), for example:
    - Distance-based payment – equivalent to average BSOG payment calculated in the normal way (i.e. for conventional diesel vehicles);
    - Increase the rate of BSOG payable to LCB to 100 per cent of fuel duty.
- Proposal 4 (longer-term proposal): Tiered Rates of BSOG (based on emissions or other quality criteria, e.g. smartcard readers).
- Proposal 6: Safe and Fuel-Efficient Driving demonstration.

The proposals as they stand could support some of the technology/fuels considered by this study, but to varying degrees. In some cases there could be negative consequences.

The proposal for capping BSOG at a minimum fuel efficiency would bring problems for conventional diesel bus operation: in congested areas, fuel efficiency will suffer, and if there was a slight fuel penalty for some newer, cleaner, buses compared to the very oldest in the fleet, the impact of BSOG would be to magnify this difference (and overrule air quality considerations). It is difficult to see how a simple yet fair approach can be designed that can accommodate these factors.

The proposal for capping BSOG at a minimum fuel efficiency would benefit hybrid-electric vehicles, but would need special arrangements for fuels such as bioethanol which have a lower energy density and therefore vehicles using this require a greater volume of fuel per distance travelled.

Proposal 2 suggests some ideas specifically to support low-carbon buses. The consultation asks for assistance in defining a low-carbon bus (to provide a threshold for rewarding under any new arrangements). It would be sensible to use a graduated approach, so that biofuel vehicles (and different sub-types of biofuel) are rewarded proportionately in line with their contribution to GHG savings, and improvements to be made over time.

Proposal 2 suggests that one option could be distance-based payment. This might be a method in which to take a technology-neutral stance across vehicles and fuels, which could be beneficial to some of the technology/fuels included in the study scenarios. The detail of this method was not sufficiently worked out in the consultation to examine the full impact. If a flat rate of BSOG was paid, based on amount of energy consumed, this could make fuels such as gas and bioethanol much cheaper to use then they currently are (if the payment exceeded the current duty element). This would be beneficial to those fuels which have clear environmental benefits, but require new investment in distribution and storage infrastructure.

Additional support for low carbon fuels and technologies would be of benefit to a number of the technology/fuel options considered in the study. It will be difficult to gain acceptance from PTE and bus operators, however, if this is not new money. If the majority of the bus fleet (diesel) was to lose BSOG this could have an overall negative impact on transport provision.

Proposal 4 is for tiered rates of BSOG based on a number of factors such as quality of vehicle and equipment for smart card transactions. In theory this is attractive, however it will be important to ensure that environmental performance criteria do not get lost among the competing demands for a definition of enhanced quality bus.

Proposal 6 for a SAFED-type scheme is to be welcomed. Training and awareness-raising among the bus driver workforce of fuel-efficiency would contribute positively to all the scenarios assessed in this study. Specific driving techniques are of benefit to the operation of hybrid-electric buses.

Following the close of consultation, it was announced in the November 2008 Pre-Budget Report that reform of BSOG would take place to incentivise low-carbon buses. Details of how this will be done and what vehicles/fuels will quality are to follow.

4.5 Practicability analysis

It is important to consider whether the scenarios modelled by this study could be realised and by what methods. One aim of the scenarios is to provide a range of options, from low to high ambition. However, it is important to understand whether these are realistic, and under what conditions.

Experience in some PTE areas has shown that raising vehicle standards for tendered services could lead to higher contract prices and fewer bidders. This could in turn result in a reduction in the size of the tendered service network – which brings with it significant social inclusion implications. Raising standards for tendered services should be done on an incremental basis, avoiding too great a step-change in technology or fuel, if excess operator charges are to be avoided. Experience from Merseytravel has shown that low-floor vehicles can be incentivised at a faster rate than normal market acceptance, and Oxfordshire's premium payment for tendered services has led to newer than average vehicles. Ideally, increases in standards required for a supported service would be done hand in hand with additional funding to support those improvements.

As the majority of the bus fleets in PTE areas (over 80%) are run as commercial services, a key issue is using mechanisms that ensure bus operators can obtain a reasonable return on any increased investment in vehicles. Although the bus divisions can still be regarded as cash generators for the large transport groups, the most recent figures[43] suggest profit levels are falling.

[43] TAS (2007) - Bus Industry Monitor.

The various scenarios modelled in this study are made up of two components: fleet replacement rate and a policy for certain technology/fuel characteristics (supporting diesel fuel efficiency and use of biofuel, or just diesel efficiency).

Dealing with the fleet replacement rates initially, figures supplied by the PTE suggest that an increase in replacement rates from 5.5% to 7.5% p.a. may be required to reach DDA compliance. This relatively small, optimistic, business as usual prediction is sufficient to make some significant impacts on the level of pollutant emissions of PM and NO_x. It might be achieved via existing bus operator investments, in order to reach DDA compliance, or in PTE areas through active programmes of BQPA.

A fleet replacement of 10% is quite a significant increase, perhaps a doubling of fleet replacement from current levels. Given enhanced regulations available in time through the Local Transport Act, this rate of replacement might be achievable in specific areas via SQP. Bus operators participating in such an ambitious programme will want to protect their investment by ensuring only they have access to the stops improved by the PTE under the contract or scheme. The question is whether the incumbent operators present in most PTE areas feel there is sufficient competition at present that would justify their investment in a SQP arrangement of this nature.

A fleet replacement rate of 16.5% is very high, and therefore is presented as an extreme scenario. The broad costs of such a programme are very significant indeed. It would involve replacing the current fleet with new vehicles within about 7 years, and hence reducing the average vehicle age to just 3.5 years. However, it may be feasible to consider using a QC programme should LTB powers be sufficient, and supported by a sound business case. A QC approach on a limited area or service basis may generate the changes necessary to achieve one of the medium-ambition scenarios proposed.

Scenarios that anticipate a policy or economic environment that supports diesel fuel efficiency have been modelled for each of the fleet replacement rates discussed above. The economic case for diesel-electric hybrids is strengthened significantly even with any increase in diesel prices. The TfL-commissioned report on diesel-electric, bioethanol and biomethane buses included an estimate that diesel-electric hybrid buses were only slightly more expensive to run (over a 10-year lifetime) than conventional diesel buses once fuel savings were taken into account. The analysis conducted then, in 2006, was based on a bunkered diesel fuel cost to operators of 80 ppl, corresponding to a net price to the operator of 42 ppl, taking into account the effect of BSOG. Under the study baseline assumptions, it was considered to be cost-effective to operate diesel-electric hybrids if the average price of diesel to operators over the 10-year life was to be 55 ppl, which has been passed for the first time during 2008 (with bunkered prices reaching over 110ppl inc duty). The key question looking forward is what will be the average price of diesel over the life-time of the bus.

Scenarios that anticipate a policy or economic environment that supports biofuel vehicles have also been modelled for each of the fleet replacement rates. These scenarios have included a proportion of biofuel vehicles, together with diesel-electric hybrids. The scenarios have included an even division between the three most common options of bioethanol, biodiesel and biomethane. This enables the potential benefits of biofuel vehicles to be assessed within the scenarios without being locked into picking one winner. In addition, there is scope for advanced and/or second generation biofuel to replace those available for vehicles at this point. The GHG emission benefits of using sustainable biofuels can be noted from the modelling estimates.

This subject area is changing rapidly, so it is difficult to predict with any certainty the exact outcomes and policy directions. In the UK the key will be an effective reform to BSOG and a favourable fuel duty differential on biofuel for buses beyond 2009/10 in order to overcome the price disincentive to bus operators.

5 CONCLUSIONS

5.1 Policy environment

EU legislation has regulated vehicle emissions through the "Euro" standards, with limit values becoming tighter over the years. Emissions of the various regulated pollutants have fallen by between 20 and 50% on average since 1995. This has contributed to major public health benefits from cleaner air. A further decrease is expected, bringing levels down to 25-50% of the 2000 level by 2020.[44]

The incentive to develop effective GHG reduction policies was galvanized by the Stern Review, which estimated that while one percent of global gross domestic product (GDP) per annum is required to be invested in order to avoid the worst effects of climate change, failure to do so could risk global GDP being up to twenty percent lower than it otherwise might be. This analysis, and recommendations about the most cost-effective sectors to target, plus environmental taxes to minimise the economic and social disruptions, are having wide-reaching impacts on UK (and International) government policy making.

UK Government is also significantly expanding the scope of its policies in this area. The Climate Change Bill was introduced in Parliament in November 2007, aiming to create a new approach to managing and responding to climate change in the UK. The Low Carbon Transport Innovation Strategy sets out a wide range of measures that the Government is taking to transform the market for lower carbon vehicles. This includes up to £20m of funding to support low carbon vehicle research, development and demonstration projects, and the Low Carbon Vehicle Procurement Programme (with a first phase of £20m) to support vehicle purchase for public organisation fleets. The King Review recently set out recommendations on setting policies to increase the development and take-up of low carbon vehicles, specifically in the car sector.

Government support for biofuel in vehicles (and gaseous road fuels) comes in the form of reduced fuel excise duty, but has tended not to incentivise bus operators towards low-carbon fuels or fuel efficiency up to this point, due to the parallel operation of the BSOG support mechanism.

More recently, the Renewable Transport Fuel Obligation (RTFO) forms one of the Government's main policies for reducing greenhouse gas emissions from road transport, placing a legal obligation on fuel suppliers in the UK to supply a certain percentage of their fuel from renewable sources. This has already stimulated a much stronger biofuel market in the UK, with low-blend biofuel becoming established as the norm. Market development could be at some risk from a Government decision to consider delaying the target date for achieving 5% biofuel by volume of all fuel sold. High blend biofuel take-up is separately at risk from a potential reduction in duty differential after 2009/10.

[44] CAFE - Clean Air For Europe (2005) – Modeling.

The UK Renewable Energy Strategy consultation document (June 2008) emphasises the use of biogas for heat and power generation, and the upgrading to biomethane for use as a transport fuel. There is increasing support for increasing biogas and biomethane production in order to generate renewable energy from waste.

PTE responsibilities and powers to influence commercial bus services in their area have been limited. The Local Transport Act is designed to enhance the existing mechanisms of VPA, SQP and QC to provide more effective methods of improving network, timetable and vehicle quality through the co-ordinating role of the PTE (or Transport Authority in non-Metropolitan areas). DfT has previously extended Traffic Commissioner powers to enable actions to be take on grounds of improving air quality via Traffic Regulation Conditions (TRC). TRC have been taken up in Bath and more recently and extensively in Norwich (as the basis for a Low Emission Zone).

PTEs have been hindered in their efforts to introduce cleaner, low-carbon vehicles, as bus operators understandably resist any increase in costs or risk to their operations (from non-conventional vehicle technology). Effective reform of BSOG will be needed to strengthen the case for investing in fuel-efficient vehicles or renewable fuels, and a favourable duty differential required into the long term.

Overall, there are significant policy steps to encourage low emission and low carbon vehicles in the UK, but at the current time there remain some sector-specific and very important barriers to their introduction for use in both supported and commercially operated bus services in the deregulated environment outside London.

5.2 Technology and fuels

It has been demonstrated how the existing and progressive policy of vehicle Euro standards means that new vehicles are considerably cleaner, for regulated pollutants, than their predecessors. The key pollutants of concern in transport activity are NO_x and PM. These are responsible for significant human health problems, and despite advances in vehicle technology are present at sufficiently high levels from road traffic to be the trigger for the declaration of over 100 Air Quality Management Areas, located in many English and Welsh towns and cities.

Trend comparisons, based on national statistics, indicate that at the aggregate per passenger level bus travel appear to have been more polluting than car travel in the previous 10 years. This is at odds with public perception and marketing messages that bus travel is cleaner. Clearly, adding one passenger that previously drove alone to a bus that is already scheduled is going to reduce their contribution to total emissions, but the analysis shows there is only so far increasing patronage could help if the fleet profile is based on a high average age. Estimates are that bus emissions will fall faster than car emissions in the future, so that on average bus travel will become less polluting for PM emissions compared to cars (on a passenger km basis). However, bus travel may remain more polluting for NO_x emissions. This analysis shows the importance of modernising the bus fleet if the bus is to be promoted as a reduced pollution option compared to the car, and show that simply increasing the passenger loading is not an option to achieve parity with car travel on all pollutants if older buses are kept in the fleet.

Retrofitting vehicles with DPF (for PM) and EGR or SCR (for NO_x) can significantly reduce emissions from older vehicles. However, this single benefit approach is not an option universally favoured (or adopted) by bus operators in the UK. The cost of this option, compared to re-engineering or purchasing new vehicles, means it should be of considerable interest for a PTE-wide strategy to reduce emissions and the comparatively high environmental impact of the early low floor buses.

For new vehicle purchasing decisions, the latest Euro standard conventional diesel buses are very attractive in economic terms and for reducing the environmental impact of PM and NO_x. A number of technology/fuel options are available that can reduce emission levels to lower than current Euro standards and more significantly reduce GHG emissions. Low-blend biofuel up to 5% by volume is becoming standard, but the key to high levels of GHG emission reduction from bus fleets is high-blend and gaseous biofuel, and/or hybrid drive-trains. The advantages and current drawbacks of these options are considered in detail in this report

Two UK bioethanol bus trials are currently underway on supported services, and TfL has committed to purchasing increasingly large numbers of diesel-electric hybrids. The TfL initiative (combined with cost savings against rising diesel oil prices) could lead to the commercial acceptance by some operators of hybrid vehicle technology in the short-medium term. Revisiting earlier analysis for TfL on the economics of diesel-electric hybrids, it would appear that if the historically high average price of diesel experienced throughout 2008 continues there is a case for operating hybrids on fuel savings alone.

The use of diesel-electric hybrids, high-blend bioethanol and biodiesel or gaseous fuels such as biomethane will require an investment in one or more of depot fuelling equipment, training and maintenance regimes and more expensive vehicles. From this study's analysis, the biofuel that appears most cost-effective future biofuel option is biodiesel, because lower investment is required in new fuelling infrastructure and maintenance practices, on the assumption that vehicles will soon be designed to tolerate high-blend fuels.

The comparable cost of biofuel buses against conventional diesel technology is a considerable barrier to overcome and requires a step change to one or more of the following:

- current bus subsidy arrangements;
- capital costs of vehicles and fuelling (to enable any saving in fuel costs to offset the difference much sooner in the vehicle lifetime;
- regulation/management of bus services in England (outside of London).

In the UK a key step for sustained take-up of high-blend biofuel will be an effective reform to BSOG and a favourable fuel duty differential on biofuel for buses in order to overcome the price disincentive to bus operators.

A complementary action for reducing fuel use (and associated emissions) whatever the technology used is for bus fleets to introduce fuel management and safe/efficient driving training and incentive schemes for bus drivers.

If a sufficient number of current policy drivers, support mechanisms and initiatives ensure momentum behind low emission technology/fuel options then a potential pathway to cleaner fleets over the next 10 years could be initially diesel-electric hybrids, followed by high-blend and gaseous biofuels and ultimately biofuel-electric hybrids.

5.3 Fleet improvement scenarios, impact and costs

A range of scenarios for the renewal of the Metropolitan area bus fleets was determined, based on the review of policy drivers, policy tools, current/emerging initiatives and trends in technology/fuels. To understand the implications of adopting newer technologies and fuels, the study has estimated broad costs and implications for GHG/pollutants of these scenarios.

Scenarios have been produced which combine in varying degrees two types of ambition for greening PTE fleets: increased vehicle replacement rates and technology/fuel selection. The choice of technology/fuel options is between varying proportions of current conventional technology, fuel-efficiency (i.e. hybrids) and GHG reductions (hybrid and biofuel vehicles). Estimates were made of the amounts of regulated and GHG emissions for each scenario and of investment costs in each PTE/SPT area.

The intention has been to present scenarios which are realisable and therefore more likely to be realistic predictors of the future. For example, the estimation method takes into account the number of vehicles that could be purchased each year on different fleet replacement rates and the fact that some new vehicles would be of conventional diesel technology. Larger emission reductions could have been projected by 'switching' greater parts of the fleet to alternative technologies, but this was deemed less realistic.

The analysis of absolute emission reductions shows that for toxic pollutants the most important tool to reduce emissions is to accelerate the vehicle replacement rates so as to remove the oldest, more polluting vehicles from the fleet. In addition, the latest conventional diesel vehicles are predicted to achieve nearly as much of a reduction in regulated pollutants as if some of this investment in new vehicles was allocated to diesel-electric and biofuel vehicles. The analysis suggests that new technologies (diesel-electric hybrid, and renewable fuels) can reduce toxic emissions further, but conventional diesel vehicles will become increasingly 'clean' and difficult to beat on regulated pollutant emissions.

The study has also undertaken a similar analysis of scenarios based on the life-cycle CO_2e emissions of producing, distributing and using a particular fuel in a particular technology. The analysis emphasises that, in contrast to the toxic emissions, fleet renewal with solely conventional diesel vehicles does not have an impact on life-cycle carbon emissions. Methods of reducing fuel consumption or substituting fossil for biofuels are required. With reasonable numbers of hybrid and high-blend biofuel vehicles the analysis shows it could be possible to achieve significant GHG reductions (of 18 - 25%). Ideally a large proportion of the conventional diesel vehicles are in parallel run on low-to-medium blend biodiesel. Some use of biodiesel by conventional diesel vehicles is therefore included in the impact forecasts for the scenario.

It is important to understand the levels of investment that would be required to achieve a given emission reduction scenario. The study has therefore built on the cost-assessment of various technology/fuel options presented in Chapter 3 to estimate a total capital cost for each scenario in each PTE/SPT area. It is clear that increasing the fleet replacement rates from the current 5.5% to the scenarios representing 7.5%, 10% or 16.5% would have a very significant cost.

The analysis has also combined the emission benefits with the costs over that of the business as usual scenario. Interestingly, when comparing the scenarios on a cost-per-tonne of NO_x and PM abated (over the business as usual), the options perform rather similarly, and the additional capital costs of hybrid and biofuel technologies are evened out. This illustrates the importance of considering the investment in cleaner technologies on a long-term basis, over the vehicle's lifetime. For GHG emissions those scenarios which contain numbers of hybrid and biofuel vehicles are the most cost-effective.

From the analysis the best overall strategy to ensure a significant reduction in regulated and GHG pollutants is to combine conventional diesel, hybrid and biofuel vehicles, in order to achieve a reasonable scale of reduction and benefit from varying cost-effectiveness.

5.4 Practicability

The study has considered what mechanisms would be important to realising any of the scenarios proposed for greening PTE bus fleets. The various scenarios modelled in this study are made up of two components: a fleet replacement rate and a policy for certain technology/fuel characteristics (supporting diesel fuel efficiency and biofuel vehicles, or just diesel efficiency).

It is possible that the 'low-ambition' scenarios with optimistic replacement rates of 7.5% may be achieved by operators alone, under influence of external factors.

A key factor that may influence the interest of operators in increasing their fleet replacement rates are the upcoming DDA compliance dates. January 2015 is the date for withdrawing all buses under 7.5 tonnes that are not DDA compliant, January 2016 for single deck buses and January 2017 for double deck buses. The study estimate is that replacement rates may need to increase from the current national rate of 5.5% to 7.5% (in PTE areas) to provide sufficient DDA compliant vehicles.

A second external factor that may influence bus operators' choice of vehicles is the price of diesel. The TfL-commissioned report estimated that diesel-electric hybrid buses were only slightly more expensive to run (over a 10-year lifetime) than conventional diesel buses once fuel savings were taken into account. The economic case for diesel-electric hybrids has probably strengthened significantly even in the last 12 months. With a predicted reduction in vehicle cost and increased experience and robustness expected from their trial operations in London, commercial interest in hybrids is much more likely.

It is not anticipated that low-ambition scenarios will include any biofuel vehicles. PTE could commit to supporting these via tendered services, such as Park and Ride, but the number of vehicles would be limited in such cases, and could be considered a demonstration of the technology/fuel, generally at a relatively high cost per vehicle.

In order that high-blend biofuel and fuel-efficient vehicles can be considered in a strategy for greening PTE fleets in more than pilot/demonstration numbers, effective changes to the relationship between fuel duty and BSOG are required. The fuel duty differential will also require supporting into the longer term.

There is an argument for supporting demonstration of biofuel technologies in the UK now that there are some large bus fleets operating in a few mainland European cities using dedicated bioethanol, biodiesel and biomethane vehicles. This could be useful and important to help overcome some of the understandably negative perceptions held by UK by operators based on early gas vehicle trials, which will otherwise be a barrier to introducing many of the GHG reducing technologies into PTE bus fleets.

Changes to the current arrangements for the organisation of bus services in PTE areas are required in order to achieve a shift sufficient to reach the medium and high-ambition scenarios proposed in this study. These are now dependent on regulations for SQP and QC derived from the recent Local Transport Act. It is hoped that the stability and removal of damaging competitive practices can enable long-term investment plan to be to properly costed, decisions made and then implemented. Work has begun at some PTEs on the opportunities that SQP and QC would provide, and this information and experience should be shared as a matter of priority as a basis for a strategy to green bus fleets.

Annex A

Scenario composition and forecasting methods

Fleet composition and forecasting methods

Fleet profiles for 2007/8, including the split of vehicles of each Euro standard and technology/fuel type, were derived for each PTE area using data provided by the PTEs. A summary of this information is given in Table A1 below.

Table A1: PTE fleet information

PTE	Fleet size (no. veh.)	Total veh km	Assumptions
Centro	2000	140696608	Estimated veh numbers (based on data on supported services and total vkm)
GMPTE	3499	105194771	None
Merseytravel	1254	72950596	None
Metro	1537	89027292	Estimated vehicle km
Nexus	1431	82887479	Estimated vehicle km
SPT	2621	155000000	None
SYPTE	948	79930406	None

This baseline information was then used to predict the number/proportions of each type of vehicle in the future fleet scenarios. Table A2 below shows the replacement assumptions used to construct each of the scenarios.

Table A2: Future fleet scenario replacement assumptions

Scenario	Year	Fleet replacement rate	% Turnover since 2007/8	Trajectory	Replacement assumption
BAUc	2012/13	5.5	27.5	BAU	5.5% E4, 22% E5
BAUo	2012/13	7.5	37.5	BAU	7.5% E4, 30% E5
1.1	2012/13	7.5	37.5	A	7.5% E4, 24.75% E5, 5.25% E5H
2.1	2012/13	10	50	A	10% E4, 33% E5, 7% E5H
2.2	2012/13	10	50	B	10% E4, 20.5% E5, 7% E5H, 4% E5R, 8.5% E5B20
3.1	2012/13	16.5	82.5	A	16.5% E4, 54.45% E5, 11.55% E5H
3.2	2012/13	16.5	82.5	B	16.5% E4, 33.825% E5, 11.55% E5H, 6.6% E5R, 14.025% E5B20
BAUc	2015/16	5.5	44	BAU	5.5% E4, 22% E6, 16.5% E6
BAUo	2015/16	7.5	60	BAU	7.5% E4, 30% E5, 22.5% E6
3.3	2015/16	16.5	82.5	BAU	21.625% E5, 28.875% E5B20, 49.5% E6B20
1.2	2015/16	7.5	60	A	7.5% E4, 24.75% E5, 5.25% E5H, 11.25% E6, 11.25% E6H
2.3	2015/16	10	80	B	10% E4, 20.5% E5, 7% E5H, 4% E5R, 8.5% E5B20, 12.4% E6H, 9.8% E6R, 3% E6B20, 4.8% E6RH
3.4	2015/16	16.5	132	B	18.325% E5, 11.55% E5H, 6.6% E5R, 14.025% E5B20, 20.46% E6H, 16.17% E6R, 4.95% E6B20, 7.92% E6RH

The replacement assumptions were calculated using two key pieces of information, also given in the table: the annual replacement rate for vehicles in the fleet, and the 'trajectory' the replacement follows.

The annual replacement rate shows what percentage of the fleet is replaced with new vehicles each year. For example, the current Business as Usual (BAUc) replacement rate is 5.5%; at this replacement rate 27.5% of the existing fleet will have been replaced by 2012/13.

The trajectory describes the type of vehicles the old vehicles are replaced with. The trajectories are summarised in table A3 below.

Table A3: Fleet trajectories used to derive fleet assumptions

New vehicles	BAU	Trajectory A		Trajectory B				
		% Hybrids	**% Diesel**	**% Hybrids**	**% Biofuel**	**% Biofuel Hybrids**	**% diesel**	**% diesel fleet on B20**
2008	E4	0	100	0	0	0	100	0
2009	E5	0	100	0	0	0	100	0
2010	E5	5	95	5	5	0	90	25
2011	E5	15	85	15	10	0	75	50
2012	E5	50	50	50	25	0	25	100
2013	E6	50	50	50	30	0	20	100
2014	E6	50	50	40	35	15	10	100
2015	E6	50	50	34	33	33	0	100

The business as usual (BAU) trajectory assumes that vehicles are replaced with the newest conventional vehicle available at that time, and the BAU column indicates what these vehicles are for each year.

Trajectory A assumes that diesel economy is favoured and that new vehicles are a mix of conventional diesel and hybrid vehicles. The table shows the proportion of each for each year.

Trajectory B assumes that diesel economy and renewables are favoured and that new vehicles are a mix of conventional diesel, hybrids, renewables and renewable hybrids. The table shows the proportion of each for each year. In addition, a proportion of the conventional diesel vehicles are assumed to run on B20, and the table shows what this proportion is for each year.