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A best practice guide for reducing emissions from taxis in London

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A Best Practice Guide for Reducing Emissions from Taxis in London

By S Latham, P Boulter, I McCrae and K Turpin

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This report has been prepared for the London Borough of Hillingdon on behalf of the West London Air Quality Group. The views expressed are those of the authors and not necessarily those of the London Borough of Hillingdon.

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Contents

Executive Summary

Within the context of the local air quality review and assessment process, locations that are shown to or predicted to exceed Air Quality Strategy Objectives are required to be declared as Air Quality Management Areas (AQMA). This process subsequently requires the local authority to develop an air quality action plan, designed to target and improve air quality within the AQMA. Road transport remains a significant contributor to local emissions and is highlighted as the main source of NO_X, within many of the declared AQMAs.

Within West London, the presence of London's Heathrow Airport is a significant generator of taxi cab movements. Whilst the Mayor of London's taxi emission strategy targets the London black cab fleet (Hackney carriages), it does not explicitly cover those emissions from private hire vehicles.

Many taxi companies are actively involved in reducing their fleet emissions through gradual fleet replacement schemes, fuelling choices and practices to encourage fuel saving. This report reviews a range of these practices and provides an initial draft of a best practice guide for taxi fleet operations, for consideration and use by the London Borough of Hillingdon and a consortium of local authorities who form the West London Alliance Air Quality Cluster Group.

Most local authorities are faced with two problems regarding vehicle emissions: regulated emissions, mainly particulate matter (PM) and oxides of nitrogen (NO_X) that contribute to poor air quality, and greenhouse gas emissions, mainly carbon dioxide (CO_2) that contribute to global warming. The vehicles and fuels that are best suited to reduce these two classes of emissions depend on the type of journeys (distance and number of passengers *etc*) and local environmental priorities (specific requirements imposed by the AQMA and the associated Action Plan).

Of the practical options currently available, diesel engines using biodiesel fuel obtained via recycled vegetable oil or obtained from a sustainable biological source are most environmentally beneficial in terms of greenhouse gas emissions, and would be the preferred option in areas *without* air quality problems. However, regulated emissions of PM and NO_X are generally greater from diesel vehicles compared to those fitted with petrol fuelled engines of a similar age and thus emission standard.

At urban speeds hybrid cars using petrol can produce reasonably low levels of greenhouse gases as well as low regulated emissions and therefore offer a good compromise for use in urban areas with air quality problems that also have an obligation to reduced greenhouse gases. The extra capital expense involved with purchasing hybrid vehicles can sometimes be justified by the high mileages and overall fuel bill savings incurred by taxis.

An alternative to purchasing a new vehicle is the retro-fitting an existing vehicle to meet more stringent emission limits. Most commonly this is undertaken through the installation of diesel particulate filters (DPFs). Depending on the type of DPF, these can reduce the mass of PM by between 50 and 90%, and can thus be used to modify a standard Euro 2 vehicle to comply with Euro 3 or Euro 4 PM limits. The Mayor's taxi emission strategy includes the retro-fitting of abatement technologies such as selective catalytic reduction systems (SCR) with particulate filters, and the use of alternative fuels such as liquefied petroleum gas (LPG). This has the additional advantage in that the life of the vehicle could be extended, thereby reducing the energy demand associated with the construction of a new vehicle and the disposal of an old vehicle. One problem with this approach is the consistency and reliability of these retro-fits, and indeed subsequent in-service compliance checks. Whilst the existing in-service emission checks are, arguably, able to check PM or smoke emissions, there is currently no in-service test available for NO_X emissions. Therefore, there remains an uncertainty in the overall environmental benefit of this combined PM and NO_X reduction approach.

Some taxi operators may have limited scope in their ability to adopt the above measures since a large proportion of their fleet may consist of significant numbers of owner drivers, some of which may be subject to lease agreements. All taxi operators should however be able to offer their drivers advice and financial incentives to purchase more environmentally beneficial vehicles. Part of this advice could be facilitated through the development of information posters, which summarise the key points from the best practice guide developed within Chapter 4 of this report.

Another measure that taxi operators could adopt to reduce emissions is to introduce a formal and coordinated system of passenger sharing to reduce overall vehicle mileage. This system could help to reduce emissions as well as offering potential improvements in traffic congestion. However, to obtain the full environmental benefit the local authority may have to manage the local traffic and to introduce additional measures to avoid reuptake of the available road space by other road users. The local authority may also intervene within the licensing of taxi fleets, through the stipulation of vehicle age. For example many local authorities restrict the age at which a taxi may be first licensed and indeed the final age of a taxi. This type of policy encourages an enhanced fleet replacement, through the removal of older vehicles and the introduction of newer vehicles.

Taxi operators also have the option of using carbon offsetting schemes to mitigate their greenhouse gases. If chosen, it is suggested that this is instigated through one of the more reputable organisations recommended in this report, and this method is used only in addition to (rather than a replacement) to the direct measures already mentioned.

Many other secondary measures (including fuel choices and changes in driving styles *etc*) may be used, which could further help to reduce emissions and improve local air quality.

1 Introduction

1.1 Overview

Despite the gradual implementation of increasingly stringent emissions regulations for road vehicles during the past few decades, road transport remains a major source of air pollution in London. Taxis have been identified as a particular problem. It is estimated that taxis are responsible for 24% of the emissions of particulate matter less than 10 µm in diameter (PM_{10}) and 12% of the emissions of nitrogen oxides (NO_X)[1] from road transport in Central London[2].

The West London Air Quality Group[3] has the overall aim of identifying measures to improve local air quality in the constituent boroughs[4], with a strong emphasis on reducing emissions from road transport. Taxis are being investigated by the Air Quality Group. As part of this work, TRL has been commissioned by the London Borough of Hillingdon to produce a Best Practice Guide for Reducing Emissions from Taxis in London.

Apart from the obvious direct environmental and fiscal incentives for taxi operators to reduce emissions and improve fuel consumption, there are also indirect benefits, including:

- The use of environmental credentials as a marketing tool.
- Brand differentiation in a competitive market place.
- The adoption of safer, environmentally friendly driving techniques, which could ultimately lead to fewer accidents and lower insurance costs.

This Report summarises the available technology and best practice for reducing emissions from road vehicles, and reviews operational experiences. The information is brought together to form of the Best Practice Guide. It is assumed that the Guide will be issued to licensed taxi operators throughout West London.

1.2 The Taxi Emissions Strategy

To address the contribution of taxis to emissions in Central London, and as a supporting action for the London Low Emission Zone (LEZ), the Mayor of London has introduced a Taxi Emissions Strategy[5]. The Strategy only affects 'Hackney Carriages' or 'black cabs' manufactured by London Taxi International (LTI) and Metrocab[6]. Around 20,000 such vehicles are currently in service in London. The Strategy includes the gradual replacement or modification of older taxis to enable more stringent exhaust emission standards to be met. Taxi drivers will be able to meet the requirements by purchasing a new vehicle, by 'retro-fitting'[7] an abatement technology, or by converting a vehicle to run on an alternative fuel. Since April 2005, the funding for such options has been provided through a small environmental surcharge (20 pence) on each fare (TfL, 2006).

The requirements of the Strategy are as follows:

- From October 2002 onwards, any new taxi licensed in London for the first time had to be

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[1] NO_X is the conventional term for the sum of nitric oxide (NO) and nitrogen dioxide (NO_2). Vehicle exhaust emissions of NO_X are dominated by NO, with the proportion of NO_2 ranging from less than 5% to over 40% (the latter largely relating to the use of specific exhaust after-treatment systems).

[2] Press release - Greater London Authority. http://www.london.gov.uk/view_press_release.jsp?releaseid=4637

[3] http://www.westlondonairquality.org.uk/

[4] Brent, Ealing, Hammersmith & Fulham, Harrow, Hillingdon and Hounslow.

[5] http://www.london.gov.uk/mayor/environment/air_quality/mayor/taxi_emissions.jsp

[6] Production at Metrocab ceased in April 2006.

[7] Retro-fitting is the addition of an emission-control device which was not installed at the time of the original manufacture.

compliant with the Euro 3 standard[8].

- From July 2006 onwards, all taxis which had been approved to a pre-Euro 1 emission standard were required to meet the Euro 3 standard for all pollutants.
- From January 2007 onwards, all taxis which had been approved to the Euro 1 emissions standard were required to meet the Euro 3 emission standard.
- From 30 June 2008 onwards, all taxis which were compliant with Euro 2 emissions standard will be required to meet the Euro 3 emission standard.

It is also worth noting that under its current Public Service Agreement (PSA), the Department for Transport (DfT) lists number of objectives, including targets for climate change and air pollution (DfT, 2005a). Local authorities need to assist the government by developing strategies to promote more sustainable personal travel options, such as those offered by taxi services, or strategies designed to reduce the impact of taxis (*e.g.* through encouraging the uptake of cleaner fuels or eco-driving).

1.3 Methodology

In this study, potential measures for reducing the emissions and improving the fuel consumption of taxis in the West London boroughs have been reviewed. The work addressed not only the types of vehicle covered by the Taxi Emissions Strategy (referred to hereafter as ‘black cabs’), but also other types of vehicle which are used as taxis, such as conventional cars and minibuses. However, the general principles involved - such as the fitting of emission-control devices and the adoption of low-emission driving styles - are very similar, and are clearly not restricted to West London.

A case study of a Hillingdon-based taxi company - Qdell Couriers and LHR Express Cars - was performed to support the review. Information on the operations and practices of this company was obtained from a combination of a postal questionnaire and in-depth face-to-face discussions.

The information collected from the review and case study was used to compile a Best Practice Guide for Reducing London Taxi Emissions.

1.4 Report structure

Chapter 2 of this Report contains a brief review of the methods available for improving fuel efficiency and reducing emissions from vehicles in London, and identifies those measures that could be applied to the taxi fleet and its associated operations. The operational practices of several taxi operators (including Qdell Couriers and LHR Express Cars) are summarised in Chapter 3, and Chapter 4 contains the recommendations for best practice. A glossary of terms used in the Report is provided in Appendix A.

[8] European emission standards are sets of requirements defining the acceptable limits for exhaust emissions of new vehicles sold in Member States. The emission standards are defined in a series of Directives which contain increasingly stringent limits (termed ‘Euro’ standards).

2 Measures for reducing emissions from taxis in West London

This Chapter provides a brief review of the methods which are available for improving fuel efficiency and reducing emissions from road vehicles, and identifies those measures that could be applied to the West London taxi fleet and its associated operations. The review covers aspects such as emission-control legislation, engine design, exhaust after-treatment, grants and incentives, alternative fuels and vehicle operation. The implications for the Best Practice Guide are also considered.

2.1 Emission standards and voluntary agreements

In view of the substantial contribution of road vehicle exhaust emissions to air pollution, European emission standards (known as 'Euro' standards) have been developed for type approval. These standards are enforced in all Member States of the European Union, and cove the pollutants carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NO_X) and particulate matter (PM). The permissible limits for these pollutants have been gradually reduced, with the latest limits (Euro 5 and Euro 6), being due to be introduced in 2009 and 2014 respectively. The emission standards for petrol and diesel passenger cars (less than 2.5 tonnes gross vehicle weight) are shown in Table 1.

Table 1*:* EU emission standards for passenger cars <2.5 tonnes (category M1).

Fuel and emission standard	Date	Pollutant (g/km)				
		CO	HC	HC+NO_X	NO_X	PM
Diesel						
Euro 1	Jul 1992	2.72	-	0.97	-	0.14
Euro 2, IDI	Jan 1996	1	-	0.7	-	0.08
Euro 2, DI	Jan 1996	1	-	0.9	-	0.1
Euro 3	Jan 2000	0.64	-	0.56	0.5	0.05
Euro 4	Jan 2005	0.5	-	0.3	0.25	0.025
Euro 5	Sep 2009	0.5	-	0.25	0.2	0.005
Euro 6	Sep 2014	0.5		0.17	0.08	0.005
Petrol						
Euro 1	Jul 1992	2.72	-	0.97	-	-
Euro 2	Jan 1996	2.2	-	0.5	-	-
Euro 3	Jan 2000	2.3	0.2	-	0.15	-
Euro 4	Jan 2005	1	0.1	-	0.08	-
Euro 5	Sep 2009	1	0.1	-	0.06	0.005[a]
Euro 6	Sep 2014	1	0.1		0.06	0.005[a]

DI; Indirect injection; DI: Direct injection; a: applicable only to vehicles using lean burn DI engines

However, the effectiveness of the road vehicle emission legislation in reducing ambient air pollution is compromised by increases in traffic, the slow replacement and poor maintenance of older vehicles, contributions from other emission sources, and differences between the pollutants which are regulated and those which are responsible for poor air quality.

The standards for NO_X and, in the case of diesel cars, PM are the most difficult to meet, and are of most relevance to local authorities; compliance with the objectives of the UK Air Quality Strategy is most difficult to achieve for NO_2 and PM_{10}. Petrol cars emit consistently lower NO_X and PM than diesel cars of the same Euro class, and are generally regarded as being the preferable option in terms of local air quality. However, diesel cars generally use less fuel and emit less CO_2 than similar petrol cars. Hence, diesel cars are usually preferable from a global environmental perspective.

For NO_2 and PM_{10} - which have both a primary traffic emission source and are formed through atmospheric chemical reactions - successful control measures need to be relatively complex. Local air quality will be dependant on a large number of factors, such as the prevailing background concentrations of pollutants from a variety of sources and locations, and the local meteorology and topology that determine photochemical processes in the atmosphere and how pollutants are dispersed. As a consequence of these complex interactions, only general advice may be given regarding best practice for taxi operations.

Other primary pollutants that are not directly regulated can also be of importance. One example is primary NO_2. NO_X is composed of NO and NO_2, and it is regulated as a limit on the combination of these two compounds. Therefore, the NO_2 component is only legislated indirectly through NO_X. The effectiveness of limiting NO_2 emissions in terms of NO_X is dependent on the proportion of NO_2 in NO_X being relatively small, relatively constant, and based on the assumption that most ambient NO_2 is formed by subsequent reactions with NO in the atmosphere. However, the proportion of primary NO_2 in NO_X is higher for diesel vehicles than for petrol vehicles, and the penetration of diesel vehicles in the UK vehicle fleet is continuing to increase. The proportion of primary NO_2 emissions has been shown to be particularly high when various exhaust after-treatment technologies, such as diesel oxidation catalysts and diesel particulate filters, are used (AQEG, 2007). Similarly, concerns have been raised about the potentially higher primary NO_2 emissions from biodiesel, given the higher oxygen content of the fuel. Furthermore, the introduction of lean-burn petrol engine technologies, such as petrol direct injection (GDI), are associated with increased primary NO_2 formation. All of the evidence therefore suggests that the 5% primary NO_2 emission factor that has commonly been assumed in modelling studies is a significant underestimation (AQEG, 2007). Despite reductions in overall NO_X from vehicle exhaust in recent years, emissions of NO_2 from the transport sector are not decreasing by the same proportion.

In addition to the pollutants which are controlled by European legislation there has been growing concern over unregulated pollutants and greenhouse gases – most importantly CO_2 - which contribute to global warming. Emissions of these pollutants can be reduced via the use of fuels which are renewable or contain less carbon, by improving vehicle fuel efficiency through technological improvements, or by modifying the way in which vehicles are operated. Moreover, emissions of all types of pollutant can be reduced by the avoidance of travel and by increasing the occupancy levels of road vehicles. However, this is a complex issue, in which all aspects of transport need to be properly considered (oil extraction, refining, vehicle manufacture, exhaust emissions, *etc.*).

In an attempt to reduce CO_2 emissions from the road transport sector, the European Commission has signed voluntary agreements (now replaced by legislation) with the automotive industry that defined fleet-average CO_2 emission targets for new cars and vans sold in the European Union (EU). Under the latest proposal, the new cars fleet will have to meet a 130 g/km average CO_2 exhaust emission limit, by means of engine and vehicle technology, by 2012. A 120 g/km emission target would be met by a combination of other means, such as by using biofuels. Any future agreements are likely to include such instruments as tax incentives or green driving initiatives.

2.2 Engine design and exhaust after-treatment technologies

The regulated emissions from internal combustion engines are controlled by two general methods:

(i) The precise control of the metering and mixing of the fuel and air in the engine cylinders to ensure near-complete combustion without incurring high localised temperature peaks.

(ii) The use of exhaust after-treatment systems to remove any residual pollutants after combustion. This is usually achieved using a trap, absorber, catalyst or additive injected into the exhaust stream.

Improved standards of fuels and lubricants have also led to the reduction of regulated emissions. Indeed, automotive fuels support emission-control technologies by complying with strict specifications.

Fuels must have properties that facilitate combustion in a controlled manner whilst limiting the concentrations of impurities such as lead and sulphur to trace quantities. Without such fuels the latest generations of exhaust treatment systems would be quickly rendered ineffective.

Different technologies are used to control emissions from diesel (compression ignition) and petrol (spark ignition) engines due to their differing combustion regimes. Most petrol engines use a pre-mixed, near stoichiometric[9] fuel/air mixture prior to entering the engine cylinders[10], whilst diesel engines inject the fuel directly into an engine cylinder that is filled with more air than is required to burn the fuel. As a consequence petrol engines produce significant amounts of carbon monoxide and hydrocarbons, whilst diesel engines produce significant amounts of particulate matter. Both petrol and diesel engines produce significant NO_x emissions.

After-treatment systems can be used to reduce 'engine-out' emissions of these pollutants to low levels. Although some after-treatment technologies can reduce emissions of one pollutant but increase emissions of another pollutant, if two or more systems are used together they can be configured in such a manner that emissions of all regulated pollutants can be reduced. Some of these technologies can be retro-fitted to older vehicles.

More recently, and in view of the mounting evidence and concern about global warming and climate change, there has been an increasing pressure to improve vehicle fuel consumption and to reduce CO_2 emissions. Diesel engines use higher compression ratios than petrol spark ignition engines. This raises their thermal efficiency and allows them to use less fuel and emit less CO_2 for a given energy output.

The specific technologies used to reduce vehicle exhaust emissions are briefly discussed in the following Sections. A trial of different technologies which was funded by the Energy Saving Trust is also summarised.

2.2.1 Engine design

Appropriate design of the engine combustion chamber offers emission-reduction benefits through the improved mixing of fuel and air, and the minimisation of fuel spray contact with the walls of the cylinder. For example, centrally mounted injectors with four valves per cylinder allow a good distribution of the fuel (Khair, 1993). Most modern engines now use electronic control of fuel injection, which can inject the fuel at very high pressures under highly controlled conditions. One of the most advanced configurations is the common-rail system, whereby fuel is constantly pressurised and injected in accordance with signals from the electronic control unit. This ensures that the fuel is more efficiently atomised and distributed within the air charge in the engine cylinders, thereby improving fuel economy and reducing particulate formation. Close temporal control of injection, sometimes involving several bursts within the same combustion cycle, can also reduce peak pressures and temperatures, and thus further reduce NO_X formation (Breitbach, 2002).

Nitrogen oxides emissions can be minimised by reducing peak temperatures and pressures within the combustion zone (Colls, 1997), retarding the injection timing (Khair 1992), through inlet air charge cooling (Khair, 1992), and exhaust gas recirculation (EGR). EGR is used in many petrol and diesel engines, and works by recirculating a portion of the engine-out exhaust gas back to the cylinders. The mixing of the incoming air with the recirculated exhaust gas dilutes the mix and (in diesel engines) reduces the amount of excess oxygen. The exhaust gas also increases the specific heat capacity of the mix, thus lowering the peak combustion temperature. Because NO_x formation increases at high temperatures, EGR limits the generation of NO_x.

Many modern internal combustion engines are equipped with a turbocharger. A turbocharger consists of a turbine and a compressor linked by a shared axle. Exhaust gases from the engine exhaust manifold are directed into the turbine inlet, causing it to rotate. This rotation drives the compressor,

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[9] Where the fuel and oxygen is metered in a proportion so that there will be just enough of each for these to completely react to water and CO_2 (assuming perfect mixing) without any additional partially combusted gases left over.

[10] There are some direct injection petrol engines which inject petrol fuel directly into the cylinder. However, like diesel engines these produce appreciable particulate emissions and are regulated for this pollutant.

which delivers air to the intake manifold of the engine at a high pressure. This results in a greater amount of air and fuel entering the cylinder. Adding a turbocharger itself does not save fuel, it does allow a vehicle to use a smaller engine whilst achieving power levels of a much larger engine. Variable geometry turbochargers offer a great deal of flexibility in controlling engine performance as well as reducing emissions, especially in modern engines where the use of electronics is more prevalent[11].

2.2.2 Exhaust after-treatment

Standard three-way catalyst

Three-way catalysts are widely used in petrol light-duty vehicles. There is an oxidising catalyst that increases the rate that CO and HC are converted to CO_2 and water, and a reducing catalyst that reduces NO and NO_2 to nitrogen. These catalysts are contained in a modular system which converts all three gases at once (Colls 1997). Pre-requisites for effective three-way catalyst operation are the close metering of the fuel-air mixture to within near stoichiometric conditions so that the oxidising and reducing catalyst can work simultaneously, and the attainment of a temperature of several hundred degrees centigrade (known as the 'light-off' temperature). Three-way catalysts cannot be used on diesel vehicles since the exhaust gases always have an excess of oxygen. However, they can use the oxidising part of a catalyst to reduce HC species and the solid organic fraction of the particulate matter.

Selective catalytic reduction (SCR)

Nitrogen oxides cannot be reduced in diesel exhaust in the same way as in petrol exhaust due to the oxidising atmosphere. Instead, an SCR system uses urea which is injected into the exhaust and subsequently undergoes hydrolysis and thermal decomposition to produce ammonia. The mixture of exhaust gases and ammonia enters the SCR catalyst, where nitric oxide is reduced by the ammonia to nitrogen and oxygen.

Currently, SCR techniques are the most likely available technology for compliance with Euro 5 NO_X emission standards for diesel engines. However, there are concerns over the reliability of this technology (Lambert *et al*., 2004). A common problem with all SCR systems is the release of unreacted ammonia (referred to as 'ammonia slip'). This can occur when catalyst temperatures are not in the optimal range for the reaction, or when too much ammonia is injected into the process.

NO_x adsorbers

Nitrogen oxide adsorbers (traps) can be used in partial-lean-burn petrol engines and diesel engines. These are being considered mainly for light-duty applications. The adsorbers are incorporated into a catalyst washcoat, and chemically bind nitrogen oxides during lean engine operation. When the adsorber is saturated the system is regenerated using a rich mixture, during which time the NO_X is catalytically reduced.

Diesel particulate filters (DPFs)

The diesel particulate filter is one of the most effective abatement technologies for the reduction of particulate mass emissions[12]. DPFs can be broadly characterised according to the following factors:

- The flow level (full-flow or partial-flow).
- The type and mode of regeneration (active or passive)

These factors determine the applicability of different filters to different types of vehicle.

The physical structure of the most common DPF is similar to that of an oxidation catalyst, in that it

[11] Turbochargers for diesel engines. http://www.dieselnet.com/tech/diesel_turbo.html
[12] Diesel oxidation catalyst and diesel particulate filters. Available from: http://www.dieselnet.com.html

consists of a monolith with multiple channels[13] coated with a catalyst material. However, the DPF differs through the use of alternatively plugged axial channels, which in effect allow gas to pass but restrict (through a combination of diffusion, inertial deposition and direct interception) the flow of particulate matter. To ensure that the DPF gas flow rates and back pressures remain within acceptable limits, trapped particulate matter needs to be removed from DPFs, continuously or periodically, through thermal regeneration.

For full-flow filters, the reduction in regulated PM mass, or the mass of solid particles, ranges from around 90% to almost 100%. For partial-flow filters there are currently too few data to enable effects to be quantified with confidence. PM mass reductions given in the literature range from around 30% to around 85% (Boulter *et al.*, 2008). However, DPFs have also raised concerns about primary NO_2.

The types of DPF most commonly used in the UK and Europe are of the continuously regenerating type. These systems use an oxidation catalyst to deliberately oxidise the NO in the exhaust to NO_2, which then oxidises the soot on the filter. Not all the NO_2 is required to regenerate the filter, so the result is that a higher proportion of the emitted NO_x is in the form of NO_2 (AQEG, 2007). The issue of primary NO_2 is of particular concern in inner city areas, where a significant proportion of the population will be exposed to primary NO_2. In London the fitting of DPFs to the entire bus fleet may have been a contributing factor in the increase in ambient NO_2:NO_x ratio measured in ambient air (Carslaw, 2006).

2.2.3 The EST London taxi demonstration trial

The role of the Energy Saving Trust is to encourage organisations to explore and develop viable alternative technologies that can become part of mainstream commercial planning in the near future. Since June 2005 EST has been carrying out an in-service demonstration trial of the effects of emission -reduction systems on London taxis. This work has been conducted on behalf of the Pubic Carriage Office (PCO). The trial has two objectives: to gather information for the taxi trade on how such systems perform during real-world London taxi operation, and to test the systems for emissions compliance at the start and end of a six-month period of in-service operation (Energy Saving Trust, 2007).

EST funded the fitment of five different emission-control systems to 38 London taxis as part of this trial. The systems were:

- Exhaust gas recirculation (EGR)
- Diesel oxidation catalysts
- Turbocharging
- Diesel particulate filters (DPF)
- Selective catalytic reduction (SCR)

These systems had varying degrees of emissions reduction, varying costs and different maintenance requirements. In each of the taxis fitted, two or more of these technologies were combined to reduce the emissions of the taxi to the required Euro 3 levels. Over 250,000 miles have been covered in service in London by taxis fitted with emissions reduction technologies as a result of this trial.

EST is recommending the approval of systems to the PCO based on emissions test results measured during this trial. If the taxis pass Euro 3 at the start and end of 6 months in service then EST will recommend to the PCO that the system be approved as a solution to the Emissions Strategy. The PCO will then communicate the approval of this system by issuing a PCO Notice. This will appear in all taxi trade press and is also available from the PCO.

Five approved systems are already available with more in development. The suppliers of the systems will be required to provide a warranty on the systems and must be fitted by a trained installer as designated by the system supplier. Most kits can be transferred between taxis, provided that this work is carried out by a trained installer. However, in all cases taxi drivers should check this with each system supplier first.

The EST claim that taxis retro-fitted with emissions reduction equipment will have their NO_X emissions

[13] There are several DPF configurations. Some variants employ gas flow direction changes to separate particulate matter.

reduced by at least 46% and their particulate matter emissions reduced by at least 34%. Owners can replace their taxi with a new taxi, or with a (newer) second-hand taxi that already meets Euro 3, or fit a PCO approved emissions upgrade system that will improve the emissions of their taxi to Euro 3.

2.3 Grants and incentives for upgrading vehicles

In June 2006 the Government realigned its grant mechanisms to encourage the uptake of alternative fuels and cleaner vehicle technologies. Instead of offering direct subsidies to individuals wishing to purchase, for example, hybrid vehicles, or to retro-fit enhanced exhaust after-treatment devices, the Government decided instead to promote consumer information on buying greener vehicles and on 'eco-friendly' driving. Initiatives which were cancelled in 2006 included the Low-Carbon Car, Low-Carbon Bus, Air Quality Retro-fit and Enhanced Environmental Vehicle grant programmes on the grounds that, if implemented, they would not achieve market transformation or provide value for money (EAST, 2006).

The Government continues to fund three existing green transport programmes, which are currently managed by the Energy Saving Trust (EST)[14]:

- The Low-Carbon Research and Development grant programme - to cultivate new low-carbon vehicle technologies that are in the vital pre-competitive stage of development.
- The Infrastructure grant programme – for organisations with a base in the UK who will be installing in the UK a refuelling or recharging point for road vehicles, where there is an environmental need to build a refuelling or recharging infrastructure for that fuel.
- The Green Fleet Review programme - providing advice to car fleet managers.

Additional funding is also being made available for the promotion of business-based workplace travel planning and the Freight Best Practice programme, including the Safe and Fuel Efficient Driving scheme for van drivers (EAST 2006). The expectation is to train 4,000 drivers in fuel-efficient driving techniques, provide for another 400 fuel efficiency reviews, and increase dissemination of advice in the van sector similar to that for truck drivers (EAST 2006).

2.4 Alternative fuels and powertrains

New fuel and powertrain technologies offer opportunities for reducing the impact of road transport on the environment both, globally in terms of climate change, and locally in terms of reduced emissions and improvements in air quality.

2.4.1 Biofuels

In 2003, the Biofuels Directive set the objective of replacing 2 % of vehicle fuel supply by 2005 and 5.75 % by 2010. The 2005 target was not met and it seems unlikely that the 2010 target can be reached. Nevertheless in 2007 the EU target for biofuels was increased to an ambitious 10 % level by 2020, under the conditions of production being sustainable and second generation technologies being commercially available. However, concern over the adverse effects of biofuels is increasing. The European Environment Agency's Scientific Committee has made public an opinion on the environmental impacts of biofuel use in Europe. The Scientific Committee recommends a new, comprehensive scientific study on the environmental risks and benefits of biofuels, and that the EU target to increase the share of biofuels used in transport to 10 % by 2020 should therefore be suspended[15].

In the UK the Government's Renewable Transport Fuel Obligation[16] requires 5% of road fuel sold at the forecourt pump by 2010 to be biofuel. Many different biofuels and fossil-biofuel blends are in

[14] http://www.energysavingtrust.org.uk/
[15] http://www.eea.europa.eu/highlights/suspend-10-percent-biofuels-target-says-eeas-scientific-advisory-body
[16] http://www.dft.gov.uk/pgr/roads/environment/rtfo/

production throughout the world. At present, the main biofuels available in the UK are biodiesel blends and bioethanol blends.

Biodiesel

Renewable diesel fuel substitutes which are produced from rapeseed, soybean, sunflower, palm, and other vegetable oils are known collectively as biodiesel, and this is the most common biofuel in Europe. Its chemical name is fatty acid methyl (or ethyl) ester (FAME). In Europe, the main source of biodiesel is rapeseed, whereas in the US the most common source is soybean. Biodiesels have long been used as fuel for diesel engines - they have similar properties to conventional petroleum diesel fuel, for which they can be substituted with little or no engine modification. Due to their renewable character, greenhouse gas (GHG) emission-reduction potential, and a generally favourable life cycle analysis, they are an attractive alternative to petroleum diesel fuel. The production of biodiesel can also result in substantially less pollutant emissions and waste by-products. However, as production methods and sources of biodiesel vary greatly, there is a large range in the CO_2 emissions per amount of fuel produced (Blumberg *et al.*, 2003; Majewski and Jääskeläinen, 2005).

Due to concerns about the potential cost, the need for fuel system modification and damage to engine components, a common approach has been blending biodiesel with petroleum diesel fuels. The most common blend in the US has been 20% of biodiesel and 80% conventional petroleum diesel, sometimes referred to as B20 (under the same convention, 'pure' biodiesel is termed B100). In Europe, biodiesel is predominantly used either as low blends (B5 or less) or as B100. Blends of up to 5% biodiesel in petroleum diesel are broadly accepted for use in existing diesel engines by engine and fuel injection equipment manufacturers (Majewski and Jääskeläinen, 2005).

Many UK suppliers can provide pure biodiesel conforming to the British Standard EN 14214. However, using more than 5% biodiesel (B5) can potentially invalidate vehicle warranties in the UK even if used with vehicles designed to use higher concentrations of biodiesel that are covered elsewhere in Europe. Most biodiesel suppliers believe that higher concentration biodiesels may be safely used, although this is dependant on the age of the engine, as newer types of engine may not be suitable. Biofuels can also potentially cause problems in some fuel systems prior to 1995 due to the use of non synthetic rubber seals, and these should be regularly checked for fuel leakage when using high blends of biodiesel[17].

Effects of biodiesel on exhaust emissions

A wide number of emission studies with biodiesel were reviewed by Majewski & Jääskeläinen (2005). Most of these studies suggest that the use of pure biodiesel typically increases NO_X emissions by approximately 10-30% and decreases total PM emissions by typically 25-50% relative to conventional diesel. Biodiesel generally reduces carbon monoxide, polycyclic aromatic hydrocarbons (PAHs) and nitro-PAH emissions and since there is very little sulphur in biodiesel, sulphate emissions are substantially reduced. Other reviews and studies (*e.g.* Ntziachristos *et al.*, 2007) have generally confirmed these findings. However, most studies have used US driving cycles and heavy-duty engines which may not be fully representative of UK taxi use. In the United States Durbin *et al*. (2007) compared emissions from a relatively modern light-duty diesel vehicle (albeit one which is not common on UK roads) using low-sulphur diesel and biodiesel. NO_X emissions did not change significantly between biodiesel and low sulphur diesel, and this general lack of change in NO_X emissions was consistent when additives were used. The literature therefore appears to consistently confirm that using biodiesel relative to conventional low sulphur diesel fuel reduces PM and increases NO_X in heavy-duty engines, but there seems to be little evidence that biodiesel significantly increases NO_X in light-duty diesel engines[18].

[17] http://www.greengoldbiodiesel.co.uk/whichbiodieselblendshouldyouuse.htm

[18] Biodiesel has slightly different combustion properties than conventional diesel fuel and emissions could potentially be re-optimised by adjustments to the engine management system (to govern the timing of fuel injections for example). The direct replacement of diesel with biodiesel is therefore a simplistic assumption and perhaps more acceptable trade off between NO_X and PM could be achieved.

Influence of biodiesel on life-cycle emissions

Biofuels are usually considered to be less environmentally damaging than conventional fuels since they absorb CO_2 by the plant feedstock during growth that is released by the fuel during combustion. However, they are not usually ‘carbon neutral’ over their entire life cycle. Energy is input and CO_2 and other greenhouse gases released during each stage prior to vehicle use, from cultivation and fertilizer production, through to harvesting, transportation, processing and refining of the biomass into liquid biofuel. Life cycle analyses show that some methods of biofuel production can lead to a net reduction in greenhouses gases, whilst others such as producing ethanol from corn grown in North America can lead to even greater greenhouse gas emissions than standard petrol and diesel fuels.

The estimated life cycle greenhouse gas emissions attributed to various biofuels varies considerably for different situations and information sources. Biodiesel made from rape seed in the UK is claimed to achieve a 50-60% reduction in greenhouse gas emissions relative to diesel (Transport biofuels, 2007). However, the logistics chain and preparation of the land for planting of the biofuel crop are vitally important factors. Biodiesel derived from palm oil, and possibility ethanol from sugar cane can produce far greater life cycle greenhouse gas emissions in the short term than conventional petrodiesel if the farmland was acquired through deforestation. One recent study found that the amount of carbon that is released to clear forests for biofuel crops is much greater than that absorbed by growing the crop over a 30-year period (Righelato and Spracklen, 2007).

Biodiesel from waste vegetable oil (WVO)

Some biodiesel in the UK is made from WVO from the food industry. Since WVO has been historically discarded into landfill, converting it into biodiesel provides a substantial environmental benefit. However, there will still be some greenhouse gases released by cleaning and refining the WVO into biodiesel. Biodiesel derived from waste (or recycled) cooking oil is estimated to reduce greenhouse gases by typically 90% relative to diesel (Transport biofuels, 2007). This large reduction probably assumes that the demand for such oils are primarily driven by catering requirements and it is therefore justified to entirely ignore the GHG emitted during the production of the original oil for its secondary use as a transport fuel. The majority of WVO in the UK is unaccounted for, and is presumed to be burnt or processed into fuels such as biodiesel, although it is likely that most cooking oil for domestic purposes is still deposited into landfill (Jowett, 2007). Therefore, perhaps the 90% figure used for lifecycle evaluation of this fuel can be justified at present. However, in view of the increasing cost of fossil fuel, the limited supply of waste vegetable oil, the increasing demand for biofuels, and the lack of suitable land to grow the biofuel crops on, this situation may change in the near future.

The potential for displacing diesel nationally in terms of energy is typically only 0.5% of the total diesel fuel used in the UK. It is quite possible that adverse publicity regarding less sustainable methods in producing certain biofuels could place heavier demand on the more acceptable sources of biodiesel made from WVO, raising its price. The recent surge in the price of crude oil has made most biofuels more commercially competitive on a per litre basis relative to conventional fuels after the fuel duty differential is taken into account.

Biofuels from lignocellulosic biomass

Another potential source of biofuel are the so called second generation or ‘ligno-cellulosic’ biofuels that are made from the whole plant, not just from the sugar or oil-rich components of food crops. Second generation technologies deliver lower emissions than first generation processes over their life cycle and achieve greater yields per hectare (Transport Biofuels, 2007). There is still not yet any commercial production of biofuel from second generation technologies which is estimated to be 5-10 years away (Transport biofuels, 2007).

Overview of the environmental benefits of using liquid biofuels relative to diesel and petrol.

Of the fuels currently available in the UK, biodiesel made from recycled cooking oil offers the greatest reduction in lifecycle GHGs relative to conventional diesel based on the assumptions discussed earlier.

However, ligno-cellulosic[19] biomass and biogas have much higher potential resources and also offer large savings in lifecycle GHGs relative to conventional fuels. None of these fuels offer substantial regulated emission advantages relative to conventional fuels. However, the latest engine technologies have substantially reduced regulated emissions for new petrol fuelled vehicles and the emphasis for replacements of petrol should be more directed towards reducing GHGs. Biodiesel made from UK rapeseed that would have emissions of approximately 35 to 45 g CO_2 eq/MJ, LPG with 70-80 g CO_2 eq/MJ, and biogas -90 to 22 g CO_2 eq/MJ. These latter figures are broadly based on the reductions quoted earlier in this section and the baseline levels illustrated here for conventional fuels.

Compressed natural gas (CNG) and biogas

Natural gas is predominantly methane that can be used in petrol-engined vehicles with suitable modification. Dual-fuel vehicles - using a combination of natural gas and diesel - are also available. Natural gas vehicles also have 100% discount from the London Congestion Charge. Natural gas vehicles tend to have lower emissions of particulate matter than diesel vehicles without a trap, and NO_X emissions are also generally lower. Fuel consumption is generally higher than for diesel, but CO_2 emissions are sometimes lower owing to the lower carbon content of the gas. The driving conditions and engine technology has a great influence on emissions (Ahlvik, 2003).

Biogas, is a mixture of largely methane and CO_2 produced from the anaerobic digestion of organic materials (NSCA, 2006). There is enough of this waste material generated in the UK to theoretically meet around 16% of transport fuel demand. Biogas needs to be refined (increasing the proportion of methane) for use in vehicles originally modified to operate on natural gas. However, there is little availability of gas-fuelled vehicles and a very limited refuelling infrastructure.

It is estimated that biogas fuelled vehicles can reduce CO_2 emissions by between 75% and 200% compared with fossil fuels. The higher figure is for liquid manure as a feedstock and shows a negative carbon dioxide contribution which arises because liquid manure left untreated generates Methane emissions, which are 21 times more powerful as a greenhouse gas than CO_2. Hence there is a double benefit by reducing fossil emissions from burning diesel and reducing methane emissions from waste manure.

Biogas will give lower regulated exhaust emissions than fossil fuels, and so help to improve local air quality, although technology changes in future years – for example, the introduction of particulate traps and selective catalytic reduction – may reduce this advantage.

Based on costs from the US and Sweden it is estimated that biogas would be about 40% cheaper to run than diesel and 55% cheaper to run than petrol, but these fuel cost savings are off-set by higher capital costs, some £25,000 for heavy-duty vehicles and £5,000 for light-duty vehicles, and potentially higher maintenance costs (NSCA 2006).

The environmental and economic factors involved suggest that electricity production from biogas offers greater CO_2 saving benefits and better economics than biogas used for road transport (NSCA, 2006). However, biogas is not included in the RTFO, yet along with other biofuels it provides a valuable indigenous resource of potential transport fuel for the future. The current rise in oil prices since this report was published may also provide increased justification for using biogas as a transport fuel.

2.4.2 Liquefied petroleum gas (LPG)

The only alternative fuel that is both practical and has a wide infrastructure base in the UK is liquefied petroleum gas (LPG). Liquefied petroleum gas consists predominantly of propane and is produced as a by-product of the refining industry and gas wells. Spark-ignition vehicles can run solely on LPG, or they can operate as dual-fuel vehicles which switch over from petrol to LPG. Liquefied petroleum gas has been a popular alternative to conventional fuels owing to its low regulated emissions of particulate and NO_X which attracted a corresponding reduction in fuel duty. Many vehicles have been converted from petrol and diesel to run on this fuel, but concerns about the quality of LPG conversions and the

[19] Lignocellulosic biomass refers to plant biomass that is composed of cellulose and hemicellulose, and lignin (such as wood residues).

subsequent emissions have been raised in the past.

The environmental advantages of LPG have gradually been eroded over the last decade due to the reduction in regulated emissions from conventionally fuelled vehicles (DfT, 2005b) and the fuel duty differential between LPG and conventional fuels has been reduced to the equivalent of 6p/litre relative to diesel fuel (Energy Saving Trust, 2007). LPG vehicles are exempt from the London congestion charge.

LPG offers a 10-15% reduction in life-cycle CO_2 emissions compared with petrol, and similar CO_2 life cycle emissions to diesel. (Energy Saving Trust, 2007). In 2005 the government withdraw grants for all alternative fuel conversions, including LPG, although grants for fuel infrastructure development are still available.

2.4.3 Hybrid electric vehicles (HEVs)

Most commercially available hybrid electric vehicles use a petrol engine as the primary source of power. This petrol engine is used to drive a generator to charge a battery which can, in turn, be used to power an electric motor to drive the wheels of the vehicle. Some ‘parallel’ hybrids - such as the Toyota Prius - can use some of the engine power to drive the wheels directly at the same time which is a more efficient method at higher speeds. The hybrid system effectively separates the power supply from the power demand requirements using the battery as an energy store, so the petrol engine can be operated at speeds and loads which are near to its maximum efficiency. In addition, some hybrids use regenerative braking, and have the ability to stop the engine when the vehicle is stationary. This reduces fuel consumption and CO_2 emissions further, especially when driving in congested traffic. However, the fuel and CO_2 advantages of some electric hybrids are also obtained through other means, such as aerodynamic improvements and low tyre rolling resistance, that could be equally applied to a conventional vehicle. This reduction in energy and fuel use also assists in reducing pollutant emissions. However, the level of technology required for hybrids comes at a premium cost that could only be recovered if high mileages are accumulated, and much of the advantage is lost if the driving occurs at high speeds.

Commercial ‘plug in’ hybrids may be available in the near future. These have the potential to use mains electricity as a power source, possibly using cheap overnight electricity, of which some will be generated by low-carbon energy sources such as natural gas, nuclear power and wind power. Although, hybrid vehicles are complex and expensive, they can be economical for high mileage users, and they can be useful to enhance the public image of both the producer and user. They may also enhance the development of cheaper, high-energy batteries which could improve the long-term viability of dedicated battery electric vehicles (see below).

Partial hybrid technologies have also been developed that just store the energy generated from braking that can be reused to supplement engine power. These combine a traditional fuel engine with a combined electric generator/motor and battery.

2.4.4 Battery electric vehicles (BEVs)

There is currently only a limited range of purely electric vehicles commercially available in the UK. Batteries store limited energy relative to their weight compared with conventional fuels, and are generally uneconomic and impractical for the long periods of use, such as those required for taxi operations. However, BEVs have obvious environmental advantages in populated areas with air quality problems, and unlike hydrogen much of the necessary supply infrastructure already exists. BEVs have greatest potential as a low-use, short-range urban vehicle that can be charged overnight using a cheap electricity tariff, although developments in battery technology may increase the role of BEVs to serve a wider range of operational requirements. The overall greenhouse gas emissions from BEVs will depend upon the nature of the driving operations and power source used to generate the electricity.

2.4.5 Hydrogen

Hydrogen is often seen as a future fuel for cleaner transport since it's emissions at the point of use consists of only water vapour if used in a fuel cell to produce power. However, fuel cells are currently very expensive and complex, and combustion of hydrogen in an internal combustion engine produces NO_X emissions. Moreover, all commercially viable methods of hydrogen production emit greenhouse gases. To have a positive impact on the environment across its whole life cycle, hydrogen needs to be produced in a sustainable manner, otherwise negative impacts during production will outweigh the positive impact of using hydrogen (CVTF, 2000). Hydrogen has other disadvantages in that it is also difficult to store and transport in large volumes because of its low density. At the present state of development, hydrogen is not practical and economic for widespread use in the automotive sector and at best should be considered only as a long-term alternative to conventional fuels.

2.5 Vehicle operation and maintenance

Several aspects of vehicle operation and maintenance have the potential to contribute to reduced vehicle emissions levels, and these aspects have been addressed in various studies. However, due to the confounding effects of different parameters, and effects which are difficult to control in real-world driving situations, the results have been somewhat variable.

For example, Latham *et al.* (2000) reviewed the influence of driving style on emissions and fuel consumption, and possible methods of providing feedback to the driver on how to reduce these. This study found that the potential for reducing CO, HC and possibly NO_X by changing driving style using a petrol vehicle was high, since only a small proportion of the driving time was responsible for most of the emissions. These periods usually coincide with prolonged states of high throttle use during which time the fuel air mixture becomes non-stoichiometric and the catalyst no longer functions. Similar emission characteristics were observed when driving a Euro 4 petrol vehicle through the city of Southampton. However, the opportunity to drive in this way can usually only be 'achieved' on urban highways. In a study undertaken by Wilbers (1999) the influence of different styles of driving on emissions and fuel consumption from a petrol car found that an 'aggressive' style of driving increased fuel consumption by 34%, CO emissions by 744%, HC by 282% and NO_X by 91%. A less aggressive cycle showed a modest reduction in fuel consumption of 5%, however, emissions of CO, HC and NO_X were increased by 78%, 31% and 6.5% respectively.

Lower constant speeds using high gears will generally produce lower fuel consumption (and possibly lower emissions as well) since the power required to travel at higher speeds increases non-linearly due to air resistance.

In practice, drivers usually attempt to travel near to the speed limit for the particular road in question, and changes in driving style are dictated by the movement of the surrounding traffic and the traffic management system. Automatics and hybrids should reduce the impact of driving style on emissions and fuel consumption, although reduced target speeds, throttle position and the avoidance of braking should provide some advantages in terms of emissions. On the other hand, the fuel consumption of automatic vehicles is higher than that of manual vehicles.

Several organisations (*e.g.* RAC[20], Ecodrive[21]) provide operational advice for optimising the fuel-efficiency of vehicles, and these ought to be applicable taxi operations. Some examples are listed below.

- **Driving off as soon as the engine has been started.** This has the additional advantage of reducing low frequency noise especially from diesels and exhausts with faulty silencers. However, vehicles should be driven gently until the engine has reached its normal operating temperature.
- **Driving 'smoothly'.** Thinking ahead, maintaining a steady speed (the most fuel-efficient speed is typically around 45-50 mph), applying light throttle and avoiding heavy braking (and using the

[20] http://www.rac.co.uk/web/knowhow/going_on_a_journey/driving_advice/responsible_driving
[21] http://www.ecodrive.org/

engine to slow the vehicle) will reduce fuel consumption (as well as wear and tear on the vehicle). I

- **Wise use of gears.** The most fuel-efficient area of the engine map usually lies at low-to-mid engine speeds and high engine loads. Driving in the highest gear possible, and at a low engine speed but without labouring the engine, is generally the most fuel-efficient way of driving. Changing-up gear before 2,500rpm (petrol) and 2,000rpm (diesel) is advisable.
- **Switching off the engine.** Whenever it is safe to do so, switching off the engine (*e.g.* when stuck in traffic for more than a few minutes) can reduce fuel consumption. However, the effect on emissions is unclear since this gives time for the catalyst to cool. Emissions can also be high immediately after start up until the combustion process has stabilised. Some hybrid cars have catalyst heaters to avoid catalyst cooling problems during periods when the engine is not used.
- **Turning off air conditioning.** Air conditioning and other auxiliaries should be used as sparingly as possible. It is likely that opening windows would be more fuel efficient than switching on the air conditioner at lower speeds, although this may be impractical if the outside temperature and humidity is uncomfortably high.
- **Avoiding the use of roof-racks and other obstacles to the air flow.** However, the availability of roof racks may allow the use of a smaller car as opposed to the use of a much less efficient larger vehicle, and the additional drag of the roof rack may only be realised higher speeds
- **Lighting the load:** The lighter the load, the lower the fuel consumption and emissions. This can apply to fuel as well as unnecessary baggage, but the advantages of using a partly fuelled tank could be compromised if having to drive off normal routes to a fuelling station.
- **Route planning.** This should avoid unnecessary mileage. Satellite navigation systems are useful for navigating as well as avoiding congested traffic, although these can be unreliable at times owing to new road building and high buildings that block the radio signal.

Most emission-related maintenance issues should be addressed during the regular service intervals. This includes changing the vehicles air, oil and fuel filters and cleaning or changing the injectors or spark plugs when appropriate. Vehicles using high blends of biodiesel should have their fuel filters changed more frequently than normal (at least every 3 months) and older models should be regularly checked for signs of fuel leakage near seals. In addition, tyre pressures and fluid levels should be regularly checked, as incorrect settings can increase rolling resistance and fuel consumption. Vehicles that exhibit any obvious malfunction such as misfiring or the observation of excessive exhaust smoke should be immediately subject to appropriate diagnostic tests and subsequent repairs or adjustments if necessary. Modern vehicles should be fitted with an on-board diagnostics package (currently OBD II) this provides the driver and service engineer with information on the state of the engine and after-treatment system that could alert them to an ongoing or potential problem.

2.6 Carbon offsetting

Carbon offsetting is the act of mitigating greenhouse gas emissions by investing in schemes that ether absorb carbon or reduce carbon emissions by projects such as tree planting; renewable energy and energy conservation schemes and methane capture offsets. Offsetting is a controversial means of ‘reducing’ greenhouse gases since it can provide an excuse for companies and individuals to continue with a ‘business as usual’ attitude, and can potentially increase demand for polluting sources since overall power consumption is not being reduced. It is also criticized as an unregulated activity that has questionable results to actually offset or reduce carbon emissions.

The ‘Consumer's Guide to Retail Carbon Offset Providers’, identifies a top tier among the providers of carbon offsets which it says are "more likely than those of other providers to result in high-quality greenhouse gas emissions reductions” (Clean Air Cool Planet, 2006). These include:

- The Oxford-based Climate Care, which turns chip-fat from Caribbean cruise liners into bio-diesel and offers efficient stoves to wood burning communities in Nicaragua.
- The UK-based CarbonNeutral Company, formerly known as Future Forests. This has contracted for more than 800,000 tons of offsets and its portfolio consists of small-scale renewable energy

projects, landfill gas collection, energy efficiency and reforestation projects.

- US-based Native Energy, the company Al Gore used to offset his flights to promote his global warming film, An Inconvenient Truth.
- The Portland, Oregon, based Climate Trust, is the biggest US-based provider. This organisation examines all its top-rated projects to make sure that they are additional and would not have happened anyway.

Some formal standards for voluntary carbon offsets are also emerging. The International Emissions Trading Association (IETA) have proposed a voluntary carbon standard (VCS) for carbon offsetting. The International Emissions Trading Association seeks to provide a credible but simple set of criteria that will provide integrity to the voluntary carbon market. In particular, the VCS will ensure that all project-based voluntary emission reductions that are independently verified to meet its criteria defined as voluntary carbon units (VCUs) represent real, quantifiable, additional and permanent project-based emission reductions.

2.7 Summary of effects and implications for best practice

An overview of the benefits of the various technologies - and some fuel options - available to taxi operators to improve their environmental performance was provided by Archer (2005). These are summarised in Figure 2.

Whilst all of these measures are worthy of consideration, 're-powering' by retro-fitting an older vehicle with an engine and after-treatment system (in combination) that conforms to a more stringent emission specification may offer the greatest environmental advantages. Purchasing new vehicles such as hybrids and those with a higher emission specification offers similar or even greater direct benefits, but will incur an environmental penalty due to the resources and emissions used to manufacture a complete vehicle. However, purchasing newer, more environmentally friendly vehicles can be justified for most taxi operators who usually drive high mileages since their emissions will be dominated by those produced by the use of the vehicle. The environmental impact of older vehicles could be mitigated by ensuring these are sold to low-mileage users, or else the emissions could be merely shifted elsewhere. In practice, many taxi companies and drivers obtain vehicles through lease arrangements and will have little choice over resale conditions.

Retro-fitting a 'mild' hybrid system may be an alternative option for private taxi owners operating in congested urban environments since this should provide fuel consumption as well as emission reductions and avoids the disadvantages of reselling an older specification vehicle onto the market.

Retro-fitting vehicles to accommodate cleaner alternative fuels such as LPG or various abatement emission technologies could be another option for operators with older vehicles, particularly those which do not travel high mileages. However, in view of the uncertainties of the benefits produced by these measures, such as NO_2 emissions and reliability concerns, replacement with the latest technology vehicles or engines (Euro 4 and 5) would be the preferred option, especially with high mileage vehicles.

In terms of fuel, biodiesel derived from a traceable source of waste vegetable oil (WVO) provides the best GHG-reduction option that is currently available to taxi operators in the UK[22] owing to its partly renewable nature and the likelihood that much WVO is probably still discarded after being used for catering requirements. However, even if this biodiesel is used with the latest diesel vehicle technology this would not provide as great a benefit in terms of PM and NO_X emissions as the latest petrol vehicles. Therefore, in urban air quality management areas (AQMAs) only, it is suggested that the petrol hybrid is currently the best option since this provides low regulated emissions with reasonably low GHG emissions due to the low fuel consumption. Although natural-gas-powered vehicles offer only limited benefits relative to modern, conventional fuelled vehicles, these still offer interesting possibilities for the future since as well as producing low regulated emissions these could be potentially upgraded to use biogas, which can offer the highest GHG benefits of any biofuel.

[22] Although it is probable that this would invalidate the vehicle warranty.

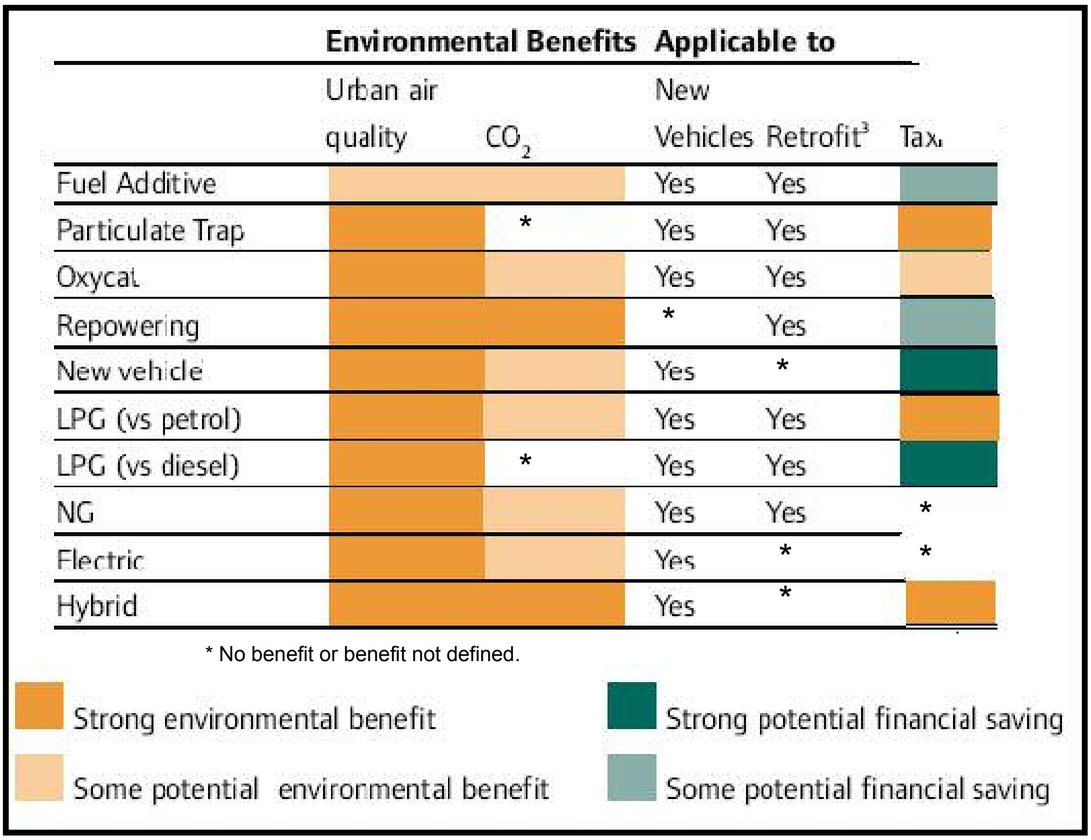

Figure 1: Options to improve the environmental performance of taxis (Archer, 2005).

These technological changes should be combined with other measures reviewed in this report such as carbon offsetting and operational changes. Carbon offsetting should be arranged through one of the companies mentioned earlier in this Report who invest in schemes that are judged to provide a good chance of achieving a net reduction in GHGs through the schemes they invest in. However, offsetting must always be used to supplement direct carbon emission reduction measures rather than using them as a replacement.

Taxi operators must also consider operational factors, particularly the average utilisation of passengers in the vehicle which should include the amount of dead running (travelling to a collection point without passengers). Whilst taxi sharing and coordinated logistics between companies could benefit customers in terms of taxi availability and reduced prices, it is unclear to what extent it would form an attractive business case for the taxi industry as a whole unless it could be used to increase the overall customer base. An environmental benefit would only be realised if this growth is achieved by attracting drivers and passengers away from under utilised private cars, and less efficient taxi operators, and by replacing under utilised public service routes, rather than simply increasing the attractiveness of travel. With these caveats in mind however, coordinated taxi operations incorporating various sharing initiatives still presents one of the best opportunities for providing a good transport service with low environmental impact.

All these measures could be supplemented by attention to regular maintenance issues, improved driving techniques and reduced use of fuel-consuming auxiliary devices such as air conditioning when appropriate, that would provide still further greater environmental benefit.

3 Review of operational practices

3.1 Examples from London

3.1.1 Westminster City Council (WSC)/ Taxi group Initiative

Westminster City Council (WSC), central government, taxi producers and fleet representatives formed a taxi group to examine the case for developing a large-scale retro-fitting programme for older taxis[23]. They commissioned a series of off-road trials on taxis to test the efficacy of retro-fitting catalytic converters in reducing NO_2 and particulate with the aim of reducing emissions in taxis registered between 1993 and 1997 (Euro I standard) to standards closer to new taxis (Euro 3 standard). These tests showed sufficient reductions in pollutants, so in 2001 the taxi group teamed up with the Energy Savings Trust to investigate the effects of retro-fitting oxidation catalysts, through its Transport Energy Clean up Campaign to conduct on-road trials. This six-month trial involved fitting 12 taxis with catalysts, which were tested both before and after the cars were fitted to test emission levels at Millbrook Testing Ground. The results were disappointing, and much smaller emissions were achieved. These reductions were too small to justify a full retro-fitting programme.

The Group has since been looking at the new technologies available to reduce vehicle emissions that may be more effective and better value than the original retro-fitting solution. It was agreed that the most effective short-term solution is to explore the opportunities for converting diesel engines to LPG. Westminster City Council are examining how to fund for this, including the potential for businesses to part-sponsor taxi conversion costs, which will cost in the region of £1800 per taxi.

3.1.2 Qdell Couriers and LHR Express Cars

Qdell Couriers and LHR Express Cars[24] are a large private hire and courier company in West Drayton, West London who operate a fleet of more than 150 vehicles for corporate and private customers. A major part of their business comes from serving passengers to and from Heathrow airport. They offer a range of vehicles from motorcycles and vans to saloon cars, estates, executive cars and multi purpose vehicles (MPVs) (Qdell Couriers and LHR Express Cars, 2007).

Qdell Couriers and LHR Express Cars are in the process of fitting a biodiesel pump at their offices in West Drayton for the use of their drivers and already offer subsidised biodiesel for their drivers personal use. They have selected a fuel supplier that offers biodiesel produced mainly from waste vegetable oil since this offers the greatest greenhouse gas benefits. Qdell also operate a number of hybrids and LPG fuelled vehicles.

More detailed information from this company was obtained in a case study (see Appendix B).

3.1.3 Greentomatocars

Greentomatocars[25] is a London-based private car hire (or minicab) service that started trading in March 2007. This company uses 57 Toyota Prius hybrids and are trialling a plug-in Prius that obtains some of its electricity from the mains grid, with a claimed 35-mile range on the larger battery (Greentomatocars, 2007). Greentomatocars find the Prius is attractively priced, with low maintenance costs and depreciation, and no compromises with passenger accommodation, with better than average rear leg room with added flexibility of the folding rear seat and additional space under the boot floor. A typical fuel economy of 50 mpg is claimed for the Prius both in and outside central London (Biss, 2007).

[23] http://www.c-london.co.uk/output/Page129.asp
[24] http://www.qdelllhr.co.uk/
[25] http://www.greentomatocars.com/

3.1.4 Radio Taxis Group

Radio Taxis which has a fleet of 3,000 black cabs and 80 executive cars[26], spends £100,000 each year on offsetting its carbon dioxide emissions. Radio Taxis is giving 80% of the cash to overseas renewable energy projects like solar panels in Sir Lanka and a Bulgarian hydro-electric plant. The remaining 20% is set to be spent on forestry projects both across the UK and in Germany. Radio Taxis says it emits almost 24,000 tonnes of carbon dioxide each year. The company says it is also committed to ensuring emissions from its vehicles are as low as possible, but admits this is difficult as the majority of its drivers own their own vehicles.

The company also uses a biodiesel blend using UK grown virgin oil stock that is specifically created for use in taxis. Developed in partnership with UK based Infinitum Limited it is claimed that the fuel blend significantly reduces NO_X and CO with a 4.7 % reduction in particulate matter (Green Car Guide, 2007).

3.2 Examples from other cities

3.2.1 New York

The mayor of New York has set an objective of achieving the world's largest low-emission city taxi fleet by 2012 by converting all yellow cabs to hybrids. In 2007 only 375 of the city's 13,000 taxis used hybrid technology. It is claimed that the higher capital cost would be recouped at a rate of $10,000 a year by improving fuel consumption from 14 mpg to 30 mpg. The complete conversion of the fleet should halve the fleet's carbon dioxide emissions, with similar cuts in the local air pollution (Kakos, 2007).

3.2.2 Graz

Taxi 878 is a company located in Graz Austria which has 220 diesel cars in its fleet and is in the process of converting these to use biodiesel. A fuelling station for biodiesel was established at its headquarters which is also open to the public, thus encouraging other companies as well as citizens to use biodiesel. Most of the taxi drivers are not employees but franchisers with responsibility for their own vehicles. It was therefore necessary to provide information to convince individual members to voluntarily change fuels which included a one day training programme for the entire company. The large-scale introduction of biodiesel in a taxi company also made it possible to gather information about repair, maintenance and service needs when using biodiesel.

Conversion to biodiesel of a private taxi fleet with many franchised individual operators with responsibility for their own vehicles was found to be more difficult than would be expected of a centrally controlled public fleet. Taxi 878 found that the participation and supporting role of experts was essential, as this helped in carrying out fuel quality tests, and determining the source of operational difficulties such as blocked fuel filters which caused the whole project to be put on hold for a period. There were also problems with the liabilities and guarantees from car manufacturers. At the time this information was written over 25% of the taxi fleet had switched to biodiesel with higher targets set for the future (CIVITAS Trendsetter, 2006)

It is interesting to compare the experiences of this company with Qdell Couriers and & LHR Taxis used as a case study in this Report, which has encountered similar maintenance issues with using pure biodiesel.

3.2.3 Singapore

Singapore has focussed on using efficient logistical operations to reduce emissions, as well as improve the efficiency and cost effectiveness of the taxi service. This appears to be a form of an optimised

[26] http://news.bbc.co.uk/1/hi/england/london/4310483.stm

spatial-temporal taxi sharing scheme using advance bookings.

A strategy of trip-chaining is used where several bookings can be arranged by allocating time periods for pick-up. Using this system the pick-points can coincide or are close proximity to the former drop-off location (Focus Singapore, 2007).

4 Best Practice Guide

In this Chapter of the Report some recommendations on how to minimise emissions from a taxi fleet are provided. Emissions can be reduced in a number of different ways. Some measures may involve major changes to existing taxi procurement and operational practices. Other measures are probably already being used by many taxi operators, but they may need to be applied more rigorously. There are also several potentially beneficial measures for the future which are currently unproven or are not widely available.

Clearly there are a number of factors to consider when providing recommendations of this type, not least the practicality and financial implications (in terms of capital investment, operational costs, and revenue) of the proposed measures. Taxi operators generally use relatively large, diesel-engined vehicles, and there are a number of reasons why this is the case. For example, space is often required for luggage, and diesel engines are more fuel efficient than petrol engines. Consequently, there will be a need to match measures to meet the operational requirements – some measures may be better suited to some operators than others. Since many taxi drivers are responsible for their own vehicles, this limits the scope of a private hire firm to implement a strategy regarding the most appropriate environmental vehicles and fuels.

The recommendations for taxi fleet operators and other organisations are provided below.

4.1 Recommendations for fleet operators

The recommendations for taxi fleet operators and drivers are divided into the following sections:

- Vehicle-related measures
- Fuel-related measures
- Operational measures
- Driver training
- Other measures

Vehicle-related measures

Purchase of new vehicles

1. Where possible, conventional petrol or diesel vehicles should be replaced with petrol hybrid vehicles. Larger companies and authorities should consider the use of electric and hydrogen vehicles, and the availability of government subsidies should be investigated. Such vehicles would be especially beneficial for taxi operations which are conducted exclusively in urban areas. However, there are relatively few such vehicles on the market at present, and probably even fewer which meet the requirements of taxi operators. Hybrid vehicles would be best suited to short journeys in urban areas.
2. All vehicle fleets will undoubtedly be subject to a continuous process of renewal. Existing vehicles should be replaced with vehicles which are compliant with a more stringent emission standard (*e.g.* replace Euro 2 with Euro 4). The optimum time for vehicle replacement will undoubtedly be a balance of lease costs, residual values, replacement vehicle costs and maintenance costs. Across the UK, many local authorities restrict licensing of taxis based upon their year of first registration, and restrict re-licensing when vehicles exceed a set age. This type of local authority intervention (or PCO intervention in London) remains a powerful tool outside London. The renewal of a vehicle fleet ought to be beneficial in terms of pollutant emissions and fuel consumption.

Retrofitting

3. Operators should consider retrofitting an exhaust after-treatment system to enable compliance with a more stringent emission standard (*e.g.* diesel particulate filter, oxidation catalyst). A list of EST-approved equipment suppliers is provided in the London taxi emissions abatement register (Appendix C).
4. Operators should consider the retrofitting of a 'mild' hybrid system[27].

Sale of old vehicles

5. Pre-Euro 3 taxis should only be sold on to low-mileage users if possible.

Fuel-related measures

6. If using diesel-engined vehicles, change to biodiesel fuel[28] but only if operating outside AQMAs. This must be sourced from a traceable, indigenous supply of biomass (such as British rape seed) or waste cooking oil.
7. If 6 applies, install local biodiesel pump facilities if none are available, and subsidise fuel for owner operators by at least 10% below that of conventional diesel to make it economical.
8. Use a fuel additive for reducing smoke. [29]
9. Consider using natural gas vehicles, and building a CNG supply infrastructure with a view to upgrading to using biomethane if this fuel becomes available.
10. Consider changing from petrol to a high concentration ethanol blend fuel obtained from a UK biomass source pending a suitable supply infrastructure.
11. Consider using biofuels from UK lignocellulosic (*i.e.* 'woody') biomass sources if these become available.
12. Consider retro-fitting to accommodate LPG fuel on pre diesel Euro 3 vehicles.

Operational measures

Vehicle operation and navigation

13. The driver should start a trip as soon as the engine has been started.
14. A responsible driving style should be adopted. Thinking ahead, maintaining a steady speed (the most fuel-efficient speed is typically around 45-50 mph), applying light throttle and avoiding heavy braking (and using the engine to slow the vehicle) will reduce fuel consumption (as well as wear and tear on the vehicle).
15. Gears should be used wisely. The most fuel-efficient area of the engine map usually lies at low-to-mid engine speeds and high engine loads. Driving in the highest gear possible, and at a low engine speed but without labouring the engine, is generally the most fuel-efficient way of driving. Changing-up gear before 2,500rpm (petrol) and 2,000rpm (diesel) is advisable.
16. The engine should be switched off if a stop of several minutes or more is anticipated. Whenever it is safe to do so, switching off the engine (*e.g.* when stuck in traffic for more than a few minutes) can reduce fuel consumption.

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[27] A mild hybrid system might consist of regenerative braking only. The warranty implications should be discussed with the retro-fit supplier and/or vehicle dealer.

[28] BS EN 14214 standard. This is an environmental recommendation only, based on CO_2 emissions. Any associated warranty implications should be negotiated with the vehicle dealer.

[29] If using this option companies should seek guidance on the legal, insurance and warranty implications from the dealer of the vehicle concerned.

17. Air conditioning and other ancillary devices should be used sparingly, as they result in increased fuel consumption.
18. Drivers should close windows, especially at high speeds.
19. The use of roof-racks and other obstacles to the air flow should be minimised.
20. Drivers and operators should remove any unnecessary weight from the vehicle. This includes removing unnecessary loads within the vehicle boot. The lighter the load, the lower the fuel consumption and emissions.
21. Operators should use logistical routing packages that minimise distances travelled and encourage passenger sharing.
22. Operators should equip vehicles with satellite navigation. Satellite navigation systems are useful for navigating as well as avoiding congested traffic. However, the drivers should be aware of the contradiction with point 17, and such systems should only be used when required.

Vehicle servicing

23. Operators should ensure that vehicles are serviced at the recommended intervals. This should include the inspection of wheel alignment and engine lubricant renewal.
24. Drivers should check tyre pressures weekly.
25. Fuel filters should be changed at least every 3 months, and a check of fuel seals for vehicles older than 1995[30] when using biodiesel.
26. A visually check for exhaust smoke should be conducted on a weekly basis.
27. Regular checks on vehicle diagnostics for engine and after-treatment malfunctions.
28. Verify any suspected problems from 26 and 27 at a test station using an opacimeter (diesel) or exhaust gas analyser (petrol), perform repairs, and retest as necessary.
29. Re-optimise engine management system when using an alternative fuel[31].

Driver training

30. Operators should instruct drivers on low-fuel-consumption and low-emission driving techniques. However, it is important that drivers do not revert to pre-training behaviour, and refresher courses, reminders, and incentive programmes are advisable. In-car equipment such as gear-shift indicators, cruise controls and fuel consumption gauges can help to maintain the initial benefits of the training over the longer term.
31. Operators should provide information and advice for drivers on issues relating to technology and fuel changes.

Other measures

32. Operators should consider using carbon offsetting schemes from a reputable offsetting company[32] to mitigate greenhouse gases further (in addition to direct measures).
33. Operators should consider calculating and publishing indicators of emissions of CO_2, PM and NO_X in g/km for their fleet. Those operators that encourage taxi sharing and use advanced logistical systems should publish lower adjusted emissions/km using a group utilisation factor. An example of how this might be done is given in Appendix D.

[30] It is however, unlikely that taxis will fall into this age band.
[31] For example Biodiesel may require a different injection timing for maximum efficiency or minimum emissions
[32] Recommended companies are Climate Care, CarbonNeutral , Native Energy, and Climate Trust.

4.2 Recommendations for other organisations

34. Vehicle manufacturers and dealers should extend warranties to vehicles in the UK that are designed and warranted for the use of these fuels in other countries, and consider extending warranties for other vehicles where there is little evidence of maintenance problems arising.
35. Local authorities should encourage the use of alternative fuels at their own vehicle premises perhaps extending fuelling facilities to environmentally compliant public transport and taxi operators.
36. Local authorities should provide transport incentives for taxi operators achieving high group utilisation such as access to bus lanes (or restricting those who don't).

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Appendix A. Glossary of terms

Abbreviation	Description
AQS	Air Quality Strategy
AQMA	Air Quality Management Area
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2	Carbon dioxide
DI	Direct injection
DOC	Diesel oxidation catalyst: a device for reducing particulate and some gaseous pollutant emissions.
DPF	Diesel particulate filter: a device which filters exhaust gas emissions, removing solid carbonaceous particles (soot).
EGR	Exhaust gas recirculation: a technique for introducing a portion of the vehicle exhaust gases into the engine air intake manifold to reduce NO_x emissions.
FC	Fuel consumption – stated either gravimetrically (g/km) or volumetrically (l/100km)
GHG	Greenhouse gas
HC	Hydrocarbons
IDI	Indirect injection
LDV	Light-duty vehicle
LEZ	Low-emission zone
LPG	Liquefied petroleum gas
MPV	Multi-purpose vehicles
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_X	Oxides of nitrogen. Routinely defined as the sum of NO and NO_2
O_3	Ozone
PM	Particulate matter
PM_{10}	Particulate matter with an aerodynamic diameter of less than 10 micrometres
PSV	Public service vehicle
SCR	Selective catalytic reduction: a technique for reducing oxides of nitrogen (NO_x) in the vehicle exhaust by catalysis.
VOCs	Volatile organic compounds – often referred to as HCs

Appendix B. Qdell Couriers and LHR Express Cars case study survey results

The taxi company selected for case study was Qdell Couriers and LHR Express Cars This is a combined large private hire and courier company based in West Drayton, West London. They operate a fleet of more than 150 vehicles (inclusive of courier vehicles) for corporate and private customers. A major part of their business comes from servicing passengers travelling to and from Heathrow airport.

Qdell Couriers and LHR Express Cars achieved ISO 9002 accreditation in 1996 and are licensed by the Public Carriage Office for Private Hire.[33] They offer a range of vehicles from motorcycles and vans to saloon cars, estates, executive cars and multi purpose vehicles (MPVs).

Qdell Couriers and LHR Express Cars were questioned about their operational activities, vehicles used, and any other environmental measures that have been adopted (Smart, 2007).

The questionnaire covered the following areas:

- The characterisation of the existing taxi fleet, in terms of factors such as:
  - Vehicle makes and models.
  - Vehicle ages.
  - Fuel types.
  - Fuel and lubricants consumed.
  - Vehicle Excise Duty (VED) bandings.
  - Vehicle mileages.
  - Maintenance schedules (including tyre replacements).
  - Costs.
- Measures applied to existing vehicles to improve their environmental credentials.
- Other measures which had been tested and rejected.
- Issues associated with the adoption measures (*e.g.* access to fuels *etc*.).
- The supporting evidence on which measures were initially considered (*e.g.* regulatory, environmental and/or fiscal).

The questions and their responses are provided in the following section. Responses from Qdell and LHR Express cars, are given in italics.

Operational details

1. Location/Address of depot's/taxi ranks/places kept overnight?

   - Nearly all are kept at residential addresses, not in a centralised depot.

2. Are the cars in service 24 hours 7 days a week?

   - Most drivers are on call for 12 to 15 hours per day

3. Percentage of taxis either on contract and or owned directly by the company?

[33] Public Hire and Private Hire: In London, hire vehicles are either licensed for public or private hire. Those that are licensed for public hire are London's black cabs which are also known as Hackney Carriages and are the only form of hire vehicle a person can legally hail on the street; they are also the only form of motor vehicle for hire that can legally advertise, display, or otherwise imply, that they are a 'Taxi'. Those licensed for private hire must be pre-ordered. Vehicles licensed for private hire cannot ply for hire neither can they advertise, display, or otherwise imply, that they are for hire. http://www.bbc.co.uk/dna/h2g2/A721144.

- 25% owner driver lease, 10% company car leased, 65% owner driver (non- leased?)

4. Do you allow taxi sharing, how is it organised and how do you view this option from an environmental and business perspective?

   - Customers are asked if they will share a taxi, and the opportunity for sharing is taken if they agree.

Vehicle specifications/maintenance

Fleet characteristics by make, model, age, fuel, annual mileage? Registration documents for 7 vehicle types have been provided which encompass most types of the taxi fleet. *The % of the fleet which these vehicle types represent, were subsequently estimated.*

5. Total taxis

   - 125[34].

6. Total mileage for all taxis/day:

   - judged to be typically *400 miles/day. For 125 vehicles this amounts to 50000 km/day or 350000 km/week.*

7. Age range/distribution

   - examples of vehicles were provided.

8. VED standard range/distribution

   - examples of vehicles were provided.

9. What technologies are used (LPG/SCR/EGR/particulate trap) and on how many vehicles?

   - The S class Mercedes have particulate filters. The two MPVs operate with LPG. Fees are reduced to drivers that choose to self fund the fitting of particulate traps, and they aim to have all diesel vehicles fitted with low emission technologies by December 2008.

10. What are the maintenance requirements with respect to emissions?

    - Cars are subject to an MOT test, twice a year and serviced every 10000 miles or prior to MOT test.

11. Do you as a general rule exceed maintenance requirements in any way?

    - Fuel filters are changed every 3 months, and more frequently when using biodiesel.

12. What is the average vehicle lifespan in years/mileage?

    - This was not known. Many vehicles are subject to lease agreements, plus vehicle life varies significantly by the type of driver.

13. Any management issues associated with adopted environmental measures (*e.g.* access to fuels, breakdowns *etc*.)

    - 2 breakdowns due to blocked fuel filters, the vehicles worked fine after changing filter. OEM warranties on vehicles may be technically invalidated due to the use of 100% biodiesel.

14. The supporting evidence on which measures were initially considered (*e.g*. regulatory, environmental and or fiscal).

    - road tested many vehicle types: examined fuel economy. However practicalities dictate that Qdell-LHR require a range of vehicle types,

15. Other measures tried and rejected.

    - Tested hybrids (Prius and Civic) with disappointing fuel economy results, passenger comfort

[34] The additional 25 vehicles quoted on Qdell&LHR express cars website may be used for the courier service.

and space. The Civic was slightly better for room. Concern about recyclability of batteries. Prius is well known in its class as a green vehicle, and liked by customers and is an easy option, although "not the most green". Four are currently operated by Qdell Couriers & LHR express.

Fuel

16. In percentage terms what fuels are used by the fleet?

    - 90% of fuel is biodiesel made from waste vegetable oil.

17. What spec of biodiesel is used?

    - EN 14214

18. Is it mixed with diesel, if so in what proportion?

    - Pure biodiesel used when possible.

19. Cost of biodiesel per litre?

    - 92p/litre for large batches Qdell LHR subsidise fuel to drivers @ 72p/litre.

20. How much biodiesel is used overall for the taxi fleet?

    - 12,000 litres/week[35]

21. Where is biodiesel obtained from/sold?*

    - This data remains confidential

22. Any issues with the biodiesel: reliability, smell, availability, need for prior order with supplier?

    - No problems except for blocked fuel filters on 2 vehicles.

23. Suitability and warranty of vehicles for fuel spec used.

    - All suitable, but OEM warranty probably invalidated.

24. Do you think the price of biofuel will increase as demand increases. Do you believe that there are sufficient supplies?

    - Qdell LHR are confident that supplier will be reasonable.

25. Are you aware of the source and supply chain for the biofuel?

    - Yes, it is derived mostly from recycled vegetable oil, but could contain up to 20% unused vegetable oil.

Regulations

26. Have you used/considered retro-fitting as an option to reduce emissions?

    - No, but Qdell are considering re-chipping vehicles so as to optimise biodiesel performance.

Business & Marketing

27. Is it cost effective to use biofuels in direct economic terms?

    - Borderline economics after administrative staff costs are taken into account.

28. Is it cost effective to use biofuels after allowing for indirect effects (for example increased

[35] This was increased to 12000 litres (2640 gallons) from the 6000 litres (1320 gallons) originally quoted, however this would still be short of the amount necessary to cover 250 miles/vehicle/day for 125 vehicles assuming that 90% of the total fuel used is biodiesel.

market share due to having an environmentally friendly image)?

- Yes because 60% of business customers require 'green' vehicles.

Future

29. What technologies and fuels are you considering for the future (*e.g.* hybrid)?

- *Re-chipping to alter engine management system, and diesel hybrids if available.*

30. What incentives do you think local/central government should offer for taxi firms which would make them adopt higher environmental standards?

- *Reduction in fuel tax on biodiesel. More regulation ensuring the fuel source is traceable and the environmental implications are known.*

Qdell Couriers & LHR express cars also supplied the operational data for 38[36] of their vehicles (Table B1). This could be used as example data for the development of an environmental database for best practice for taxi operators. For example the emissions from the diesel vehicles, assuming that biodiesel was used, could be compared with the emissions using standard diesel over each trip. Similarly the emissions from various vehicle types, such as hybrids could be compared with a similar sized vehicles using conventional drive trains.

[36] Two entries are omitted from the original 40 supplied, due to possible incorrect data.

Table B1: Taxi operational data from Qdell Couriers & LHR express.

Trip No.	Vehicle Make	Vehicle type	Fuel	Car Reg	Location S	Location f	Distance T	Time start	Time finis	Time Journey	Av Speed
					Grid Ref	Grid ref	miles	Hr,Min,Se	Hr,Min,Se	Hrs	mph
1	Toyota Prius	Toyota Prius	hybrid	lmo7kut	ec2	rm6	11	23:03:00	23:38:00	0.583	18.85714
2	Toyota Prius	Toyota Prius	hybrid	lmo7kut	tw6	nw2	16.8	18:57:00	19:58:00	1.017	16.52459
3	Toyota Prius	Toyota Prius	hybrid	lm07kup	ub7	n13	21.8	22:52:00	23:35:00	0.717	30.4186
4	Toyota Prius	Toyota Prius	hybrid	lm07kup	sw1	ha4	22.5	22:10:00	23:08:00	0.967	23.27586
5	Volkswagen	Phateon	biodiesel	lc55zse	tw6	mk40	57.5	11:38:00	12:43:00	1.083	53.07692
6	Mercerdes	E270	biodiesel	kw54olx	ub8	sl6	33	18:15:00	19:45:00	1.500	22
7	Mercerdes	E270	biodiesel	kw54olx	w1	ub3	15	22:10:00	22:59:00	0.817	18.36735
8	Ford	Galaxy	biodiesel	nao5fzb	ub7	gu19	18.6	09:24:00	09:52:00	0.467	39.85714
9	Ford	Galaxy	biodiesel	nao5fzb	tw6	tw20	8	13:58:00	14:16:00	0.300	26.66667
10	Mercerdes	C180	biodiesel	10tre	ub11	ec3	20	11:17:00	12:51:00	1.567	12.76596
11	Mercerdes	C180	biodiesel	10tre	tw6	rg27	32	09:46:00	10:23:00	0.617	51.89189
12	Mercerdes	C180	biodiesel	10tre	tw9	nw1	10.4	06:20:00	06:47:00	0.450	23.11111
13	Citroen	Piccaso	biodiesel	wn57dvk	ub8	ub8	2.6	11:10:00	11:15:59	0.100	26.07242
14	Citroen	Piccaso	biodiesel	wn57dvk	w1	tw6	16.1	06:41:00	07:09:00	0.467	34.5
15	Volkswagen	Golf	biodiesel	fh03jwv	tw6	gu52	30	21:10:00	21:55:00	0.750	40
16	Volkswagen	Golf	biodiesel	fh03jwv	tw6	sl5	15.4	11:31:00	12:04:00	0.550	28
17	Mercerdes	E320	biodiesel	ou03zmz	sl7	tw6	20.2	06:58:00	07:31:00	0.550	36.72727
18	Mercerdes	E320	biodiesel	ou03zmz	ec4	ub8	21.5	17:16:00	18:32:00	1.267	16.97368
19	Chrylser	Voyager	LPG	j4lhr	ub8	tw6	9.4	11:37:00	11:57:00	0.333	28.2
20	Chrylser	Voyager	LPG	j4lhr	ub3	ub11	4.3	08:20:00	08:39:00	0.317	13.57895
21	Volkswagen	Sharan	biodiesel	tn07kuk	rh6	ub3	39.4	08:02:00	09:34:00	1.533	25.69565
22	Toyota	Previa	biodiesel	gvo4atn	ub7	ub4	3.7	06:55:00	07:07:00	0.200	18.5
23	BMW	525	biodiesel	lk52abz	tw6	kt18	28.8	19:25:00	20:23:00	0.967	29.7931
24	BMW	525	biodiesel	lk52abz	ub7	rh6	40.7	08:09:00	08:48:30	0.658	61.82278
25	BMW	525	biodiesel	lk52abz	sl4	rg12	25.3	01:24:00	01:58:00	0.567	44.64706
26	Jaguar	X type	LPG	ra53zht	u19	e16	38.7	14:53:00	16:46:00	1.883	20.54867
27	Jaguar	X type	LPG	ra53zht	ub7	sl0	7.4	11:29:00	11:44:00	0.250	29.6
28	Jaguar	X type	LPG	ra53zht	tw6	sl9	17.5	08:54:00	09:35:00	0.683	25.60976
29	Jaguar	X type	biodiesel	lc53ywt	wd18	tw6	19.8	05:53:00	06:27:00	0.567	34.94118
30	Mercerdes	S320	biodiesel	d11lhr	tw6	w12	13.25	10:30:00	11:02:00	0.533	24.84375
31	Mercerdes	S320	biodiesel	d11lhr	ub7	ub4	3.5	08:07:00	08:17:00	0.167	21
32	Mercerdes	S320	biodiesel	d11lhr	ub7	ub9	7.2	19:10:00	19:22:00	0.200	36
33	Citroen	C5	biodiesel	lb53vna	tw6	kt14	16.3	21:46:00	22:21:00	0.583	27.94286
34	Citroen	C5	biodiesel	lb53vna	ha3	tw6	13.1	12:59:00	13:32:00	0.550	23.81818
35	Citroen	C5	biodiesel	lb53vna	ub9	ub7	8	23:14:00	23:55:00	0.683	11.70732
36	Ford	Galaxy	biodiesel	nd55ugn	tw14	tw6	6	14:17:00	14:31:00	0.233	25.71429
37	Ford	Galaxy	biodiesel	nd55ugn	sl4	hp14	20.7	01:15:00	01:43:00	0.467	44.35714
38	Ford	Galaxy	biodiesel	nd55ugn	sl1	sl4	4.6	12:44:00	13:00:00	0.267	17.25

Appendix C. Approved emission-control equipment suppliers

Table C1: Approved emissions system suppliers.

Supplier	System description	Applicable cabs	Contact details
Dinex	Ammonia SCR system plus DPF	Pre-Euro LTI Fairway Euro I LTI Fairway	Systems not available commercially
Cawdell Limited	ECS TaxiCat system: EGR plus DOC	Pre-Euro Fairway Euro I Fairway Euro I LTI TX1 Euro 2 LTI TX1	Bob Cawdell Cawdell Limited, PO Box 6121 Belper, Derbyshire, DE56 1WG Email : bob@cawdellgroup.com Tel/Fax 01773 880349 Mob 07776 225725
Motor and Diesel Engineering	Nissan re-power & STT* CleanCab system: Engine change, addition of turbocharger and intercooler, STT cooled EGR system plus DOC	Metrocab series I, II and III	London Central Cab Company Ltd, 1 Herne Hill Road, London. SE24 0AU Web Site:- www.mdengineering.co.uk Tel 0207 501 9998 Fax 0207 501 9777
Partsworld Ltd:	PEAK system: cooled EGR plus DOC	Pre-Euro Fairway Euro I Fairway Euro I LTI TX1 Euro 2 LTI TX1	Mark Evans, Partsworld Ltd, Girton Road Cannock, Staffs, WS11 0EB Web Site :- www.gmpartsworld.com Tel 01543 431 941 Mob 07798 582 376
STT Emtec AB	CleanCab system: Turbocharger, intercooler, cooled EGR plus DOC	Pre-Euro and Euro I Fairway	Glenn Berglund Business Area Manager Emissions Systems STT Emtec AB Web Site:- www.sttemtec.com Email:- glenn.berglund@sttemtec.com Tel 0046 60 64 10 41 Mob 0046 70 580 6880
van Aaken Developments Ltd.	vADDERS system: EGR plus DOC/DPF	Pre-Euro and Euro I Fairway	David Silverleaf, van Aaken Developments Ltd. Telford Avenue Crowthorne, Berks, RG45 6XA Web Site:- www.vanaaken.com Tel 01344 777553

* STT Emtec AB, Swedish company specialising in exhaust emissions after-treatment, and in particular, NO_x reduction by EGR.

Appendix D. Calculation of emission indicators

A common measure of emissions per vehicle-km could be compiled to judge the relative improvement in the environmental performance of a taxi operator over time and between companies operating in a similar area. The distances travelled by each car should be recorded along with the tailpipe CO_2, NO_X and PM emissions based on VCA new car fuel consumption data. This would allow a weighted average emission (E/km) of CO_2, PM or NO_X to be calculated for each taxi operator by the following calculation:

$$E/km\ overall = (E/km\ car_1 \times km\ car_1 + E/km\ car_2 \times km\ car_2 + \ldots E/km\ car_n \times km\ car_n)/Total\ km\ cars_{1..n}$$

Taxi operators who employ alternative fuels, such as biodiesel could use pre-agreed adjusted VCA emission factors[37]. These data could then be published on the local authority website so the environmental credentials of taxi companies could be made transparent to the public. These official figures should exclude emissions that are offset, although perhaps a footnote should be allowed to state that these CO_2 emissions are mitigated though offsetting where appropriate.

Taxi companies which use more sophisticated logistics packages which record how many 'groups'[38] are sharing a taxi at any one time could be allowed to quote a lower adjusted emission level E/km_a based on the following calculation.

$$E/km_a = E/km\ overall \times group\ utilisation\ factor$$

Where the group utilisation factor = distance actually travelled / distance travelled if all the groups were travelling separately.

The group utilisation factor could also be used as a measure of the effectiveness of taxi sharing for releasing road space or capacity. This could be used as a criterion by local authorities to grant permission to taxi operators that meet a group utilisation threshold to potentially use priority access schemes such as bus lanes.

Verifying the validity of such information, especially on patronage, would require some formal auditing. However, taxi sharing and other methods of optimising the logistics should provide more competitive fares per passenger journey than a taxi operator who does not use sharing. Moreover these prices should be quotable in advance.[39] This should allow some transparency in these figures. If lower-cost taxis fares could be shown to reduce overall traffic by enticing single occupant drivers away from private transport (rather than increasing overall road use) perhaps the cost of taxi fares per group could be used directly as a qualifying criterion for using priority access schemes.

[37] A workbook could be produced that provides emission adjustment factors for alternative fuels, and the average speed of the journey. The operators should also provide proof of the alternative fuels purchased and used.

[38] Where a 'group' is defined as the passengers taken from a single booking (in practice this could be 1 or more people).

[17] Variations in transit time due to congestion *etc* could be averaged out for the location and time, so a fixed price could be provided.

Abstract

Within London, taxi activities from both the black cab and private hire fleets represent a significant source of transport emissions. This is due to both a combination of a relatively large fleet, but also as a consequence of the high annual mileages accrued by their activities. Within West London, the presence of London's Heathrow Airport is also a significant generator of taxi cab movements, and thus this area is particularly impacted by taxi emissions. Whilst the Mayor of London's taxi emission strategy targets the London black cab fleet (Hackney carriages), it does not explicitly cover those emissions from private hire vehicles.

Many taxi companies are actively involved in reducing their fleet emissions through gradual fleet replacement schemes, fuelling choices and practices to encourage fuel saving. This report reviews a range of these practices and provides an initial draft of a best practice guide for taxi fleet operations, for consideration and use by the London Borough of Hillingdon and a consortium of local authorities who form the West London Alliance Air Quality Cluster Group.

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Within London, taxi activities from both the black cab and private hire fleets represent a significant source of transport emissions. This is due to both a combination of a relatively large fleet, but also as a consequence of the high annual mileages accrued by their activities. Within West London, the presence of London's Heathrow Airport is also a significant generator of taxi cab movements, and thus this area is particularly impacted by taxi emissions. Whilst the Mayor of London's taxi emission strategy targets the London black cab fleet (Hackney carriages), it does not explicitly cover those emissions from private hire vehicles.

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