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Final Report

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Assessment of the impact on costs and emissions of technical measures on existing heavy duty vehicles and captive fleets

- *How can the EU help support the most promising technical measures to reduce NOx and PM from existing heavy duty vehicles and captive fleets*

Prepared for DG Environment, November 2006

By

Sadler Consultants

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Thanks

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Those who input into the NOx compliance testing issue.

Disclaimer

This report is based on the work of the team, with input from colleagues around Europe and the US, and in the case of the technical measures data, peer review and information from an operator survey. It DOES NOT include any views from the EU Commission, and inclusion of proposed policies in this document should not indicate that they have support from the Commission, or are necessarily implementable by the Commission.

Executive Summary

This project was commissioned by the European Commission to identify cost effective technical measures to reduce PM and NOx emissions from existing heavy duty vehicles and produce concrete policy proposals for the European Commission to support their use. Technical measures are defined in this project as technical interventions that lead to lower pollutant emissions per vehicle km under comparable operating conditions, and those identified for detailed assessment included retrofits and cleaner fuels. The project also produced data and scenarios to enable the Commission to undertake cost effectiveness modelling of the most promising technical measures, to assess their potential impact and costs.

A wide range of technical measures were reviewed. The review of the technical measures found that the most promising were diesel particulate filters (DPF) for reducing particulate emissions and selective catalytic reduction (SCR) for reducing NOx. The most promising fuels were diesel water emulsion and dual-fuel natural/bio gas, although they were less promising in terms of cost effective emissions reduction than the existing diesel vehicles fitted with DPF and SCRs.

Full flow Diesel Particulate Filters (DPFs) reduce PM by 90% for particulate mass, 99% for solid particulate mass and in excess of 99% for particles in the size range 10 – 1000nm. These are considered to be the most important technology for particulate emissions reduction and should be prioritised. There are two main types of DPF. Catalysed DPFs offer the most practical solution to PM reduction. However, these systems need duty cycles that enable continuous regeneration and can increase NO_2. Systems employing fuel borne catalysts or active regeneration offer no increase in NO_2 but can present more complex application challenges, sometimes needing interaction with the operational mode of the vehicle.

Selective Catalytic Reduction (SCR) can reduce NOx emissions by up to 85%, and uses ammonia (either as 32.5% urea solution in water or as 16% liquid ammonia) as a reductant. SCR, preferably in conjunction with DPF, should be prioritised as a retrofit option for NOx and PM control. SCR systems require a minimum of 200°C exhaust temperature, so system, engine and duty cycle need to be matched.

In the context of this project, only diesel water emulsion (DWE) is considered a practical alternative liquid fuel or fuel additive at this stage and can reduce emissions of NOx by 15% and PM by 50-60%, although results appear extremely variable. At present, it is usually a niche fuel for captive fleets due to the fuel storage issues, although Italy is incentivising the fuel through tax reduction to encourage more widespread availability. The use of “dual fuel” engines using a mix of methane gas (65-85%) and diesel is an option which achieves Euro 4 emissions. Availability of the refuelling infrastructure, and for bus fleets and refuse vehicles space for on-vehicle storage tanks remain issues. Given competitively priced gas supplies dual fuel can be a commercially viable option. However, diesel engines fitted with SCR+DPF systems are likely to be more cost effective from a purely vehicle perspective and offer lower PM emissions.

In terms of support for these technical measures, there is a clear and urgent need for the Commission to take action to help support the use of retrofits through a common EU-wide certification scheme. Such a scheme is described in this report. It would enable Low Emission Zones (LEZs) to use retrofits without risking falling foul of the EU freedom of movement issue. It would also allow LEZ emissions standards or emissions variable road tolling schemes to require, for example, Euro X plus 90% emissions reduction – giving clear incentives for retrofits and cost effective emissions reductions. The EU-wide certification scheme could, depending on state aid reviews, also enable financial incentives to be streamlined through the notification process, give reassurance for those member states not yet using retrofits that they are robust technology and could act as Best Available Technology (BAT) references for retrofits.

Other measures to technical measures have been identified; including LEZ guidance, labelling of Euro standards, informal/semi-formal groupings of LEZ cities, information sharing on LEZs, certification schemes and financial incentives. There are also a number of fiscal measures that would support increased use of technical measures, including guidance and modifications to the state aid procedure, allowing lower or zero-rated VAT on technical measures and further investigation into procurement consortia.

The measures should be as all-inclusive as possible, in line with the interoperability principle. Measures should be for all vehicles, including light duty vehicles, and not aimed just at heavy duty and captive vehicles and technology neutral.

There is a clear priority on policies – EU-wide certification. Within that, there is a priority for a mechanism to enable PM retrofits certification for the currently proposed LEZs over the next two years. The policies that are recommended to be implemented are outlined below in order of priority:

Recommended concrete proposals (by priority):

1. Short term mechanism for retrofit certification for currently planned LEZs including web information on LEZ and certification schemes
2. *Labelling of Euro standards for LEZs (out of remit for this project)*
3. *Enforcement against foreign vehicles (out of remit for this project)*
4. An EU-wide certification scheme
5. LEZ guidance (some high level LEZ guidance is planned in the EU Urban Transport Strategy, due out at the end of this year, but further guidance is needed)
6. Informal/semi-formal grouping of LEZ cities
7. Information sharing (2)
   - Web information on existing financial incentives
   - Maps and GPS information on existing LEZs
8. Improvements to the state aid procedure

There are some differences between priority and best/possible timescales. The grouping of LEZ cities and the second set of information sharing could be done relatively easily quickly to the benefit of cities and LEZs particularly in the shorter term. The timescale for state aid issues is determined by the current reviews of the environmental guidelines, de minimis ruling and the state aid action plan set an imminent timescale for resolving the state aid issues.

The EU-wide certification scheme is needed as soon as possible, and the technical issues could be resolved in around 6-9 months. However, the choice of legal mechanism/framework is likely to be the key timescale factor, and if the scheme needs to be through a legal mechanism timescales are likely to be longer.

The Commission will be able to model the impact and costs of these technical measures with TREMOVE using the data and scenarios provided in part 3 of this report.

Introduction

1. Background

Road vehicles are among the most important sources of air pollution leading to adverse health effects, acidification of soils and surface water, damage to buildings, and eutrophication. The Commission Thematic Strategy on Air Pollution has identified the introduction of more ambitious emission standards for new vehicles as a major measure to reduce emissions. This works together with the many non-technical and other measures that are being implemented throughout the EU towards meeting the air quality limit values.

However, it takes a long time for the new vehicles penetrate into the fleet, and older vehicles still contribute to a large share of pollutant emissions in the medium term.

While Low Emission Zones (LEZs) and municipal bus replacement programmes will assist, there are a wide range of technical measures[1] for emissions performance enhancement, that will enable quicker and further reductions of pollutant emissions: retrofitting of vehicles with after treatment equipment, the use of alternative fuels or additives, low viscosity oil and low rolling resistance tyres, etc. These are being used in varying degrees across Europe, but how can this be further encouraged? Answering this question is the purpose of this work.

The most obvious type of technical measure in this context is retrofitting – currently mainly for particulates (diesel oxidation catalysts (DOCs) or diesel particulate traps (DPFs)), and increasingly for NOx (selective catalytic reduction (SCR) and exhaust gas recirculation (EGR). Cities are increasingly deciding to implement Low Emission Zones (LEZ, also referred to as Environment Zones) whereby minimum emissions standards are set for vehicles to enter the city. Member states and cities are also increasingly introducing road charging/tolling systems (referred to here as road tolling) where the charge varies by emission, where retrofits could also be used to great effect.

2. Project Objectives

This work has been commissioned by the EU Commission to identify which technical measures could be effective to reduce particulate and nitrogen oxide (NOx) emissions from existing heavy duty and captive vehicles, how the Commission could help them to be used more, and to define concrete policy proposals.

In the context of the revision of the National Emissions Ceilings Directive[2] and the assessment of Air Quality Directives and to support any policy action, it is necessary to perform an evaluation of the potential costs and benefits associated with each technical measure. The appropriate technical measures also need to be matched to the right vehicle categories . On that basis, a concrete agenda for further policy actions – both at Community and Member States level - can be defined.

The purpose of this project is two-fold:

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[1] Technical Measures are defined in this project as technical interventions that that lead to lower pollutant emissions per vehicle km under comparable operating conditions

[2] Agreed national emissions reduction targets

1. To provide detailed information on the costs and removal efficiencies of available technologies on air pollutant emissions from existing vehicles, and their implication on emissions of greenhouse gases.
2. To define concrete policy proposals at EU level, which could help to support the most promising technological options. In particular, the feasibility of a common system at EU level for vehicle certification that takes on board improvements of existing vehicles, in the context of LEZs, road tolling, economic incentives, public procurement policies, etc.

3. Method

3.1. General approach

This project has three main parts – and the report has been split as such:

1. A technical review of potential technical measures
2. Development of policies at an EU level to support the promising technical measures
3. Presenting scenarios and data for TREMOVE modelling for the most promising technical measures and in the light of the policies developed.

Stakeholder discussion and re-validation through questionnaires and a workshop held on the 11th September 2006 was a key part of this project. The output of the technical review fed into the policy and scenario development. The potential policies also guided the technical review towards the technical measures that could be either required to meet LEZ emissions standards or incentivised through financial incentives.

3.2. Technical Review

One of the first tasks undertaken during this project was to gather and validate information on cost, operation and impact on emissions information for technical measures on existing heavy-duty vehicles (HDVs) and urban captive vehicles.

DG Environment prepared and circulated a detailed technical questionnaire to the relevant industries to collect technical evidence on the available technologies for the reduction of air pollutant emissions and the 11 responses were made available to the team at the start of this project. This questionnaire asked for information on the technical measures available, including costs and emissions impacts. A slightly altered version of the questionnaire[3] was circulated more widely, and received a further 13 responses. Inputs from a total of 53 responses on the technical side were received before the end of August, including papers sent in and advice gathered from technical measure providers, fleet operators, policy implementers and other experts, in addition to questionnaire responses.

As a parallel activity, published information on the technologies represented by the questionnaires returned was reviewed to validate the responses provided. Overall, 250 papers were obtained and reviewed. This included many technical papers and reference to California Air Resources Board (CARB), United States Environmental Agency (USEPA), BAFU/SUVA (Swiss Federal Environment Agency) and VERT

[3] See Appendix 3

(Swiss particle filter certification for construction vehicles) lists of certified measures. Technical measures additional to those represented by the questionnaire responses were also included.

These data were reviewed to determine:

- What technologies are available
- What benefits are conferred, primarily in terms of regulated emissions (PM, NOx, VOCs, CO), but also in terms of Greenhouse Gas Emissions and most problematic non-regulated emissions such as particulate number, NO_2, N_2O, attrition residues e.g. Platinum, Vanadium etc
- The quality and credibility of the questionnaire responses
- The capital and operational costs of the technical measures identified
- Other issues such as where they are appropriate, such as any disadvantages etc

The technical measures covered were:

Exhaust emissions retrofit measures

- Diesel Oxidation Catalyst (DOC)
- Diesel Particulate Filter (DPF)
- Exhaust Gas Recirculation (EGR)
- Selective Catalytic Reduction (SCR)
- Lean NOx Traps (LNT)
- Measures to reduce impact of idle emissions
- Re-powering / Re-engining

Alternative liquid fuels

- Di-methyl-ether (DME)
- Ethanol
- Fatty Acid Methyl Esters (FAME)
- Synthetic Diesel (Fischer-Tropsch)
- Diesel Water Emulsion (DWE)

Alternative gaseous fuels

- Natural Gas
- Bio-methane

Complimentary measures

- Low Ash Lubricants
- Closed Crankcase Ventilation systems
- Measures to reduce impact of idle emissions – use of Auxiliary Power Units (APUs), truck stop electrification

Other measures

- Fuel Additives
- Retrofit hybrid drives
- Low Viscosity Lubricants
- Low Rolling Resistance Tyres

The two sets of information were combined, reviewed by experts within the team, and collated into an initial technical paper. The technical measures within the paper were categorised as set out below, as well as the most preferable options identified:

Primary measures

- measures which have quantifiable benefits and are considered the most promising technical measures for reducing PM and NO_x appropriate for the policies within this project.

Secondary measures

- measures which, whilst not providing significant impact upon PM and NO_x, should be encouraged to be used in conjunction with primary measures.
- measures which appear to offer potential PM and NO_x benefits but which should be further examined to explore their potential in a European context.

Other measures[4]

- immature or technologies not close enough to market
- measures not able to impact significantly upon the emissions from existing heavy-duty vehicles
- measures which appear to be too expensive versus other technologies offering similar or better emission benefits

3.3. Stakeholder input

Stakeholder input was an important part of this project to ensure that:

- Correct data was collected on technical measures
- That the policies developed are solutions to the issues experienced by cities, member states and also technical measure producers.

3.3.1. Revalidation of technical data

The technical review was peer reviewed by 3 external experts before the workshop, and the subsequent paper was presented and discussed at a workshop, giving a wider peer review both during and following the workshop from external input.

3.3.2. Stakeholder policy input

To ensure that all potential support was included the team prepared a policy questionnaire[5] asking: what are the current barriers to introducing technical measures, what could the EU do to assist, what policies (e.g. LEZs, cleaner vehicles incentives) were already in place, and relevant experience of using technical measures. This was sent to a wide range of contacts who are implementing air quality policies, fleet operators, technical measure providers or other experts. Input was received from 57 respondents in 16 countries before the end of August. A number of issues were raised that were outside the remit of this project, and a list of these can be found in Appendix 4.

This input was combined with team expertise to outline draft policies for discussion at the workshop, and the existing and planned air pollution measures also helped input into the model scenario development.

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[4] Categorisation as 'other measures' is within the context of this project, and does not mean that they are not valid technologies, particularly in many cases in terms of CO_2 emissions.

[5] See Appendix 3

3.3.3. Workshop discussion and re-validation

A pre-workshop paper[6] was prepared including both the technical data and the draft policies, which was circulated to the 47 workshop attendees representing 14 countries prior to the workshop to enable the paper to be read before the workshop to enable full discussion at the workshop. It was also sent to a wider audience to enable further input, including vehicle operators to enable the data and policies to be 'tested on the market' and in particular re-validation of the maintenance costs by those operating the vehicles, as well as being made available on the web.

The workshop and pre-workshop paper focused on the policy side of the project where discussion was most needed. The questions to be resolved were highlighted; firstly deciding which of the policies identified would help and secondly discussing some of the details of the identified policies. The technical measures data were presented and asked for 'stop-the-press' issues at the workshop itself and further comments invited by email. Responses on issues that we were not going to be able to discussed at the workshop and more detailed comments were also requested by email and a pro-forma provided for this. A ranking of the technical measures was presented for comment, as well as information requested on likely technical measure penetrations for the modelling. Workshop presentations and the ranking spreadsheet can be found in Appendix 5, and are also available on the website.

The workshop write-up[7] collates the information from the workshop, and was used as a basis for the final report, together with comments received after the workshop from attendees and other stakeholders.

3.3.4. Re-validation of developed policies

At the end of the process the policies developed were re-validated by a city implementing an LEZ (London) and a national Government operating a certification scheme (the Swiss federal environment department), before the final versions of the policies were presented here.

3.4. Define concrete policy proposals at EU level,

Concrete policy proposals were developed to help support the most promising technological options for NOx and PM emissions in the context of Air Quality and Noise Directives. This included in particular the feasibility of a common system at EU level for vehicle certification to support Low Emission Zones, charging systems, economic incentives and public procurement policies.

Responses to the policy questionnaire were used as the primary input to develop and focus policy development. These were combined with team expertise and literature reviews of existing policies both within the EU and elsewhere. The workshop was a key part of firming up these policy proposals, together with discussions with DG Environment to help identify where Commission could assist and steer the policies developed.

[6] available from www.airqualitypolicy.co.uk

[7] Also in Appendix 5

3.5. TREMOVE Modelling scenarios and data

The data on costs and impacts of the technical measures as well as which technical measures were chosen for the scenarios was taken from the technical review. The data on the technical measures is based on current experience and expert reviews, and can be said to be robust.

Setting future modelling scenarios is always difficult - they are always 'guestimates'[8] of what could happen, based on current experience. To help shape these scenarios input was requested from stakeholders and experts on views of potential future technical measure penetration rates. Information was also collected on existing and planned policies so that the plans and attitudes of different countries can be assessed, and the scenario designed accordingly. Views on eastern Europe were also gained the Hungarian Institute for Transport Sciences who has done a lot of work in this area in central and eastern Europe. This was combined with team experience and discussion with the Commission TREMOVE modelling contractors (LAT (Laboratory of Applied Thermodynamics - Aristotle University) and Katholieke Universiteit, Leuven and Transport & Mobility Leuven) to produce the scenarios presented.

These data and scenarios are presented in this report and in the accompanying spreadsheet sent to the Commission, in a format that can be directly analysed by the model TREMOVE for the analysis of the cost-effectiveness of the scenarios and the analysis of the impact on pollutant emissions.

4. Report structure

The remainder of the report is set out in the three main parts:

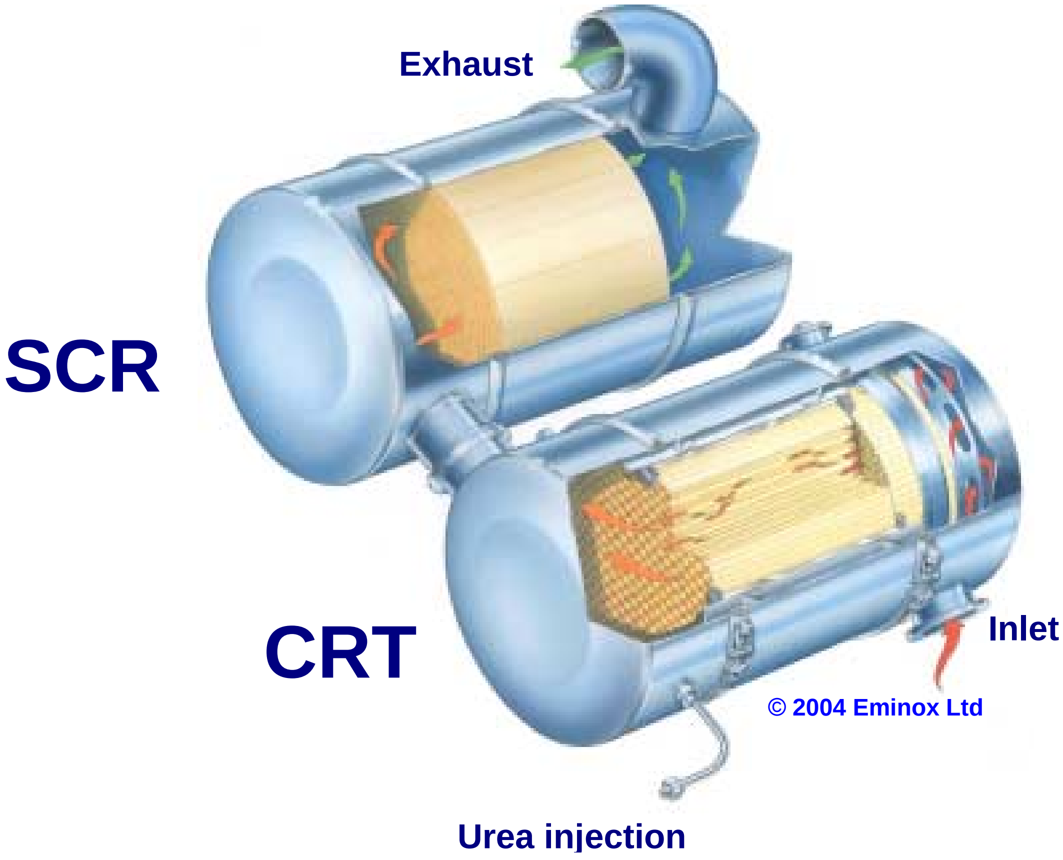
Part 1 Technical review – sets out the information collected and review of possible technical measures including technical data, costs, emissions impact, operational aspects and conclusions on the most promising technical measures.

Part 2 Policy formulation – sets out the concrete policy proposals that could be implemented by the Commission to support the uptake of the most promising technical measures

Part 3 TREMOVE scenarios and data – sets out the scenarios that have been developed and data provided to allow the Commission to model the policy proposals.

The final element of the report is a conclusions.

[8] A combination of an estimate and a guess


Exhaust
SCR
CRT
Inlet
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Urea injection

Part 1 - Review of Technical measures

This section of the report provides an overview of all the technical measures reviewed in the study. For each of the technologies review it sets out:

- the operation of the measure and its impact on emissions;
- fuel requirements;
- maintenance issues;
- and cost information.

The types of measures review have been grouped into 5 main categories:

1) Exhaust emissions retrofit measures
2) Alternative liquid fuels
3) Alternative gaseous fuels
4) Complimentary measures
5) Other measures

The measures in each of these categories are described in the sections below.

1. Exhaust Emissions Retrofit Measures

1.1. Diesel Oxidation Catalyst (DOC)

Heavy Duty diesel engines up to Euro 4 level have generally achieved emission reductions through engine modification. For light duty vehicles (including those used as taxis) oxidation catalysts have been in use for some vehicles since Euro 2. Over 1.5 million oxidation catalysts have been fitted to new heavy-duty trucks in the US since 1994 although they have not been much used as a retrofit technology in European on-highway vehicles since the 1980's. They are of interest in some of the less developed markets. Whilst they are often applied to older engines which are generally perceived to be unsuitable for particulate filter systems, it should be noted that a Saurer bus of 1948 vintage has been successfully fitted with an HJS trap system[9].

Operation, control and impact on emissions

As measured by mass within the regulatory filter test protocol, particulate matter (PM), or total particulate matter (TPM) is composed of three major fractions including the carbonaceous particles (soot), the organic particles – soluble organic fraction (SOF), and sulphates (SO_4). Each of these fractions behaves differently over diesel oxidation catalysts. Oxidation catalysts reduce the SOF fraction but have little effect on the carbonaceous portion of PM in the diesel exhaust. This limits the amount of reduction the DOC can achieve. The maximum reduction is dependent upon the magnitude of the SOF in the engine out exhaust and is typically between 20 and 40%. The sulphate fraction of diesel particles (SO_4) is increased in the DOC due to the oxidation of SO_2 with subsequent formation of sulphuric acid. Under certain conditions, however, the SOF decrease can be more than offset by an increase in

[9] Dieselfilter-Nachrustung einer Antiquitat: F. Legerer: Osterreichische Ingenieur- und Architekten-Zeitschrift 2005

sulphate PM, leading to an overall increase in TPM emission, therefore low sulphur fuels and special catalyst formulations are necessary to limit the formation of sulphate particles from sulphuric acid in the exhaust gas.

Diesel engines have inherently low CO and HC emissions which can be further reduced by application of a DOC. DOCs have no impact upon overall NO_x emissions. However, DOCs are known to increase the proportion of NO_2 in the exhaust. When testing a heavy-duty DOC with a high Platinum coating, VERT found NO_2/NOx ratios of 10% at around 220°C exhaust gas temperature rising to ratios between 40 and 45% in the range 310°C - 390°C [10]. However, it is not absolutely clear whether the DOC used in these tests was a standalone oxidation catalyst intended for oxidation of PM, HC and CO, or one intended for production of NO_2 to assist downstream regeneration of a DPF (see also comments below relating to NO_2 generation in DPF systems).

From work carried out during the UNECE Particulate Measurement Programme, measurement for solid particle number (PN) of particles below 1000nm aerodynamic diameter, may be introduced in Euro 6 [11]. It could be expected that particle number counts downstream of DOCs would be at least equal to that in engine pre-catalyst exhaust.

Fuel requirements

Generally, oxidation catalysts can be used with fuels up to 500ppm sulphur, but some of the sulphur in the fuel will be converted to sulphate which also contributes to PM emissions. The amount of sulphate formed depends on the strength of the oxidation catalyst and the gas temperature. Sulphates will form at around 350°C. Catalyst formulations have been developed which selectively oxidise the SOF whilst minimising sulphate formation. However, with current market fuels having sulphur levels of 50ppm and likely to reduce further, on-road fuel availability in Europe presents no barrier to the use of oxidation catalysts and generally allow higher levels of PM reduction.

Operation and Maintenance

Oxidation catalysts have been retrofitted to over 750 000 on-road and off-road vehicles worldwide[12]. Oxidation catalysts are essentially maintenance free up to any need for replacement and, if properly applied present little or no impact on fuel consumption (<0.5%). However, the increased presence of sulphuric acid in the exhaust can increase corrosion of silencers leading to earlier replacement.

Costs

DOCs cost between €350 for a small replacement catalyst-silencer to €1500 for a full modular system on an 8 litre engine fitted to large vehicle. Cost is dependent on size, volume, configuration and degree of engineering. Large fleets in the order of 100 or more can promote up to 20% cost reduction. Costs vary also with content of platinum which is increasing in cost on the market, and its partial substitution by palladium.

There is no significant impact on operational cost, other than ultimate replacement.

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[10] Diesel NO_2 Emissions with Different DPFs and DOCs: J Czerwinski, J.L.Petermann, A.Mayer, J.Lemaire: 2006

[11] Diesel and CNG Heavy-Duty Transit Bus Emissions over Multiple Driving Schedules: Regulated Pollutants and Project Overview: A. Ayala, Norman Y Kado, Robert A. Okamoto, Britt A. Holman, Paul A. Kuzmicky, Reiko Kobayashi, Keith E. Stiglitz: SAE 2002: UN-GRPE PMP working papers: PMP Working Groups 14 – 17

[12] Retrofitting Emission Controls On Diesel Powered Vehicles: MECA 2006

Conclusion

DOCs reduce PM emissions by between 20 (Euro 2/3)and 40%, (pre-Euro 2). They increase NO_2 and sulphates, and do not reduce particle number counts, probably even increase ultrafines. The DOC may appear cost effective due to their low cost, however, the above concerns, coupled with potential precious metal emissions suggest that DOCs should not be considered as a long term HDV retrofit technology for PM reduction.

1.2. Diesel Particulate Filter (DPF)

Diesel Particulate Traps (DPF) primarily comprise a filter through which the exhaust gas passes whilst the particulate material is deposited within the filter. As the filter becomes more loaded its resistance to flow increases requiring it to be cleaned of particulate matter or “regenerated”.

Operation, control and impact on emissions

A number of different filter materials have been employed in diesel particulate filters. These include fibre wound cartridges, knitted silica fibre coils, ceramic (cordierite) and silicon carbide, ceramic foam, wire mesh and sintered metal structures. Perhaps the most common filter employed for heavy-duty automotive applications is the high efficiency wall-flow cordierite or silicon carbide filter. These filters have been demonstrated and certified to give particulate mass reduction of greater than 90% although performance in service is more likely to be between 85 and 95% reduction. They also demonstrate outstanding reduction of all sizes of solid particles 10-1000nm in the order of 99%. It should be noted that the overall 90% PM reduction is due to condensate measured by the current gravimetric systems employed in homologation tests.

Regular and efficient regeneration of the filter in service is a key function of its continued efficient operation. There are a number of methods employed, principally divided into “passive” or “active” systems. There are essentially two types of active systems: those which regenerate periodically using an additional energy source to raise temperature and those which use active controls to change the conditions in the exhaust system. The principle methods of regeneration are described below;

Passive Systems

- Base or precious metal catalyst applied to the filter surfaces reduces the ignition temperature required to oxidise the accumulated particulate matter.
- Continuously Regenerating Trap® (CRT®) diesel particulate filter system comprising an oxidation catalyst followed by a particulate filter. The oxidation catalyst placed upstream of the filter oxidises nitric oxide (NO) to nitrogen dioxide (NO_2). The NO_2 reacts with the accumulated particulate and reduces the temperature required to regenerate the filter. In some application the filter may also be catalysed (CCRT®)
- Fuel borne catalysts can also be considered as an active system. They employ a fuel additive (normally iron, cerium or platinum based) which is either injected into the fuel line or dosed into the vehicle’s fuel tank. The soot emitted from the engine becomes impregnated with catalyst. The catalytic effect

lowers the temperature required for combustion of the accumulated particulate matter.

Active Systems

- Throttling of the intake air to one or more cylinders can increase exhaust temperature thus initiating combustion of the accumulated particulate matter.
- Post top dead centre (TDC) fuel injection into the cylinders introduces unburned fuel into the exhaust gases. This can also be effected by injection into the exhaust system. Oxidation of the fuel within or upstream of the filter can then be used to combust the accumulated particulate matter.
- Fuel burners or electrical heating elements within or upstream of the filter can be used to assist combustion of the accumulated particulate matter.
- Valves for thermal management of the aftertreatment system
- Remote "off-board" electrical heaters can provide hot air to assist combustion of the accumulated particulate matter.
- Whilst not strictly an on-board regeneration process, some systems simply replace the filter element with a new or cleaned filter.

Currently, the most widely used systems for retrofit heavy-duty automotive applications are those employing passive regeneration either with catalysed filter media or with, continuous regeneration and fuel borne catalyst systems. It should be noted that in Switzerland the largest retrofit activity, albeit applied to construction machinery, has shown an increase from 25 to 35% of active filter systems (burners, catalytic burners, electric heating etc). Although development of active systems pre-dates that of passive systems, with a few exceptions application of active systems is limited on on-road heavy-duty vehicles in Europe. However, there is continuing development in this area.

Whilst filters with active regeneration systems can be applied to all types of engines, filters employing passive regeneration systems, including continuous regeneration and catalysed filter media are more generally applied to heavy-duty engines Euro 1 and later. Both types of system do not nominally impact upon total NO_x emissions although in the case of CRT® systems there is some indication of a small NO_x reduction, probably caused by the catalysed reduction of NOx by hydrocarbons. However systems with very strong catalytic action can increase NO_2 significantly. NO_2/NOx ratios of 10% have been noted at around 200°C exhaust gas temperature rising to ratios up to 50% in the range 300°C - 350°C[13]. When conducting chassis dynamometer tests on city buses EMPA observed higher NO_2:NOx ratios at medium/low speed and load, synonymous with city driving conditions[14]. In a paper presented at SAE 2006, Koltsakis demonstrated increased oxidation efficiency of NO at low space velocity compared with similar tests at high space velocity in laboratory scale reactors[15]. Therefore NO_2 formation rate appears to be more complex than being only dependent on exhaust temperature. Key factors are at least Pt loading of

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[13] Diesel NO_2 Emissions with Different DPFs and DOCs: J Czerwinski, J.L.Petermann, A.Mayer, J.Lemaire: 2006
[14] Emissions measurement on CRT-equipped city buses on chassis dynamometer: L. Emmenegger et al: EMPA 2004
[15] Design and Application of Catalyzed Metal Foam Particulates Filters: G C Koltsakis: LAT – Aristotle University Thessaloniki: SAE 2006-01-3284

DOCs upstream of filter, temperature and space velocity in these DOCs and possible Pt coating in the DPF itself.

This is of concern, particularly in inner city areas where a significant proportion of the population will be exposed to primary NO_2. As part of its control equipment verification programme CARB has proposed a post-control NO_2 emission limit to be introduced from 2007, applicable to both new and existing verifications. The new limit is defined as a maximum incremental increase of 30% over the baseline NO_2 emission level to become 20% from 2009.

Continuously Regenerating Trap® systems require a NO_x:soot ratio 20:1 and min exhaust temperature of 250°C to regenerate. Systems employing fuel borne catalysts have limited impact upon NO_x. Nor do they increase NO_2 emissions, in some cases substantially reducing NO_2. These systems are also more suitable for older pre-Euro 1 engines.

Active regenerating systems without oxidation catalyst support using precious metals do not increase NO_2 and therefore may increase in population in future.

Diesel engines have inherently low CO and HC emissions. These are generally further reduced by over 80% by application of catalysed and continuously regenerating traps. It should be noted that FBC systems do not reduce CO and HC unless the system incorporates a DOC.

Regeneration of FBC based systems is not continuous and is dependent on achieving a temperature at the front face of the filter sufficient to initiate combustion of the retained soot. This may be as high as 400°C.

CRT® systems generally require an average of around 250 - 275°C for 40% of operational time for reliable regeneration. If operated over long periods of time without soot combustion, either due to low temperature operation or due to lack of additive, the mode of regeneration of FBC based systems could potentially lead to increased exhaust back pressure, leading to increased engine load with associated increases in CO_2 and possibly NO_x emissions. In extreme cases this could also result in a high temperature exothermic reaction that could be detrimental to other emissions reduction technology it may be combined with e.g. SCR systems. These generally use vanadium based catalysts as a basis for NOx reduction and may be degraded by high temperature operation.

In terms of application to heavy-duty vehicles, catalysed trap and CRT® systems perhaps offer the most practical approach of all DPF systems, having no external additive supplies and associated controls; nor do they require interface with engine management functions to initiate, for example, throttling of intake and exhaust. This needs to be weighed against the increasing concern over increased NO_2 emissions

A more recent technology is the particle oxidation catalysts (POC, partial-DPF or flow-through filter). These systems employ catalysed wire-mesh structures or tortuous flow metal foil based substrates with sintered metal sheets to reduce diesel particulate. They have the potential to reduce PM reductions by around 50% and have the “advantage” of not becoming clogged or needing maintenance. However, this attribute may cause degradation of the filtration efficiency of the filter and so could be of concern from an air quality standpoint. Furthermore the impact on the reduction of ultrafine particles needs further investigation. These systems can be very useful for reducing PM emissions in applications not suitable for full flow DPFs, for example with high sulphur fuel or with engines emitting high PM levels. They are approved in the US at CARB Level 2 certification which requires PM reduction of 50%. It should be noted that MAN uses this technology for its Euro 4 engines.

Fuel requirements

Sulphur in fuel significantly affects the performance of catalysis based DPFs which work best with sulphur levels of less than 50ppm. The main effect on CRT® and catalysed systems is an increase in the exhaust temperature required for regeneration. Systems employing fuel borne catalysts have been successfully demonstrated with sulphur levels of 500ppm. Active systems appear more sulphur tolerant than passive.

Operation and Maintenance

In the UK the whole of the London bus fleet – over 6800 buses - is now equipped with diesel particulate traps, most of which employ a regeneration systems based on catalysis. Whist initially there were a number of reliability issues, over the past 5 years, since introduction, maintenance and reliability has improved. It has been a contributing factor to the increase in ambient NO_2:NO_x ratio measured in London which has multiplied by 3 between 2002 and 2006[16], other contributing factors include increased proportion of diesel vehicles and changes in fuel quality; also the number of hours per year exceeding 200µg/m3 in Central London has increased from about 60 in 2001 to close to 600 in 2004; in 2010 this number of events is required to be lower than 18.

In Sweden more than 4000 buses have been equipped with passive filter systems.

In Switzerland more than 15 000 on-road and off-road vehicles are equipped with DPFs with an increasing % of active systems. At least 80 000 buses worldwide and 60 000 fork lifts are DPF-equipped. (A total of 200 000 retrofits is estimated by TTM).

OE-applications are now in excess of three million.

Diesel Particulate Traps can be fitted in conjunction with exhaust gas recirculation (EGR), selective catalytic reduction (SCR) and Lean NOx traps to make significant reductions in NOx and PM levels. Engines equipped with combined SCR and DPF systems can make reductions of 60-80% NO_x and over 90% PM as long as the duty cycle can promote high enough exhaust temperatures. In combined SCR and DPF systems employing DPFs with catalysed regeneration systems it is normal practice to mount the filter upstream of the SCR catalyst as close to the engine as possible in order to maximise operating temperature and such that the SCR system can benefit from increased NO_2 in the exhaust which increases NOx conversion at low temperatures However, as noted above, DPF systems mounted upstream of an SCR system may present the potential for high temperature exothermic reaction if duty cycle is not matched or the system suffers severe malfunction. Systems employing active regeneration systems which are less dependent on high exhaust temperature for filter regeneration, can be mounted downstream of the SCR catalyst. This approach does not result in an increase in NO_2.

The effect on fuel consumption is generally accepted to be around 1%. However, this can rise to 3% or higher if regeneration is insufficient.

Diesel Particulate Traps therefore require regular cleaning. This involves removal of the filter from the vehicle, baking in a kiln and washing to remove residual ash. The

[16] D.Carslow, Leeds University: Second Conference on Environment and Transport: Reims June 2006

cleaning frequency is dependent on duty cycle and mileage. Typical manufacturers recommendations are:

- Trucks – once per year
- Buses – twice per year
- Fire tenders, Refuse vehicles – four times per year

The use of lubricating oil with low sulphated ash content should always be considered in association with DPF operation.

Costs

CRTs and passively regenerating DPFs cost from €3000 to €7000 depending on vehicle size and complexity of the application/engineering. Largest single cost is the filter element which would reduce with volume. However another significant cost is platinum which does not reduce with volume.

Systems employing fuel borne catalyst cost from €3000 to €10 000 depending on vehicle size and complexity of the application/engineering and volume required. For OEM implementation cost could reduce to €6000 per vehicle. Competition between the different DPFs is also likely to level out costs. Therefore when considering system costs for the purposes of cost effectiveness modelling, it is assumed that the costs of all types of system will be of a similar order.

Partial flow filter systems for small applications are quoted as less than €3000.

Cleaning of filters costs in the order of €300 to €350. Other estimates place the cost as high as €900 Euro if sent in back to supplier. This is considered high.

Conclusion

Full flow DPFs reduce PM by 90% for particulate mass and in excess of 99% for particles in the size range 10 – 1000nm. There are two main types of DPF. Catalysed DPFs offer the most practical solution to PM reduction. However, these systems need duty cycles that enable continuous regeneration and can increase NO_2. Systems employing fuel borne catalysts or active regeneration offer no increase in NO_2 but can present more complex application challenges, sometimes needing interaction with the operational mode of the vehicle.

Particle oxidation catalysts, partial-DPF or flow-through filter systems reduce PM reductions by around 50%. However the ultrafine particles reduction will be less than full flow filters.

The different full flow DPFs are considered to be the most important technology for particulate emissions reduction and should be prioritised.

1.3. Exhaust Gas Recirculation (EGR)

Retrofitting exhaust gas recirculation on a diesel engine offers an effective method of reducing NOx emissions. Both low-pressure and high-pressure EGR systems exist. The high pressure route is favoured by OEMs but low-pressure is used for retrofit applications because it does not require fundamental engine hardware modifications. However, it is only applicable for use in urban operations.

Operation, control and impact on emissions

EGR involves recirculating a portion of the engines exhaust back to the charge air inlet of turbocharged engines, or intake manifold, in the case of naturally aspirated engines. In most systems an intercooler lowers the temperature of the recirculated gases. The cooled recirculated gases have a higher heat capacity than the normal ambient air and contain less oxygen, thus reducing combustion temperature and inhibiting NOx formation. However, due to the NO_x:PM trade off relationship, higher PM engine out emissions are produced which are usually reduced by use of a DPF. Recirculated exhaust gases are usually taken from downstream of the DPF so ensuring that large amounts of particulate matter are not recirculated to the engine which could result in excessive lubricating oil loading. However, in the case of naturally aspirated engines the pressure balance between the exhaust taken from downstream of the DPF and the intake air conditions will need to be favourable to ensure recirculation. EGR systems are capable of achieving NO_x reductions of between 40 and 60%.

An advantage of EGR is that it does not require additional fluid or the related distribution network as is required with SCR systems (see below). However it has the disadvantages of slight reduction in vehicle performance, slight increase in fuel consumption and increased maintenance of engines. There is also a potential risk of accelerated engine wear which needs to be considered.

Operation and Maintenance

Demonstration on two Euro 2 double deck buses in the UK has shown NO_x reductions of 54 and 48% over the standard Euro 2 bus[17]. These reductions were accompanied by increases in fuel consumption of 7.5 and 1.1%

Results from FTP engine dynamometer tests presented by the system supplier at the 2003 SAE World congress showed NOx reductions of 46 – 58% over Cummins 2000MY and International 2001MY engines[18]. These reductions were accompanied by a 2% increase in fuel consumption.

Costs

The cost of retrofitting an EGR system to a truck or bus ranges from €14 000 to €16 000 depending on vehicle size and complexity of the application/engineering.

Conclusion

EGR reduces NOx by up to 50%, and does not require addition of reductant as with SCR systems. For retrofit, low pressure EGR is required, limiting the application to relatively low speed operation - as in urban areas. Therefore, retrofit EGR is only relevant for buses and delivery vehicles less than 7 tonnes. The increase in particulate emissions and risk of accelerated engine wear requires that they are fitted in conjunction with a DPF, resulting in similar capital cost to a combined DPF+SCR system, so where possible DPF+SCR should be favored.

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[17] Emissions database: TfL: 2006

[18] NOx and PM Control from Heavy-Duty Diesel Engines using a Combination of Low Pressure EGR and Continously Regenerating Diesel Particulate Filter: S Chatterjee, R Conway, S Vishwanathan et al: Diesel Exhaust Emissions: Control: SAE 2003

1.4. Selective Catalytic Reduction (SCR)

SCR systems have been applied to stationary sources for many years and with the advent of Euro 4 emissions regulations are becoming more prevalent as OEM fit equipment on heavy-duty vehicles. Applying SCR to diesel powered vehicles provides simultaneous reductions of NOx, PM and HC emissions.

Operation, control and impact on emissions

SCR systems use a metallic or ceramic wash-coated catalysed substrate, or a homogeneously extruded catalyst and a chemical reductant (ammonia) to convert nitrogen oxides to molecular nitrogen and oxygen in an oxygen rich environment as found in diesel engine exhaust. In Europe, the chosen route of engine and vehicle manufacturers is to use aqueous urea solution with 32.5% urea as the reductant. This is also used for retrofit applications, although some systems use liquid ammonia as a reductant. Liquid ammonia is used at 16% concentration to achieve the same effect per litre as urea.

Both open loop and closed loop systems are available. Open loop systems use an algorithm to determine the amount of reductant required based on engine speed, exhaust temperature, load etc. Closed loop systems are sensor based. SCR systems can reduce NOx by up to 85% although 60 – 80% is typical for retrofit systems. The level of conversion depends not only on careful matching of the system to the engine but ensuring that the vehicle is matched to the duty cycle. Experience in London has demonstrated that it is feasible to maintain exhaust temperatures in excess of 300°C in normal operation[19]. Conversely, in Paris, where bus engines are generally larger than those operated in London, exhaust gas temperature has been found to be often lower than 200°C in the congested traffic conditions experienced in normal operation.

HC emissions can be reduced by up to 80% and PM emissions by 20 – 30%. It should be noted that, as with diesel oxidation catalysts, principally only the SOF is reduced, leaving the carbon essentially unaffected. However, there is possibly some soot reduction due to presence of NO_2 and low space velocity in the catalyst. Performance is enhanced by the use of low sulphur fuel which is also a requirement when the system is fitted with a CRT®.

The potential for "ammonia slip" is a characteristic of SCR systems. If an additional catalyst is used downstream of the main SCR system to convert ammonia, this can result in increased N_2O emissions. N_2O is a greenhouse gas, 310 times stronger than CO_2.

OEMs have been able to meet Euro 4 emission limits with SCR and no additional aftertreatment for PM reduction, resulting in Euro 4 vehicles having higher PM and particle number emissions than Euro 3 engines with retrofit DPFs.

For retrofit applications SCR systems are usually fitted in conjunction with a full flow DPF, providing high levels of PM and ultrafine particle reduction as long as the duty cycle can promote high enough exhaust temperatures. SCR is not active when inlet temperature drops below 200°C as documented by in SAE paper 2005-01-1862[20]. NO_x and therefore NO_2 reduction is nil in this temperature range.

[19] Discussion STS/TfL: 2006

[20] Combined SCR and DPF Technology for Heavy-Duty Diesel Retrofit : R Conway, S Chatterjee, A Beavan et al: SAE 2005

Fuel requirements

Combinations of SCR and DPF require fuel with sulphur levels of less than 50ppm. SCR alone does not require reduced sulphur content.

Operation and Maintenance

Retrofit SCR systems are an emerging technology option. Over 100 mobile SCR retrofit systems have been fitted in the US since 1995 and several hundred systems have been retrofitted to heavy-duty vehicles in Europe.

Costs

The estimated cost for city bus with a Euro 3, 8 litre engine is in order of €10 000 for low volumes anticipated (without DPF) or €15 000 with DPF. Urea usage is of the order of 5% of fuel consumption for retrofit applications. The cost of urea solution is around €0.60/litre. This results in urea cost of around €0.60/100 km for a 16 tonne rigid truck, €1/100 km for a 40 tonne truck and €1.70/100 km for a large bus operating in an urban environment.

Conclusion

Using ammonia (either as 32.5% urea solution in water or as 16% liquid ammonia) as a reductant, NOx emissions can be reduced by up to 85%. SCR systems require a minimum of 200°C exhaust temperature, so system, engine and duty cycle need to be matched. Therefore SCR, preferably in conjunction with DPF, should be prioritised as a retrofit option for NOx and PM control.

1.5. Lean NOx Traps

Lean NOx traps (LNT) are currently the technology of choice for treating the NO_x emissions from lean-burn gasoline engines and is still an emerging technology for removing NO_x in lean diesel exhaust.

Operation, control and impact on emissions

In LNT technology Nitric Oxide (NO) is catalytically oxidised to Nitrogen Dioxide (NO_2) and stored in an adjacent trapping site as a nitrate. The stored NO_x is removed in a two-step reduction process by temporarily inducing a rich exhaust condition using a pulsed charge in fuelling i.e. using diesel fuel as a hydrocarbon reductant. This gives an advantage over SCR systems of not needing to provide an additional reductant.

NO_x adsorbers employ precious metal catalyst sites to carry out the NO to NO_2 conversion step. The NO_2 is then chemically stored in alkaline-earth oxide as a nitrate. To operate effectively, the NO_x adsorber must remain stable for extended periods, during which time the exhaust environment modulates between rich and lean conditions.

Lean NOx Technology can produce very high NOx conversion efficiencies (70 – 90%) when new. Unfortunately, Lean NOx Traps are drastically poisoned by sulphur dioxide (SO_2) derived from the sulphur in the fuel. This reacts catalytically with oxygen and then with the NO_x storage components, such as $BaCO_3$, forming stable sulphates and rendering the adsorbing capabilities of the system ineffective. In addition, SO_2 can be catalytically converted to sulphate in the exhaust stream, resulting in higher particulate emissions.

Fuel Requirements

The higher sulphur dioxide concentration in the exhaust, the faster poisoning occurs. LNT is also sensitive to sulphur content of engine oils. Therefore very low Diesel sulphur fuel (<5ppm – even <1ppm) does not necessarily prevent sulphur poisoning as sulphur content of the lubricant becomes very important and must also be reduced to minimise the poisoning effect. LNT requires regular desulphation strategy. De-sulphurisation requires temperatures in excess of 600°C, difficult to achieve easily in diesel operation.

Costs

Based on US information the cost to fit a combined LNT+DPF system to a heavy-duty truck is in order of €12 000 to €16 000 including the DPF

Conclusion

LNT can reduce NOx by 70–90% when new, however it is not considered in the EU due to cost, fuel non-flexibility, efficiency, complexity of control and durability. There is now no LNT development in the EU, so it is not a current retrofit option.

1.6. Repowering / Re-engining

Repowering involves replacing an old engine with a more modern one to achieve better emissions performance from an existing vehicle. This can be expensive, so is only likely to be worthwhile in vehicles that are likely to have a long service life, such as refuse collection vehicles, buses and airside vehicles.

Operation, control and impact on emissions

Repowering can lead to reductions of all regulated pollutants, lower fuel consumption and improved reliability, although this can vary significantly from case to case. Replacing a pre-Euro engine with a Euro 2 engine in a bus could lead to reductions of around 60% for PM and 40% for NOx, depending on duty cycle. However, replacement of a Euro 2 engine with a Euro 3 engine may result in no benefit to NOx emissions. In certain cases these have been known to increase. With the inclusion of the European Transient Cycle in the heavy-duty homologation requirements, repowering to Euro 4 would be expected to provide both NOx and PM benefits, although these may not be significant in real world conditions. Reductions in particle number may, however, not be as significant as might be expected and needs to be assessed against emerging data. As Euro 5 engines are already becoming available, repowering with Euro 5 engines is considered more effective, both in respect of regulated emissions but also of emissions of greenhouse gases, as these engines offer up to an 8% saving on fuel. In all cases it is important to ensure that the new engine will be properly matched to the vehicle transmission. This may require the transmission to be replaced also. Furthermore, repowering older vehicles with newer engines which have electronic control is likely to require the introduction of new power and control sub-systems. Therefore whilst repowering might be attractive for vehicles with long service life, offering a route to extended life, improved reliability and potentially lower operating and maintenance costs, it may prove to incur a high initial cost.

Costs

Typical costs for repowering to Euro 3 with a heavy-duty engine are in the region of €16 000 to €24 000 for the basic engine and fitting. This cost should be considered against the cost to repower the vehicle on a like for like basis i.e. with a remanufactured engine of the same Euro level. The cost to repower would be increased if the gearbox is also replaced. Costs to repower to Euro 4 have yet to be established.

Conclusion

Due to the expense, repowering is aimed at vehicles with a long service life, such as refuse collection vehicles, buses and airside vehicles. As Euro 5 engines are already becoming available, repowering with Euro 5 engines is more effective than with Euro 4 engines for both regulated and greenhouse gas emissions due to their 8% fuel saving.

2. Alternative Liquid Fuels

There are a number of alternative liquid fuels becoming available, produced by a variety of methods which can be used as blends with conventional diesel or as 100%. The fuels considered are ethanol, biodiesel (or Fatty Acid Methyl Ester – FAME) and synthetic diesel. These fuels share distinct advantages over gaseous fuels:

- No requirement for special distribution infrastructure apart from transport to existing refineries and depots
- Little or no modification to existing vehicles
- Can be used in various proportions as blends with conventional fuels in relation to their availability.

These fuels, when used in blends up to 5% with conventional fuels, have no significant effect upon the energy efficiency of the vehicles. However, blends with oxygenated components tend to produce higher levels of aldehydes than conventional diesel.

Di-methyl-ether or DME does not share the above advantages but is available as a direct substitute for diesel fuel and can be produced in a similar way to synthetic diesel. DME is gaseous at ambient conditions but can be liquefied under moderate pressure. However, compared with the other fuels considered, it requires a dedicated distribution infrastructure and modification to vehicles to allow its use.

2.1. Di-Methyl-Ether (DME)

DME is currently used on a very small scale, around 150 000 metric tonnes per year, mainly as an aerosol propellant for the cosmetics industry.

DME is synthesised from syngas, and can therefore be produced from a range of feedstocks. The most likely feedstock in the short term is natural gas, but coal or wood can be envisaged. Asia is considered the first market for DME to break through. DME Development Co is working to validate a direct synthesis process in Japan. China is to start construction of its largest DME project with an annual output of three million tonnes to reduce rising oil consumption.

Operation, control and impact on emissions

As a fuel for compression ignition engines, DME has very attractive characteristics. It is an oxygenated fuel with 35% wt oxygen with a high cetane number (68), burning very cleanly and producing virtually no particulates. The lower heating value of DME is, however around 66% of conventional diesel fuel. It is also less dense. It therefore requires around 1.49% more fuel per injection stroke when compared with conventional diesel.

In a study on DME as an alternative fuel for diesel engines for CANMET Energy Technology Centre and Transport Canada, Advanced Engine Technology Ltd found emissions of PM were reduced by 75% and NOx emissions by 5.9%[21]. These results were obtained following development and modification of the injection system and engine to run on DME. Further NOx reductions were anticipated through optimisation of injection timing. Methane emissions, however, increased by 24%, admittedly from a very low baseline. Total HC (THC) emissions, mainly unburned DME increased by 237%.

Due to the lower flashpoint and higher vapour pressure as compared with diesel, additional safeguards were needed to minimise the potential for fire or explosion. There are additional concerns regarding compatibility of materials with DME.

In a paper presented at SAE 2006[22] AVL concluded that as DME combustion is virtually soot free, it would allow high rates of EGR to reduce NOx emissions. Combined with strategies to counter the longer injection durations needed it is considered that DME fuelled engines might be able to meet US 2010 heavy-duty emissions legislation without further exhaust aftertreatment.

Costs

At the time of writing no costs for sales at automotive volumes of DME are available.

2.2. Ethanol

Ethanol is a well established substitute for gasoline in spark-ignition engines and is now firmly established as an alternative fuel in Sweden where it is used both as a low (5%) blend in all gasoline and as an 85% blend for “Flex Fuel” vehicles. As far as heavy-duty vehicles are concerned it has been successfully applied as 92.5% ethanol plus cetane improver and other additives. This fuel is 50% renewable. The engine used in Sweden is a development of the 9 litre compression ignition Scania engine. Around 600 ethanol buses have been delivered so far. Scania is now developing its third generation ethanol engine, planned to be ready for introduction in late 2007

Operation, control and impact on emissions

The current Scania ethanol engine generation introduced in 1996 reaches Euro 4 levels, which will be required from October this year. Scania will introduce an ethanol bus meeting Euro 5 emissions levels later in 2006.

[21] A Study of Dimethyl Ether (DME) as an Alternative Fuel for Diesel Engine Applications: C Gray, G Webster:Advanced Engine Technology Ltd 2001

[22] Can Heavy-Duty Diesel Engines Fueled with DME Meet US 2007/2010 Emissions Standard with a Simplified Aftertreatment system: H Teng, J C McCandless: New Diesel Engines and Components and CI Engine Performance for Use with Alternative Fuels: SAE 2006

Whilst it would appear feasible that existing heavy-duty diesel engines could be converted to run on ethanol by retrofit measures, it is not considered a practical proposition due to being an extremely niche market with one established OEM player. It can be argued that competition within that market is desirable but until sufficient market pull is generated this is unlikely to occur, however the joint certification scheme and further exporting of the Swedish experience may encourage this market.

Costs

As with most new or low volume technologies, the additional purchasing cost varies with the kind of contract agreed with the provider.

Stockholm has during the last 10 years paid approximately €10 000 extra per bus, compared to a ordinary diesel bus.

A few factors may influence this price difference:

- economy of scale - currently, Stockholm is almost the only buyer of these buses, except for a few small pilot fleets in Italy, Spain, NL and Poland
- Public Transport buses are generally over-priced - due to the fact that each city requires it's own standard and the series hence are small.
- next generation of ethanol buses, where experiences from first generation should lead to cheaper construction. However this might be reflected in increased performance rather than lower price.
- upcoming emission standards - Euro 4, and especially Euro 5 will make conventional diesel buses more expensive

Information from the ethanol bus operation in Stockholm showed that the average fuel cost per kilometre of ethanol fuelled buses was between €0.36 and €0.39/km compared with an equivalent cost for diesel of €0.37 to €0.38/km. However this is based on an average consumption of 69litres/100km of ethanol compared with 41litres/100km for diesel. The cost of ethanol in Sweden is stated as €0.537/litre and diesel as €0.906/litre.

The total operating cost, including maintenance per kilometre was between €0.62 and €0.742/km compared with an equivalent cost for diesel of €0.539 to €0.653/km.

2.3. Fatty Acid Methyl Esters (FAME)

Fatty Acid Methyl Esters or FAME, are produced by reacting vegetable oils with methanol. The operation stabilises the oil and makes it suitable for use as a standard diesel fuel component. They can be used without problems in standard diesel engines as blends up to 5% with conventional diesel. They can be used in blends up to 100% but are liable to the formation of gums and are therefore not acceptable as a mainstream product. However, Scania and DAF have recently announced that B100 can be used in its new trucks, subject to meeting EN14214 and adhering strictly to service requirements. Renault also support B30.

Operation, control and impact on emissions

As part of the Particulates programme for DG TREN, Concawe tested a number of fuels. The presence of 5% FAME in 10 ppm diesel showed no impact on PM or NOx. In principle, the presence of oxygen in the fuel tends to produce less soot, which is confirmed by extensive literature. However, FAME has a high boiling range, in the back-end of diesel distillation, and this can lead to higher emissions of hydrocarbons in some cases, particularly under cooler, e.g. city, driving conditions. The overall effect on PM emissions is therefore variable and depends on driving conditions. Whilst biodiesel content in EN590 is limited to 5%, higher percentages (30% typical) have been used for captive fleets.

Results of tests on RME/diesel blends up to 100% reported to SAE in 2005[23] concluded that RME does not worsen emissions but also provided no significant emission benefits. Despite curtailing soot a DPF is still considered necessary.

The Finnish oil company Neste Oil is currently building a plant for production of hydrogenated biodiesel (NExBTL). The process can use a variety of fatty acids as feedstocks, resulting in a paraffinic diesel resembling Gas to Liquid (GTL) that can be used as such in existing vehicles, with significant emission reductions claimed. Compared with EN 590, PM reductions of 30%, NOx reductions of 15% and CO_2 reductions anywhere between 60 and 85% are claimed depending on the feedstock. The capacity of Neste's plant will be 170 000 t/a, and they have signed Memoranda of Understanding (MOUs) with Total and ÖMV on additional plants (200 000 + 200 000 t/a). Some 600 000 t/a is actually sufficient for a very large number of buses in Europe.

Costs

Biodiesel (to fuel standard EN 14214) tends to cost more than regular diesel to produce. Therefore appropriate tax regimes need to be adopted in order to encourage take-up. For instance, in July 2002, to compensate for these additional costs and to encourage the production and use of this fuel, the UK Government reduced the tax on biodiesel by 20 pence per litre. As a result, biodiesel pump prices are now roughly the same as standard diesel.

2.4. Synthetic Diesel (Fischer-Tropsch)

Fischer-Tropsch is a generic name for fuel produced from a range of feedstocks via gasification. Feedstocks for Fischer-Tropsch process can be highly varied. The principle source, natural gas (GTL) is convenient but not a future solution. Volumes are limited today but expected to increase significantly before 2020; however its contribution to world demand is expected to be limited to around 4%. Its main use is expected to be as a blending component in conventional diesel but limited volumes may be available for fleet use. Synthetic diesel can also be produced from coal. Sasol has a large production based on gasification of coal and still produces about 160 000 barrels per day of Fischer-Tropsch products. Production from biomass provides advantageous life-cycle Greenhouse Gas emissions but supplies are not yet commercially available.

Fischer-Tropsch products are composed almost exclusively of paraffins and olefins. They contain very little aromatic compounds. Furthermore, they are practically free from sulphur, as well as from other compounds that are found in crude oils, such as nickel, vanadium, or nitrogen.

[23] Impact of RME/Diesel Blends on Particle Formation, Particle Filtration and PAH Emissions: A Mayer, J Czerwinski, M Wyser, P Mattrel, A Heitzer: CI Performance for use with Alternative Fuels, and New Diesel Engines and Components: SAE 2005

A very important feature of synthetic fuels is their compatibility with existing diesel engines. The only adjustment that may be required is increasing the lubricity of fuel in order to prevent excessive wear of the fuel injection system, achievable using commercial lubricity additives.

Compared with current production diesel fuels, Fischer-Tropsch diesel is expected to reduce NOx by around 10% and PM by around 25-30%.

Costs

At the time of writing no costs for sales at automotive volumes of DME are available.

2.5. Diesel Water Emulsion (DWE)

This fuel cannot be regarded strictly as an alternative liquid fuel, but is placed in this category for convenience of grouping. It is based on homologated Diesel fuel with around 10% water and 1-2% additives. These additives keep water droplets in emulsion with diameter centred around 700nm. Water droplets of this size are important to allow diesel droplets vaporisation and emulsion stabilisation during storage. The fuel has gained popularity in Europe, notably in Italy, and also in Scandinavia. The European Emulsion Fuel Manufacturers' Association (EEFMA) established a CEN[24] Workshop Agreement in 2005 to promote Europe-wide emulsion fuel technical requirements.

Operation, control and impact on emissions

The water suspended in the fuel creates a cooling effect in the combustion chamber thus inhibiting NOx formation. Lower PM formation is also claimed. Tests carried out for Norwegian Public Road Administration reported a reduction in NOx of 11% and a reduction in PM of 62%[25]. This was accompanied by a reduction in fuel consumption of 1.7%. The tests were carried out over the ISO 8178 8-mode steady-state cycle which includes no transient elements. NO_x and CO_2 emissions were measured at all modes of this cycle, However, PM emissions were only measured at mode 6 (60% load). The test fuel used in these tests had a sulphur content of <10 ppm.

PuriNox is detailed on the EPA list of verified technologies. PM reductions are stated as 16 – 58%; NOx reductions as 9 – 20%.

CARB details three executive orders on its listing of approved technologies. These are for PuriNox, Aquazole and Clean Fuel Technologies. All three fuels are approved at around 15% reduction in NOx and around 60% reduction on PM.

Tests in the UK on a Euro 2 bus as tested on a chassis dynamometer over a cycle representative of bus operation in London showed a NO_x reduction of 13% compared with ULSD[26]. However, this was accompanied with a 10% increase in particulate matter and a slight (<1%) increase in CO_2 emissions.

Tests on a Euro 3 refuse collection vehicle[27] as tested on a chassis dynamometer over a cycle representative of refuse vehicle operation, showed no reduction in NOx emissions when compared with those from ultra low sulphur diesel (ULSD).

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[24] European Committee for standardisation, see www.cenorm.be
[25] Engine Performance test of water and urea emulsified fuel: O A Bergh: Marintek 2005
[26] Emissions database: TfL: 2006
[27] A. Savage, S.C.Rowlands, PuriNOx WDE Fuel Evaluation on a Camden Borough RCV, London Borough of Camden

The impact of DWE on emissions therefore appears to be generally positive although the results do appear to be variable and influenced by drive cycle and level of engine technology.

Operation and Maintenance

In general, emulsions can be used on all heavy duty vehicles, from Euro 1 to Euro 3. However emulsions should not be used primarily to solve existing problem or improve deteriorated engines. Injectors and fuel pump have to be checked and in good state, if not they have to be replaced.

For new engines with common rail, and possible some older engines, manufacturers indicate problems with DWE due to low thermal stability of DWE giving separation of water and fuel, leading to pump seizing. Cavitation problems on injectors can also appear.

For pre-Euro to Euro 3 (without common-rail), durability is equivalent to Diesel. For new engines, manufacturers may reduce or remove warranties when using DWE.

Fuel storage and dispensing infrastructure is identical to standard diesel fuel. Normal practice is to use existing diesel tanks and pumps, although it is recommended, if not a mandatory requirement, that tanks and dispenser systems are cleaned prior to use with DWE.

The fuel can be stored without any degradation for at least four months (but normally a much quicker turnover than this would be expected). Agitation of the fuel to prevent degradation is not necessary.

Costs

The pricing structure of these fuels can be complex and depends on the tax structure of the fuel. The fuel costs more to produce than ULSD. In the UK, for example, the water content of the fuel (around 10%) is exempted from paying tax. This allows DME to sell at roughly the same price as ULSD. However, this will result in an increase in fuel costs of around 10% due to the lower energy density of the fuel. In Italy oil suppliers pay oil tax when buying oil. Producers of DWE are granted a tax rebate (currently €0.256 per litre) which is deducted prior to paying the tax. The DWE is not taxed, except for oil tax. The tax deduction was increased in 2006 by €0.10 per litre in order to promote the use of DWE in Italy and to assist creating a proper distribution system for DWE throughout Italy.

Conclusion for alternative liquid fuels

In the context of this project, only diesel water emulsion (DWE) is considered a practical alternative liquid fuel or fuel additive at this stage, and can reduce emissions of NOx by 15% and PM by 50-60% PM, although results are extremely variable. At present, it is usually a niche fuel for captive fleets due to the fuel storage issues, although Italy is incentivising the fuel through tax reduction to encourage more widespread availability. All other alternative liquid fuels are considered to either have no significant impact or are too far from market, although hydrogenated bio-diesel may change in the near future *if* it provides the emissions benefits claimed (30% PM, 15% NOx reductions). An exception could be ethanol, which offers Euro 4/5 levels of emissions but is only currently offered as an OEM product in a niche market. Given sufficient market pull, there may be potential to offer ethanol fuelled vehicles as retrofit engine conversions.

3. Alternative (gaseous) fuels

3.1. Compressed Natural Gas, Liquid Natural Gas and Liquid Petroleum Gas (CNG, LNG, LPG)

Spark ignition engines, particularly when used in stoichiometric mode and employing three-way catalysts can produce very low emissions. For light-duty applications including taxis gasoline vehicles are available, but these cannot match the durability or fuel efficiency of the diesel vehicles generally used today.

For heavy-duty applications, gaseous fuels, especially CNG, provide an alternative to diesel at least for urban fleets, and CNG bus fleets are in service in some European cities. However, the higher fuel consumption and greenhouse gas emissions associated with spark-ignition engines needs to be considered. The JEC well-to-wheels study shows that the greenhouse gas emissions reductions associated with use of CNG are small, and do not justify its widespread use, but suggests that use in captive fleet markets might be more appropriate[28]. However, the use of bio-methane in natural gas vehicles can bring significant reductions in greenhouse gas emissions.

Replacing or retrofitting a vehicle to run on CNG is expensive, however emission reductions compared with an older diesel vehicle can be considerable. However, diesel vehicles equipped with combined DPF+SCR systems have been demonstrated to give NOx and PM emissions equally as low as CNG vehicles. CNG fuelled vehicles will generally be most attractive where the fleet operator can manage their own fuel supply, since CNG is not expected to become widely available at normal filling stations.

LPG has been primarily used in light-duty vehicles, and its use is not expected to expand significantly.

For long haul applications the use of “dual fuel” engines using a mix of methane gas (typically between 65-85%) and diesel can be commercially viable. The new generation of electronic controlled systems using closed loop technology operate on equal gas substitution even in low load conditions making bus fleets and refuse vehicles potential candidates.

Operation, control and impact on emissions

A number of dual fuel systems are currently offered, principally in the UK, as retrofit conversion. This involves adaptation of the diesel engines in HD vehicles to run on a blend of methane gas and pilot injected diesel and also requires installation of LNG or CNG tank(s) on the tractor unit with optional additional CNG tanks on any trailer unit. Packaging of these tanks and other system components is non-trivial, particularly if such a system were to be used on an urban bus. The consequent reduction in payload also needs to be considered. The vehicle retains the capacity to run on pure diesel fuel (in areas where refuelling with methane gas is not feasible).

The actual share of methane and diesel respectively to a significant extent depends on driving patterns and diesel injection systems supplied by the manufacturer. HD trucks used in long distance transport are able to achieve a very high share of methane use with average substitution levels of around 70%.

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[28] Well-to-Wheels Analysis of Future Automotive Fuels in a European Context: R. Edwards et al: EUCAR/Concawe/JRC: version 1 2003; version 2a 2005

Solutions for Euro 3 (and earlier used emission classes) have been successfully implemented with work on Euro 4/5 diesel vehicles ongoing.

Emissions reduction benefits will differ somewhat depending upon the original vehicle used and the conversion solution used. NO_x may be somewhat reduced, and the vehicle will cause less vibrations and emit less noise. CO_2 emissions will be significantly reduced (with 80% methane in the form of natural gas and with, in principle, the same engine efficiency in dual fuel mode as in diesel mode, the CO_2 reduction will be around 20%. Emissions of PM and NMHC will be reduced by some 80%. As with all natural gas engines the treatment of the exhaust with an appropriate system to convert methane emissions is important. There have been significant studies on particle emissions from natural gas engines. VTT showed that, on average, buses equipped with CNG engines produce levels of small particles at least equivalent to CRT equipped Euro 3 diesel engines[29]. However, no data has been obtained on any particle distribution work on dual-fuel engines.

Tests on dual fuel diesel/natural gas engines to the European ESC and ETC protocols have concluded that with the latest technology a Euro 3 diesel engine can be promoted to Euro 4[30].

Costs

The conversion option has within the EU so far mainly been used in the UK. The complete conversion package, including training of drivers and warranty may end up in the €22-25 000 bracket (dependant on fuel containment packages and sizes). It could be envisaged that these costs could reduce by up to 20% given sufficient production volume.

Net savings on operational costs (much lower fuel costs, marginally increased maintenance costs) could for an 18 tonne truck reach some €0.11/km, for a 44 tonne truck €0.13 - €0.19/km, this is dependent on purchase price of diesel and gas and the vehicle's achievable fuel consumption

Maintenance costs are slightly increased due to extra gas filter changes and some small servicing costs for gas injectors; however this is a very small addition. Serious conversion offers will include a warranty on the converted engine. The choice of suitable synthetic lubrication oils is very important as it is necessary to protect the after-treatment in the exhaust, however this adds to the fuel efficiency of the engine and because gas is a clean burning fuel adds operational life to the engine.

One disadvantage faced by natural gas vehicles has been poor resale value. Modern retrofit dual fuel vehicles can be converted back to pure diesel operation so protecting residual value.

3.2. Bio-methane (biogas)

Biogas, produced by the anaerobic digestion of organic waste such as food and animal manure, could be a valuable fuel for road vehicles. This would reduce dependence on imported oil and benefit the environment by providing a disposal option for waste that otherwise might be land filled and reducing emissions of carbon

[29] Transit Bus Emission Study: Comparison of Emissions from Diesel and Natural Gas Buse: N-O Nylund, K Erkkilä, M Lappi et al: VTT 2004

[30] CAP Euro III C12 and Euro IV C12 compliance to 88/77/EEC: VCA North America 2003

dioxide and methane, which are both important greenhouse gasses. Biogas is firmly established in Sweden where it has found heavy-duty applications in bus fleets and rail traction. As produced by anaerobic digestion the gas has a methane content of about 65%. Before being able to be used in vehicle engines the methane content is increased to around 95% by removal of CO_2 and hydrogen sulphide (H_2S) and cleaned of other contaminants such as water, grit etc.

The main sources of waste for biogas production are agricultural manure and food wastes. Vehicles equipped to run on natural gas can run on biogas without further modification and produce similar levels of air quality emissions. Biogas fuelled vehicles can reduce CO_2 emissions by between 75% and 200% compared with fossil fuels when measured on a Well-to-Wheel (WTW) basis.

Costs

The availability of cost data for biogas production is poor. Many of the costs are very plant specific depending on the site, other infrastructure required, what feedstocks are being used and so on. Also biogas is often viewed as a by-product from what is a waste treatment process, and so the economics are viewed from the point of view of how much does it cost to treat a tonne of waste. However, as regards the UK, for example, data from Sweden and the US suggest that biogas can be produced and sold in the UK at a cost of between 50-60pence/kg, including duty (at the reduced rate of 9pence/kg) but excluding VAT, which is comparable to the current price of CNG to transport operators in the UK at around 55pence/kg.

Conclusion for alternative gaseous fuels

Retrofitting a vehicle to run on CNG is expensive. Whilst emission reductions compared with an older diesel vehicle can be considerable, diesel vehicles with combined DPF+SCR systems give equally low NOx and PM emissions. With the lower efficiency (and therefore higher GHG emissions) of spark ignition engines, problems with the space for storage tanks and provision of CNG refuelling infrastructure, the adoption of CNG fuelled vehicles is not an attractive option.

However, the use of “dual fuel” engines using a mix of methane gas (65-85%) and diesel is an option, and given competitively priced gas supplies dual fuel can be commercially viable and achieves Euro 4 emissions. Refuelling infrastructure is still an issue, and for bus fleets and refuse vehicles space for on-vehicle storage tanks. Whilst an option, diesel engines fitted with SCR+DPF systems are likely to be more cost effective from a purely vehicle perspective and offer lower PM emissions.

4. Complimentary Measures

4.1. Low Ash Lubricants

Lubricating oil characteristics impact upon the effectiveness over time of exhaust aftertreatment systems containing poisons for catalysts e.g. sulphur, phosphorous and ash which builds up in DPF systems, increasing exhaust back pressure and necessitating cleaning.

Tests on a range of oils with different ash content have shown the rate of EBP increase to be 5 times greater with 1.8% ash oil compared with 1% ash oil. This equates to a 2% increase in fuel consumption compared with a 0.4% increase in fuel consumption after 100 000km. This will provide a proportional effect on CO_2.

Costs

Cost information for the use of low ash lubricating oils is currently not available.

Conclusion

Low ash lubricants should be encouraged as part of the supply for diesel particulate filters.

4.2. Closed Crankcase Ventilation Systems (CCV)

In turbocharged heavy-duty diesel engines the engine blow-by gases are traditionally vented via a crankcase breather to atmosphere, usually via a downward directed draft tube. Whilst this system usually employs a rudimentary filter or flame trap, there is potential to release a substantial amount of PM to atmosphere. MECA report that emissions through the breather may exceed 0.7 g/bhp-hr at idle[31].

Operation, control and impact on emissions

One solution to this problem is the use of Closed Crankcase Ventilation (CCV) where the blow by gases are directed back into the engine intake system via a multi-stage filter designed to collect, coalesce and return the emitted oil back to the engine sump, whilst filtered blow-by gases are returned to the combustion air intake. Typical systems comprise a filter housing, pressure regulator, pressure relief valve and oil check valve.

EPA [ref.] state in its report on reducing emissions from the US legacy diesel fleet that the use of CCV could reduce total PM emissions (exhaust and crankcase) by 5 – 10% or more. Whilst this figure should be examined against European operational experience, it would seem appropriate to encourage this relatively low cost technology.

Operation and Maintenance

CCV systems have been available as OE fit on heavy-duty engines at Euro 3 level, on some engines, although these appear to optional. There are major retrofit programmes in the US, notably on school buses as part of the Clean School Bus USA programme. There is currently one system identified on the USEPA list of verified measures. This is specified in conjunction with a diesel oxidation catalyst. A number of Executive Orders refer to this type of technology on the CARB database

USEPA requires all OEMs to adopt CCV for model year 2007. In Europe this is likely to come into focus for Euro 6.

Costs

Based on US experience the cost of fitting a CCV system to a bus or truck is typically between €350 and €550. Filter elements will need to be replaced at normal oil change intervals.

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[31] Closed Crankcase Filtration: The Next Step in Diesel Engine Emissions Reduction: Marty Barras, Donaldson Corporation: MECA 2005

Conclusion

Closed Crankcase Ventilation (CCV) have been stated as giving 5-10% or more PM reduction, and they are retrofitted in the US in conjunction with a DOC. This needs to be investigated in the EU context, and where DPFs should be favoured.

5. Other Measures

5.1. Measures to reduce impact of idle emissions from trucks

In the US in May 2001, President Bush issued the National Energy Policy directing EPA and US Department of Transport to work with the trucking industry to establish a programme to reduce emissions and fuel consumption from long haul trucks. This programme included an examination of idling fuel consumption and emissions from these vehicles, which it is estimated have idle times of between 1500 and 2400 hours per year.

EPA measured the emissions from a selection of mid-1980's to 2001 trucks under ambient conditions from 0°C to 32°C[32]. They compared the engine emissions generated whilst maintaining a cab temperature of 21°C. with those generated by auxiliary power units (APU) and direct fired heaters (DFH).

EPA concluded that on average, a typical 1980's- 2001 model year truck emitted 144 g/hr of NO_x and 8224 g/hr CO_2 and consumes about 3.1 litre/hr of diesel fuel. The use of an APU can reduce idling fuel consumption by 50% to 80% and reduce NO_x by 89% to 94%. The use of a DFH can reduce idling fuel consumption by 94% to 96% and reduce NO_x by 99%.

Whilst these figures do not necessarily apply to European operations it would seem appropriate to examine typical European operations to determine equivalent data.

In California CARB has introduced the Transport Refrigeration Unit (TRU) Air Toxic Control Measure (ATCM) which is designed to use a phased approach over 15 years to reduce diesel particulate matter emissions from in-use TRU and TRU generator sets that operate in California, irrespective of whether they are registered in or out of the state. The TRU ATCM will require in-use TRU and TRU generator set engines to meet in-use performance standards that vary by horsepower range. Standards can be met by:

- Using an engine that meets the required engine certification value
- Equipping the engine with the required level of verified diesel emission control strategy
- Using an alternative technology

Compliance schedule requirements will be phased, depending on engine model year.

EPA has also launched the SmartWay Transport Partnership. EPA focuses on technologies to reduce idle emissions e.g.

- Auxiliary Power Units (APUs) to provide power to the truck when the main engine is switched off.

[32] Study of Exhaust Emissions from Idling Heavy-Duty Diesel Trucks and Commercially Available Idling Reducing Devices:H Lim: Diesel Emissions Measurement and Modelling:SAE 2003

- Automatic engine idle systems which start and stop the truck engine automatically to maintain cabin temperature or battery state of charge.
- Truck electrification stops to allow trucks to use power from an external source. Each truck will need to be equipped with electrical heating and air conditioning system and inverter.

Costs

Costs derived from EPA and The State of New Jersey[33] has identified costs for some of these measures as follows;

- Cost of APU: €5500
- Truck stop electrification infrastructure: €1870 per truck stop
- Electrical heating and air conditioning system and inverter: €1960 per truck

Conclusion

There are essentially two initiatives in the US aimed at reducing idle emissions from trucks, EPA's SmartWay Transport Partnership and CARB's Transport Refrigeration Air Toxic Control Measure. These initiatives may not be wholly applicable to truck operations in Europe and are not able to be quantified in a European context at this stage. However, the principles embodied appear to be worth examining in future studies.

5.2. Retrofit hybrid drives

Retrofit hybrid drives are gradually becoming available. Technologies include diesel-electric series hybrid and hydraulic hybrids. They can vary in complexity ranging from simple start/stop systems to fully integrated powertrain systems offering both series/parallel or mixed mode operation, although the more complex systems are unlikely to be offered as retrofit options.

Operation, control and impact on emissions

The main advantage of hybrid drives is the ability to recover energy spent in start-stop conditions through regenerative braking. The energy is stored in a rechargeable energy storage system (RESS) and can then be released during acceleration from stop.

The main focus of hybrid drives in Europe is as a means of improving fuel efficiency and reducing greenhouse gases. Improvements of 30% have been demonstrated.

The impact on regulated emissions is often expected to be similar to the benefits to greenhouse gas emissions. However, careful calibration of the energy management system is needed to avoid increases in NO_x due to the operation of the power unit being shifted to ranges with higher specific NOx (e.g. outside from the ESC-control range), compared with operation of a conventional powertrain.

The widespread application of start/stop technology to captive fleets operating in an urban environment on a start/stop cycle may offer significant savings in fuel consumption. This technology is extremely cost effective and offers good potential for NO_x reduction.

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[33] Workgroup Recommendations and Other Potential Control Measures – Diesel Initiatives Workgroup: Amy Hilman: State of New Jersey 2006

Costs

Capital cost of these technologies is currently very high. However, depending on vehicle mileage and fuel cost payback can be achieved in 2 – 3 years.

Conclusion

These may be of interest, but are as yet too far from market

5.3. Low Viscosity Lubricants

Engine lubricant characteristics impact directly and indirectly engine emissions and consumption. Oil viscosity (kinematic, dynamic and HTHS (high temperature, high shear)) and friction additives are directly linked with engine friction performance, which impacts upon engine fuel consumption and emissions. For example, 20% friction reduction in rings / piston will give around 3-5 g CO_2/km reduction.

Operation, control and impact on emissions

Tests on a range of oils (engine, transmission, axle) indicate that fuel economy can be improved by 2 – 3% with oils with improved and optimised viscosity characteristics.

The impact on other emissions has not been documented but there is the potential to marginally reduce other pollutants, perhaps, but not necessarily, in proportion to fuel savings.

Conclusion

The impact on emissions other than CO_2 has not been documented but there is the potential to marginally reduce other pollutants, perhaps, but not necessarily, in proportion to fuel savings. Further work is needed to assess this for PM and NOx.

5.4. Low Rolling Resistance Tyres

Rolling resistance clearly makes an important contribution to the fuel consumption and emissions from a vehicle, although at high speed aerodynamic effects may be more significant.

Operation, control and impact on emissions

Low rolling resistance tyres and wide base single tyres for drive axle of long haul vehicles are available for long haul transportation. These are applicable to all vehicles operating in that sector and at all Euro levels

A fuel saving of between 0.5 and 1.5 l/100km fuel consumption has been claimed by one supplier.

Wide base single tyres can also be applied to urban buses.

A fuel saving of 1.5 l/100km FC per single 12m bus, 3 l/100km fuel consumption per articulated 18m bus is quoted. This could equate to between 2 and 8% on fuel costs.

In a report on work carried out by USEPA on the effect of wide based tyres on fuel consumption and NOx emissions of Class 8 Line-Haul tractors under track simulated suburban and highway conditions indicated that there were both fuel economy (mean of from 6 to 12% improvement) and NOx emission (mean of 14 to 37% reduction) benefits conferred by wide based tyres[34].

Conclusion

Emissions reductions are claimed by one suppliers study. However, the results do not appear to be sufficiently robust to be able to confirm such benefits at this stage. Further work is needed to assess this adequately.

5.5. Fuel Additives

There are a number of hydrocarbon fuel additives marketed which aim to reduce emissions.

The impact of additives is very difficult to determine on a generic basis and can only be determined by extensive fleet trials and emissions tests. Results will be specific to the additive formulation, design of the trial and emissions tests and the age and condition of the vehicles used in the trial. Furthermore, if the trial is a long term test the effects of seasonal variations on vehicle baseline performance must be considered.

Conclusion

Further testing of each specific fuel additive is needed to assess their impact.

6. Summary of technical assessment

The technical measures were reviewed with the objective of identifying the most promising options for the Commission to support. In respect to this the technical measures have been categorised as follows:

- *Primary measures*: measures which have quantifiable benefits and are considered the most promising technical measures for reducing PM and NO_x appropriate for the policies within this project.
- *Secondary measures* : measures which, whilst not providing significant impact upon PM and NO_x, should be encouraged to be used in conjunction with primary measures; measures which appear to offer potential NO_x and PM benefits but which should be further examined to explore their potential in a European context.
- *Other measures*: immature or technologies not close enough to market, measures not able to impact significantly upon the emissions from existing heavy-duty vehicles; measures which appear to be too expensive versus other technologies offering similar or better emission benefits

The measures that have been assessed to lie within each of these categories are set out below:

[34] Effect of Single Wide Tyres and Tralor Aerodynamics on Fuel Economy and NOx Emissions of Class 8 Lin-Haul Tractor-Trailers: L J Bachman, A Erb, C L Bynum: SAE 2005

Primary measures

Exhaust emissions retrofit measures

- Diesel Oxidation Catalyst (DOC)
- Diesel Particulate Filter (DPF)
- Exhaust Gas Recirculation (EGR)
- Selective Catalytic Reduction (SCR)
- SCR+DPF
- Re-engining

Alternative liquid fuels

- Diesel Water Emulsion (DWE)

Alternative gaseous fuels

- Dual-fuel Natural Gas
- Dual-fuel Bio-methane

Secondary measures

- Low Ash Lubricants
- Closed Crankcase Ventilation systems
- Measures to reduce impact of idle emissions – use of APUs, truck stop electrification

Other measures

Exhaust emissions retrofit measures

- Lean NOx Traps (LNT) – due to the early stages of development, difficulties with sulphur poisoning and very low sulphur fuel and lubricating oil requirements

Alternative liquid fuels

- Dimethyl-ether (DME) – due to the early stages of production and volume uncertainties
- Fatty Acid Methyl Esters (FAME) – due to the low impact on PM and NO_x emissions
- Synthetic Diesel (Fischer-Tropsch) – due to early stages of production and volume availability, and therefore uncertainties
- Biodiesel (e.g. RME)– as does not improve air quality
- Ethanol – as not currently practical as retrofit measure, although this could be a market forces, rather than technical. issue

Other measures

- Dedicated Gas conversions – expensive for little advantage over diesel with DPF+SCR
- Fuel Additives (other than FBC) – due to the low impact on PM and NO_x emissions
- Retrofit hybrid drives – due to their early stage of development, and therefore supply uncertainties

- Low Viscosity Lubricants – due to the low impact on PM and NO_x emissions
- Low Rolling Resistance Tyres – due to the uncertainty of the impact on PM and NO_x emissions

The characteristics of the most promising technical measures are shown in Table 2 below. A review of the technical measures found that the most promising were diesel particulate filters (DPF) for reducing particulate emissions and selective catalytic reduction (SCR) for NOx. The most promising fuels were diesel water emulsion and dual-fuel natural/bio gas, although they were less promising in terms of cost effective emissions reduction than DPF and SCRs. Ethanol may become a retrofit option, but again is likely to be less cost effective than DPF and SCR.

The data included in this table was then assessed for applicability against the following vehicle categories:

- BUS diesel
- COACH diesel
- HTD1 heavy duty vehicle 3,5-7,5 tonne
- HTD2 heavy duty vehicle 7,5-16 tonne
- HTD3 heavy duty vehicle 16-32 tonne
- HTD4 heavy duty vehicle +32 tonne

The vehicle categories were further split down into the following technology levels

- RTH1 - Conventional
- RTH2 - Euro 1 - 91 542 EEC Stage I
- RTH3 - Euro 2 - 91 542 EEC Stage II
- RTH4 - Euro 3 - 2000 Standards
- RTH5 - Euro 6 - 2005 Standards
- RTH6 - Euro 5[35]

This then enabled the development of a technology impacts table to be fed into the TREMOVE model for scenario modelling.

The technical measures were ranked, using the data presented and the ranking spreadsheet presented in Appendix 5. Alternative rankings were presented at the workshop and comments requested. It was decided to use a non-weighted ranking that included PM, NOx, NO_2, solid particles under 1000nm and cost, and not include CO, HC and other pollutants. The outcome of the ranking is presented in Table 1 below, and concurs with the technical review conclusions. This ranking was used to decide which technical measures to include in the model scenarios.

It should be noted that the costs submitted to this project were all current costs, which were validated when tested on the market as being correct. These must therefore be considered the most robust figures at this time. However, widespread national or EU-wide take up of retrofit systems i.e. hundreds of thousands rather than tens of thousands of units will create substantial economy of production resulting in cost reductions. These figures would be less robust, but may be more representative of what might happen. Actual costs in reality (ex-ante costs) are also often lower than

[35] Roman numberals are often used for Euro standard numbers

predicted costs. The only costs that we have received in terms of these larger volumes were for catalysed DPFs, given as 2200 for small and 2800 for large systems, but have not been included in the table due to the different basis of these numbers. The Commission may therefore wish to examine this in more detail before undertaking any modelling activity.

Table 1. Technical measure ranking

Measure	Overall ranking
SCR+DPF (active regeneration)	86
DPF (active regeneration)	86
DPF (FBC)	86
SCR+DPF(CRT®, catalysed)	81
DPF (CRT®, catalysed)	81
DOC	79
DWE	72
SCR	71
Dual fuel diesel/natural gas/biogas	69
DPF (partial flow)	67
Repower to Euro 4	65
Ethanol	64
EGR	60

Table 2. Summary of technical measures applicable to heavy-duty vehicles and captive fleets - primary measures only*

Measure	Vehicle category	Emission standard/age	Emission reductions/changes related to the base case vehicle						Costs		Restrictions, Drawbacks
			NOx	PM	NO_2	Fuel cons/ CO_2	<1000 nm Solid particles	Other	Capital	Operation	
DOC	All heavy-duty	Pre-Euro: >14 yrs Euro 1: 10 -14 yrs Euro 2: 7 -10 yrs Euro 3: <7 yrs	Zero Zero Zero Zero	20 to 40% 20 to 40% up to 20% up to 20%	up to 50% up to 50% up to 50% up to 50%	Zero Zero Zero Zero	Risk of increase	CO and HC: typically 80%. 90% with 50ppm Sulphur	€350 (small system) €1500 (large system)	Zero Zero Zero Zero	Sulphation (corrosion), NO_2 emissions, Pt emissions, other secondary emissions. Use as low sulphur fuel as possible to reduce effects
DPF (CRT®, catalysed)	All heavy-duty	Euro 1: 10 -14 yrs Euro 2: 7 -10 yrs Euro 3: <7 yrs	-2 to -4% -2 to -4% -2 to -4%	>90% >90% >90%	up to 50% up to 50% up to 50%	<+1% <+1% <+1%	>99% >99% >99%	CO and HC: typically 90%.	€3000 (small system) €7000 (large system)	Cleaning costs: Trucks - €350/yr Buses - €700/yr RCVs - €1400/yr Up to 1% increase in fuel cost	Needs ultra low sulphur fuel (<50ppm) to meet 90% PM reduction Some older DPFs increase NO_2
DPF (partial flow)	All heavy-duty	Pre-Euro: >14 yrs Euro 1: 10 -14 yrs Euro 2: 7 -10 yrs Euro 3: <7 yrs	Zero Zero Zero Zero	up to 50% up to 50% up to 50% up to 50%	up to 50% up to 50% up to 50% up to 50%	Zero Zero Zero Zero	Potentially zero	CO and HC: typically up to 80%. 90% with 50ppm Sulphur	<€3000 (small system) €7000 (large system)	Will require cleaning but possibly at lower frequency than full flow filter	Lower PM reduction, potentially minimal impact on ultrafines.
DPF (FBC)	All heavy-duty	Pre-Euro: >14 yrs Euro 1: 10 -14 yrs Euro 2: 7 -10 yrs Euro 3: <7 yrs	-2 to -4% -2 to -4% -2 to -4% -2 to -4%	>90% >90% >90% >90%	Zero Zero Zero Zero	<+1% <+1% <+1% <+1%	>99% >99% >99% >99%	CO and HC: If fitted with oxycat typically 90% with 50ppm Sulphur fuel. Can reduce to 30 – 40% with 500ppm fuel.	€3000 (small system) €7000 (large system)	Cleaning costs: Trucks - €350/yr Buses - €700/yr RCVs - €1400/yr Up to 1% increase in fuel cost	Requires fuel additive and dosing system. Best with low sulphur fuel (<50ppm)
DPF (active regeneration)	All heavy-duty	Pre-Euro: >14 yrs Euro 1: 10 -14 yrs Euro 2: 7 -10 yrs Euro 3: <7 yrs	-2 to -4% -2 to -4% -2 to -4% -2 to -4%	>90% >90% >90% >90%	Zero Zero Zero Zero	<+1% <+1% <+1% <+1%	>99% >99% >99% >99%	CO and HC: zero to 90% depending on system	€2300 (small system)	Cleaning costs: Trucks - €350/yr Buses - €700/yr RCVs - €1400/yr	May increase exhaust back pressure outside of manufacturers

								of regeneration	€7000 (large system)	Up to 1% increase in fuel cost	limits prior to regeneration.
EGR	**All heavy-duty**	**Euro 2: 7 -10 yrs Euro 3: <7 yrs**	**Up to -50% Up to -50%**	**Risk of increase. Likely to need mitigation by DOC/DPF**	**Zero Zero**	**+2% +2%**	**Increases**		**Cost for large vehicle: €14000 to €16000**	**Up to 2% increase in fuel cost**	**Fuel consumption increase, potential accelerated engine wear. Mitigation of increased PM by DOC or DPF**
SCR	**All heavy-duty**	**Euro 2: 7 -10 yrs Euro 3: <7 yrs**	**-60 to -80% -60 to -80%**	**-20 to -30% -20 to -30%**	**Zero* Zero***	**Zero Zero**	**Risk of increase**	**HC: typically 70% reduction. CO: up to 20% increase.**	**Cost for city bus: €10000 €15000 (with DPF)**	**Cost of urea 5% of fuel consumption(~ 16T rigid €0.6/100km, 40T truck €1/100km, large bus €1.7/100km)**	**Needs urea injection system *Can increase N_2O through oxidation of NH_3**
SCR+DPF	**All heavy-duty**	**Euro 2: 7 -10 yrs Euro 3: <7 yrs**	**-60 to -80% -60 to -80%**	**>90% >90%**	**+10 to 50% +10 to 50%**	**<+1% <+1%**	**>99% >99%**	**CO and HC: typically 90% with <50ppm Sulphur.**	**€12000 (medium system) €15000 (large system)**	**Cleaning costs: Trucks - €350/yr Buses - €700/yr RCVs - €1400/yr Up to 1% increase in fuel cost Cost of urea 5% of fuel consumption(~ 16T rigid €0.6/100km, 40T truck €1/100km, large bus €1.7/100km)**	**Needs low sulphur fuel (<50ppm) Needs urea injection system Can increase NO_2 through oxidation of NH_3**
Repower to Euro 4	**All heavy-duty**	**Euro 2: 7 -10 yrs Euro 3: <7 yrs**	**Zero Up to 50% Note; based on real world emission tests.**	**Up to 45% Up to 43%**	**Zero Zero**	**Up to +20% Zero**	**Could increase**	**E2 TO E4: HC: 60%, CO:55% E3 to E4 HC: 30%, CO: 25%**	**€16000 to €24000 Cost needs to be compared with like for like replacement cost**	**Maintenance costs expected to reduce. Fuel cost could increase up to 20%**	**Expensive. May not give reductions in solid particles Real world emissions benefits do not follow Euro standards**
Ethanol	**All heavy-duty**	**Euro 3: <7 yrs**	**Meets Euro 4**	**Meets Euro 4**		**60% increase due to lower energy**	**Could increase**	**Meets Euro 4**	**Additional cost can be in region of €10000**	**Maintenance cost could be +50%**	**Dedicated engine**

						density						
DWE	**All heavy-duty**	**Pre-Euro: >14 yrs Euro 1: 10 -14 yrs Euro 2: 7 -10 yrs Euro 3: <7 yrs**	**-15%**	**-50% to -60%**	**Zero unless used with DOC (see comments ref. DOC)**	**10% increase**	**Could increase**	**Wide variation of results but CO and HC could increase up to 35%**		**Fuel cost could increase by 10%. However depend upon tax regime.**	**Emission benefits appear to be influenced by engine technology level and duty cycle**
Dual fuel diesel/natural gas/biogas	**All heavy duty, but primarily long haul trucks**	**Euro 3: <7 yrs**	**Meets Euro 4**	**Meets Euro 4**	**Zero**	**20% lower**	**Likely to be higher than diesel with DPF**	**HC: 80%, CO: 80%**	**€22000 to €25000**	**Payback possible in 2 years**	**Reduced payload, slightly increased maintenance costs. Catalyst required for CH_4 management**

* RCVs = Refuse Collection Vehicles


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Part 2 – Policy formulation

1. Introduction

From the input gathered and team experience a range of policies were proposed for discussion at the workshop, and presented in the pre-workshop papers. The policy measures that were consider by the stakeholders to be the most necessary and effective at the European level were:

- A common EU system for certification for retrofit measures – both a full EU-wide scheme and interim measures until this is able to be in place. This scheme would also cover:
    - Retrofit and vehicle OEM warranty issues.
    - Certification of fuels and alternative fuel conversions
    - Enforcement against foreign vehicles is raised here, as a wider issue outside the remit of this project, but important for fairness across the EU and effectiveness of the certification scheme

- Guidance and support for cities implementing or planning LEZs
    - LEZ guidance
    - Labelling of vehicle Euro standard for LEZs (outside the remit of this project, but important as part of LEZs that could encourage retrofits)
    - Information sharing
    - Informal / semi-formal grouping of LEZ cities
- Fiscal and regulatory issues including:
    - State Aid issues
    - Reduced/removed VAT on technical measures
    - Procurement consortia

These measures were the focus of the policy formulation work within the study and are developed further in the sections below. A number of measures (OEM warranty, foreign vehicle enforcement and fuels) presented as separate measures in the pre-workshop paper have now been combined under the certification scheme.

By far the most important measure is the development of a common European certification scheme, both a new, full scheme and interim measures until such time as a full scheme is in place.

Those policies considered and ruled out during the project are listed below, and further discussed in Appendix 6.

- Harmonisation of road signs for LEZs
- LEZ enabling directive
- EU Technical Measure Guidance
- Supportive legislation for natural gas targets
- EU-wide framework for retrofit programs
- Increased availability of SCR reactant
- Fuels and EU working groups.

2. A common EU scheme for the certification of technical measures

Retrofits have the potential to be encouraged through LEZs and road charging, either requiring retrofits to be fitted or operators choosing to use retrofits to comply with set emissions standards. Commission action could give significant assistance to this. The main reason for this is that the freedom of movement aspect of the Treaty of Rome requires that member states do not operate barriers for vehicles from other member states. This means that LEZs have to be equally easily accessible for both foreign vehicles and national vehicles. This has two key impacts:

a. LEZ emissions standards must be non-discriminatory, which is at present best achieved by using Euro standards as a basis.

b. National proofs for retrofits are not allowed to be the sole requirement for LEZs, and LEZ operators need to know emissions standards / retrofit status of foreign vehicles, in the context of many vehicle registration agencies not having and/or sharing the relevant information.

Both of these would be eased by a EU-wide certification scheme, as retrofits would be clearly identified across Europe and it would enable emissions standards to be set as Euro standard plus X% emissions reduction. It would also help cities implement tighter LEZ emissions standards than would be possible otherwise including NOx emissions reductions – for example London to implement a Euro 4 (PM and NOx) standard in 2012, instead of the currently planned Euro 4 (PM)[36]. A mechanism for knowing the emissions of vehicles more generally in terms of Euro standards for non-retrofitted vehicles is also needed (see section 3.1).

There are already a number of LEZs planned throughout the EU, The Netherlands (10 cities allowed from 1/4/07), Munich (start date 1/10/07), London (start date February 2008), Berlin (start date 2008), Denmark (5 cities allowed from 1/7/08). This is in addition to the 4 current LEZs in Sweden and the one in central Amsterdam. They are one of the effective ways of working towards the EU air quality limit values, and are required to be considered before an extension to the limit value target is considered, and further zones should be expected. Further information on these schemes can be found in Appendix 7.

Many road tolling schemes already have differential charging for newer Euro standards, including the German 'Maut' scheme, Eurovignettes in 5 Member States, 2 road tunnels and the Swiss heavy duty vehicle fee. These would also be able to choose to use retrofits if there were an EU-wide scheme.

Retrofits need to be certified as doing what they say they do, and there are already several PM certification schemes in the EU (see Appendix 8). Without a common certification scheme, each additional member state introducing LEZs allowing / requiring retrofits needs to set up a separate certification scheme – which gives an additional barrier to using retrofits. If it is decided to have a common scheme now, it will also enable one single scheme to be designed for NOx retrofits, as there are not as yet any NOx certification schemes in the EU.

[36] Reference: London LEZ Strategic Review Report, TfL

A certification scheme would assist in other ways, including:

- Promote retrofits as an option – and allow a percentage reduction to be required.
- Allow consumers to know what they are buying – whether for LEZs, road tolling, national incentives or altruism / marketing.
- Allow cities / member states to know that what they are incentivising / requiring will work
- Provide reassurance and confidence to member states and cities not yet using retrofits – which would encourage their use.
- Improve the quality of retrofit offered in the EU – as it has done in the US.
- Reduce costs: a) through increased demand, b) reduce certifying costs to manufacturers, that at present have to certify in each country.
- Reduce costs to implement each LEZ scheme.
- Resolve the issue of retrofits invalidating the vehicle OEM (original equipment manufacturer) vehicle warranty.
- Would offer a framework for emissions standards for LEZs, and effectively form a key part of any LEZ guidance. It would clarify what is allowed, ensure that standards set were not too divergent for operators, while not being prescriptive.
- Provide a clearer framework for national incentives when they are applying for state aid approval.
- Ensure that testing and experience is shared throughout the EU.
- Could act as BAT (Best Available Technology) Reference Documents, as exist in the US. Not all technical measures certified might be designated as such – either by the member state or the certification scheme itself[37].

2.1. Structure of the Proposed Scheme:

The scheme should be technology neutral, allowing for treatment of each pollutant separately, and set up to be able to be used for all pollutants that are, or may be in the future, a problem. It would be for retrofits, and could also be for conversion to alternative fuels, and non-petrol / diesel fuels / additives if desired (see section 2.3), probably at a later stage. It should be clear, straightforward and user friendly to transport operators who will be purchasing the retrofit devices

There is a strong call for the scheme to cover all vehicles, so it would cover heavy duty vehicles, light duty vehicles and off-road vehicles. The German LEZs include light duty vehicles, the German and Dutch incentive schemes both started with light duty vehicles. Taxis are also an issue in some cities, and light duty vehicles are often used more predominantly in urban areas, particularly in the eastern EU countries. However, the requirements for these light-duty vehicles would be different, and are outside the remit of this project. This report focuses on a heavy duty vehicle scheme, due to the project remit.

The scheme should be designed initially for PM and NOx, and be built to allow extension to other pollutants as the need may arise, including CO_2.

[37] This could link with EU Joint Research Centre in Seville work on BAT

2.1.1. Outline of the proposed scheme:

In the short term to enable currently envisaged LEZs

In the short – interim - term the LEZs proposed need to allow the mutual recognition of current certifications from other EU Member States, so that their LEZs do not contravene EU law. This requires interim reciprocal arrangements for the current PM-based certification schemes. This needs to be in operation well before April 2007 – i.e. in around 6-9 months - when the first LEZs are expected to be in place. This could be done by the Commission, but it may well be that it would be more appropriate and faster through LEZ cities and Member States working together and with Commission support / involvement (see section 3.4). The technical arrangements for a EU-wide scheme as set out below could be agreed within 6 months. It is less likely that the legal/formal structure around that could be arranged within the 9 months needed – hence the need for a shorter term solution. However, it may be that the option of a framework is possible within the timescale, in which case the interim solution would not be needed.

In the medium-long term an EU-wide certification scheme

There would be two parts to the certification. Firstly approving the device. Secondly certifying that the vehicle has a certified device fitted. The first part would be operated by a certifying body to the standards set out in the scheme, which would also set out what technical measure could be fitted to which vehicle. The second part would be operated by the technical measure provider who would then inform the certifying body that a measure has been fitted, which is then spot-checked by the certifying body.

There is a clear requirement for any EU-wide certification scheme to offer both Euro standard equivalence and percentage reduction from baseline emissions performance under real-world operating conditions. This is required to provide comparison with Euro standards which many LEZs will base compliance upon, and, importantly to ensure that technical measures perform correctly under real-world operating conditions. An EU-wide certification scheme should therefore be based on an engine dynamometer (bench) test[38] utilising current engine homologation test[39] cycles (ESC, ELR, ETC[40]) for validating the performance of the technical measure under controlled laboratory conditions; coupled with a period of in-service operation over a representative duty (chassi dynamometer[41], drive cycle or on-road[42]) cycle to prove that the retrofit works for specific applications and is durable, including issues such as regeneration of the particulate trap. Overall certification would be for different operations, such as lorry, urban bus, coach, refuse vehicle using different drive cycle tests for each operation, together with one engine homologation test required per technical measure per engine family i.e. a series of engine ratings based upon a common set of major components e.g. cylinder block, head, air and exhaust systems, but with detail differences in fuelling strategies, speeds and other components.

[38] In the context of this project it is specifically as per the homologation test where the engine is tested on the engine dynamometer without being installed in a vehicle. The test is designed to enable the assessment of power, torque, fuel consumption, emissions under controlled conditions.

[39] Engine dynamometer test conducted under controlled laboratory conditions to determine if the engine meets the regulatory requirements for emissions compliance

[40] ECS: European steady-state cycle, ELR: European load response (for smoke), ETC: European Transient Cycle

[41] Where the whole vehicle is put on a rolling road and tested through a simulated drive (test) cycle. There tend to be a wider range of chassi dynamometer tests used than engine tests.

[42] Where a vehicle is tested on a normal road or road track with emissions monitoring equipment in the vehicle itself

The scheme should build on existing schemes. Within this project we have examined and documented all certification schemes currently available (see Appendix 8 for a summary). There are many similarities between the schemes. It is considered that the VERT scheme tests developed in Switzerland and also now used in a number of other countries offers the most rigorous and scientifically robust approach, at least for the certification of diesel particulate filters, ensuring that the emissions are related to health impacts. The new scheme described in this report seeks to combine the best out of the schemes currently available.

An engine dynamometer based test is needed for baseline certification on an engine family basis using Euro standard test cycles - ESC, ELR, ETC (analogous to VFT1[43] of the VERT protocol). To test each engine power rating within a family would be prohibitive in cost, therefore a worse case approach i.e. most/least arduous operating conditions (e.g. the highest rated engine operating at most arduous condition to give maximum exhaust flow and temperature *plus* operate same engine at the lowest speed and exhaust flow to give worse case for regenation etc) should be taken to ensure that the device operates in all conditions and loads. Whilst a diesel particulate filter will provide high filtration efficiency at all speeds and loads an SCR system might operate efficiently at high load and speed (due to the high exhaust temperature) but not at low load and speed (due to the low exhaust temperature). The certifying scheme should give guidelines on the scope and extent of engine test speed/load sites applicable to the technical measure being assessed, together with data and reporting requirements. This will allow comparison with Euro standards. However it will result in pre-Euro 4 diesel engines being baseline tested over test cycles they were not originally homologated to in order to determine percentage benefits conferred by retrofit technologies that can be compared with Euro 4 and later engines.

Durability and operational aspects will be covered by in-service and chassis dynamometer drive cycle demonstration, (analogous to VFT2[44]), but including additional chassis dynamometer testing after the durability test (analogous to VFT3[45]). The specification and provision of the specific drive cycle would be the responsibility of the technical measure supplier, carried out to scheme requirements, and would be approved by the certifying body before testing. This test would provide the application/operation-specific aspect of the certification. This may use approved drive cycles or may be bespoke to the application. The durability and in-service demonstration phase would be followed by further engine dynamometer tests to confirm performance after 2000 hours field operation (analogous to VFT1).

New EU-wide scheme vs interim arrangements

The question could be raised: what advantage has a new scheme agreed at EU level and implemented by all Member States got over the interim arrangements? There are several:

- Present certification schemes are limited to Euro standards. A new joint scheme, depending on how it is set out legally, could enable emissions standards of Euro 3

[43] To determine the filter efficiency. Tests on the engine test bed, burdened with soot, during and after regeneration, and including a test at the highest design space velocity. Filters must pass 95% reduction in particle count in the size range 20-300nm, and 90% reduction in elemental carbon (EC) mass concentration. Similarities with the UNECE particulate measurement program (PMP) for measurement of PM with metrics other than PM_{10}.
[44] A 2000 hour field endurance test with datalogging of exhaust temperature and back pressure, engine speed. Includes periodic checks on smoke opacity, additive dosage (if appropriate), noise emission, and fuel composition.
[45] A shortened version of VFT1, carried out after VFT2 to test durability.

+ 90% PM emissions reduction –higher than Euro 5, while being cheaper and therefore more politically acceptable to be imposed earlier than a Euro 5 limit would.

- Swedens LEZs have had several iterations with and without retrofit, and the current proposal is without retrofit. An EU-wide certification scheme could resolve this.
- There are indications that countries which do not at present favour retrofits, due to concerns about their operation, are more likely to use retrofits in their schemes with a EU-wide scheme, which robustly tests and certifies equipment.
- The economies for manufacturers only having to certify their equipment once rather than several times for each country should lead to a) an increasingly open market across Europe where competition will reduce prices and b) reduced prices due to the lower overheads from certification.
- Second hand vehicles tend to leave the western part of the EU, and are sold to the eastern part of the EU, and then later further east again. This will include vehicles with retrofits, which could have continued benefit as they move east, if they are recognised and appropriately maintained and checked. NOx equipment in particular still needs compliance testing, or operators are likely to be tempted not to replace the urea/ammonia reactant – particularly 2nd and 3rd hand operators operating in more constrained economic circumstances wherever they are based.
- Cities which would like to operate NOx schemes, but with no current NOx certification available in their country could use the certifying bodies in their country to use the EU-wide scheme, making NOx retrofit more likely.
- NOx certification schemes are just starting to be discussed around the EU – this gives an opportunity for there to be one harmonised system from the start. This is particularly important if On-Board Diagnostic (OBD) protocols are to be developed by the retrofit manufacturers, to ensure that there are common protocols throughout the EU for both retrofit and OEM.
- The present legal EU-metric is PM, but the new scheme could use the improved Particle Measurement Programme (PMP) method. It has significant advantage over the present PM_{10} gravimetric method, allowing for lower detection levels, greater repeatability than the current gravimetric method and determination of particle number and ultrafine PM (<100nm diameter) thought to be more harmful to health.

2.1.2. Timeframes for scheme

The short-term solution is needed as soon as possible. In terms of timescales for the EU-wide scheme, there are two main factors here, the speed of agreement on a scheme (could be relatively quick), and the speed of the legal or other framework that is chosen (the options are discussed in section 2.1.7). Other factors such as whether the forthcoming World Harmonised Duty Cycle[46] (WHDC) and the forthcoming PMP particulate measurement protocol also play a part. If the legal process is the Euro 6 Directive, then 2009 is a likely date. The PMP protocol is likely to be agreed for HDVs by the end of 2008 and used in Euro 6, and should be able to be used from then. It would be recommended that this is included in the technical measure certification to

[46] This would give read-across the world, and enable a greater market share, and potentially a world-wide certification scheme. This is likely to go with choosing Euro 6 option – if the WHDC is used there.

allow for providing all PM fractions. The WHDC is aimed to be agreed in time for the Euro 6 Directive. If the scheme can be completed sooner than the Euro 6 timescale, then an allowance for including the PMP protocol and WHDC when they are available should be included.

The scheme could aim to be for both PM and NOx when it starts, but be structured to be able to add additional pollutants as and when needed. If adding NOx at the start would slow the scheme down, then it could start with a PM-scheme only, and add NOx when agreed.

How long the scheme would be needed to run would depend on several factors including:

- Whether it would be useful for CO_2 technical measures, for fuels, tyres or retrofits.
- The speed of renewal of the fleet in the eastern part of the EU. The scheme may also be exported/used elsewhere in other countries which take the older vehicles from eastern Europe.
- Whether there is further tightening Limit Values and Euro Standards, and whether the Limit Values are met.

2.1.3. Interoperability

There needs to be as much interoperability in the EU-wide scheme as possible and it should aim be able to satisfy all potential LEZ/road tolling scheme uses in all EU countries, and even beyond, or as many as possible/practical. These could require different enforcement, such as manual (sticker), vehicle number plate recognition (database), transponder (such as Autopass, database), satellite tracking and other intelligent infrastructure enforcement of LEZs/road tolling, so that each scheme could choose their appropriate enforcement method. All would be linked with the same certificate id-number, e.g. DE 123456Y or UK 987654Z.

2.1.4. Transition

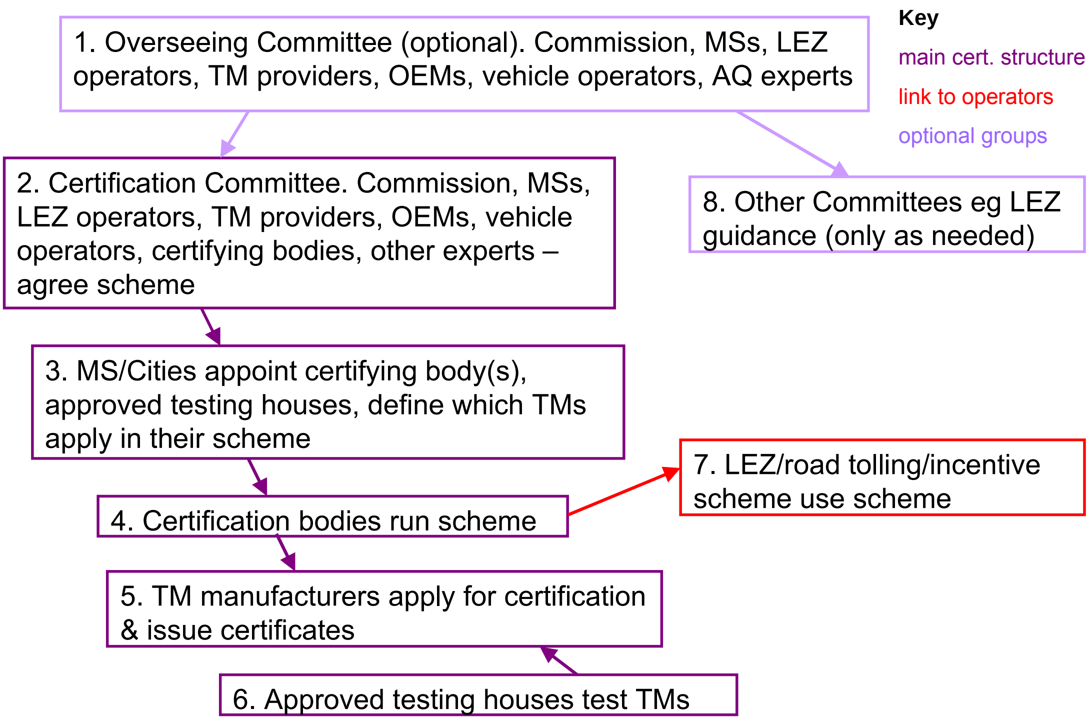
Existing schemes will need to be allowed until the EU scheme is up and running. The transition needs to be thought through and made future proof. This will require examination of existing schemes to identify whether there is compatibility of compliance requirements, and which certifications or data can be used with the new EU scheme, and where existing certification data needs to be supplemented or replaced. Grandfathering of all or some existing certifications could be considered.

The current stickers, e.g. in Germany and Sweden, should be continued to be used in their own country after the joint scheme is in place, although it may be that EU-wide stickers may be required for the vehicle to enter foreign schemes. Replacement stickers on renewal would gradually mean that all stickers would eventually conform to the EU scheme.

2.1.5. Scheme Management

A possible management structure to the scheme could be as outlined in Figure 1 below. Groups 2-7 are those envisaged for the certification scheme, groups 1 and 8 are optional for other technical measure or implementation mechanisms. This structure may be appropriate as part of the legal/framework arrangements of the scheme, or the management structure which sits under them.

Figure 1. Certification scheme structure.



The Certification Committee would agree the details of the scheme, and produce the scheme guidelines. In setting the scheme up, this committee should be serviced with a) a detailed outline of the scheme and b) a secretariat to assist in speeding up the agreement of the scheme. Member States and/or cities operating LEZs would nominate certifying bodies and approved testing houses. In some countries the certifying body may be Government Agencies, in others private sector bodies. There could be more than one certifying body and test house per country, if they are linked by a common website. Cities and national Governments would then specify which technical measures apply in their schemes. All certifying bodies would comply with the scheme rules. The facilities of the current official technical services and approval authorities that homologate OEM vehicles could be used.

The technical measure manufacturer would apply to the certification body for certification. They would discuss the drive cycle test to be used with the certifying body according to set scheme guidelines to assess in interoperability between different drive cycles. An approved list could be defined within the scheme set up to assist this. The manufacturer would then provide the test results agreed using an approved testing house. The technical measure manufacturer/fitter would provide a manufacturers certificate to the vehicle operator with the technical measure installation. The manufacturer/fitter should be enabled to issue certificates, stickers and transponder data directly and send a copy of the certificate and all information including vehicle operator details to the certifying body to enter the details on the database for enforcement. Spot checks would be carried out to ensure compliance (see 2.5.3).

The Certification Committee would need a ‘home’ in the Commission. One option could be under the air quality committee (a regulatory committee), with the air quality forum providing the overseeing committee (Committee 1 in Figure 1), and a further more technical committee as the certification committee. An alternative umbrella, if its remit was altered, could potentially be through the ERA-NET network, which co-ordinates research on transport issues and brings many of Member State transport departments and emissions testing houses together.

The scheme should be self-funding, by charging the manufacturers to certify their technical measures. However, as demand for certification in each city/member state LEZ is unknown, some form of financial underwriting by the city/member state may be needed, depending on the arrangements of the certifying body chosen.

The scheme should periodically review each certifying body to ensure they all adhere to appropriate quality control. This could be done through ‘audits’ by a delegation from the Certification Committee.

Vehicle operators and technical measure manufacturers/suppliers should to be able to apply for certification in any member state. As it is the technical measure manufacturers/suppliers that issues the certificate a certifying body is not needed in each member state, as most of the manufacturers operate EU-wide. A mechanism to control compliance (section 2.4.1) would need to be in each country, but should, in most cases, be covered by existing or planned (for Euro 4 and 5 vehicles) inspection and maintenance schemes – although this should be confirmed in the detailed development of the scheme. Vehicles registered outside the EU are also an important issue for many countries. Foreign operators should be able to apply for certificates through certified technical measure providers in the EU, however there should be nothing to stop a country outside the EU adopting the certification scheme.

2.1.6. Scheme Implementation Mechanisms for short-term arrangements

These need to be in place as soon as possible, well before October 2007.

- A common website listing all the certification schemes and LEZ schemes in operation, with links to and from each scheme. LEZ schemes would agree to accept other certification, although there would be an acceptance that they may not all be equal. Foreign vehicles may have to register with LEZs in different countries, if data sharing cannot be arranged. Certified technical measures would be publicised, including through websites, so that vehicle and LEZ/road toll scheme operators know what devices are available. Lists of valid certificate numbers will need to be shared by the LEZ/road toll scheme operators to ensure that operators registering have valid certificates, but would not be publicly available. It could also have a role in sharing best practice. This could be done either through the Commission, or through LEZ cities acting together (see below). Timescales and organising funding are likely to be deciding issues here, although through the Commission would be best if possible and LEZ cities may be able to provide funding if needed.
- Alongside this, it would be useful for the LEZ cities/Member States to work together informally, to share experience and knowledge, through email, telephone dialogue, and potentially a password protected message board on the LEZ website, and a central co-ordination point (see section 3.4). The website could

also have a list of the grant and other financial incentives that are in existence across the EU.

- The certification scheme website information should be widely disseminated amongst Member States and cities considering LEZs and could become the EU-wide website. It would help LEZ scheme operators inform vehicle operators EU-wide, and could be a very effective – and cost effective – method of communication and support for new and existing LEZ schemes.

2.1.7. Scheme Implementation Mechanisms for EU-wide scheme

There are several options, and timescales. The scheme itself could be defined in around 6 months. The legal framework may take longer, depending on the choice made. Below are some options:

- Through the Directive for Euro 6 to be agreed in 2009. However, if the scheme is likely to be subject to changes or updates, the Euro 6 Directive may not be the right mechanism. This would be similar to the type approval for replacement catalysts etc.
- A (non-legislative) EU framework providing guidance on the design of LEZs, and as part of that provide the certification of retrofits for them. This certification process could then be used for road tolling and other incentive schemes etc
- A Directive or Council Framework Decision[47] on LEZs focusing on the EU-wide certification scheme – which could also be used for other schemes such road tolling and financial incentives. It should be noted that the workshop was firmly against a Directive for LEZs in general – fearing that this could have the effect of restricting cities' ability to address local problems in a flexible way, and also due to time concerns.
- A common international standard through an ISO technical standard, that could then be used by all, with a framework around it for the scheme itself. The Swiss are considering using this or a CEN (see below) standard with an altered VERT scheme, and it would make sense for there to be dialogue, if not combination between this Swiss proposal and the EU-wide scheme. The EU, US and Japan others already use the off-road test cycle ISO 8178.
- CEN standards and guidelines may be a mechanism that could be used, under CEN T03 road vehicles, as CEN standards can give a wider framework than the ISO technical standards through guidelines. Relevant examples of where CEN standards / guidelines / groups technical committees etc already exist include guidelines for transport city logistics[48], and groups on gas supply for Natural Gas Vehicles[49] and emulsion fuel standards[50]. However both CEN and ISO standards/norms etc have the disadvantage of not being freely available. An ISO or CEN standard or guideline could be used in conjunction with one of the other options to make it an implementable EU-wide scheme.

[47] effectively a non-Commission initiated equivalent to a Directive
[48] DIN EN 14892:2006 Transport service – City logistics - Guideline for the definition of limited access to city centres
[49] Sector forum CEN/TC 326NGV, Gas supply for Natural Gas Vehicles (NGV), developing CEN standards for filling stations and Vehicle refuelling appliances
[50] CEN Workshop Agreement (CWA) 15145:2004

- The need to facilitate workable LEZs in cities should be addressed in the forthcoming EU urban transport green paper, which may also be able to provide a framework for the certification. However it is only consultative and follow-up action is not likely until 2008.
- It may be that operation of the certification scheme, or at least agreement of the details, could be through an (informal) EU working group – preferably with a secretariat to speed the process up.

The Commission decision as to which approach to choose has several factors, including political ones. Some options may be quicker than others, and each has its pros and cons, which are discussed through the report as they are relevant. It was argued at the workshop that, given the likely timescales for implementation of schemes (e.g. in Munich, London and Berlin), preparatory work on a certification scheme should continue, even if it is not yet clear what shape a final scheme might take. The key elements are summarised in Table 3 below.

Table 3. Key pros and cons of different legal mechanisms

Mechanism	Pros	Cons
Euro 6 Directive	• A potentially tidy mechanism • Easily allow easier incorporation of the PMP protocol, & WHDC if used	• Not possible before 2009
Directive on LEZs, especially certification	• Could potentially be a mechanism to require all member states to implement scheme • A minimum Directive may be quicker to implement than a 'full' Directive	• May take a long time, and may not be passed by the Parliament and Council of Ministers • Workshop was firmly against a Directive
Framework on LEZs, especially certification	• Could be a quicker mechanism • If could be certain of being implemented within 9 months could avoid the need for an interim scheme/mechanism	• May not have as much legal weight
ISO technical standard	• Could be used in conjunction with other mechanisms	• May still need legal mechanism • Not necessarily a quicker mechanism • The standard is not freely available
EU working group	• Could be a quicker mechanism • More likely to be an option for helping decide on the final scheme	• Unlikely to have sufficient weight
CEN standards / guidelines	• Could avoid a lengthy Directive process • Could include wider issues than an ISO standard	• Not necessarily a quicker mechanism • The standards and guidelines are not freely available
EU urban transport green paper,	• Could be a mechanism for a framework	• It is consultative only • Follow-up action is not likely until 2008.

Whichever mechanism used, it is essential that the information is widely disseminated, including through a website.

2.2. Emissions requirements

The scheme should be output-driven and technology neutral, and not require fitting of particular technical measure.

The test certificate should set out the test results required in an ‘impacts table’. This will allow the LEZ/road tolling/incentive scheme to choose the technical measures that are valid for its scheme. It would allow existing requirements to be serviced, as well as allowing the option in the future of percentage emissions reduction requirements – for example 90% reduction in PM, which would allow significant emissions reduction through retrofits.

The scheme would provide categorisations of the technical measures, so that cities and Member States can indicate which category(s) of technical measures are covered in their scheme. Depending on the views of the LEZ operators, a small number of categories would be simpler.

Emission tests are not perfectly repeatable, there is an error margin – presenting an average of a number of back to back tests required (section 2.5.1) allows for this. The exact measurement method(s) required for each emissions covered in the scheme needs to be agreed in the detailed design of the scheme and specified in the scheme guidelines.

2.2.1. Emissions reduction

The ‘impacts table’ should include the percentage emissions reduction, g/kWh or g/km, and what Euro standard original vehicle the technical measure takes to which Euro standard for each pollutant. It would also label Euro standard for each pollutant. The Euro standard level would be taken from the engine dynamometer test. This would allow both comparisons with current Euro standards and greater flexibility about the emissions standards set.

The particulate metric needs to be set. PM_{10} is the current legal EU-metric. Having the metric as PM_{10} would allow consistency with Euro 1-5 standards and allow comparison with and use of previous data. It is recommended that the PMP protocol should be introduced as the main measure of PM emissions reduction when possible, in addition to the PM_{10} metric. This protocol allows for much lower detection levels and greater degrees of repeatability than the current gravimetric method. It also allows for the determination of particle number. Without a protocol to count particle numbers, the existing gravimetric mass-based metric for PM measurement may permit technical measures which still allow high emissions of nano particles, with their greater health impact. While this could speak for the Euro 6 mechanism, however the PMP protocol is expected to be validated by mid 2007 for HDVs, and is already validated for LDVs. Once both validation exercises are complete and reported, work on the proposed measurement techniques will be finalised. The next step will be to consider whether to adopt either or both techniques in future vehicle standards. It should be noted that including the PMP protocol may allow less use of previous data, so greater thought needs to be given to the transition between the interim and full scheme.

The percentage reduction should be given for both the engine dynamometer and drive cycle. For full flow particulate traps the percentage reduction should be similar. For NOx devices the choice of drive cycle can impact significantly on the emissions performance. Care would have to be taken that this factor does not affect the drive cycle chosen. Guidance should be given for both LEZ/road tolling and vehicle operators as to how to interpret the different percentages.

2.2.2. Secondary Pollutants

Secondary toxic emissions are defined as all toxic substances, which are either absent or found only in much smaller concentrations from engines without exhaust aftertreatment systems[51]. The 'impacts table' would also include the impacts on these other secondary pollutants that would be specified in the testing regime. These could include

- The PMP protocol to be used to count for particle number, ultrafine particulate, other PM metrics[52] when it becomes available. It is likely to be used for Euro 6, and the protocol is expected for HDVs by late 2008. The protocol for LDVs already exists.
- A Greenhouse Gas (GHG) count – the impact of a defined basket of pollutants including CO_2, methane and N_2O – given as "CO_2 equivalence" according to their relative GHG potential[53] .This simplifies the scheme to the operator, gives what is required for the output. Alternatively each pollutant could be included separately either instead or as well.
- Percentage increase in NO_2, defined as NO_2:NO_x ratio, particularly for PM devices
- Other regulated pollutants; CO, HC, NOx for PM devices, and PM for NOx devices would be measured in the primary measurements
- Potentially an allowance within HC for non-methane hydrocarbons for dual fuel gas vehicles with the methane included in the GHG count.
- Ammonia (for SCR),
- Dioxins,
- Nitro-PAHs

Exactly what would be required to be measured would have to be decided in the final discussion on the exact scheme, which should start with those outlined here.

Certification would not exclude technical measures that increased emissions of other pollutants, but would state their impact (average of the tests $\pm$ error). The detailed scheme guidelines needs to define what constitutes an increase, based on the emission tests and the error margins. It would then be up to the city or member state when setting its LEZ or incentive scheme to choose which were allowable. In practice

[51] Note, this definition of secondary *emissions* is different to that in air quality when NO_2 is often called a secondary *pollutant* as it is converted from the NO emitted from the vehicle tailpipe.
[52] Ways of measuring
[53] based on methane having 21 times more global warming potential than CO_2 and N_2O having 310 times more global warming potential than CO_2 etc

some increases (always to be considered as those over that allowed for error/test repeatability, explained above) may always be chosen to be ruled out of schemes. Therefore the certification scheme should either give guidance on which pollutants are usually ruled out – based on the existing and planned schemes, views of implementors, or state what the different existing schemes request.

When deciding the exact requirements of the secondary emissions tests there are three main issues to consider. One is the desire to ensure that the technical measures do what they need to do, and not cause any un-intended consequences. The second is the practicality and cost of measuring each pollutant. The third is the level playing field, or otherwise, between what is required for OEM vehicles and retrofits.

2.3. Fuels

An option within the EU-wide certification scheme could be to include non-diesel/petrol fuels or additives through the first part of the technical measures certification as is done in CARB. This would enable the fuel to be certified as having X impacts so that vehicle operators could be assured that they ‘do what they say on the box’, for use in financial incentives. The vehicle using the fuel would not be certified in the same way as retrofits. The fuels in particular in question are Diesel Water Emulsion (DWE) and ethanol. While ethanol is not yet available as retrofit, it may be the lack of a policy driver / competition rather than a technical reason – hence including ethanol/fuels may help create this driver.

However there was not a clear case made for this as there were for the other issues included in this report with a mixed reaction from stakeholders, but generally a joint scheme was supported. Therefore it is given here as an option for the Commission to consider – particularly from a policy point of view – together with stakeholders, rather than a recommendation of issues to be taken forward as has been done for other issues. The priority for the EU-wide certification scheme should be to resolve first the PM and then NOx retrofit issue for LEZs, and any decisions on fuels could follow later, as long as the system is designed with this in mind.

In terms of the tests needed, diesel and petrol fuels are normally subject to extensive and extremely expensive tests before being certified – e.g. CEN working groups, standards etc. As well as emissions, there is also the issue of long term impact of fuels on engine components, deposit build up etc.. Within this certification scheme fuel tests would be best done predominantly on engine test bed, under extremely closely controlled conditions. This is likely in some cases to negate the need for chassis dynamometer tests. However there is evidence to suggest that e.g. Diesel Water Emulsion (DWE) emissions are influenced by drive cycle, so the detailed specification of the scheme should give guidance to the certifying body as to what types of test regimes are appropriate to different categories of fuels. In general it is felt likely to be:

- For Natural/Bio Gas: Engine Dynamometer.
- DWE: Engine dynamometer and drive cycle.

2.4. Scheme operation issues

2.4.1. Controlling compliance

In order to ensure that the certification scheme is not abused, vehicles need to be periodically checked through the annual inspection and maintenance programs, and also spot-checks (if desired). This would require validation of the vehicle, against the certification database to ensure that all is complied with. Controlling compliance is needed, and emissions are already part of inspection and maintenance annual/bi-annual tests.

There needs to be a mechanism in each Member State for the inspecting authority to be made aware that the vehicle is certified as having such a device, so that this device is checked. The inspecting authority also needs to know the details of the certification (e.g. engine/vehicle model/family, operational conditions certified) on vehicles in service is provided with the data set.

The mechanism for this may have to vary across the EU. Ideally the check would be through the annual inspection and maintenance. However, this can require a legal mechanism that may not always be available – for example in the UK the (only) available mechanisms are either the annual vehicle inspection (and diesel smoke opacity test) and/or Reduced Pollution Certificate scheme (both administered by VOSA, the Vehicle and Operator Services Agency). Where testing under the annual inspection and maintenance regime is not possible, the certification scheme in that Member State would have to have an additional compliance test – as was done in the UK Powershift and CleanUp schemes – as the responsibility of the certifying bodies with the costs of this either included in the fees charged or paid for by national Government or the LEZ schemes. This option would be more expensive to administer, and it may be that the introduction of new tests for OEM Euro 4 and 5 vehicles can be used as they are developed, particularly if the national legislation for this has not yet been finalised. Any systematic fault found with a device would lead to the device being de-certified. The technical measure in question would then have to prove that the issue had been resolved during its re-certification.

Selecting the appropriate test is relatively straightforward for diesel particulate filters devices (DPFs) using current tests. It is less straightforward for diesel oxidation catalysts and for NOx compliance where there are no standard in-service test.

For NOx retrofits the conclusion is that OBD (On Board Diagnostics) or some Diagnostic Tools are required particularly to ensure that the operator is using the reductant for SCR, and to give a test for NOx. It is not practical to retrofit power reduction, as is required for OEM Euro 5. However, it could be a system that supported only the retrofit, and did not interact with the engine – i.e. shows a warning light rather that reduce engine power when the device does not work, so the diagnostic is broadly in line with OEM Euro 4 requirements with an additional warning light additional.

It could be that the certification scheme allows for several options of diagnostic, and as with the other pollutants, the city / Member State schemes decide which are valid, and the certification scheme providing guidance on which are likely to be accepted.

For NOx retrofits the options could include:

- For SCR or EGR a NOx sensor could be placed in the tailpipe, which provides data to a data-storage module that can then be interrogated – at the annual inspection or random tests. Procedures and error codes should be harmonised as much as possible with the OEM requirements for ease of testing. This could have a warning light attached to it. A similar system is already used on some DPF systems, storing up to 24 months data. This would entail some additional extra cost. These will need to be included in the annual inspection tests due to the OEM Euro 4 and 5 vehicles, so the same tests should be able to be used as long as the same standard OBD codes are used – which is recommended.

- For SCR systems, urea-fuel-km monitoring through fuel and urea fill automatic datalogging systems and vehicle mileage would be possible. Urea usage will vary with load, as will fuel, and a range of reasonable urea/km and fuel/km would be provided by the certification scheme. Monitoring would entail no/little extra cost. It would tested through an inspection of urea usage data. It could be combined with urea quality sensors to ensure that urea is filled, not other liquids. These are available (from Japanese and US companies), with a dash-board indicator indicating an error such as no urea any more or wrong urea quality.
- Either of the above with remote data collection via GPRS (General Packet Radio Service[54]) systems and could provide for spot checks but would entail greater additional costs. This would be a parallel system operated by the certifying body. However, this alternative is more than is required for the OEM vehicles, so is unlikely to be an.
- Visual checks of the NOx device, possibly in conjunction with the above. If these are within the annual inspection and maintenance tests for OEM vehicles, then these are easily used. They could also be part of any alternative testing arrangement. For SCR it would also be useful to an inspector to be able to easily see the urea/ammonia tank. Whilst packaging may be an issue, it could be a mandatory requirement that the tank should be “readily accessible for inspection”

For particulate filters, electronic service indication (backpressure control) should be mandated (unless it is proven that a bypass system or other failsafe is built in) with alarms to alert the driver (optical or acoustic) and data stored to clarify failures. Testing options for particulate retrofits could include:

- DPF condition monitoring of exhaust temperature and back-pressure providing data to a data-storage module that can then be interrogated – at the annual inspection or random tests.
- Free Acceleration Smoke Test.
- Visual inspection of the PM device, again possibly in conjunction with the above.

For Gas Conversion the compliance test would be the idle emissions test as per petrol vehicles, although with dual fuel diesel/gas engines this may need further development.

In addition for both conformity of production and conformity in service, there should be random sampling of a number of devices each year for each manufacturer – co-ordinated over the EU - which would replicate the real world cycle element of certification, as is done by VERT, USEPA, CARB and the UK Powershift/CleanUp schemes. This is very effective means of policing measures, which gives a powerful and objective tool to a committee overseeing the scheme to control quality, and has two parts. Firstly a failure would require the equipment manufacturer to investigate

[54] a mobile data service available to users of GSM mobile phones

and report back and put right. If they do not rectify the problem then the sanction of postponing or removing from scheme can be used. Secondly, it could include a points system whereby the number of failures for each specific technical measure is monitored, for each specific retrofitters and for each specific equipment manufacturer. As with a driving licence too many points in a period of time and sanctions could be taken.

2.4.2. Control of suppliers / fitters

These are an important part of the equation, and there are four options.

1) A register of suppliers and fitters
2) Certification/accreditation of suppliers and fitters to certain minimum standards of competence, by the certification body.
3) A requirement for manufacturers/suppliers to provide evidence that their fitters comply with requirements laid down, and it is the suppliers responsibility to police the suppliers/fitters – and if one of the fitters is found to have fitted equipment not to the requirement, that equipment is de-certified[55]. This requires an on-going testing to ensure technical measures fitted comply with the certification.
4) To use a meta standard i.e. one which comprises or recognises other organisations certification as part of certification to your scheme[56]. It effectively allows the running of options 2 and 3 combined. Either trade associations could run certifying schemes for fitters that could be adopted, or ISO 14001 etc could be used.

The second option may be the more practical one, and lead to a more streamline scheme – however it would need to be policed, as would most options.

The Dutch system also requires that only fitters which have a licence for the annual inspection are certified as retrofitters. Only suppliers which have a contract with the government and have a certificate for COP (conformity of production) will receive a certificate for their filters.

2.4.3. Data and enforcement

This is an important issue, and has several levels. While enforcing for national vehicles should be fairly straight forward, enforcing against foreign vehicles is particularly difficult, and while this is an issue outside the remit of this project, is one that should be urgently addressed by the Commission.

Ideally an LEZ scheme should be able to:

a. take the vehicle registration number of a foreign vehicle if automatically enforced or sticker number or registration number if manually enforced
b. look the number up on a database to find out whether or not it confirms to the emissions standard through the retrofit certification scheme or a database of Euro standards (See section 3.1), and

[55] A similar system is used by the UK LPGA (Liquid Petroleum Gas Association) that has a certified fitters list which requires the organisation to achieve accreditation. If there are any complaints the LPGA investigates and rules whether they can continue or be struck-off.

[56] such as Powershift did with the LPGA scheme

c. if the vehicle does not comply send and enforce a penalty notice to the vehicle operator.

To confirm the certificate is valid the LEZ/road tolling schemes will need to be able to find out:

- Certificate number (e.g. UK 399948875)
- Is certificate valid ?
- When is it valid to and from ?
- Licence number of the vehicle – for enforcement
- Transponder / satellite system details (if relevant) – for enforcement

These data need to be able to be shared across the schemes. For national vehicles, this provides no legal problems, and the data could be attached to the appropriate vehicle databases. For foreign vehicles this requires several layers of data-sharing between countries, however not all are willing to do this due to Data Protection concerns or the legislation under which the vehicle registration organisations operate, and different countries have different approaches[57].

Sharing this information will need a mechanism, possibly through a shared or shared database where by each certifying body ensures that the above information are entered on a shared database accessed by those operating LEZ/road tolling schemes. There would be an acceptance that there may necessarily be a number of days delay for this to occur. The data should be able to be shared legally, as the vehicle registration number is public information. Due to the issue of vehicle registration cloning[58], it would also be useful if the colour, make and model of the vehicle were also collected.

The alternative to this is for vehicle operators to have to register with the LEZ operator in the other country, and giving their certificate number, which is then checked with the relevant member state certifying body – but is not ideal and gives additional work.

Being able to enforce the penalty on an offending vehicle is more difficult, particularly if – as may well be the case for many LEZs and road tolls – the offence is administrative or civil, for which there is no satisfactory EU-wide system of enforcement, and not a criminal offence. Criminal offences can be enforced throughout Europe due to the Council Framework Decision on Mutual recognition of judicial decision, and the EU project VERA is developing soft- and hardware to enable penalties to be translated.

Non-payment and non-enforcement of penalties of traffic offences for foreign vehicles is a significant issue for many countries[59], with local operators demanding a level playing field. At present non-criminal penalties are either not sent (as funds collected do not cover recovery costs), collected by debt-agencies (with limited success), through bi-lateral agreements or collected on the spot or as the vehicle leaves the country. None of these are satisfactory. There are a number of projects looking at this

[57] For example a very tight approach in France; in the UK the licensing authority has no legal power to accept foreign data or give UK data to foreign agencies; in the Netherlands data is able to be shared; and in Finland members of the public can get vehicle keeper information by text message.

[58] Whereby duplicate registration numbers are used illegally for different vehicles, often without the knowledge of the owner of the original registration number

[59] As an illustration of the issue, foreign registered vehicles in London are around 2% of the fleet but disproportionate in the congestion charge non-payers, and lost revenues are significant - including millions of Euros in unpaid parking charges.

issue, but again, they have not resolved it satisfactorily[60]. A new EU-wide project called EuroSparks[61] aiming to resolve this issue is awaiting an announcement on funding by DG Justice Liberty & Security. The Commission launched a consultation which includes the issue of cross-border enforcement on the 6th November[62], which may also help start to resolve this issue.

LEZs and road tolling schemes have the potential to be exploited in this way, bringing the requirement to treat foreign vehicles equally into sharp relief, as the identified foreign non-compilers may then not get penalised. Enforcement of foreign vehicles is a key partner to the EU-wide certification scheme and the EU should give priority to investigating an EU level system of cross-border enforcement of fines for traffic offences. Taking this issue further is outside the remit of this project, but raises the issue as an important one to be taken up elsewhere.

Solutions to the issue of foreign vehicle enforcement include:

- Currently, bi-lateral agreements are needed between different countries to allow penalties to be enforced. Most member states have such an agreement with at least one other member state
- EU action on this issue so that data can be shared between different national vehicle databases, and penalties enforced.

2.4.4. Dissemination of information

The certification scheme would disseminate information through a joint website that is linked to the certifying bodies' websites. This should provide information for technical measure manufacturers to be able to be aware of the schemes and to certify their products for vehicle operators to know what technical measures are available. Information provided on the websites would include:

- The technical Measures approved, their 'impacts table' and contact details and websites for technical measure providers/suppliers – through which suppliers/fitters would be accessed.
- Contact details for the certifying body to report failed devices.
- Background information on the technical measures, pros, cons, any issues – similar to that provided in the technical review in Part 2 of this report.
- The LEZ / road tolling / financial incentives that exist where the certified technical measures are relevant, and what is required for each one in terms of emissions reduction, pollutants measured, enforcement method etc.

Vehicle operators would be informed through trade bodies, helplines, leaflets, LEZ / road tolling / incentive schemes etc.

[60] These include EUCARIS/REGNET, Prum Convention, RESPER, RISER, eNFORCE, VERA Programme, CAPTIVE, London ALG "SPARKS" project, Dutch Government
[61] www.eurosparks.org
[62] http://ec.europa.eu/transport/roadsafety/enforcement/introduction_en.htm

2.5. Further Details of Scheme Operation

2.5.1. Number of tests required

The certification scheme needs to provide guidance on both the number of tests to be undertaken and whether previous data is accepted for either new approvals or extension to existing ones. A realistic approach needs to be taken to this, balancing certainty and costs. The USEPA approach of requiring a minimum of 3 hot start tests and 1 start cold test with a 95% confidence interval and additional tests required if the confidence interval is too wide would seem a sensible approach, although for Europe it is recommended that the cold start test is deleted. Other alternatives are to take a similar number of tests as is currently required to type approve replacement devices, or a similar number of emissions tests as OEM homologation. As far as possible, data used for previous certifications should be accepted and augmented as necessary.

2.5.2. Compatibility with other Technical Measures

Any retrofit should state whether it is compatible or not with biofuels or other fuels.

Equipment should also state whether it is only able to be used on its own, or whether it can also be used in combination with other stated certified equipment (e.g. SCR can often be fitted with together with a DPF).

Any additive used in conjunction with a retrofit should be agreed and tested as part of the certification process, and confirmed as not being toxic. Options for this include:

- A statement of no objection of the combination of additive & system from Government Agency (as per German/Dutch scheme)
- Proof that it must not damage vehicle or device, submit a safety datasheet, explain consequence of lack / excess, set the correct use, meet EN590 and must be safe to be used alone (Italian scheme).
- Provide a monitor to shut off the additive if there is a problem. The manufacturer should submit environmental, toxicological, epidemeological report data on the additive every 2 years and the system should be able to run with the additive at greater concentration than 50 ppm or 10 times the usual rate without adverse affects (CARB).

Any additive to be used on its own as a technical measure should be certified as a fuel within the scheme (if this option is chosen).

2.5.3. Durability requirements

Abatement equipment durability requirements (vehicle mileage/years) should, where possible, follow original equipment practice. As from October 2005 for new type approvals and October 2006 for all type approvals, OEMs should demonstrate that engines comply with emissions limit values for useful life periods which depend on the vehicle category, as shown in Table 4.

Table 4: Emission Durability Periods

Life Period*	Vehicle Category†
100 000km or 5 years	N1 and M2
200 000km or 6 years	N2 N3 ≤ 16 tonne M3 Class I, Class II, Class A, and Class B ≤ 7.5 tonne
500 000km or 7 years	N3 > 16 tonne M3 Class III, and Class B > 7.5 tonne
* km or year period, whichever is the sooner † Mass designations (in tonnes) are "maximum technically permissible mass"	

The scheme should include a meaningful production conformity assessment programme, based on production and in-service volumes that would act as a deterrent to suppliers submitting incomplete or inappropriate data to support application for equipment approval. The approach taken in the German/Dutch certification scheme of fulfilling the requirements in directive 70/156/EEC with ISO9001:2000 or equivalent could be used. Also effective from October 2005 for new type approvals and October 2006 for all type approvals, type approvals also require confirmation of the correct operation of the emission control devices during the normal life of the vehicle under normal conditions of use ("conformity of in-service vehicles properly maintained and used").

Therefore both durability demonstration (including regeneration events) and emissions deterioration (DFs) should be undertaken, to a test plan mutually agreed between the certifying body and abatement equipment supplier.

2.5.4. Warranty

A few OEMs claim that retrofitted equipment invalidates the warranty, and most state if a fault occurs that is traceable to retrofit equipment then they will not be liable as it is not their responsibility. This has a significant deterrent effect for vehicle operators retrofitting vehicles still in warranty. Retrofit also has increasing issues due to the increasingly complex engine management systems of Euro 4 and 5 vehicles.

For example if a DPF does not regenerate, the filter will clog up with soot which increases the backpressure on the engine and could have an adverse effect on the engine. DPFs such as continuously regenerating traps (CRTs, catalysed DPFs) regenerate continuously and therefore the filter loading should not get to the point where there is excessive exhaust back pressure out of manufacturers specifications. Therefore the manufacturer could provide a letter of no objection to the trap supplier, and warranty should not be infringed. If a trap system with strategies that initiate regeneration at high filter loading is used the engine back pressure might follow a saw tooth pattern and in the period prior to regeneration the backpressure might be higher than manufacturers specification. In this case the engine supplier could object and not offer a letter of no objection. Hence fitting the trap might invalidate warranty, and if it is proven that the DPF was the cause of any problem, then the OEM would not pay out the warranty.

Some vehicle OEM warranties can also be invalidated by using biodiesel and other emerging fuels at more than 5% blends. DWE risks water separating out from the fuel which could lead to problems in injectors and pumps, and higher biodiesel blends can be incompatible with some engine components. Insurances could also be used to resolve this issue for fuels, where the insurance would cover those parts that the OEM would consider likely to be affected by the fuel e.g. injectors, fuel pumps.

Some retrofit providers have liased with vehicle OEMs to get their retrofits accepted for certain vehicles. Another way round this issue is for the retrofit provider to provide a warranty for their equipment or fuel provider to arrange insurance, as described.

Certification should require that the technical measure provider provides a warranty to accompany the equipment covering anything that the OEM can reasonably state could be affected by the technical measure. Ideally this should be 2 years or 100 000 kilometre parts & labour warranty – or the balance of the vehicle OEM warranty (if longer). This would cover what should be expected for a newly purchased system, as well as assisting in resolving the OEM warranty issue where relevant. Warranty exclusions should be written in clear, easy-to-understand language such that the vehicle operator is in no doubt to his duties and obligations in complying with the warranty provisions.

Vehicle OEMs should be part of the discussion to produce a final certification scheme, to ensure that issues such as this are resolved. The Commission should lead this discussion as part of the development of this certification scheme. Technical measures should only be certified for vehicles/engines where these – and any other – issues have been resolved. The certification for each device should also state any vehicles/engines where these issues have not yet been resolved, or are unresolvable.

2.5.5. Operation and Maintenance requirements

The scheme should require suppliers to provide an operation/maintenance handbook with every retrofit device with specific information on correct vehicle operating procedures and preventative/scheduled maintenance, and stress the importance of operator training and the need to report problems promptly. A service schedule, agreed and documented with the certification body, should form part of the supplier's deliverables to the vehicle operator.

Low ash lubricants reduce emissions and fuel use by around 2% and could be encouraged for DPFs through the maintenance guides.

2.5.6. Vehicle Registration Document alterations following retrofit

It is not seen as an absolute requirement that vehicle registration documents MUST be amended to indicate retrofit status (particularly as some member states would not want this option), although feedback from the consultation process indicated that it would be desirable if this was possible. Therefore a note of the adaptation / modification or other identifier (such as RPC status in the UK) would be a sensible approach.

If the EU legislation is changed to require member states to provide Euro standards on the vehicle registration (see section 3.1) then an option of being able to change the vehicle registration documents for retrofit should be done at the same time.

2.5.7. Legal status of retrofitted vehicles

The legal status of retrofitted vehicles appears to be open to interpretation at Member State level, and appears to vary around the EU. For instance, in the UK, as long as vehicles meet national legislative requirements (Construction & Use Regulations), including in-service inspection and maintenance (I/M) limits (smoke opacity for diesel vehicles), it is understood that retrofitting abatement equipment would not affect the vehicle's legal status.

In Germany retrofitted road vehicles have a legal status. Once a technology has been certified and registered in the vehicle registration document it's perfectly legal to install and use it.

It appears that this issue can be relatively simply resolved by the member state, and does not need Commission intervention, however guidance via the certification scheme as to the legal implications of retrofitting vehicles would be helpful.

3. Support for LEZs to support technical measures

3.1. Labelling of Euro standard for LEZs/road tolling

Most LEZs planned have a requirement for Euro standards as well as in most cases retrofit either as a requirement or as an option to meet the Euro standards set. If LEZs are to go ahead and be able to require retrofits, they also need information on the Euro standards. It would be easiest and most in line with interoperability if the two pieces of information were in the same system with most of the same issues in respect of issuing the certificate/sticker/database entry etc.

While there is a field in the EU vehicle registration database for Euro standard, not all countries (e.g. UK) have this filled in. At present vehicles without age on the vehicle registration documents are usually assessed on age – which does not give exact Euro standard[63].

The automatic enforcement methods could work on pre-registration of vehicles for foreign vehicles where the age is not clear from looking at the vehicle[64] and/or vehicle age does not give a 100% match for Euro standard. However, manually enforced sticker systems would still need to have the Euro standard on the sticker. Having 2 stickers would be against the interoperability principle.

EU legislation should also be amended to make Euro standard mandatory to be on the vehicle registration documents for new vehicles. This would require amending of Directive 1999/37/EC to make Euro standard mandatory on the vehicle registration certificate, with an option to amend for retrofit equipment. It could be added by manufacturer for new vehicles (there would be an issue about imported vehicles). If necessary, such amendment should be possible to decide upon by the Commission assisted by the Committee established by Article 8 of Council Directive 96/96/EC (see Article 7 of directive 1996/37/EC).

It is recommended that this issue is resolved urgently by the Commission. It could be a common Euro standard label, to which the technical measure certification is added, or a single joint certification mechanism could be developed together. However, it is recognised that this is a wider issue for LEZs and beyond the remit of this project.

3.2. LEZ Guidance

LEZs are a key mechanism to help meet the air quality Limit Values, are supported by the Commission[65], and are one of the measures that have to have been considered before an extension to the Limit Value deadlines can be considered. Schemes such as LEZs and road charging need to be notified to the EU, due to the freedom of movement issue in the Treaty of Rome.

Guidance is needed on LEZs as soon as possible if they are to reach their full potential. The guidance needs to be specific enough to assist, but not too specific so as to exclude appropriate measures at the local level – for example Berlin including cars in their LEZs, others not - providing guidelines, not obstacles to existing LEZ's and appropriate local measures. The most important piece of information for the

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[63] Some manufacturers complied before the deadline for all vehicles to comply, some did not. In the London LEZ these vehicles are required to register and identify their emissions, as are foreign vehicles, where the Euro standard is not known by the scheme operators

[64] For example non-personalised UK number plates give the date of registration of the vehicle within 6 months

[65] http://ec.europa.eu/environment/urban/pdf/com_2005_0718_en.pdf

guidance to contain is “Think about the EU when you are designing your LEZ”, and that the EU and freedom of movement issues need to be taken into account carefully and early when designing an LEZ.

The guidance should also include:

- Links to the certification scheme – both interim and EU-wide
- Recommendations/best practice on how to enforce a LEZ
- Recommendations on how to notify the LEZ under procedure 98/34, when schemes should be notified, what information is needed, and that 12 months should be allowed for this process – particularly with respect of the freedom of movement aspects
- A description of the difficulties of implementing a LEZ and how they can be best overcome
- Examples of the different LEZs in the EU
- The pitfalls of what to look out for and the things that would definitely not work or be legal in LEZs.

The guidance needs to be focused enough to be of assistance, but not limit local flexibility - for example the Dutch LEZs also include noise and therefore other legislation. It should serve to explain the procedure to those implementing LEZs, who are likely to be cities may well not have experience of EU issues. The main thing is for LEZ schemes to be talking first to their national Government, and those who should have experience in notifying and complying with EU law, and also to the Commission itself. In general, schemes such as LEZs need to be notified to the Commission under Directive 98/34 via their national government[66] - although local schemes may be exempt from this requirement. This procedure enables the Commission and other Member States to check whether the scheme would cause a barrier to trade and if so to request amendments. If there are freedom of movement problems the Commission responds (within a fixed timetable). Where schemes do not have to notify (as in London's case, because it was not implemented through national legislation) they nevertheless have to ensure that it does not breach freedom of movement principles. Any alterations to TransEuropean Road Network roads can cause issues with the EU, and should be considered.

Guidance should help avoid issues such as that in the Swedish LEZs, where the standards have been changed a number of times (partly in response to freedom of movement issues) as well as assist cities implement LEZs faster so as to be more able to meet the air quality Limit Values.

Guidance at EU level should collate, or provide reference to both information on the relevant case law of the European Commission Journal and details of existing or planned LEZ, to give a better idea (albeit not definitive) of the limits within which LEZs should be designed.

The guidance needs to be implemented in discussion with those developing LEZs, and not risk becoming a further – later - barrier to developing an LEZ. It could also include best practice from current experience.

The Commission will be producing guidance elements on LEZ implementation in the Urban Transport Strategy - expected to be published by the end of this year - as

[66] http://ec.europa.eu/enterprise/tris/index_en.htm

actions from the Thematic Strategy on the Urban Environment. This could be followed up with more detailed guidance, that was consistent with the outline guidance, and that would not produce further barriers to the LEZs that are/will be in operation.

A possible mechanism/place for the LEZ guidance could be the CEN transport city logistics guideline[67] where LEZs could be included, referenced or that guideline built upon. This CEN guideline is a EU Standard describing possible restrictions for access to city centres, providing guidelines, and a code of good practice that can be applied when efficient transport and protection of the environment presupposes restrictions. However, through the Urban Transport Green Paper may be more visible, but is only consultative and not due to be published until Autumn 2007, particularly as the CEN guidelines are not freely available and need to be purchased. Whichever mechanism used, and particularly if the CEN white paper is used, then the guidance needs to be circulated to cities and member states as fully as possible.

3.3. Information sharing

It is often difficult for vehicle operators to know what schemes are available, and those operating LEZs/road tolling to make the information widely available. Sharing information on this would help vehicle operators know what schemes exist so that they can plan accordingly. It would also help potential LEZ/road tolling scheme operators know what schemes existed and are allowed, and enable them to contact the relevant cities/Member States for advice.

The Commission should ensure that there is a single website with information on all current, and preferably planned, LEZs as well as the EU-wide certification scheme (and interim scheme). It would also be useful to have information on financial incentives/support that are available in each member state to support retrofit or LEZ compliance. Both sets of information are already on the EU website to some extent. Those LEZs that are notified are on the notification 98/34 Procedure database. However this information is in a legal-ese language from which it is difficult to understand what is intended from a policy point of view, and the database is difficult to search for LEZs unless one already knows about it and has the notification number. LEZs that are not notified are not on the site. Information on financial incentives that have been agreed through state aid are on the state aid website, but only in the language of the applicant, and not easily searchable.

Schemes that could prove themselves as being very similar to existing schemes may be able to be considered for 'fast-track' consideration under 98/34, and the list of LEZs that exist and the EU-wide certification scheme would assist with this.

Ideally maps would be available for operators to know where the LEZs were, as well as and information on the schemes such as where they are, what they require, penalties, when in operation etc. This information would also be available to be able to be linked into GPS navigation databases.

This would give a huge benefit from the freedom of movement point of view – particularly mapping LEZs - and the Commission is best placed to undertake this, as opposed to each city/member state separately trying to spread the information EU-wide. If there is a need to register, obtain stickers etc, this should to the greatest

[67] DIN EN 14892:2006 Transport service – City logistics - Guideline for the definition of limited access to city centres

extent possible be do-able on the web, and again it would limit free movement less if this could be accessed/linked for all LEZs via a single centralised website.

3.4. Informal/semi-formal grouping of LEZ cities

As briefly discussed in section 2.1.6, an informal grouping of all LEZs cities to support each other would be of assistance where they could discuss issues and solutions and could LEZs be implemented quicker. Many of the cities and Member States are finding the same issues and such a group would save each city 're-inventing the wheel'. Formal or informal input and support from the Commission would be very useful for this group.

It would allow LEZ cities and potential LEZ cities to discuss issues, gain from others experience and share solutions. For example where one city has already resolved an issue such as exemptions, it could help provide justification of decisions for other cities tackling the same issue, as stakeholders and cities can see that they are not alone with this issue. This group could also provide the vehicle to develop and share best practice on LEZs, including on information campaigns to the public in general and those affected by the scheme in particular - including on how to register with the various schemes and how to obtain stickers (where needed).

If, for any reason, the Commission is unable to provide a common website with information on LEZs, interim certification schemes and financial incentives/support on a website either at all or quick enough, it may be that such a grouping could do so. The group may also be able to provide more detailed information complimentary to the EU LEZ guidance.

4. Fiscal issues

When collecting the initial input, there have been many calls for funding of technical measures. There was an acceptance that research, development and demonstration (RD&D) is needed to assist technologies to come to market. There is a chicken-and-egg situation[68] with technologies and setting LEZ standards - unless a technology exists and is well developed, it cannot be an LEZ standard. Once it has been set as an LEZ standard, there is sufficient certainty in the market to enable manufacturers to develop them. Credibility and experience from pilots is needed before promoting technical measures wider. It is generally accepted that public funding of RD&D is needed to bridge this gap and overcome these issues, and public procurement can help in market development, although there may be some problems with NOx retrofit development still ongoing while LEZ standards are being set.

There should also be a realisation that LEZs are rarely, if ever, going to be self-funding, and are often politically difficult to implement, especially at the local level, so all the support possible is needed.

In many member states, grant funding for technologies and lower duty rates for fuels have been used to encourage uptake of technical measures, often to great effect. Some member states see financial incentives to fit the whole fleet, others that it is to kick-start the market and develop trials. Taxation and financial incentives are subsiduarity issues, and the therefore remit of the member states. The EU has a role

[68] Meaning it is difficult for one cannot start without the other coming first

in terms of the state aid rules – which many of these schemes have had issues with – and guidance. EU action on funding is therefore focused on state aid, VAT levels and potential procurement consortia.

4.1. State Aid Issues

State aid rules follow from the Treaty of Rome, and have been an issue for many of the grants and fuel duty incentives, as these need to be notified and approved by the EU Commission. To help support technical measures, it would be useful to have a framework for state aid that allows, enables, and potentially even encourages, national and local subsidy, tax regimes for the use of technical measures.

Most of the workshop was focused on the certification scheme, both because it was the key issue for discussion and as those particularly involved with state aid issues were not able to attend the workshop. Therefore there was less call for changes / clarifications on the state aid issue than there were when collecting the initial input, and in the subsequent pro-formas returned both by those attending and the wider circulation. Due to this and that there is currently a review of the state aid procedures in the 'State Aid Action Plan', a review of the state aid environment guidelines[69] and of the de-minimis levels[70], issues that did not come out clearly from the workshop are also included here.

Clearer guidance on what is and is not allowed would be very welcome, and is already provided for some issues such as regeneration[71]. It would also help increase the transparency with which these issues are treated. There is a recognition that every scheme will be different, so providing guidance will be difficult as each situation is different and the approach taken may affect its legality.

A list of the incentive schemes that had been approved and in operation, possibly with case studies was identified in the workshop and other input as being very useful as a form of guidance. This would allow member states to see outlines of what is possible, therefore be better able to understand the precedents, and know which member state to contact with any queries. What issues had been resolved and how they have been resolved would also be useful if possible. As with LEZs, information is already on the Europa website, but is in national languages only and not easily searchable. If the Commission is not able to provide such information on a website, it may be that the LEZ cities working (see section 3.4) together could.

Other things that might help could include:

- Technical measures should be able to be considered as environmental measures, and so be able to use the current de minimis ceiling of 100 000€ over 3 years, which exempt the transport sector[72]. In the present consultation the Commission proposes that subsidies of €200 000 or less will not constitute state aid for measures for where the exact amount can be calculated in advance, and was

[69] Current guidelines expire at the end of 2007. The review is to give a clear, comprehensive framework, clarify the rules, and be more efficient, transparent and streamlined. Aims: growth, jobs, social and regional cohesion, favouring environmental protection and cultural diversity. Also due to an enlarged EU. Use more block exemptions, with fewer measures notified and control proportionate to the effect on competition and trade.
[70] The de minimis level under which subsidies are not considered as state aid, and do not have to be notified to or approved by the Commission
[71] For example see http://ec.europa.eu/comm/competition/state_aid/others/vademecum.pdf on regeneration
[72] Last year, the EU Commission consulted on a draft Proposal to delete the exclusion of the transport sector from the de minimis rule, but this was rejected.

generally supported in the consultation[73]. The environmental classification currently includes waste management, energy-saving, renewables, combined head and power (CHP).

- The Commission has the power under certain conditions to exempt aid related to the environment, SMEs, R&D, employment, training and regional development from the obligation to notify to the Commission – called block exemptions. This may also be able to be used for technical measures.
- Consistency in case officers dealing with each case to reduce the delays that occur when the case officer changes during a notification leading to questions being re-asked and the topic re-learnt. Co-ordination of similar schemes could also be beneficial.
- The amount of time taken for the state aid notification process is a key issue. Anything that could be done to speed up the time taken to responded to questions would be useful. For example any guidance that could better prepare applicants to be able to answer all the Commissions likely questions in their original application and the pre-submission discussions would assist in reducing the time spend to-ing and fro-ing with questions and answers. Schemes that could prove themselves as being very similar to existing schemes may be able to be considered for 'fast-track' consideration – and the EU-wide certification scheme should be able to help in that determination.
- It would be useful and could potentially save a lot of time, that in the case of a member state approaching the Commission with a scheme that is not allowed in the form it is presented but whos aim is in line with other EU policies, Commission officials were able to say "what you aim to do could be done like this".
- Amending the environmental aid guidelines to raise the present maximum of incentives from 30% where it is clear that there is no commercial advantage to the operator from receiving a subsidy would be useful. In particular the present guidelines make it particularly difficult to promote cleaner and energy efficient vehicles, as costs are calculated on a 5 year basis, and if the measure breaks even/make money within that 5 years, then financial incentives are not allowed.

4.2. Reduced VAT on environmental technical measures

Allowing a reduced or zero rate of VAT (Value Added Tax) for technical measures and other environmentally devices, or allowing member states to do so, could also help reduce costs and increase their usage. Current VAT derogations include books; stamps; new, second-hand and company cars and parts; agriculture; fishing; tobacco; coffee; houses.

4.3. Procurement consortia

Where a product is in the early stages of being brought to market, a procurement consortium could reduce the costs and start setting up the market. If the EU facilitated an information exchange of those wanting to do this EU-wide, this would increase the potential markets and cost reductions. Examples of where this has been done is public procurement of ethanol in Sweden, which would be more effective done over a larger area.

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[73] http://ec.europa.eu/comm/competition/state_aid/others/action_plan/consult/saap.pdf

A similar mechanism can be used where a product does not yet exist to meet the requirements, where a procurement consortium spreads risk and specifies the product needed, knowing it will take years to bring to market. The “Forward Commitment” is that you commit to buy significant volume if the product is developed satisfactorily and you enter into a contract to say that. This could be used to encourage development of technical measures, and was outlined in work for the UK DTi[74] and Cenex[75].

Whilst there was little call for this, it was a detailed issue and there was not much opportunity to discuss this. Further work is needed to determine whether this would be an effective support mechanism.

[74] UK Government Department for trade and industry
[75] UK Centre of Excellence for low carbon and fuel cell technologies

Part 3 - TREMOVE Modelling

1.1. Introduction

Modelling within this project has two aims: to assess the potential impact and cost effectiveness of the most promising technical measures to reduce PM and NOx emissions from existing heavy duty and captive vehicles. There are three scenarios set aside to be modelled by TREMOVE for this project, which are defined in this section.

TREMOVE is a policy assessment model to study the effects of different transport and environment policies on the emissions of the transport sector. The model can be used to estimate the impact of policies such as road pricing, public transport pricing, emission standards, subsidies for cleaner cars etc. It estimates the transport demand, modal shifts, vehicle stock renewal and scrappage rates as well as the emissions of air pollutants and the welfare level. The model covers passenger and freight transport in the EU 25 and the period 1995-2030[76].

The modelling task in this study provides data to model the most promising technical measures in the light of the policies developed, so that they can be directly analysed by the model TREMOVE for the analysis of the cost-effectiveness of the scenarios and the analysis of the impact on pollutant emissions. This section provides information on the scenarios are presented here, to be used together with the data Table 2 from Part 2: the technical review that provide the corresponding variations in the user costs and fuel consumption / emission factors.

It should be noted that the costs submitted to this project were all current costs, which were validated when tested on the market as being correct. These must therefore be considered the most robust figures at this time. However, widespread national or EU-wide take up of retrofit systems i.e. hundreds of thousands rather than tens of thousands of units will create substantial economy of production resulting in cost reductions. These figures would be less robust, but may be more representative of what might happen. Actual costs in reality (ex-ante costs) are also often lower than predicted costs. The only costs that we have received in terms of these larger volumes were for catalysed DPFs, given as 2200 for small and 2800 for large systems, but have not been included in the table due to the different basis of these numbers. The Commission may therefore wish to examine this in more detail before undertaking any modelling activity.

The Excel spreadsheets in the format for the TREMOVE model are difficult to present in a report, but have been sent to the Commission, with the same information as in this report. The requirements for the scenario building and the data structure were discussed with the Commission TREMOVE modelling contractors (Laboratory of Applied Thermodynamics, LAT).

1.2. TREMOVE Input for Scenarios

Scenarios to estimate the effects of technical measures on existing captive fleets are designed as a variation of the TREMOVE base case. Therefore, the following information is needed for each technical measure analysed:

[76] www.tremove.org

- Impact on emissions and fuel consumption as correction factor related to the base technology (e.g. EURO-standard) of each vehicle category for the road categories “urban”, “non-urban” and “motorways” – or an averaged factor.
- Costs (as cost difference from the base technology) for capital and operation costs
- Penetration in the fleet as a share of each of the six heavy duty vehicle classes (Buses, Coaches, HDV<7.5T, 7.5-16T, 16-32T, >32T)

A scenario run needs a lot work for definition, data input and calculation. To reduce this work and the number of scenarios it is proposed:

- to focus on the most important technical measures,
- to define combinations of technical measures to be implemented within the same scenario,
- to define different degrees of penetration rates (e.g. optimistic, realistic) of vehicle stock.

1.3. Scenarios chosen

As there are only a limited number of model runs available, the pre-screening from the technical review has been used to select the technical measures to model. The output of the technical review and ranking exercise was clear that full DPFs and SCR are the most promising technical measures, and these are therefore modelled in the scenarios. Together they give 90% PM_{10} and 70% NOx emissions reduction.

The EU-wide certification scheme will help increase the numbers of retrofits used in the EU. It will enable LEZs to operate throughout the EU and to require retrofit technologies and/or newer vehicles. The inclusion of retrofits as a compliance option for emissions standards set will enable both tighter emissions standards than would be politically possible with just new vehicles, and the requirement of technologies that reduce PM by 90% and NOx by 70% - much further than an additional Euro standard pre-Euro 4. Depending on state aid reviews, it may also enable financial incentives to be streamlined through the notification process. It will also give reassurance for those member states not yet using retrofits that they are robust technology and could act as Best Available Technology (BAT) references for retrofits.

It is difficult to predict the impact of the policies outlined in this report, as it also depends on decisions about incentives and numbers of LEZs, therefore optimistic and realistic penetration scenarios have been presented. As LEZs can give significant incentives for retrofitting, and LEZs are one of the measures that have to be considered before an extension of the deadline to meet the air quality limit value is given by the Commission, an LEZ scenario is also included.

In all scenarios, the technical measure below has been assumed to be fitted to the Euro standard stated, for the efficiency given in Table 5 below. SCR or DPF is noted in the scenarios themselves.

Table 5. Type of technical measure:

Euro Standard	Type of TM
Pre-Euro 1	DPF PM 90% efficiency, with fuel borne catalyst
EURO 1	DPF PM 90% efficiency, with fuel borne catalyst
EURO 2	DPF PM 90% efficiency, any can be used,
EURO 3	DPF PM 90% efficiency, any can be used
EURO 3	SCR (NOx 70% efficiency)
EURO 4	NONE
EURO 5	NONE

Currently the only retrofit that would be valid for Euro 4 would be active traps. However as Euro 4 and 5 have the same PM levels, this retrofit is not a realistic policy to model, as it is NOx that would want to be aimed at. It may be that Euro 4 NOx emissions could be improved by up-rating the SCR, but more needs to be known about this before it can be recommended or modelled.

TREMOVE models buses as travelling only in urban areas, coaches as travelling only non-urban areas.

1.4. Scenario Designs

The following 3 scenarios are presented:

Scenario 1: Optimistic penetration.

Scenario 2: Realistic penetration

Scenario 3: Influence of Low Emission Zones (LEZ)

These scenarios should be combined with the effects on emissions, energy consumption and costs of the different technical measures from the technical review, shown in detail in Table 2.

Scenario 1: Optimistic penetration

Main objective: Analysis of the impact on pollutant emissions and costs with an optimistic penetration of retrofit measures for the bus, coach and heavy duty vehicle fleet for all countries.

Main assumptions:

- From 2007 to 2010 a part of the existing European pre-Euro 4 vehicle fleet will be equipped with technologies to reduce PM and NOx emissions. Penetration rates will reach a maximum in 2010;
- Only pre-Euro 4 vehicles are retrofitted, and the numbers below relate to the percentages of pre-Euro 4 vehicles.
- Estimation for total road traffic (all road categories); no influence of LEZ on the inner urban vehicle population
- The rate of fitment is equal for all pre-Euro 4 standard vehicles fitted

Table 6. Penetration rates for EU-15 countries, except Ireland, Iceland, Finland, where no action is assumed (little air quality problem):

Vehicle type	% of pre-Euro 4 vehicles retrofitted			
	2007	2008	2009	2010 and later
Bus (urban)	40%	60%	75%	90%
Coach (non-urban)	10%	10%	15%	30%
HDV<7.5T	10%	15%	30%	50%
HDV 7.5-16T	10%	15%	25%	40%
HDV 16-32T	5%	10%	18%	25%
HDV >32T	5%	10%	13%	15%

Table 7. Penetration rates for Eastern Europe, except Malta where no action is assumed (little air quality problem):

Vehicle type	% of pre-Euro 4 vehicles retrofitted			
	2007	2008	2009	2010 and later
Bus (urban)	20%	30%	40%	50%
Coach (non-urban)	0%	0%	8%	15%
HDV<7.5T	0%	15%	18%	20%
HDV 7.5-16T	5%	15%	18%	20%
HDV 16-32T	0%	5%	10%	15%
HDV >32T	0%	5%	8%	10%

Scenario 2: Realistic penetration

Main objective: Analysis of the impact on pollutant emissions and costs with a realistic penetration of retrofit measures for the bus, coach and heavy duty vehicle fleet for all countries.

Main assumptions:

- From 2007 to 2015 a part of the existing European vehicle fleet will be equipped with technologies to reduce PM and NOx emissions.
- Only pre-Euro 4 vehicles are retrofitted, and the numbers below relate to the percentages of pre-Euro 4 vehicles.
- Estimation for total road traffic (all road categories); no influence of LEZ on the inner urban vehicle population
- The rate of fitment is equal for all pre-Euro 4 standard vehicles fitted
- The countries that do not yet have LEZs include eastern European countries, where heavy duty vehicles do not often enter cities, hence the lower penetration for the two heavier categories

Table 8. Penetration rates for countries with stated LEZ-regulations (Germany, Netherlands, UK, Norway, Sweden, Switzerland, Austria, Italy)

Vehicle type	% of pre-Euro 4 vehicles retrofitted				
	2007	**2008**	**2009**	**2010**	**2015**
Bus (urban)	30%	50%	60%	80%	90%
Coach (non-urban)	5%	10%	15%	20%	25%
HDV<7.5T	10%	15%	20%	40%	40%
HDV 7.5-16T	10%	15%	25%	30%	30%
HDV 16-32T	5%	8%	15%	20%	20%
HDV >32T	5%	8%	13%	15%	15%

Table 9. Penetration rates for countries who are as yet without stated intentions for LEZ-regulations (ie those other than above, including Greece, Belgium, France, Spain, Portugal, Eastern Europe, (except Ireland, Malta, Iceland, Finland, where no action is assumed (little air quality problem)

Vehicle type	% of pre-Euro 4 vehicles retrofitted				
	2007	**2008**	**2009**	**2010**	**2015**
Bus (urban)	10%	30%	50%	60%	80%
Coach (non-urban)	0%	2%	5%	10%	15%
HDV<7.5T	2%	8%	15%	20%	25%
HDV 7.5-16T	2%	5%	8%	15%	20%
HDV 16-32T	0%	2%	5%	10%	15%
HDV >32T	0%	2%	5%	8%	10%

Scenario 3: Low Emission Zones (LEZ)

LEZs are assumed to be widely used in the EU due to the air quality problems in the EU, their being one of the most effective measures, and the requirement of member states to have considered LEZs before being granted extension to the limit value deadline. Countries have been divided into three categories, those who are currently implementing or planning LEZs (assuming 2008), those who are not yet planning LEZs, but are assumed to implement them at a later stage (assuming 2010), and those countries with no or little air quality problem.

While LEZs are assumed to be implemented widely, they are unlikely to be implemented in every urban area as defined in TREMOVE. TREMOVE gives total emissions by Member State, therefore a proportion of urban mileage is used to account for the proportion of roads in the cities assumed to be implementing LEZs. This proportion is shown in Table 10.

Table 10. Share of cities with LEZ regulations (related to vehicle mileage)

Region	% of pre-Euro 4 vehicles retrofitted				
	2007	2008	2009	2010	2015
Countries with actual LEZ-regulations					
Metropolitan	0%	100%	100%	100%	100%
Other cities	0%	50%	50%	50%	50%
Countries without stated intentions for LEZ-regulations					
Metropolitan	0%	0%	0%	100%	100%
Other cities	0%	0%	0%	50%	50%

As TREMOVE cannot model urban areas with LEZs with a different penetration as the non-urban areas, the LEZ scenario needs to be run with urban areas only, and combined with the realistic (or optimistic) scenario for non-urban areas. All cities in each country would have to be modelled has having a LEZ. Therefore the output of scenario 3 would have to be combined with the output of scenarios 2 or 1. The combined scenario consists of the urban results from scenario 3 and the extra urban results from scenarios 2 or 1.

Main objective: Analysis of the impact of LEZ on pollutant emissions, based on the main assumptions of Scenario 2 for non-urban areas.

Difference: Exclusion of vehicles which do not meet the regulations for access of LEZ in inner urban traffic. TREMOVE itself accounts for fewer of the larger HGVs entering the cities, so all HGVs are modelled similarly. Coaches are not affected, as they only operate outside urban areas, and are covered by the scenario 2 (or 1). Numbers of Euro 4 and 5 vehicles increase where the emissions standards are met by buying new vehicles as opposed to retrofitting.

Table 11. LEZ Scenarios (all countries with LEZ):

	Emissions Standards	**Scenario**
2008-2010	Euro 3 (PM)	Euro 2: 60% buses retrofitted with DPF, and 25% HGVs + DPF. 40% of buses and 75% HGV to Euro 4. Pre-Euro 2: all replaced by Euro 4
2012-2015	Euro 4(PM)	Euro 3: 100% buses and 50% HGVs + DPF. 50% HGVs replaced by Euro 5.
2015-2020	Euro 3 + 90% reduction PM, 70% reduction NOx or Euro 4 / 5	All buses and 70% HGV Euro 3 + DPF from before + SCR. 30% HGVs replaced by Euro 5.

Table 12. LEZ Scenarios (all countries with no current LEZ intention):

	Emissions Standards	**Scenario**
2008-2010	none	As per scenario 2 (or 3) for non-LEZ countries.
2012-2015	Euro 3 (PM)	All Euro 2 + DPF, pre-Euro 2 replaced by Euro 3.
2015-2020	Euro 3 + 90% reduction PM, 70% reduction NOx or Euro 4	All buses: + DPF+ SCR. HGVs: 65% + DPF + SCR, 35% replaced by Euro 4.

Conclusions

The aim of this project is to identify cost effective technical measures for reducing PM and NOx emissions from existing heavy duty vehicles, and produce concrete policy proposals for the European Commission to support their use. It is also to produce data to enable the Commission to undertake cost effectiveness modelling of the most promising technical measures, to assess their potential impact and costs.

1. Most promising technical measures

The most promising technical measures were identified as:

Exhaust emissions retrofit measures

- Diesel Oxidation Catalyst (DOC)
- Diesel Particulate Filter (DPF)
- Exhaust Gas Recirculation (EGR)
- Selective Catalytic Reduction (SCR)
- SCR+DPF
- Re-engining

Alternative liquid fuels

- Diesel Water Emulsion (DWE)

Alternative gaseous fuels

- Dual-fuel Natural Gas
- Dual-fuel Bio-methane

From the technical review, diesel particulate filters (DPF) for reducing particulate emissions and selective catalytic reduction (SCR) for NOx, stood out in terms of cost effectiveness to take forward. Diesel water emulsion and dual-fuel natural/bio gas were the most promising fuels, although they were less cost effective in terms of emissions reduction than DPF and SCRs. In addition if ethanol becomes available as a retrofit option it could also be a promising option.

Diesel Particulate Filters (DPF): Full flow DPFs reduce PM by 90% for particulate mass, 99% for solid particulate mass and in excess of 99% for particles in the size range 10 – 1000nm. These are considered to be the most important technology for particulate emissions reduction and should be prioritised. There are two main types of DPF. Catalysed DPFs offer the most practical solution to PM reduction. However, these systems need duty cycles that enable continuous regeneration and can increase NO_2. Active regeneration or fuel borne catalyst systems offer no increase in NO_2 but can present more complex application challenges, sometimes needing interaction with the operational mode of the vehicle.

Selective Catalytic Reduction (SCR): can reduce NOx emissions by up to 85%, using ammonia (either as 32.5% urea solution in water or as 16% liquid ammonia) as a reductant. SCR, preferably in conjunction with DPF, should be prioritised as a retrofit option for NOx and PM control. SCR systems require a minimum of 200°C exhaust temperature, so system, engine and duty cycle need to be matched.

Alternative Fuels: In the context of this project, only diesel water emulsion (DWE) is considered a practical alternative liquid fuel or fuel additive at this stage, and can reduce emissions of NOx by 15% and PM by 50-60% PM, although results are extremely variable. However, it is usually a niche fuel for captive fleets due to the fuel storage issues, although Italy is incentivising the fuel through tax reduction to encourage more widespread availability. The use of “dual fuel” engines using a mix of methane gas (65-85%) and diesel is an option, and achieves Euro 4 emissions. Availability of the refuelling infrastructure is an issue, and for bus fleets and refuse vehicles space for on-vehicle storage tanks is also a concern. Given competitively priced gas supplies dual fuel can be a commercially viable option. However, diesel engines fitted with SCR+DPF systems are likely to be more cost effective from a purely vehicle perspective and offer lower PM emissions.

The Commission will be able to model the impact and costs of these technical measures with TREMOVE using the data and scenarios provided in part 3 of this report.

2. Policy recommendations

In terms of support for these technical measures there is a clear and urgent need for the Commission to take action to help support the use of retrofits with a common certification scheme. It would enable LEZs to use retrofits without risking falling foul of the EU freedom of movement rules. It would also allow LEZ emissions standards to require improvements relative to existing emission standards, for example Euro X plus 90% emissions reduction – giving clear incentives for retrofits and cost effective emissions reductions, as well as support retrofits more generally.

The EU-wide certification scheme could, depending on state aid reviews, also enable financial incentives to be streamlined through the notification process, give reassurance for those member states not yet using retrofits that they are robust technology and act as Best Available Technology (BAT) references for retrofits.

Other measures to support LEZs and financial incentives have also been identified, including LEZ guidance, labelling of Euro standards, informal/semi-formal groupings of LEZ cities, information sharing on LEZs, certification schemes. There are also a number of fiscal measures that would support increased use of technical measures, including guidance and modifications to the state aid procedure, allowing lower or zero-rated VAT on technical measures and investigation into whether procurement consortia could assist.

The measures should be as all-inclusive as possible, in line with the interoperability principle. Measures should be for all vehicles, including light duty vehicles, and not aimed just at heavy duty and captive vehicles, and technology neutral.

There is a clear priority on policies – EU-wide certification. Within that, there is a priority on some mechanism to enable PM retrofits certification for the currently proposed LEZs that are planned, including: The Netherlands (allowed from 1/4/07), Munich (start date 1/10/07), London (start date February 2008), Berlin (start date 2008), Denmark (allowed from 1/7/08).

A list of the policies that are recommended to be implemented in order of priority are outlined below.

Recommended concrete proposals (by priority):

1. Short term mechanism for retrofit certification for currently planned LEZs including web information on LEZ and certification schemes
2. *Labelling of Euro standards for LEZs (out of remit for this project)*
3. *Enforcement against foreign vehicles (out of remit for this project)*
4. An EU-wide certification scheme
5. LEZ guidance (some high level LEZ guidance is planned in the EU Urban Transport Strategy, due at the end of the year, but further guidance is needed)
6. Informal/semi-formal grouping of LEZ cities
7. Information sharing (2)
   - Web information on financial existing incentives
   - Maps and GPS information on existing LEZs
8. Improvements to the state aid procedure

There are some differences between priority and best/possible timescales. The grouping of LEZ cities and the second set of information sharing could be done relatively easily quickly to the benefit of cities and LEZs particularly in the shorter term. The timescale for the state aid issues is determined by the current reviews of the environmental guidelines, de minimis ruling and the state aid action plan.

The EU-wide certification scheme is needed as soon as possible, and the technical issues could be resolved in around 6-9 months. However, the choice of legal mechanism/framework is likely to be the key timescale factor, and if the scheme needs to be through a legal mechanism timescales are likely to be longer.

There are number of technical measures for which there is as yet not enough information to determine whether they could be cost effective options as technical measures for existing heavy duty and captive vehicles. Further work is required to assess whether:

1. Ethanol could be appropriate near-term as a retrofit option
2. Low friction tyres give cost effective emissions reduction of PM and NOx
3. The application in the EU of US initiatives to reduce impact of idle emissions – e.g. refrigeration units

Procurement consortia could well be a useful mechanism to support technical measures, however this is not yet clear, due to the required focus of discussion on the higher priority of the EU-wide certification scheme, and further investigation is required.

3. Modelling scenarios

Three scenarios with data have been outlined to model the most promising technical measures – full DPFs and SCR for TREMOVE modelling. Scenarios have been given for both LEZs and encouraged penetrations through the whole fleet – through both LEZs and other incentives. TREMOVE can differentiate between different road types, however it cannot model urban areas with different penetrations of technical measures to other roads. Therefore the LEZ scenario would be run for the cities only, and combined with the results of the out-of-city areas from scenario 2, or scenario 1.

The three scenarios outlined in this project are:

1. An optimistic scenario
2. A realistic scenario
3. A LEZ scenario for urban areas only, to be combined with scenario 2 (or 1) for non-urban areas.

This will enable the impact and cost effectiveness of the technical measures to be assessed.


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Appendices

Appendix 1 Glossary

°C: degrees centigrade
APUs: Auxiliary Power Units
$BaCO_3$: barium carbonate
BAFU/SUVA: Swiss Federal Environment Agency
BAT: Best Available Technology
CARB : California Air Resources Board
CCRT®: Catalysed Continuously Regenerating Trap®, a form of DPF
CCV: Closed Crankcase Ventilation
CEN: European Committee for standardisation, see www.cenorm.be
Cenex: UK Centre of Excellence for low carbon and fuel cell technologies
Chassi dynamometer: where the whole vehicle is put on a rolling road and tested through a simulated drive (test) cycle. There tend to be a wider range of chassi dynamometer tests used than engine tests.
CHP: combined head and power
CleanUp: Previous UK Government grant scheme for retrofitting existing vehicles
CNG: Compressed Natural Gas
CO: carbon monoxide
CO: carbon monoxide
CO_2: carbon dioxide
CRT®: Continuously Regenerating Trap®, a form of DPF
DFs: emissions deterioration factors
DFH: direct fired heaters in relation to heating lorry driver cabs
DG ENT: European Commission Department of Enterprise
DG ENV: European Commission Department of Environment
DG TREN: European Commission Department of Transport and Energy
Dioxins: halogenated organic compounds, the most common consisting of polychlorinated dibenzofurans (PCDFs) and polychlorinated dibenzodioxins (PCDDs)
DME: Di-methyl-ether
DOC: diesel oxidation catalyst
DPF: diesel particulate filters
DTi: UK Government Department for trade and industry
DWE: Diesel Water Emulsion
EC: elemental carbon
ECS: European steady-state cycle,
EEFMA: European Emulsion Fuel Manufacturers' Association
EGR: exhaust gas recirculation
ELR: European load response (for smoke),
Engine dynamometer (bench) test: In the context of this project it is specifically as per

the homologation test where the engine is tested on the engine dynamometer without being installed in a vehicle. The test is designed to enable the assessment of power, torque, fuel consumption, emissions under controlled conditions.

Engine homologation test: Engine dynamometer test conducted under controlled laboratory conditions to determine if the engine meets the regulatory requirements for emissions compliance

EPA: USEPA, United States Environmental Agency

ETC: European Transient Cycle

EU 15: EU countries existing before the expansion in 2004

EU 25: all EU countries

EU: European Union

Euro standards, Euro 1, …Euro 6: Commonly used terminology for European emissions standards for road vehicles

FBC: Fuel bourne catalyst

FAME: Fatty Acid Methyl Esters

Furans: a heterocyclic organic compound

GHG: greenhouse gas

GPRS: General Packet Radio Service, a mobile data service available to users of GSM mobile phones

GTL: natural gas

H_2S: hydrogen sulphide

HC: hydrocarbons

HDV: heavy duty vehicle

HGV: heavy goods vehicle

I/M: inspection and maintenance

LAT: Laboratory of Applied Thermodynamics - Aristotle University

LDV: light duty vehicle

LEZ: Low Emission Zone (also called Environmental Zone)

LGV: light goods vehicle

LNG: Liquid Natural Gas

LNT: Lean NOx Traps

LPG: Liquid Petroleum Gas

MOUs: Memoranda of Understanding

N_2O: nitrous oxide (a greenhouse gas)

NH_3: ammonia

Nitro-PAH: nitrated polycyclic aromatic hydrocarbons

nm: nanometers

NO: nitric oxide

NO_2: nitrogen dioxide

NOx: nitrogen oxides, a combination of NO_2, NO and N_2O

OBD: On Board Diagnostics

OE: original equipment

OEM: original equipment manufacturer, often in relation to road vehicles

On-road test: where a vehicles emissions are tested on a normal road or road track with emissions monitoring equipment in the vehicle itself

PAH: polycyclic aromatic hydrocarbons

PM: particulate matter

PM_{10}: particulate matter less than 10 microns in diameter

$PM_{2.5}$: particulate matter less than 2.5 microns in diameter

PMP: UNECE Particle Measurement Programme to better measure particle emissions

Powershift: UK Government grants for new alternatively fuelled vehicles. Now existing mainly as a register so that the very cleanest alternatively fuelled vehicles can get a 100% discount from the central London congestion charge.

ppm: parts per million

R&D: research and development

RCVs: Refuse Collection Vehicles

RD&D: research, development and demonstration

RESS: rechargeable energy storage system, in relation to hybrid vehicles

SCR: selective catalytic reduction

Secondary emissions: defined as all toxic substances from a retrofitted engine, which are either absent or found only in much smaller concentrations from engines without filters

SMEs: small and medium sized enterprises

SO_2: sulphur dioxide

SO_4: sulphates

SOF: soluble organic fraction

TDC: Post top dead centre in relation to fuel injection

THC: total hydrocarbon

TPM: total particulate matter

TREMOVE: EU-wide emissions and cost effectiveness model, see www.tremove.org

TRU ATCM: Transport Refrigeration Unit Air Toxic Control Measure

ULSD: ultra low sulphur diesel

UNECE: United Nations Economic Commission for Europe

USEPA: United States Environmental Agency

VAT: Value Added Tax

VERT: Swiss particle filter certification for construction vehicles

VOC: volatile organic compounds

WTW: Well-to-Wheel, calculating overall CO_2 from use, manufacture and disposal

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Appendix 3. Questionnaires circulated

Technical Questionnaire:

QUESTIONNAIRE ON THE COSTS AND IMPACT ON EMISSIONS OF TECHNICAL MEASURES ON EXISTING HEAVY DUTY VEHICLES AND URBAN CAPTIVE FLEETS

1. Key Points

This project looks at what the EU Commission can do to support and encourage the use of after-treatments, fuels, oils and tyres to reduce emissions from in-use heavy duty and urban captive fleet vehicles.

If the EU Commission is to assist cities and member states to introduce these technologies, which can bring significant emissions and therefore pollution reductions, it needs to know what is available, and for that, we need your help.

This work concentrates on heavy duty vehicles, and also urban captive fleets – so taxis, buses, refuse vehicles, as well as lorries.

2. Background information

Road vehicles are among the most important sources of air pollution leading. The Thematic Strategy on Air Pollution has identified as a major follow-up measure the introduction of more ambitious emission standards for new vehicles. However, it takes a long time for new vehicles to penetrate into the fleet, and older vehicles would still contribute to a large share of pollutant emissions in the medium term.

There are a wide set of technical options for emissions performance enhancement, in order to speed up the reduction of pollutant emissions: Improved Maintenance, retrofitting of vehicles with after treatment equipments, gear shift indicators, the use of alternative fuels or additives, low viscosity oil and low rolling resistance tyres, etc.

In the context of the revision of the National Emissions Ceilings Directive and of the assessment of Air Quality Directives, it is necessary to perform a detailed evaluation of the potential costs and benefits associated with each option, as well as matching the right vehicle categories with the appropriate enhancement technology. On that basis, a concrete agenda for further policy actions – both at Community and Member States level - can be defined.

3. Objectives

The objective of the present questionnaire is to collect technical evidence from the relevant industries on the available technologies for the reduction of air pollutant emissions from existing vehicles, namely on the cost and impact on emissions of the retrofitting of exhaust emission control technologies, the introduction of alternative fuels or additives, low viscosity oil and low friction tyres, focusing on heavy-duty vehicles and captive fleets.

The replies to the questionnaire will be analysed, together with a literature survey, by an external consultant (Sadler Consultants, appointed 1st June 2006). On that basis, a first screening of the most relevant options to be further assessed will be performed, and the preliminary findings will be discussed in a workshop organised by DG Environment, to be held in Brussels on the 11th September 2006. In that workshop, representatives of the industry and experts will discuss the preliminary findings and present additional information.

The objective of that workshop and of the final report is double:

- To perform with the model TREMOVE[78] an analysis of the cost-effectiveness of the scenarios and the analysis of the impact on pollutant emissions, in the context of the forthcoming revision of National Emissions Ceilings Directive.
- To define concrete policy proposals at EU level, which could help to support the most promising technological options. In particular, the feasibility of a common system at EU level for vehicle certification that takes on board improvements of existing vehicles will be thoroughly assessed, in the context of Low Emission Zones, charging systems, economic incentives, public procurement policies, etc.

4. technical options covered by the questionnaire

The questionnaire focuses on the implementation of technologies which require no modifications or only minor ones to existing HDV diesel engines.

- For retrofitting, the installation of diesel oxidation catalysts (DOCs), diesel particle filters (DPFs) / Continuous Regenerating Traps (CRT), selective catalytic reduction (SCR) systems, exhaust gas recirculation (EGR) or combinations (e.g. DPF+SCR, DPF+EGR)
- For fuels, the use of emulsified diesel, biodiesel blends or synthetic diesel
- Low viscosity oil
- Low rolling resistance tyres

5. EU-wide measures that would help support technology introduction

We would like to hear from you about any EU-wide measures that, in your experience or view, would help support the use of the technology options covered in this questionnaire, and cities/countries you have worked with that could give us more information on this topic.

6. How to proceed

You will find below a list of open questions referring to a specific technology or application. Please use the template for any technology on which you would like to report.

[78] See details on the TREMOVE model on www.tremove.org

Please send your reply by e-mail to Lucy Sadler (Lucy.Sadler@airqualitypolicy.co.uk) ideally by 5th July 2006, together with any report, presentation, background information that could be useful for the further assessment (Reviews, case studies, measurements, etc.). If you need more time to reply, please let me know.

Please do not hesitate to send requests for clarification by e-mail, or telephone, +49 (0)7641 9375 335.

If you need any of the response to be in confidence, then please let us know. While we would prefer information to be able to be fully available, we want you to be able to tell us confidential information that would be relevant, safe in the knowledge that it will be treated in confidence.

Questionnaire

(please copy the template for each technology on which you want to report)

1. Name and description of the technology

2. Vehicle type

2.1. category, type of use

2.2. emission class before aftertreatment used

2.3. any other relevant information of the original vehicle(s)

3. Impacts on Emissions

3.1.1. emission values with aftertreatment (all regulated pollutants, specifying the test conditions)

3.1.2. NOx exhaust emissions: please provide if available additional information on the share of NO and NO_2

3.1.3. PM exhaust emissions: please provide if available additional information on the size distribution of PM (PM_{10}, $PM_{2.5}$, $PM_{1.0}$, ultrafine)

3.1.4. Impact on CO_2 and other greenhouse gases (e.g. N_2O, CH_4…)

3.1.5. Other exhaust emissions

3.2. Has there been a re-certification to a higher emission class?79

3.3. Impact on fuel consumption

[79] Please note that the questionnaire also considers retrofit technology that does not permit an upgrade to a higher emission class (e.g. fitting a DPF that leaves NOx unchanged). The revised Eurovignette directive opens the possibility of rewarding vehicles by their certified emission values and not just their emission class -precisely in order to be able to reward retrofit, which is not expected to lead to upgrades.

3.4. Impact on non-exhaust emissions (i.e. tyre and break wear, re-suspended road dust)

3.5. Impact on noise

4. Costs

4.1. Please indicate implementation costs, operating costs e.g. impact on fuel consumption, cost of additives, and maintenance and management costs, where available

4.2. Please indicate how the above costs would evolve depending of the production volume / fleet size

4.3. Please add any other information, such as durability, maintenance requirements, influence on warranty or operating costs

5. Other

5.1. Observations and additional information (e.g. availability, reliability, degradation of the performance over the lifetime, etc.)

5.2. references, if published or available

5.3. any associated literature and presentations

5.4. Any information on technology that is being developed. If available, likely costs, emissions information (as above), introduction date etc.

5.5. Whether any of this information is commercial in confidence, and if so, which information

5.6. Contact details for any queries

Policy Questionnaire:

HOW CAN THE EU HELP TO ENCOURAGE TECHNICAL MEASURES ON EXISTING HEAVY DUTY VEHICLES?

1. Key Points

This project looks at what the EU Commission can do to support and encourage the use of technical measures such as: after-treatments, fuels, oils and tyres, which are able to reduce emissions from in-use heavy duty and urban captive fleet vehicles.

If the EU Commission is to assist cities and member states to introduce these technical measures, which can bring significant emissions and therefore pollution reductions, it needs to understand the experience of those who have introduced such technical measures, and get their advice on how they could be encouraged.

Key issues mechanisms that can be used to increase technical measures include low emission zones, road user charging and tax incentives, many of which may be able to be assisted by the EU. Some of the issues that are coming out of the work so far include: EU-wide certification and 'homologation/validation' of technical measures, a technical measures register, EU guidance for subsiduarity issues, state aid rules.

2. Background information

Road vehicles are among the most important sources of air pollution. The EU is developing further Euro standards for new vehicles, however, it takes a long time for new vehicles to penetrate into the fleet, and older vehicles will still contribute to a large share of pollutant emissions in the medium term.

There are a wide set of technical measures for emissions performance enhancement, which can accelerate the reduction of pollutant emissions. For the purpose of this project a technical measure is defined as any measure relating to a vehicle, its fuel, lubricants and other consumables, that leads to lower pollutant emissions per vehicle km under comparable operating conditions from in service heavy duty vehicles.

The project will identify what technical measures are available, assess their cost effectiveness at reducing pollution, identify barriers to their up-take and make concrete policy recommendations to the EU to encourage greater use of these measures.

3. Objectives

The objective of this questionnaire is to collect information on what the EU can do to help those implementing schemes and policies to encourage the use of technical measures on existing vehicles, from those who are involved with implementing these measures.

For example, what is preventing schemes being implemented, what could help increase the use of technical measures, what has worked well?

Low Emission Zones, charging systems, economic incentives, public procurement policies, may be some of the most relevant schemes.

The replies to the questionnaire will be analysed by our team. On that basis, we will present the most relevant options to be further investigated, and the preliminary findings will be discussed in a workshop organised by DG Environment, to be held in Brussels on the 11th September 2006. The objective of that workshop and of the final report is double:

- To perform with the model TREMOVE[80] an analysis of the cost-effectiveness of the scenarios and the analysis of the impact on pollutant emissions, in the context of the forthcoming revision of National Emissions Ceilings Directive.
- To define concrete policy proposals at EU level, which could help to support the most promising technological options. In particular, the feasibility of a common system at EU level for vehicle certification that takes on board improvements of existing vehicles will be thoroughly assessed, in the context of Low Emission Zones, charging systems, economic incentives, public procurement policies, etc.

The team will produce a report before the workshop, outlining the conclusions so far, and the questions that need to be resolved at the workshop. This will be circulated to workshop participants, as well as a larger audience, so that we can ensure that the recommendations are appropriate as many implementors around Europe as possible.

4. How to proceed

You will find below a list of open questions referring to your experience, and barriers to implementation. Any details that you are able to provide would greatly assist us.

The most important question is what could the EU do to help increase the use of technical measures to reduce emissions.

Please send your reply by e-mail to Lucy Sadler (Lucy.Sadler@airqualitypolicy.co.uk) by the 4th August 2006, together with any report, presentation, background information that you think might be useful.

Please do not hesitate to send requests for clarification by e-mail, or telephone, +49 (0)7641 9375 335.

If you need any of the response to be in confidence, then please let us know. While we would prefer information to be able to be fully available, we want you to be able to tell us confidential information that would be relevant, safe in the knowledge that it will be treated in confidence.

[80] See details on the TREMOVE model on www.tremove.org

Policy Questionnaire

1. What can the EU do to help?

1.1. What could the EU do to help increase the use of technical measures to reduce emissions?

1.2. What barriers to increasing the uptake of technical measures did you experience / are you experiencing ?

1.3. Are you planning policy measures to increase the uptake of technical measures, and if so, what barriers are you finding?

1.4. What could help reduce these barriers? In particular, by the EU?

2. What has helped increase the uptake of technical measures

2.1. What national or other policy measures/support have assisted in increasing the uptake of technical measures?

2.2. What national or other policy measures/support could have assisted more if they had been operated differently – and how could it be improved?

2.3. Who can we contact with more questions on this measure/support?

2.4. Do you know of other support elsewhere that might be of interest to us?

3. Other

3.1. Contact details for colleagues or contacts that would have views on these topics.

3.2. Your contact details for any queries.

Appendix 4. Issues raised from questionnaires that are outside the project remit

Some issues raised are outside the remit of this work, or have been already tried and ruled out, or excluded from further examination by the technical review. These include:

1. Technical measures for cars and light duty and off road vehicles
2. Overall Clean Vehicle Standard
3. Requests for the EU to require member states to undertake measures – unlikely to be feasible, incorporated elsewhere
4. Low rolling resistance tyres, biofuels such as RME, dedicated Natural Gas – technical review indicated not effective for air quality
5. Issues affecting off-road vehicles and light duty vehicles
6. A lower rolling resistance tyre scheme for passenger cars
7. Inspection and maintenance
8. Wider issues about cleaner and more sustainable public transport
9. Non-technical measures, (traffic management; modal shift through promotion of “low emission” transport modes such as attractive public transport, walking and cycling; etc.)
10. Limited availability of hybrid vehicles and other low carbon vehicles
11. Telematics
12. Calls for greater funding for technical measures
13. Euro standard issues
14. Allowing larger lorries
15. Intrinsic barriers such as the emission trade-off between NOx and PM
16. Speeding up introduction of lower sulphur non-road diesel fuel
17. Adapt the Common Agriculture policy to promote the production of biofuels
18. Lift off tolls from imported biofuels
19. Making the Biofuels Directive compulsory
20. Lack of (global) sustainability audit on biofuel raw materials
21. Limits on the use of studded road tyres and winter tyres – the solution is normal tyres, and local measures are tackling these issues where they are appropriate.
22. It could also allow member states to set environmental standards for imported used vehicles.
23. Interpretations of the EU air quality Directives.

Appendix 5. Workshop presentations, write-up and ranking spreadsheet

Workshop presentations

Policy talk

Summary of policies

Lucy Sadler

Sadler Consultants

Specialists in air quality policy

read this way →

Policies identified so far

Low Emission Zone (LEZ) issues
- **Common EU certification system**
- Labelling scheme for Euro standards for LEZs
- Foreign vehicles enforcement
- Common road sign for LEZs
- LEZ guidance
- LEZ enabling directive
- Vehicle manufacturer and warrantee issues

Non-LEZ issues
- **State aid and Notification process issues**
- Common approach to cleaner fuels
- EU Technical Measure (TM) Guidance (EU retrofit scheme)
- Information sharing resources
- SCR additive availability

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Common EU certification system

- Provide a common system throughout the EU
  - Able to be used for all LEZs and road tolling - however enforced
  - Assist with current & envisaged LEZ issues
- Potential mechanism
  - Run by certifying bodies in Member States (MSs) using approved testing-houses
  - EU-facilitated overseeing Committee
  - Manufacturers certify TM & provide a manufacturers certificate
  - Certification body issue label/database entry/transponder data
  - Vehicle registration & certificate number key data to be shared with LEZ/road toll scheme operators
- Allow different emissions reduction levels
- Data shared for enforcement

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Other LEZ issues

- Labelling scheme for Euro standards for LEZs
  - Most LEZs require Euro standard, some allow retrofitting to meet standard, or have additional trap requirements
  - Combined Euro standard labelling & certification system would facilitate & enable LEZ operation
- Foreign vehicle enforcement
  - Key issue with present traffic enforcement & planned LEZs
  - Some places foreign vehicles not enforced; others this is not acceptable
- Vehicle manufacturer and warrantee issues
  - Particularly with newer vehicles
  - Certification system could help & EU-led discussions
- Common road sign for LEZs
- LEZ guidance
- LEZ enabling directive

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State aid & Notification process

- Key aspect of Treaty of Rome
- An issue for LEZs and financial incentives
- Some *Perception* of lack of consistency
- Need clear guidance
  - Publish list of schemes already approved for policy developers
  - Further open guidance on what allowed / not allowed to do
- Faster, more consistent decisions
- Co-ordination of applications for similar types of scheme
- "What you want to do can be done like this" advice
- TM in environment classification & de-minimus ceiling
- Raise 30% maximum assistance allowed
- Enable lower CO_2 and environmental incentive schemes

Other

- Common approach to non-diesel/petrol cleaner fuels
  - Allow harmonisation & recognition of cleaner fuels & reassurance of fuel impact
  - Fuel standards via EU working group &/or in certification scheme
- EU Technical Measure Guidance
  - Give advice & encouragement in areas outside EU's remit
  - Spread information on what works / doesn't, in what situations
- Information sharing resources
  - Sharing info on technical measures, schemes, costs, contacts etc
  - Procurement consortia for bringing to market &/or development
- Other
  - Increasing the availability of SCR additives (eg AdBlue®)
  - EU-wide outline for retrofit programs

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End of presentation on policies

Any burning questions?

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Absolute Key Workshop Questions for policy direction

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Key Questions: Certification

- Is a certification system needed?

If so:
- On what timescales?
- Adopt / Adapt / Build new / Adopt while Building new ?

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Key Questions: State Aid & Notification

- Will any of the policy suggestions improve the state aid and notification procedure?
  - List of schemes already approved
  - Further guidance on what allowed / not
  - "what you want to do can be done like *this*"
  - Faster, more consistent decisions
  - Co-ordination of applications for similar schemes
- What else could help?

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What else could be done by the EU to support the use of technical measures in existing vehicles?

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The present work is focused on Heavy Duty Vehicles

Does this need extending to

Light Duty Vehicles?

Off-road Vehicles?

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Key Questions: Other LEZ issues

- Is a Euro standard labelling scheme needed for LEZs?
- Should it be combined with the certification scheme?
- Is enforcement of foreign vehicles an issue?
- Would EU LEZ guidance help?
- Do we need an LEZ enabling directive?
- Should there be an agreed common road sign for LEZs?
- Is vehicle manufacturer and warrantee an issue?

Key Questions: Other

- Should a certification scheme include non-diesel/petrol fuels and fuel conversions?
- Should fuel standards be set by EU working groups for all relevant fuels?
- Would EU guidance on how Member States and cities can best support technical measures help?
- Would the information schemes discussed help?

Where is most discussion needed this afternoon?

Certification

State Aid?

Other?

Breakout groups

- To record views & focus discussion use post-its & discussion
- Put your answers to the questions on post-its
- Post-it answers collated by question on the wall
- Consensus reached either through
  - post-its giving a clear consensus, or
  - discussion based on post-it answers
- Consensus / outstanding issues written on flipchart
- Brought to the plenary discussion

Next Steps

- We will not have resolved all the issues fully today
- Please send further comments to us by email asap
- Report & question also circulated to wider group for remote feedback BY 15th SEPTEMBER
- Write up todays conclusions & circulate

Then:

- Prepare TM data for cost effectiveness modelling
- Further develop policies & then re-validate with a number of Member States & Cities
- Report to the EU draft report end October, final report end December

Further comments to

Lucy.Sadler@airqualitypolicy.co.uk

preferably by 15th September

papers available on website

Technical measures talk

Impact on costs and emissions of technical measures on existing heavy duty vehicles and captive fleets

Preliminary findings

Steve Bell

Sadler Consultants

Technical Measures - Methodology

- Review information through questionnaire sent to stakeholders and literature survey
- Summarise all the findings in a format that can be directly analysed by the model TREMOVE for:
  - the analysis of the cost-effectiveness of scenarios
  - the analysis of the impact on pollutant emissions.
- Feed information into policy review

TREMOVE model

- TREMOVE is a policy assessment model to study the effects of different transport and environment policies on the emissions of the transport sector.
- For each year, the TREMOVE produces figures on the vehicle-kilometres and vehicle speeds for road transport disaggregated according to:
  - Vehicle type
  - Fuel type
  - Vehicle technology
  - Vehicle age (age and technology are related to each other)
  - Network (urban road, non-urban road, motorway)
  - Region (metropolitan, other cities, non-urban)
  - Period of day
- For each of this disaggregated vehicle-km, TREMOVE calculates the emissions (NO_x, CO_2, VOC, PM_{10} etc.)

read this way →

TREMOVE scenario analysis

- A scenario run needs a lot of work for definition, data input and calculation. To reduce number of scenarios it is proposed to:
  - Select the most effective and cost efficient technologies
  - Define combinations of technical measures to be implemented within the same scenario,
  - Define different degrees of penetration rates (e.g. maximum, optimistic, realistic, low penetration) of vehicle stock.
- Scenarios will be variation of the TREMOVE base case. Following information needed for each technical measure:
  - Impact on emissions and fuel consumption as correction factor related to the base technology of each vehicle category for the road categories "urban", "non-urban" and "motorways" – or an averaged factor.
  - Costs (as cost difference from the base technology) for capital and operation costs
  - Penetration in the fleet as a share of each of the six heavy duty vehicle classes (Buses, Coaches, HDV<7.5T, 7.5-16T, 16-32T, >32T)

Review of Technical Measures – results to date

- Information gathered to determine:
  - What technologies are available
  - Reductions in regulated emissions (CO, NO_x, VOCs, PM_{10}), also Greenhouse Gas Emissions and most problematic non-regulated emissions such as PM in number, NO_2, N_2O
  - Capital and operational costs

Sources of information

- Detailed questionnaire
  - 24 responses reviewed
- Literature search of published information
  - >250 technical papers accessed and reviewed
- Reference to CARB, USEPA, BAFU/SUVA and VERT lists of certified measures.

Technical measures - categorisation

- **The technical measures reviewed have been categorised as follows:**
- *Primary measures*
  - most promising technical measures for reducing PM and NO_x
- *Secondary measures*
  - should be encouraged to be used in conjunction with primary measures.
  - should be further examined to explore their potential in a European context.
- *Other measures*
  - not close enough to market
  - no significant impact upon the emissions from existing heavy-duty vehicles
  - Not as cost effective as other
  - ***This does not mean that they are not valid technologies, particularly in terms of CO_2 emissions.***

Primary measures

- Exhaust emissions retro-fit measures
  - Diesel Oxidation Catalyst (DOC)
  - Diesel Particulate Filter (DPF)
  - Exhaust Gas Recirculation (EGR)
  - Selective Catalytic Reduction (SCR)
  - SCR+DPF
- Re-powering
- Alternative liquid fuels
  - Ethanol
  - Diesel Water Emulsion (DWE)
- Alternative gaseous fuels
  - Natural Gas (as diesel/CH_4 dual fuel)
  - Bio-methane (as diesel/CH_4 dual fuel)

Secondary measures

- Low Ash Lubricants
- Closed Crankcase Ventilation systems
- Measures to reduce impact of idle emissions – use of APUs, truck stop electrification

Other measures

- Exhaust emissions retro-fit measures
  - Lean NO_x Traps (LNT)
- Alternative liquid fuels
  - Dimethyl-ether (DME)
  - Fatty Acid Methyl Esters (FAME)
  - Synthetic Diesel (Fischer-Tropsch)
- Other measures
  - Fuel Additives (other than FBC)
  - Retro-fit hybrid drives
  - Low Viscosity Lubricants
  - Low Rolling Resistance Tyres

Primary measures – issues (1)

- Diesel Oxidation Catalyst (DOC)
  - Produces NO_2, little impact on soot reduction, can increase PM through SO_4 formation, potentially high ultrafine emissions, may present corrosion issues
- Diesel Particulate Filter (DPF)
  - Some filters require cleaning, catalysed and continuously regenerating systems can increase NO_2, small fuel consumption penalty
- Exhaust Gas Recirculation (EGR)
  - Potential slight reduction in performance and fuel economy and increased maintenance of engines. Potential risk of accelerated engine wear.
- Selective Catalytic Reduction (SCR)
  - Needs reductant, potential for N_2O formation, ineffective under "cool" operating cycles, little impact on soot reduction (although can be offset by calibration)
- SCR+DPF
  - As above but combination reduces soot by >90%

Primary measures – issues (2)

- Repowering
  - May not confer expected emissions benefits in real world conditions, expensive, niche market
- Ethanol
  - Lower energy density than diesel, good regulated emission performance but information required on particle number
- Diesel Water Emulsion (DWE)
  - Impact on emissions appears to be influenced by drive cycle and level of engine technology, potential warranty implications
- Natural Gas (as dual fuel)
  - Payload and packaging, expensive, potential for CH_4 emissions, ultrafine emissions could be similar to diesel, potentially poor resale value, fuel infrastructure
- Bio-methane (as dual fuel)
  - As above but potential to reduce GHG on WTW basis. Fuel availability

Secondary measures - issues

- Low Ash Lubricants
  - Cost information required to be factored into DPF operational costs
- Closed Crankcase Ventilation systems
  - Quantification of contribution to air quality and potential benefits in a European context needed
- Measures to reduce impact of idle emissions – use of APUs, truck stop electrification
  - Quantification of contribution to air quality and potential benefits in a European context needed

Other measures - issues

- Lean NOx Traps (LNT)
  - early stages of development, difficulties with sulphur poisoning, very low sulphur fuel and lubricating oil requirements
- Dimethyl-ether (DME)
  - Good emissions but early stages of production and volume uncertainties
- Fatty Acid Methyl Esters (FAME)
  - low impact on PM and NO_x emissions
- Synthetic Diesel (Fischer-Tropsch)
  - early stages of production and volume availability, and therefore uncertainties
- Fuel additives (other than FBC)
  - low impact on PM and NO_x emissions
- Retro-fit hybrid drives
  - early stage of development, and therefore supply uncertainties
- Low viscosity lubricants
  - low impact on PM and NO_x emissions
- Low rolling resistance tyres
  - low impact on PM and NO_x emissions

Ranking of primary measures

- "Quick and Dirty" ranking exercise
- Non-weighted approach at this stage
- Each measure compared scored 1 – 19
  - 1 = worse, 19 = best, 10 = no impact
- Scored for NO_x, PM, NO_2, HC, CO, FC/CO_2, particle number, cost (capital/operational)
- HC/CO impact and cost removed

Non-weighted ranking of measures

Measure	Overall ranking
DPF (active regeneration)	102
SCR+DPF (active regeneration)	102
DPF (FBC)	101
DPF (CRT®, catalysed)	99
SCR+DPF(CRT®, catalysed)	99
DOC	93
Dual fuel diesel/natural gas/biogas	87
DPF (partial flow)	85
SCR	81
Ethanol	79
DWE	77
Repower to Euro 4	76
EGR	70

Non-weighted ranking of measures - excluding cost, HC, CO benefits

Measure	Overall ranking
SCR+DPF (active regeneration)	70
DPF (active regeneration)	68
DPF (FBC)	68
SCR+DPF(CRT®, catalysed)	65
DPF (CRT®, catalysed)	63
SCR	59
Dual fuel diesel/natural gas/biogas	58
Repower to Euro 4	56
DWE	53
Ethanol	51
DPF (partial flow)	49
EGR	48
DOC	46

Non-weighted ranking of measures - excluding, HC, CO benefits

Measure	Overall ranking
SCR+DPF (active regeneration)	86
DPF (active regeneration)	86
DPF (FBC)	83
SCR+DPF(CRT®, catalysed)	81
DPF (CRT®, catalysed)	81
DOC	79
DWE	72
SCR	71
Dual fuel diesel/natural gas/biogas	69
DPF (partial flow)	67
Repower to Euro 4	65
Ethanol	64
EGR	60

Penetration scenarios

Vehicle category	Low penetration	Realistic	Optimistic	Maximum
Bus				
Coach				
HDV<7.5T				
HDV 7.5-16T				
HDV 16-32T				
HDV >32T				

Questions

- Are there any serious errors in the data?
- Have we got the categories correct?
- Are the measures in the right categories?
- Are there any measures we have not considered?
- Do you broadly agree with the relative ranking of the measures?
- Can you provide data for penetration scenarios?

Further comments to

Lucy.Sadler@airqualitypolicy.co.uk

preferably by 15th September

papers available on website

Workshop write-up

Notes of EU workshop on support for Technical Measures
11th September 2006, Brussels,
Hosted by DG Environment, run by Sadler Consultants

This write-up is in two parts. The first part is the conclusions of the workshop, together with the team's conclusions of how things should be taken forward.

The second part is a more detailed write-up of the discussions at the workshop. In both cases, later input – either from the team or others – is notated with text in italics. While this is not usual in meeting notes, we felt that this would enable our conclusions as to the way forward to be circulated and commented upon.

We would welcome any comments on any errors in the notes of the meeting, additional views that there was not time to raise at the meeting or have occurred to you or colleagues since the meeting, or things you disagree with – in the latter case with your reasons please.

Not every question from the pro-forma was discussed in the workshop, so not all are detailed below. It should be noted that the policy breakout group discussed the non-certification questions, whereas those in the technical breakout group focused on the technical certification questions. Also not many of those involved with the state aid issues were able to attend the workshop, which may have influenced the answers here. The remote feedback, and any comments on the notes of the meeting should rectify this as far as possible.

The workshop papers, talks, ranking spreadsheets and fleet penetration tables that were presented by the project team are available from www.airqualitypolicy.co.uk, have been circulated to attendees and so are not covered in this write-up, which focuses on the discussions. Feedback was requested on the technical issues by 15th September, and on policy issues by the 22nd September in order to be taken into consideration.

As with the pre-workshop paper, discussion at the workshop or inclusion in these notes does not constitute Commission support.

Conclusions of what should be taken forward

1. Common system at EU level for technical measure certification

2.1) Is a certification scheme needed?
A unanimous, clear yes. As soon as possible.

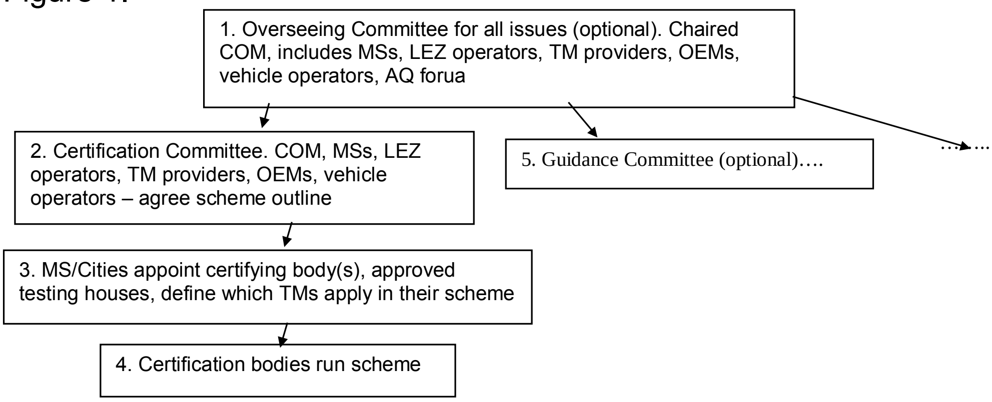
2.2) & 2.13) Adopt, adapt or new scheme? And Interim arrangements.
Adopt while building a new scheme building on present schemes.

1. In the short term the LEZs proposed need to work to allow the current certifications from different countries, so that their LEZs do not contravene

EU law. This requires a list of certification schemes and LEZs. This could be done by the Commission, but may well be better done by the LEZ cities working together.

2. In the medium term, an EU-wide certification scheme based on an engine dynamometer (bench) test utilising current engine homologation test cycles (ESC, ELR, ETC) for validating the performance of the technical measure under controlled laboratory conditions coupled with a period of in-service operation over a representative duty (dynamometer or on-road) cycle to prove that the retrofit works for specific applications and is durable. This could be implemented through the Directive for Euro 6 in 2009, which can include other issues as well as the new Euro 6 standards – as the Euro 5 did. *However, if the scheme is likely to be subject to changes or updates, the Euro 6 Directive may not be the right mechanism.*

A possible structure to the scheme could be as outlined in the diagram below. Groups 2-4 are those envisaged for the certification scheme, groups 1 and 5 are optional for other technical measure or implementational mechanisms. Figure 1.



Outline of the proposed scheme:

1. *For the short term: Possible systems of sharing information about current schemes will be outlined. It may well be that the most appropriate way forward will be through LEZ cities and Member States working together to ensure that there is a system that can function when the first LEZs are in place, starting October 2007.*

2. *For the Medium Term: This could be by the end of 2009. In terms of timescales, there are three factors here, the speed of agreement on a scheme (could be relatively quick), the speed of the legal processes, and whether the forthcoming World Harmonised Duty Cycle (WHDC) is wanted to be used. If the legal processes are the Euro 6 Directive or the WHDC is chosen, then 2009 is a likely date.*

The scheme will be based on existing schemes. The key candidates are VERT, CARB, USEPA, other European schemes. Whilst these schemes will be more closely examined it is felt that the VERT scheme offers the most rigorous and scientifically robust approach, at least for the certification of diesel particulate filters. With suitable modifications it is felt that this scheme could be adapted to other technologies.

The scheme will be based on engine dynamometer tests for baseline certification on an engine family "worse case" basis using Euro standard test cycles (ESC, ELR, ETC). The use of these test cycles will allow read across to Euro 4 (and later) engine performance. This will result in pre-Euro 4 diesel engines being baseline tested over test cycles they were not originally homologated to in order to determine percentage benefits conferred by retro-fit technologies that can be compared with Euro 4 and later engines.

Durability and operational aspects will be covered by in-service and chassis dynamometer drive cycle demonstration. This will be the responsibility of the supplier, carried out to scheme requirements, and approved by a certifying body. This may have approved drive cycles or may be bespoke to the application. The certification scheme will provide the guidance and data and reporting requirements.

This will be followed by further engine dynamometer test to confirm performance after durability test.

Existing schemes will need to be allowed until the EU scheme is up and running. The transition needs to be thought through and made future proof. This will require examination of existing schemes to identify whether there is compatibility of compliance requirements, and which certifications or data can be used , with the new EU scheme.

The next step in the project is to outline the schemes in more detail, and outline the different certification scheme options with what they would require, next steps and timetables.

2.3) & 2.4) Engine family / vehicle application approval & Test Requirements.?

A new scheme is required. At present only engine manufacturers can homologate engines (and with devices if part of base engine/system). A new scheme could ultimately be a Directive to certify retrofit technologies.

Certification scheme should be designed to meet the requirements of all parts of the market e.g owners of vehicles will only be interested in compliance with the LEZ requirements whereas operators of an LEZ may wish to know actual emissions performance

Certification of any technical measure can be in two parts:

1. Engine test bench for emissions using current engine homologation cycles:
   a. On-road – ESC/ELR/ETC
   b. Off- road – Non-Road Transient Cycle (NRTC) and Non-Road Steady-State Cycle (NRSC - ISO 8178 c1)
2. Drive-cycle for durability, regeneration (for DPFs) and real-world operation (for other technical measures) e.g. exhaust temperature regime for SCR systems

It was considered important that the technical measure is tested under similar conditions as engine homologation but that the ability to operate appropriately in real-world operational (e.g. durability, trap regeneration or appropriate drive cycle for NOx retrofits) impact should be assessed on a drive-cycle or in-use basis. This drive cycle assessment would require the instrumentation and data logging of vehicles and presentation of data to the certification body to support the assessment of the technology. This would be the responsibility of the technology supplier and owner of the vehicle in partnership.

Certification protocol will include an overarching process defining the steps needed for certification of retro-fit measures in general. The overall principle will be one employing engine dynamometer testing followed by in-service demonstration of operation and durability, followed by confirmatory engine dynamometer tests. The detailed test and demonstration requirements specific to individual technologies (including non-regulated pollutants – see below) will be provided in a series of Annexes of the certification.

Ideally:

1. Certify that a device works on a specific application
2. Should not be more onerous that current OEM engine legislation

There should be a shared responsibility between:

1. OEM
2. Certifying body
3. Owner/operator of vehicle

2.5) What should be required?

The test certificate should set out in a table all metrics[81] for emissions reduction i.e. an 'impacts table' which gives the percentage emissions reduction, g/kWh, and what Euro standard original vehicle the technical measure takes to which Euro standard for each pollutant. This will allow the LEZ/road tolling/incentive scheme to choose the technical measures that are valid for its scheme. It should be technology neutral, and allow treatment of different pollutants separately.

In practical terms, it might be useful to categorise the retrofits somehow, so that it is easier for cities to say 'these categories of technical measures'. There could be several classifications e.g. one for emissions reduction, other(s) for other pollutants.

2.6) Other pollutants:

The 'impacts table' should also include the impacts on other pollutants. Of most immediate concern were: percentage increase in NO_2 for diesel oxidation catalysts and some particulate traps, particle number, ultrafine particulate, other PM metrics, CO_2, other Greenhouse gases (GHGs) - in particular methane and N_2O -, ammonia (for SCR), dioxins, Nitro-PAHs and other air toxics to be considered. It was recognised that this might be a 'wish-list' that practicalities or costs may lead to this list being shortened in the actual scheme. Also that this was probably more than was required for OEM certification, which was an issue that needed consideration.

The technical and policy groups views differed on this, the policy groups conclusion seems to make more sense: that there certification would not exclude technical measures that increased emissions of other pollutants, but would state their impact, and it would be up to the city or Member State when

[81] Ways of measuring

setting its LEZ or incentive scheme to choose which were allowable. *In practice some increases may always be chosen by the policy-maker to be excluded from their scheme, so it may be best if the certification scheme gave advice on this – collected from the views of different policy-makers.*

The approach taken by existing schemes will be a basis, and the scheme would set out expert guidance on what is required to be measured, and how. Secondary emissions will be specified but this could lead to the testing being more onerous than current Euro 4, which may not be appropriate – so the Euro 4 requirements could be an alternative.

2.7) What should it include?

It should be technology neutral, and be able to include any technical measure that could meet the set standards. The economics and market forces would determine whether they were then used. So it should include conversions to natural gas or ethanol. Any retrofit should also state whether it is compatible or not with biofuels or other fuels.

There was no clear view about whether fuels should be included. The technical group post-it survey had 5 in favour of a completely combined system, 2 stating fuels should not be included. Remote feedback was requested.

2.9) Controlling compliance.

Controlling compliance is needed, and is relatively straightforward for PM devices.

OBD (On Board Diagnostics) is the option that was identified for NOx retrofits, particularly to ensure that the operator is using the reductant for SCR. It is possible – 'just' a question of price, and what the OBD does. Some said OBD was too costly for retrofit, others said simple OBD could be affordable. Monitors already exist in current NOx retrofits to ensure dosing and correct functioning of the system. Further information was requested by email, particularly on NOx OBD costs and capabilities.

It was not considered realistic to require power reduction as is required for OEM, but it could be a system that supported only the retrofit, and did not interact with the engine – i.e. shows a warning light rather that reduce engine power when the device does not work. It maybe that it is more of a diagnostic tool.

Some from the policy perspective felt that power reduction would be needed for NOx retrofit, others not. The policy drivers need to be clear what is needed – or what range of options are needed - and then the technical solutions can be developed.

Visual checks of the NOx sensor were also raised as an option within the technical post-its (time ran out to discuss this further in the technical group).

The overwhelming view is that some form of OBD – or better called 'diagnostic tool' to differentiate from usually understood OBD - is essential for NOx systems. Therefore potentially a simple system which doesn't interact with engine.

An option could be a NOx sensor in the tailpipe, which provides data to a data-storage module that can then be interrogated – at the annual inspection or random tests. This could have a warning light attached to it. A similar *system is used on some DPF systems, storing up to 24 months data. This could be a requirement for NOx systems, and an option for PM systems. The other alternative for PM systems being a Free Acceleration Smoke Test, which would be failed if the PM device failed. Comments on this would be welcome.*

Further input was requested, particularly on potential costs of OBD, and this is awaited.

2.10) Start with PM technical measures only due to time considerations?

Yes, as a clear consensus – particularly for the forthcoming LEZs. However, the new scheme should be designed from the outset to deal with NOx at a later stage, and include measurements of relevant other pollutants for all technical measures.

2.11) Should there be registration of suppliers / fitters as well as equipment?

From the technical groups post-it survey, 3 delegates thought it was very important, one thought it was not.

We will assess what current schemes do, but it does appear an important part of the equation. Another option is along the lines that it is a requirement for suppliers to provide evidence that their fitters comply with requirements laid down, and it is the suppliers responsibility to police the suppliers/fitters – and if one of the fitters is found to have fitted a equipment not to the requirement, that equipment is de-certified. A similar system is used by the UK LPGA (Liquid Petroleum Gas Association) that has a certified fitters list which requires the organisation to achieve accreditation. If there are any complaints the LPGA investigates and rules whether they can continue or be struck-off. However this requires an on-going testing to ensure that technical measures fitted comply with the certification.

2.12) Should the scheme also be open for light duty and off-road vehicles?

Yes. There was a clear view that the scheme should not be limited to heavy duty vehicles, but cover all vehicles. Taxis should also be included due to their high mileage.

2. Labelling of Euro standard for LEZs/road tolling

3.1) Is labelling of Euro standard needed?

A clear yes.

EU legislation should also be amended to make Euro standard mandatory to be on the vehicle registration documents for new vehicles. However, this will not help with existing vehicles.

3.2) Should it be combined with the retrofit certification, or another mechanism?

Yes. Euro standard should be noted on the certification database / sticker / certificate etc

3.3) Should it also include light duty and off-road vehicles?

A clear yes. The German LEZ framework also requires light duty vehicles to be included.

3. Enforcement against foreign vehicles

4.1) How much of an issue is foreign vehicle enforcement for LEZs/road tolling?

A significant one that needs to be dealt with for many countries, and is an issue local operators demands for a level playing field. In London foreign registered vehicles are around 2% of the fleet *but disproportionate in the congestion charge non-payers.* Further input was requested on what could be done on this. *Taking this issue further is outside the remit of this project, but can raise the issue as an important one to be taken up elsewhere.*

4. Harmonised road sign for LEZs

5.1) Is a harmonised road sign for LEZs needed?

No. It might be nice, but not needed and could risk delaying schemes. Each LEZ scheme will have its own requirements for information that it needs to be in the sign.

5. LEZ enabling Directive

6.1) Is an LEZ enabling directive needed?

No. Guidance instead please, to avoid the complications of the Swedish schemes. The CEN standards are sufficient.

6. Vehicle OEM and warranty issue

7.1) Is OEM warranty and retrofit a significant issue?

There was a mixed reaction on this one, and more information was requested by email. It seemed as though it was probably an issue in some places, particularly if newer vehicles were to be retrofitted, there were relatively straightforward solutions, *such as including warranty of retrofit and engine as a requirement of the certification scheme, or letters of no objection can often be obtained from the OEM*. This issue may be able to be solved through the certification scheme*, especially if OEMs are involved in the process*.

7. EU notification and LEZ guidance

8.1) Should there be an EU LEZ guidance?

Yes, and as soon as possible. The most important thing it should say is "Think about the EU when you are designing your LEZ". The other key things it should contain are the pitfalls, what to look out for and a list of current LEZs and certification schemes in operation in a database / website.

Notification through Directive 98/34 is a set process, which cannot be changed or rules added. In general, national schemes need notifying, and it is the responsibility of the national Government to ensure that local schemes comply with EU legislation – in particular freedom of movement of goods and services.

Guidance is needed on notifying LEZs - *which could be through the LEZ guidance rather than any notification guidance*. Closer working and contact between the cities operating or planning LEZs would also help.

A common website with a list of LEZs in operation, pitfalls and certification schemes should be set up, with links to other relevant websites. The list of LEZ and incentive schemes in operation would not have to be undertaken by the EU, and it may be a quicker and more appropriate solution for the LEZ cities to undertake this as a group – perhaps in conjunction with other joint working*, and may also be a mechanism of getting some more detailed informal guidance earlier*.

The EU and freedom of movement issues need to be taken into account carefully and early when designing an LEZ. Alterations to TransEuropean Road Network roads can cause issues with the EU.

There appears to be some confusion amongst LEZ scheme managers about whether they have to notify. *A contributing factor to the confusion may be due to the fact that LEZs are compiled on the more regional level, experience with European law is limited, which is covered by national Governments.*

All schemes should be talking to first their national Government who have experience in notifying and complying with EU law, and also to the EU. *The EU will be producing guidance elements on LEZ implementation - expected to be published by the end of this year - as actions from the Thematic Strategy on the Urban Environment.*

8. Non-LEZ related issues

9. Common approach to cleaner fuels

9.1) What is needed for cleaner non-diesel fuels?
No clear consensus on this, and further feedback requested by email.

The technical group's certification discussion came down (narrowly) on the side of a joint retrofit and fuel scheme, but this was not straight forward or agreed with consensus.

The policy group felt that there was a need for a recognised standard for fuels.

9.2) Should the EU working group system be used for other fuels?
No clear views were expressed, and feedback requested by email.

9.3) Should vehicle conversion be certified through the technical measures certification as a single certification process?
Yes, as it is one of the methods that can be used to meet the LEZ standards.

10. Financial Incentives

10.1) Is EU guidance needed on which financial incentives work best?
No. However a list of which schemes are in operation would be very useful – see below.

11. State Aid and Notification Issues

11.1) Would any of the suggestions below help to improve the way state aid and notification operates for technical measures and LEZs?

This question is in two parts: one for notifying the EU for state aid (incentive schemes), and the other notifying the EU about schemes such as LEZs.

Incentive schemes:
The workshop felt that there should be a list of the incentive schemes that had been approved and in operation and that this would be very useful, possibly with case studies, to see outlines of what is possible, and better understand the precedents. There was a recognition that there were issues with state aid, but no strong call for any further actions in the plenary sessions, but an acknowledgement that time was needed to be allowed for this process and each scheme would be different. While it was raised as an issue when collecting input to this project, nobody in the room stated that their scheme had been refused. In the technical groups post-it survey, the options of financial incentives guidance, reviewing the state aid process and consistent case officers also got one vote each.

Every scheme will be different, so it will be difficult to lay down guidance. The state aid rules for environment are under revision at present.

LEZ notification – discussed above section 8.1.

12. EU Technical Measures Guidance

12.1) Should there be an EU guidance on technical measures?

No. However readily accessible data on schemes in operation or systems approved would be useful – as discussed above in the state aid section.

13. Information sharing resources

13.1) Would the information sharing schemes help?

Yes for information schemes on which LEZs and incentive schemes were in operation.

Remote feedback requested for procurement, with one post-it vote against the procurement schemes due to supplier confidentiality.

14. Technical measures: impacts, costs and modelling

The data were presented, and 'stop-the-press'/'show-stopping' issues were requested, with remote feedback was requested on any further details. Three different ranking options were presented for feedback on different weightings by email. Suggestions for TM penetrations were also requested by email.

There was no huge cry that the data were wrong, however the following points were made:

- Retrofitting dual-fuel and ethanol were not a realistic option
- The CRT data fuel economy data was questioned
- Stated that CRTs need servicing more frequently than once a year

- Need to remember that retrofits are often not compatible with biofuels, esters etc
- Question whether the full economics of the technologies taken into account – especially relevant for dual fuel with the economic advantage of the payback ratio. Answer: yes (payback is stated as 2 years. Operational costs were ranked at 10 (mid-way between 1 (worse) and 19 (best) i.e. zero impact).
- There was a request for reference to wider non-technical issues, such as modal shift. The response was made that there was a clear role for action at an EU level on technical measures, whereas issues such as traffic management was a subsiduary issue.
- The discarding of spark ignition gas vehicles was questioned. Answer: due to costs, and advantages over diesel have reduced
- Capital costs are not on the same level. DOCs are already in large numbers, so the costs have come down. CRT has low volume, so the costs have not come down similarly. Use of the Boston model was suggested to assess volume costs.
- Should combine air quality and noise (as the Dutch LEZ schemes do). *Noise is included in the impacts*
- CO_2 is a very important issue to include - *which it is.*

15. Other issues from discussion

- Draft report to the Commission will be circulated to workshop participants
- It was agreed to circulate contact details of attendees to attendees
- Question of whether CO_2 impacts are known. Response yes.
- Surprise that public procurement not more of an issue. Answer: it was raised in Sweden with respect of ethanol, where a larger number of purchasers would be beneficial. The need for funding of both public and private schemes was raised, but is outside the remit of this project due to it being a subsiduarity issue. It may be that it is just accepted that the public fleets will lead the way in the first to retrofit and clean vehicles.
- Retrofitting results in a change of the legal status of the vehicle. The EU Directive means that a retrofitted vehicle can no longer be used on public roads without specific arrangements. Further information by email would be useful on this to collate what is done throughout Europe.
- It would be useful to do something about the export of older vehicles to the eastern part of the EU – which will also have retrofit issues as well.
- Volunteers were requested to re-validate further developed schemes. London volunteered.

Further details of the discussion – again by question.

In the breakout groups, the policy group decided against using the post-its, and had discussions in the round. The technical group used post-its, and then discussed as many issues that needed discussion as possible – but were not able to get through them all. For the technical group, the discussion conclusions supersede some of the post-it comments, but it is useful to get the overview.

1. Common system at EU level for technical measure certification

2.1) Is a certification scheme needed?

The scheme is needed, but is not a pre-requisite for LEZs. In the Swedish LEZs 10% of vehicles retrofit to meet the standard.

2.2) & 2.13) Adopt, adapt or new scheme? And Interim arrangements.

Plenary discussions

Speed is of the essence, and a EU-wide certification scheme was needed yesterday, rather than in several years time.

Any new scheme should be as compatible with other schemes as possible. *Any new scheme proposed should be able to demonstrate that it will provide much better retrofitting systems – i.e. what are the advantages of developing a new scheme compared to adapting an existing scheme?*

An option to progress the certification scheme could be through type approving retrofits, with the new world heavy duty cycle as part of the Euro 6 heavy duty directive, which is timetabled to be agreed in 2009. After agreement on the World Harmonised Duty Cycle in 2009 the cycle could be used even if the Directive does not come into force until 2012.

There was a discussion as to whether regeneration on filters works. *They do work as long as they are well maintained, and used in appropriate duty cycles.*

Technical group: The consensus was Adapt. One post-it said to speed things up the well-established VERT scheme should be adopted and if necessary adapted.

Policy group:

- London will have to allow certifications from other countries, for countries with no certification, need to accept manufacturers certificate etc. London therefore needs to know what the different certificates mean.
- Danish system has suppliers from different countries, and manufacturer certificates are issued, so can be relevant in any country. *This is useful for other countries if a manufacturers certificate is given with all devices.*
- RPC is UK-specific, but linked with type approval for the device.
- All filters will be approved somewhere.
- Need to know how the retrofits operate at in urban areas – that they do what we expect and need. An important issue for the London Mayor.
- All of the above points out the need for a harmonised EU-scheme

From the technical post-it survey, 7 felt that existing schemes should be allowed until EU scheme comes into force, one felt that this would result in chaos. *The status of* *the existing certifications needs to be considered, and that the certification / data should be carried forward / useable to any new scheme.*

2.3) Engine family / vehicle application approval?

The policy group felt this was a question for the technical group. The outcome of the technical group was split. From the post-it notes there were 11 votes for engine family certification, 6 votes for vehicle-based approach, and 4 wanted a combined approach I got different numbers when I counted up!. It was then discussed in great detail – the conclusions are given in the previous section. In addition, the following comments were raised by post-it notes:

- There should be engine family approval for a given application field.
- Engine family with realistic "worse case" testing
- As per normal homologation, but real life cycle is important, need to consider real life load patterns for all certification in the future
- Needs to include endurance, certification, bench, real world. Certify measure rather than engine.
- Certification should be given to engine family with responsibility for e.g. regeneration picked up by manufacturers warranty. Engine Back Pressure data loggers etc to allow Conformity of Production testing along with Free Acceleration Smoke (FAS) tests
- There should be an engine family approach. In particular as exhaust output is rather a function of the engine in use than its application.
- Each engine can be used for different vehicles and drive cycles. Euro standards are related to the engines certification. Retrofit is related to vehicles.
- Certify engine application as Type Approval (or Homologation) is engine based.
- We need different cycles for different vehicles

2.4) Test Requirements.

Again, the policy group deferred to the technical group on this issue, however, they raised that:

- They wanted the test requirements to take account of inner city drive cycle and performance, to ensure that the technical measure gives the required emissions reductions in real world urban applications.
- They would like the test results to also produce emissions factors, which would be useful in modelling and justifying LEZs.
- There is type approval for replacement traps at the moment. This could be an appropriate mechanism for retrofit as well. It would be through amending directive 2005/55 for Euro 6, which can amend other things as well as the OEM Euro 6 testing, as it is a split level directive. The Euro 5 directive also did this, sweeping up a number of other issues with it.
- The difference between retrofit and replacement is that retrofit is improving the emissions, not replacing what was there, and the engine control management will be different.
- Would be 'happier' if the technology legally met Euro 4 – for whichever pollutant – which would speak for the type approval approach.
- Bench test may be less appropriate for NOx abatement retrofits
- Could use ESC for durability, then urban/suburban/motorway aspects of the test
- These issues need to be checked with the appropriate Commission DG.

The post-it survey revealed that engine dynamometer based tests alone were favoured by 6 delegates. 3 delegates preferred chassis dynamometer testing on actual vehicle, partly on cost basis but also to reflect real world duty cycle. 11 delegates were in favour of a combined approach.

There was an indication (3 responses) that a list of approved drive cycles would be useful. The certification solution presented in the first section, of a combined engine dynamometer for actual validation, and drive cycle for durability and application fits with the results of the post-its, and will give a robust scheme. Other specific issues raised in the post-its were:

- A model has to be verified and is time consuming and costly
- Combining essential for securing compliance
- Combining is probably the best solution. Both high speed/high load and low speed/low load conditions should be explored within any drive cycle approach.
- Bench test used as basis for family certification with drive cycle option – for unusual or "difficult" cases
- Bench test for DPF. Combined for DOC, SCR,DPF, dual fuel, EGR.
- The list of approved drive cycles should be MLTB (Millbrook London Transport Bus) test for urban, FIGE for extra urban. These should be equivalent to ESC/ETC. *Cycles should not be UK only, and it is unlikely to get agreement EU-wide on the MLTB. The ESC is a steady-state test and not equivalent to a transient chassis dynamometer test. There has been little correlation work done between chassis dynamometer and engine dynamometer so the "equivalent to ESC/ETC" may be difficult to achieve. The better approach may be to seek use of ARTEMIS but this needs further investigation*.
- There should be a list of "approved" drive cycles equivalent to ESC/ETC, possibly for each technology/technical measure
- Bench test provides more detailed info and provides better understanding.
- Bench test for Heavy Duty because of compliance with Euro standards. The test is combination of ETC and ESC
- Bench disadvantage: high cost for testing/certification, and limited test cycles.
- Engine bench test because of lower cost and compatibility with type approval
- Combined would provide check on real-world cycle for specific urban e.g. bus, application
- The drive cycle is easier to test, lower cost, only way to test hybrids. It is a test of the actual application
- The durability aspect needs to be defined
- Very important - need a level playing field

Bench tests can reflect Euro 4 test cycles, so you will be able to compare Euro 4 OEM vehicle to the emissions given by Euro 2 + SCR/DPF. *The proposal is to have both the Euro standard met (for that pollutant) depending on which Euro standard the original vehicle was, as well as the percentage reductions obtained, to allow fuller comparison, as the retrofit can often achieve emissions that fall between two Euro standards. There may be some variation, depending on the condition of the engine, as if it is a high emitter with a worn engine the results are not likely to be as good, but these are less likely to be retrofitted if the engine is already very worn.*

a. If a drive cycle should be included, if so which one(s) for which technical measures?

There was a consensus that existing drive cycles should be used even though these might not explore all operational conditions

2.5) What should be required?

Most agreed that it should be technology neutral (one post-it exception), and be able to treat pollutants separately.

Within the policy group, different members wanted different requirements – hence the suggestion of tabulating what each technical measures does, so that the LEZ/road tolling/incentive scheme can chose which technical measure meets its requirements. It was also raised that:

- the percentage reduction, particularly for NOx depends on the test cycle, and if it is tested on an engine dynamometer cycle, this will not be the percentage reduction achieved in practice in urban areas. This needs to be accounted for in the certification 'impacts table' , and approval could state something like "technology is approved for XX engine family and meets Euro Y as tested over ESC/ELR/ETC (QQQ% reduction) and is approved as demonstrated in field trials for the following applications giving ZZZ% emissions reduction…."
- It was strongly recommended against designing new tests, due to the very long time this takes
- It was discussed that at present the standards, or percentage reductions are all framed around Euro Standards – as it is understood is required by EU law. The Eurovignette was raised as the legislation that allows for reducing emissions for amounts other than by Euro standards.

Technical group:
From the post-its, 5 delegates preferred a set limit value with 6 preferring a percent reduction. Only 2 delegates considered requiring to meet a Euro level as a priority but 3 more included this as a good idea/option.

There were a number of additional points:

- A number of respondents requested a combination of the options
- Percentage reduction needs to be able to be related to changes in Euro level for LEZs.
- Need to understand baseline condition of the engine and its emission level
- A Euro 2 engine might need to be baselined on ETC to enable demonstration of aftertreatment to ETC cycle

2.6) Other pollutants:

The technical group had a much stronger on no allowable increases with most comments raised saying no or very limited increases. However the conclusion of the policy group that all increases (or decreases) should be noted and the LEZ/incentive scheme should be able to choose what devices they allow from the list makes more sense, giving policy-makers more flexibility.

In addition to the pollutants raised above, from the technical group:

- Suggested to take the approach of USEPA and Swiss in that there should be no new air toxics. – US Clean Air Act 2002 and Swiss Secondary Emissions approaches
- USEPA/CARB allow the inspector to investigate further if there is any suspicion of new emissions
- It is a big issue which needs serious further consideration and guidance

- Particle number should also be included as per UN-ECE PMP (particle measurement program) methodology
- PM numbers/ultrafines important but need EU/International agreement/protocols
- No increase in regulated pollutants, no tolerance of increase – staying within pre-technical measure Euro standard limit.
- No maximum allowable increase in NO_2
- A tolerance of increase probably makes most sense since some pollutants might show an increase in non-continually working systems which only amounts a very low increase
- Definition of "no increase" is a must. Is +2% an increase? Measurement accuracy needed
- No increase in regulated pollutants, slight increase in CO_2, IN TIME a maximum NO/NO_2 ratio
- How about health effects e.g. carcinogenicity, mutagenicity, metal from FBC
- Tolerance of increase OR max allowable where it is shown that a net health benefit results e.g. NO_2 increase vs PM decrease
- Stick to regulated pollutants and no increase in other regulated pollutants
- No additives without DPF

2.7) What should it include?

In the technical group post-it survey, 5 delegates opted for a combined technology neutral scheme. 2 delegates considered that fuel was a different scheme. 2 delegates suggested that comparison of emissions reduction through e.g. DPF and alternative fuels needs careful interpretation.

Other issues raised included:

- Ideally they should be a combined system. However, there is a recognition that this is likely not to be before 2008 – when it is needed for the current LEZs.
- It might be difficult, but the scheme protocol should be adjusted to the problem.
- It should be technology neutral but it is important that vehicle technology and fuel are evaluated as a combination
- Fuel will need to be treated differently, and care would need to be taken when considering differing technologies e.g. PM reductions with DPF or Natural Gas
- All technical measures, not including consumables e.g. fuel, oil, tyres
- Durability performance to be included. A technical validation of a concept including working temperature, regeneration of DPF, ammonia slip for SCR, cleaning of device, in-use verification annually by inspection and maintenance (I/M) programme
- First start with DPF, then add DENOX, then add fuel.
- Failure to get a common scheme will lead to missing A/Q targets

2.9) Controlling compliance.

From the post-it survey, 10 delegates stated that OBD would be a requirement and that in-use compliance was essential. 2 delegates suggested that OBD was unnecessary. In addition 1 delegate perhaps appeared in favour of OBD but questioned how in might be done.

Other issues/suggestions:

- Free Acceleration Smoke test is good proxy for PM in DPF testing not other types. OBD could download conformity data. Certification body to sample for more detailed tests as required.
- OBD is very costly and since SCR is a technology that is well understood and manageable a regular check (yearly or two yearly) should do just fine. *There was team concern about this comment, due to the risk of non-refilling of SCR reactant.* Maybe something similar to the German ASU that garages could use e.g NOx sensors currently available for passenger cars.
- Standard PM checks should do fine for the measurement since ultrafine particle tests should be part of homologation and visual tests at the garage only check the filter's integrity.
- Compliance is guaranteed by Conformity of Production and warrantee for 200,000 km or 5 year. Spot checks in-use not feasible
- Needs to ensure that it is not more onerous than the OEM homologation
- LEZ cities need NOx retrofit to help meet the EU Limit Values, which is available today.

2. Labelling of Euro standard for LEZs/road tolling

Camera enforced schemes need to look on a database. Labelling should combine the Euro standard.

The London scheme is envisaged that: UK vehicles come into zone and are checked via DVLA. Foreign vehicles need to register, and are estimated to be about 2% of the fleet, but a large political issue with UK vehicle operators. There has been discussions with the Commission, which is accepting the need for foreign vehicles to register as there is no other option to get the data, and London is making this process as easy as possible. UK 'grey-phase' vehicles, where the age does not give a 100% definition of the Euro standard also need to register.

It could be an option for Member States to chose to change the vehicle registration documents, but not every MS would want to do this, and it is much more important to know on the database.

There should be an allowance interoperability and the acceptance of existing labels elsewhere – for example the German label will be in use before any EU-wide one is in place.

3. Enforcement against foreign vehicles

There was a question as to whether the nationality be determined from the vehicle number plate.

4. Harmonised road sign for LEZs

Road signs are an UNECE issue rather than an EU issue, and there is a general understanding that road signs do not need to be notified.

There is a German-wide LEZ road sign proposed, and they have been told that they are required to notify the Commission – *but this may be because it is part of the national LEZ framework*

Signs for LEZs within the UK are all developing differently, due to different requirements.

5. Is an LEZ enabling directive needed?

The CEN standards are sufficient.

6. Vehicle OEM and warranty issue

Cummins has a limit on back pressure on engines. This allows only passive traps, and also not biofuels.

Warrantees generally last 3-5 years. *Different parts have different warrantee length, for some parts up to 8 years.*

7. EU notification and LEZ guidance

The safest thing for any scheme to do is to notify, to reduce the chance of a complaint to the EU succeeding in closing a scheme down. However, dialogue with the Commission to ensure that the scheme complies with all EU law is an alternative. Notifying is also part of informing other Member States. If a scheme is not notifying, other information methods are needed, such as publicity in ports, to and in other Member States etc.

LEZ scheme managers do not seem to be aware that they may have to notify. *A contributing factor to the confusion may be due to the fact that LEZs are compiled on the more regional level where experience with European law is limited. European law is normally covered by national Governments.*

Notification is needed due to the freedom of movement of goods, and proportionality. It provides an official contact point and is circulated to get consensus.

It was asked whether there was a definition of LEZ, the response was that there are a range of differing types of LEZ schemes. Each scheme will be different, and as such each notification will be different. For example

- the Dutch LEZs include noise as well as emissions
- some are charging-based (London, Oslo) and some are bans (Germany),
- some are national frameworks (that are notified) under which local schemes operate (e.g. Germany, Netherlands, Denmark) and others individual local schemes (London, Oslo) which while they do not need to be notified they do need to ensure that they are in accordance with EU law (role of the Member State to ensure this).

Guidance can raise awareness of issues and what they mean. If schemes follow the advice, it does not guarantee that there will be no problems with the notification process – as each scheme is different

Guidance can be produced relatively quickly when it is non-controversial, slower when it is controversial. Bulled point style guidance first is an option. *There is expected to be a framework on LEZs included in the EU Urban transport white paper*

Informal advice and discussion groups could be done by cities co-operating *and would be freer in what it included*. Information sharing sessions of LEZ cities/Member States could be useful. There are already examples of information on the web and cities co-operating, and where it has helped.

Guidance should include:

- Remember the EU – if you have to notify it takes time that needs to be planned in.
- The pitfalls, what to look into and out for

- How to share information to allow mutual recognition for retrofit schemes until a EU-wide scheme is developed is one of the main issues
- XYZ is not recommended/legal, xyz can be under xyz circumstances.
- *The most important issues in some understandable and clear guidance - something like a nice, helpful check-list.*
- Need to know how to best avoid complaints being upheld. Sweden got a complaint when it included foreign vehicles in its scheme – and at that point it also got rid of the retrofit aspect
- *Which LEZs have to be notified and what are other traffic regulations. Where is the limit*
- *What information concerning the LEZ is needed by the Commission*
- *How are air quality limits weighted against the subject of a free movement of goods*

8. Non-LEZ related issues

11. State Aid and Notification Issues

LEZ notification:
See above

Incentive Notification
There could be an option of fast-track approval for schemes that are similar to existing or previously approved schemes.

Both
- Notifying itself will take time – at least 7 months with no changes needed, and 8 months for a small change in the scheme. 12 months should be built into the process of implementing LEZs. Guidance may be able to shorten the time this takes.
- It was agreed that transparency is needed.
- How long notification takes is the result of communication between the member state and the Commission.
- Precedents and transparency would be useful in policy terms.
- The EU can provide guidance, and have done on Regeneration issues.

12. EU Technical Measures Guidance

Information sharing scheme of which vehicles can be retrofitted with what, so that when vehicles request being exempt from LEZ retrofit requirements, a wider experience is shared about whether or not these vehicles can be retrofitted.

The Netherlands has a list on their website of the retrofits available, and what vehicles they are relevant for. At the moment this is only for light duty vehicles, but from the 1st October this will include heavy duty vehicles.

The specification for the guidance was requested – and can be found in appendix 5.

Ranking Spreadsheet

The technical measures were ranked according to their impacts, the results of which are shown in Table 14. Technical measure ranking table*

.

Key:

19= Benefit,

10= No change,

1= Disbenefit

The key for costs to rank is given in Table 13 below.

Table 13. Key for costs to rank

Cost	Rank
350€	19
1500€	14
2500€	13
4000€	12
7000€	10
10000€	7
20000€	3
>20000€	1

Table 14. Technical measure ranking table*

Measure	Emission standard / age	Emission reductions/changes related to the base case vehicle												Costs			Operational		Ranking		
		NOx	NOx Rank	PM	PM Rank	NO_2	NO_2 Rank	Fuel cons/ CO_2	CO_2 Rank	<1000 nm Solid particles	Particles Rank	Other	Other Rank	Capital	Capital Rank	Operation	Operation Rank	Restrictions / Drawbacks	Overall	Without Cost, HC,CO	Without HC, CO
DOC	Pre-Euro	Zero	10	-20 to -40%	13	up to 50%	5	Zero	10	Risk of increase	8	CO and HC: typically 80%. 90% with 50ppm Sulphur SO_4, corrosion, Pt etc	14	€350 (small system) €1500 (large system)	14	Zero	19	Sulphation (corrosion), NO_2 emissions, PT emissions, other secondary emissions. Use as low sulphur fuel as possible to reduce effects	93	46	79
	Euro 1	Zero	10	-20 to -40%	13	up to 50%	5	Zero	10		8		14		14	Zero	19		93	46	79
	Euro 2:	Zero	10	up to -20%	12	up to 50%	5	Zero	10		8		14		14	Zero	19		92	45	78
	Euro 3	Zero	10	up to -20%	12	up to 50%	5	Zero	10		8		14		14	Zero	19		92	45	78
DPF (CRT®, catalys-ed)	Euro 1	-2 to -4%	11	>90%	19	up to 50%	5	<+1%	9	>99%	19	CO and HC: typically 90%	18	€3000 (small system) €7000 (large system)	10	Cleaning costs: Trucks - €350/yr Buses - €700/yr RCVs - €1400/yr Up to 1% increase in fuel cost	8	Needs low sulphur fuel (<50ppm)	99	63	81
	Euro 2	-2 to -4%	11	>90%	19	up to 50%	5	<+1%	9	>99%	19		18		10		8	Some older DPFs increase NO_2	99	63	81
	Euro 3	-2 to -4%	11	>90%	19	up to 50%	5	<+1%	9	>99%	19		18		10		8		99	63	81

		NOx	NOx Rank	PM	PM Rank	NO_2	NO_2 Rank	Fuel cons/ CO_2	CO_2 Rank	<1000 nm Solid particles	Particles Rank	Other	Other Rank	Capital	Capital Rank	Operation	Operation Rank	Restrictions / Drawbacks	Overall	Without Cost, HC,CO	Without HC, CO
DPF (partial flow)	Pre-Euro	Zero	10	up to 50%	14	up to 50%	5	Zero	10	Potentially zero	10	CO and HC: typically up to 80%. 90% with 50ppm Sulphur	18	<€3000 (small system) €7000 (large system)	10	Will require cleaning but possibly at lower frequency than full flow filter	8	Lower PM reduction, potentially minimal impact on ultrafines.	85	49	67
	Euro 1	Zero	10	up to 50%	14	up to 50%	5	Zero	10		10		18		10		8		85	49	67
	Euro 2	Zero	10	up to 50%	14	up to 50%	5	Zero	10		10		18		10		8		85	49	67
	Euro 3	Zero	10	up to 50%	14	up to 50%	5	Zero	10		10		18		10		8		85	49	67
DPF (FBC)	Pre-Euro	-2 to -4%	11	>90%	19	Zero	10	<+1%	9	>99%	19	CO and HC: If fitted with oxycat typically 90% with 50ppm Sulphur fuel. Can reduce to 30 – 40% with 500ppm fuel.	18	€3000 (small system) €10000 (large system)	10	Cleaning costs: Trucks - €350/yr Buses - €700/yr RCVs - €1400/yr Up to 1% increase in fuel cost	8	Requires fuel additive and dosing system. Best with low sulphur fuel (<50ppm)	104	68	86
	Euro 1	-2 to -4%	11	>90%	19	Zero	10	<+1%	9	>99%	19		18		10		8		104	68	86
	Euro 2	-2 to -4%	11	>90%	19	Zero	10	<+1%	9	>99%	19		18		10		8		104	68	86
	Euro 3	-2 to -4%	11	>90%	19	Zero	10	<+1%	9	>99%	19		18		10		8		104	68	86
DPF (active regeneration)	Pre-Euro	-2 to -4%	11	>90%	19	Zero	10	<+1%	9	>99%	19	CO and HC: zero to 90% depending on system of regeneration	16	€2300 (small system) €7000 (large system)	10	Cleaning costs: Trucks - €350/yr Buses - €700/yr RCVs - €1400/yr	8	May increase exhaust back pressure outside of manufacturers limits prior to regeneration.	102	68	86
	Euro 1	-2 to -4%	11	>90%	19	Zero	10	<+1%	9	>99%	19		16		10		8		102	68	86
	Euro 2	-2 to -4%	11	>90%	19	Zero	10	<+1%	9	>99%	19		16		10		8		102	68	86
	Euro 3	-2 to -4%	11	>90%	19	Zero	10	<+1%	9	>99%	19		16		10		8		102	68	86

		NOx	NOx Rank	PM	PM Rank	NO_2	NO_2 Rank	Fuel cons/ CO_2	CO_2 Rank	<1000 nm Solid particles	Particles Rank	Other	Other Rank	Capital	Capital Rank	Operation	Operation Rank	Restrictions / Drawbacks	Overall	Without Cost, HC,CO	Without HC, CO
EGR	**Euro 2**	**Up to -50%**	**14**	**Risk of increase. Likely to need mitigation**	**8**	**Zero**	**10**	**+2%**	**8**	**Risk of increase**	**8**		**10**	**Cost for large veicle: €14000 to**	**3**	**Up to 2% increase in fuel cost**	**9**	**Fuel consumption increase, potential accelerated**	**70**	**48**	**60**
	Euro 3	**Up to -50%**	**14**	**by DOC/DPF**	**8**	**Zero**	**10**	**+2%**	**8**		**8**		**10**	**€16000**	**3**		**9**	**engine wear. Mitigation of increased PM by DOC or DPF**	**70**	**48**	**60**
SCR	**Euro 2**	**-60 to -80%**	**18**	**-20 to -30%**	**13**	**Zero***	**10**	**Zero**	**10**	**Risk of increase**	**8**	**HC: typically 70% reduction.**	**10**	**Cost for city bus: €10000**	**3**	**Cost of Urea estimated at**	**9**	**Needs urea injection system**	**81**	**59**	**71**
	Euro 3	**-60 to -80%**	**18**	**-20 to -30%**	**13**	**Zero***	**10**	**Zero**	**10**		**8**	**CO: up to 20% increase.**	**10**	**€15000 (with DPF)**	**3**	**€1-2/100km**	**9**	***Can increase N2O through oxidation of NH3**	**81**	**59**	**71**
SCR+DPF	**Euro 2**	**-60 to -80%**	**18**	**>90%**	**19**	**+10 to 50%**	**5**	**<+1%**	**9**	**>99%**	**19**	**CO and HC: typically 90% with <50ppm Sulphur.**	**18**	**€12000 (medium system) €15000 (large**	**3**	**Cleaning costs: Trucks - €350/yr Buses - €700/yr**	**8**	**Needs low sulphur fuel (<50ppm) Needs urea injection system**	**99**	**70**	**81**
	Euro 3	**-60 to -80%**	**18**	**>90%**	**19**	**+10 to 50%**	**5**	**<+1%**	**9**	**>99%**	**19**		**18**	**system)**	**3**	**RCVs - €1400/yr Up to 1% increase in fuel cost Cost of Urea estimated at €1-2 /100km**	**8**	**Can increase NO_2 through oxidation of NH_3**	**99**	**70**	**81**

		NOx	NOx Rank	PM	PM Rank	NO_2	NO_2 Rank	Fuel cons/ CO_2	CO_2 Rank	<1000 nm Solid particles	Particles Rank	Other	Other Rank	Capital	Capital Rank	Operation	Operation Rank	Restrictions / Drawbacks	Overall	Without Cost, HC,CO	Without HC, CO
Repower to Euro 4 Note; based on real world emission tests.	**Euro 2**	**Zero**	**10**	**Up to 45%**	**14**	**Zero**	**10**	**Up to +20%**	**7**	**Could increase**	**8**	**E2 TO E4: HC: 60%, CO:55%** **E3 to E4 HC: 30%, CO: 25%**	**15**	**€16000 to €24000 Cost needs to be compared with like for like replacement cost**	**1**	**Maintenance costs expected to reduce.**	**11**	**Expensive. May not give reductions in solid particles Real world emissions benefits do not follow Euro standards**	**76**	**49**	**61**
	Euro 3	**Up to 50%**	**14**	**Up to 43%**	**14**	**Zero**	**10**	**Zero**	**10**		**8**		**13**		**1**	**Fuel cost could increase up to 20%**	**8**		**78**	**56**	**65**
Ethanol	**Euro 3**	**Meets Euro 4**	**14**	**Meets Euro 4**	**14**		**10**	**60% increase due to lower energy density**	**5**	**Could increase**	**8**	**Meets Euro 4**	**15**	**Additional cost can be in region of €10000**	**7**	**Maintenance cost could be +50%**	**6**	**Dedicated engine**	**79**	**51**	**64**
DWE	**Euro 1** **Euro 2** **Euro 3**	**-15%**	**12**	**-50% to -60%**	**15**	**Zero unless used with DOC (see comments ref. DOC)**	**10**	**10% increase**	**8**	**Could increase**	**8**	**Wide variation of results but CO and HC could increase up to 35%**	**5**		**10**	**Fuel cost could increase by 10%. However depend upon tax regime.**	**9**	**Emission benefits appear to be influenced by engine technology level and duty cycle**	**77**	**53**	**72**
Dual fuel diesel/natural gas/biogas	**Euro 3**	**Meets Euro 4**	**14**	**Meets Euro 4**	**14**	**Zero**	**10**	**20% lower**	**12**	**Likely to be higher than diesel with DPF**	**8**	**HC: 80%, CO: 80%**	**18**	**€22000 to €25000**	**1**	**Payback possible in 2 years**	**10**	**Reduced payload, slightly increased maintenance costs. Catalyst required for CH4 management**	**87**	**58**	**69**

***RCVs = Refuse Collection Vehicle**

Appendix 6 Possible policies ruled out

Ruled out at workshop

Harmonised road sign for LEZs

This was raised by the EU Environment Zones working group, however it was decided at the workshop that while it might be nice, it was not needed. Each LEZ scheme will have its own requirements for information that it needs to be in the sign and it could risk delaying schemes. Harmonisation of road signs is also a responsibility for ECE and the Inland Transport Committee rather than the Commission.

LEZ enabling Directive

Also raised by the EU Environment Zones working group, it was felt at the workshop that it was not needed and that guidance should be prepared instead. Guidance would help avoid the complications of the Swedish schemes. The CEN standards and national legislation were found to be sufficient – with the exception of EU-wide certification, see that section.

EU guidance on which financial incentives

There were many calls for greater funding of technical measures. Technical measures either need to be required or save money for significant uptake – either inherently, or with funding. There is a chicken-and-egg issue of lower volume production giving higher prices, so fewer purchases. Some member states see financial incentives to fit the whole fleet, others that it is to kick-start the market and develop trials. Taxation and financial incentives are subsiduarity issues, and the remit of the member states. The EU could give guidance, however It was felt that this was not needed and would change very fast. However a list of financial incentives in existence would be very useful, and would help member states design appropriate new incentives.

Legislation on natural gas targets

Supportive legislation to follow up the target of 2% natural gas by 2010 set in 2001 by the EU (as for biofuel targets). This is mainly targeted at new gas vehicles and would have little impact on dual fuel conversions

EU-wide framework for retrofit programs

An EU-wide framework for retrofit programs along the lines of the California Diesel Risk Reduction Program is likely to be difficult to agree and be adopted by the member states, due to their very different approach to retrofits and funding.

Increased availability of SCR reactant

This will be a greater issue for new Euro 4 and 5 vehicles, and will be resolved in that arena. There was a mixed view on this one member state said there was no evidence of this as an issue, and a number of technical measure suppliers and a fleet operator said this would be useful.

Fuels

Whilst it would appear that more could be done to encourage greater use of cleaner fuels in existing vehicles, there was no strong call or consensus for this, except for including the conversion of vehicles to alternative fuels in the EU-wide certification scheme, and potentially the certification of fuels themselves.There is at present no common EU-wide specification for non-diesel or petrol fuels for in-use vehicles, which limits their use. There is also no test for vehicles using such a fuel - for example all ethanol vehicles are tested when operating on petrol. Where the use of a different fuel requires a conversion, the quality of any conversions also needs to be controlled to control both safety and emissions.

In terms of fuels identified through the technical assessment as being relevant for this project were limited to Diesel Water Emulsion (DWE) and dual-fuel natural/biogas. These issues are also raised for biofuels more generally (where well-to-wheel CO_2 is also a key issue), ethanol, ethanol blends, and other fuels such as Synthetic Diesel (Fischer-Tropsch), as well as any other additive-based fuels. It also needs to be remembered that DWE is quite a niche fuel for captive fleets only.

There was no call for additional working groups, and the view was that where there is a sufficient interest, these would be set up.There are a number of processes that are working towards harmonised fuel standards:

- Gas fuel standards are being discussed in Euro VI negotiations
- There is an EU working group under CEN on is looking at producing a specification for ethanol / E-85 (an ethanol blend), which would allow vehicles to then be optimised with this fuel.
- The European Emulsion Fuel Manufacturers' Association (EEFMA) established a CEN Workshop Agreement in 2005 to promote Europe-wide emulsion fuel technical requirements.
- The UK and the Netherlands are developing biofuel carbon certification schemes and co-operating with each other in the process. When this is finished, in around 18 months time, then carbon content of fuels will be known for Biofuels rather than estimated.

Certification of non-diesel/petrol fuels could also be included in the first part of the certification scheme as is done in CARB and discussed above, if the Commission on discussions with Stakeholders feels that this is an appropriate way forward.

Ruled out due to technical assessment:

All the non-primary technical measures should be considered here. However, these two in particular are covered, as they were more borderline than the others, and more investigation could change this conclusion.

Tyres

We consider tyres to be a potential technical measure for emissions reduction but require more data and information on which to form an assessment of the benefits conferred and the method, if appropriate, of certification.

Ethanol

Whilst it would appear feasible that existing heavy-duty diesel engines could be converted to run on ethanol by retrofit measures, it is not considered a practical proposition due to being an extremely niche market with one established OEM player. It can be argued that competition within that market is desirable but until sufficient market pull is generated this is unlikely to occur, however the joint certification scheme and further exporting of the Swedish experience may encourage this market. The option has therefore been left open to include fuels – dual-fuel CNG and ethanol - in the certification scheme.

Appendix 7. LEZ Schemes in place or planned

National legislation – at various levels of finalising

German overarching legislation for LEZs

Federal Emissions Control Act - BImSchG) Article 40 (1).
Emissions standards set as options for all diesel vehicles, LDV and HDV:
Class 1: no standard
Class 2: All diesel vehicles Euro 1; Euro 2 for particles
Class 3: Euro 2; All diesel vehicles Euro 3; Euro 4 for particles plus petrol vehicles Euro 1
Particulate trap retrofitting requirements:
Class 1 Euro 1 only, LDV >30%, HDV >50%
Class 2 Euro 2 only, LDV >30%, HDV >50%
Class 3 Euro 3 only, LDV >30%, HDV >65%

Danish LEZ framework:
Affecting diesel-powered vehicles over 3.5T entering LEZs in Copenhagen, Frederiksberg, Århus, Aalborg and Odense:

- After 1 July 2008, vehicles 7+ years old (registered < 1/7/2001) must fit DPF or meet Euro 3 particle standard.
- After 1 July 2010, vehicles 4+ years old (registered < 1/7/2006) must fit DPF or meet Euro 4 particle standard.

Enforcement: compliant HDVs > 3.5T entering LEZ shall have an environmental zone mark visibly affixed to the vehicle. Foreign vehicles instead must be able to produce documentation at any time to show that the vehicle complies with the first two particle emissions requirements and a registration certificate showing the vehicle's age. Danish government supporting for plans for subsidies.

LEZs in the Netherlands
10 cities and 3 biggest transport employers unions signed the convenant for LEZs for trucks in March 2006. Cities will start LEZ at the 1st of April 2007 if the national government has a subsidy program for retrofit DPFs are in place by the 1st of October 2006.
The emission standards **until 2010** are:

- Euro 1 and less are not allowed in LEZs.
- Euros 2 & 3 will require a DPF (either open (50% PM_{10} reduction) or closed) allowed in.
- Retrofitted with natural gas, hydrogen. E85, LPG allowed in.
- Euro 4,5,6 and EEV allowed in.

The emission standards **after 2010** are:

- Euro 2 and less are not allowed in LEZs.
- Euros 3 will require a DPF (either open (50% PM_{10} reduction) or closed) and are not older than 8 years, allowed in.
- Retrofitted with natural gas, hydrogen. E85, LPG allowed in.
- Euro 4,5,6 and EEV allowed in.

DPF certification and registering by RDW. RDW holds a list of Euro 2 & 3 vehicles for which DPFs are not available, and which are therefore exempt. The international component is an issue.

Italy

Italy recently notified (Notification - 2006/259 /I Draft Text) a Draft Ministerial Decree laying down provisions for approval and installation of particulate retrofits. The Decree articles lay down procedures for type-approval request, general characteristics of the system, frames and engines for the sole purpose of retrofit particulate reductions, indications for updating vehicle registration certificate and requirements for the system manufacturer.

Local schemes - Already in place

Amsterdam

HGVs have needed a permit to drive in the city centre since mid 1990's, except on the main roads. It is primarily a restriction on the size of vehicle, with Euro standard requirement added. A permit is given if the vehicle is: less than 10 meters, less than 8 years and at least Euro 2 standard.

Swedish Environmental Zones

Affects diesel HDVs over 3.5T in Stockholm, Malmo, Gothenburg and Lund. Exceptions for main roads and harbour areas. The rules have changed a number of times.

Previous rule was that HDVs have to be at least 8 years old, with up to 12 years if fit a DPF or re-engine to the current Euro standard. Approved devices were either Level B: PM & HC -80%, NOx & noise no increase. Level C NOx –35%, no increase in other emissions. Other exemptions for vehicles with: Euro-IV or better and “special body” vehicles

New scheme without retrofits was sent to the Commission in May 2006.

Greece, Athens

- Within the city centre ring road: vehicles with registration number ending in odd digit are allowed to enter this ring on odd dates only and even numbers on even dates only
- All vehicles are must pass an idle emission test and are provided with a certification card.
- Economic incentives to replace old taxis and private buses.
- Tax incentives for new electrical or hybrid vehicles that can enter the ring without restriction.
- Daily field emission control of vehicles (~30,000 vehicles annually)

Lombardia

A ban on pre-Euro and Euro 1 vehicles during peak times in the winter months (08:00-10:00, 16:00-19:00 Mon-Fri from November to March except over Christmas). Applies for all vehicles, passengers and goods (with some exceptions, including foreign vehicles). Includes Greater Milan, Bergamo and Brescia zones.

Additional controls on Sunday and expected in a law for limitation of circulation from 1.7.2007, where Euro 4 petrol and 4 with DPF are/will be allowed.

Tokyo
Since 2003 all commercial vehicles/Heavy Duty Diesel vehicles older than 7 years must fit an approved particulate reduction device to reduce enter the city. Older engines needed retrofits with higher efficiencies, and subsidies were available. The ban is enforced by number plate recognition technology, windscreen stickers and vehicle inspection.
All fleets of over 30 vehicles must have an environmental management plan, outlining the steps to reduce pollution and report on the implementation progress. Fleets of over 200 vehicles must contain a certain percentage of "low emission vehicles". The "low emission vehicle" designations are issued by the Government.

Korea
Vehicles which fail an inspection and have higher than permitted particulate emissions must fit a DPF, DOC or change the engine. All are then exempt from inspections, but those which fit DOCs still have to pay environmental charge.

Planned

Berlin:
Area covered Area about 88 km² (of 892 km² total for Greater Berlin), population 1 million (of 3.4 total).
2008: German sticker class 2
2010: German sticker class 4
About 1.4 million Berlin vehicles need sticker, within about 15 months plus an unknown number of external vehicles. They are using many distribution networks. Enforcement with light manual control, with sticker, available at the borders for foreign vehicles.

London
Covering the whole of Greater London, 1600km^2, motorways currently not fomally included.
from Quarter 1 2008, Euro III (PM) for HGVs over 12T;
from Quarter 3 2008 Euro III (PM) for HGVs 3.5T – 12T, buses and coaches;
from 2012, a standard of Euro IV (PM) for HGVs, buses and coaches.
from 2010 address emissions from heavier LGVs and minibuses.
Enforcement: with Automatic Number Plate Recognition (ANPR). Fixed cameras supplemented by mobile patrol units fitted with ANPR cameras. A database would be established to assist the identification and matching process, using data from licensing authorities such as the DVLA. Only require registration from vehicles for which emission characteristics could not be determined from these records, which include retrofitted vehicles, foreign vehicles and those where age does not give the emissions standard.

Oslo
Charge for Euro 3 and earlier heavy duty vehicles to enter Oslo, dependent on Euro standards. Cost based on the cost of 1kg NOx and PM.

Enforcement likely be through AutoPASS transducers for the annual payments (and monthly), and also with cameras and vehicle registration numbers for foreign vehicles and daily payers. The penalty is envisaged as about half the price for one year if you drive in without paying. Reductions for annual and monthly payments.

Munich
Inside a circular road (Mittlerer Ring), with a starting date of October, 1st 2007. Will be based on the German LEZ framework. The discussion and lobbying on exceptions is on the way.

Karlruhe
Inner city using the German LEZ framework:
from 1st January 2008 class 2
from 1st January 2012 class 3.

Other cities in Germany and the UK are also expected to announce LEZs, as are cities in the rest of the EU. France has stated that it is not currently planning LEZs.

There are also various financial assistance packages around the EU for both retrofits and fuels.

Appendix 8 Summary of current certification schemes

	To prove	In-use compliance	Durability	Require:	Other Emissions	Back Pressure	Additive	Monitoring	Safety	Noise	Other
VERT	EU homolog. off-road bench test 4 points of 8178 100 / 60% engine speed; and 100 – 50% engine load. Deviations only at 1 test point, and <1 standard deviation. Filtration is independent from engine raw emission. One family of DPFs is tested on a standard engine and is applicable for all diesel engines sized accordingly.	Free accel <0.24 m-1 by manufacturers annually on every deployed device. Failure rate >5% results in delisting	Free accel >0.12m-1 after 2000hrs op. >2000hrs before cleaning. Maintenance interval >500hrs. Materials guarantee 2yrs/1000hrs. Life expectancy >5000 op hrs	PM count. 20-300nm >95%, PM mass >90%, particle size distribution, particle composition, worst case conditions (filtration during regen. with full & empty filters), dynamic effects, &more	No increase in secondary emissions. CO, HC, NOx & PM, incl. during regen. as usual % of cycle average. No incr NO_2, dioxins, furans, PAH, Nitro-PAH, sulphuric acid aerosols, secondary PM, mineral fibre	Fresh filter <50mbar. During regen. <150 mbar Max <200 mbar 95% percentile Alarm at >5 sec above 200 mbar	Automatic interrupt if filter ruptures	Monitor filter performance, backpressure, & additive	Cause no additional risks. Mounted as per instruction Meet Swiss safety standards.		Label must be durable etc w filter family, serial no, manufacturer data. The only cert. scheme to look at particle number, ultrafines and particle composition. Cannot confirm that regen will happen for each engine application.
German & Dutch HDV. Not yet finalised	Engine bench certification according to 88/77/EC. ESC & ETC cycles. Maybe also modified ESC (tbc). Engine family approach like the US - 100-6% of base engine within the scope of application (engine family with respect to annex I item 8.2 of directive 88/77) & smallest used filter volume within the scope of application. Emissions tests every 5th ETC cycle to test regen.		efficiency guaranteed when operating according to its intended to 200000 km. Engines with swept volume <0.75 dm^3/cylinder & speed >3000 min^{-1} require 80 000 km. Endurance test of >25 ETC cycles – also to test regen. Free maintenance included in sale contract as often as required up to 80000 /200000 km	gravimetric PM reduction. Class A 90% reduction. Class B 50%. Systems for engines with a swept volume <0.75 dm^3/ cylinder & speed of >3000 min^{-1} a minimum of 30% is applicable.	As per originally approved Euro class. NO_2/NOx ration recorded in initial and retrofitted state. Opacity according to 88/77 <0.8m^{-1}. Maximum 4% fuel penalty	Regen. test under boundary loaded conditions - boundary loading or after maximum 100 hours a thermal regeneration is initiated – <15% deviation from pre-loading test data for gases & <20% for PM. Must state that exhaust gas temps in regen. are non-critical	No additive allowed with Class B. If additive used, issue statement of no objection of the combination of additive & system from Government Agency	Temporarily disabling of the system if not meet requirements. Prove: a) conditions disabling activated / deactivated b) disabling only to protect engine or DPF & not permanent. c) lasts max 2 test cycles d) durability criteria still met e) driver informed. Existing OBD /engine management not impaired.	Normally >2m between system & turbocharger	No deterioration	Requirement phrasing different in DE and NL due to legal structure, but in practice identical. Dutch scheme presented here as per mid August. Conformity of production requirements. Specifies fuel. Installation manual requirements specified. Each system sold have installation manual & copy type approval. Can withdraw approval

German & Dutch LDV	EU homologation cycle, NEDC. Under all instances average PM deviate <15%	Opacity test during free accel with respect of article 2.3.12 of the Regulation on permanent requirements	>4,000 km on dyno with urban & extra-urban on Euro3 N1, N1 class II or III, Euro2. <70kph, 300°C, or realistic urban cycle. Shorter test if reduced PM by same %. Efficiency guaranteed if used according to intended use for 5yrs / 80000km. Range of use for engine capacity 65 -130%, with respect of engine capacity.	Gravimetric. PM reduced < 0.025 g/km; vehicles > 2.5T & N1 class II & III, 0.050g/km. Retention coefficient 30-90%, during soot oxidation 30%.	arithmetic mean of NEDC in initial state without a reduction system for HC, CO, NOx, CO_2, worst case regen. disregarded	Must be designed & built so that no unacceptable increase in exhaust gas back pressure occurs during load when no regen. takes place or after extended use,					Worst case regen tested as proof of thermal stability. Conformity criteria required. Customer has copy of type approval certificate. Installation manual required
RPC (UK)	To certify a DPF: test on 'worst case' examples of engine families for different vehicle types. Witnessed test on ETC. Previously used dyno on FiGE as 'real-world' proxy for ETC.	Free accel. smoke test & visual test matching serial no of DPF with chassis & vehicle registration		Euro 4 (PM) 0.03g/kWh on ETC. Previously was provisional E4(PM), 0.08 g/kWh equiv. on dyno 0.08g/km							
Danish	stationary 13-mode on Euro1. Measured emissions must be representative of emissions in practical use. Manufacturer sends declaration, safety DTI assess design & guide	Free accel K-value < $0.2m^{-1}$. Must be possible to insert opacity test.	Designed to be operational in full lifetime of vehicle if engine & filter maintained with service guidelines	80% PM reduction (E3→E4)	Present CO, HC, NOx, NO_2 data	Back-pressure <20kPa at max power	If required must be added during normal operation. Bunked vehicles are exempt	Filter status continuously warning lamp for driver if back-pressure >limit	No fire risk. assess design & guide	> same	provide service & disposal guide. Use maximum 50ppm S fuel.

WVTA - CNG cars	EU homologation tests basis. Type approval procedure and self-certification procedures.	Simplified procedures for small numbers									For new vehicles only Whole Vehicle Type Approval.
Italian	With reference to Directive 88/77/EEC & another decree, group of engines tested. Tested with & without device. For discontinuous regen. systems test a) new system and b) under conditions similar to critical conditions (before regen.)	At users request civil motoring authorities check conformity. Installation instruction must be followed.	>50000 km drive cycle or dyno bench collection program for >1000 hours. Specify operating conditions & test before durability. PM increase <20% by end.	PM reduction. Euro1 : 0.36g/kWh, if power = 85kW coefficient of 1.7. Euro 2: 0.15 g/kWh Euro 3: 0.10 Euro 4: 0.02 Euro 5: 0.02	CO, HC, NO_x, PT tolerance band of <20% cf. those in standard the engine is type approved to. No increase in CO & HC. NOx increase by <5%	Back-pressure alarm when excessive	Must not damage vehicle or device, provide safety datasheet, consequence of lack / excess, set correct use, meet EN590				Not technical solutions that facilitate exclusion or chocking of system by bypass devices. Label device. Conformity of production. Recognise other EU/EEA/Turkey schemes. Amends vehicle registration documents
EST Clean-Up	Chassis dynamometer based. Cycles include Millbrook London Transport Bus (MLTB), FIGE institute, and Refuse Collection Vehicle (RCV) cycles	Not a certification scheme as such, but included out of completeness as it uses drive cycles	6 month in-service use followed by repeat emissions tests	All PM and NOx reduction technologies.	Ultrafine measurements with Electrostatic Low Pressure Impactor (ELPI). NOx speciation for CRT and catalysed traps						
Sweden	Chassis dynamometer, using the Braunschweig transient test cycle by AVL-MTC										
France	UTAC. Dynamometer testing, with a certification system										
Others	There have been other dynamometer testing in Holland, Belgium, Denmark, Sweden, and Finland, either certifications, or testing to support public procurement, often of buses										
Tokyo	Board of experts conducting the inspections and the designations, with data			Certification of DPFs and DOCs							
Korea	Various tests such as actual test, emission reduction efficiency test, performance test		Warranty : Type 1 3y/ 160000km, Type 2&3 3y/80000 km,	Type 1 PM, NOx reduction >70% (DPF). Type 2 >50%, Type 3 > 25% (DOC)							

CARB	Cycle (% reduction) or bench (absolute level & %). Incl. during regen, include aborted/ uncompleted tests & state why not completed. Field demonstration an option. Filter break-in 25-125 hours.	No annual test. >=4 devices tested after 50 units sold. Each <=90% lower bound of initial verification level. Total no tested <=10.	Min stability demonstration 80500km/1000 hrs. Field / lab-based demo with chassis / dyno. Warrantee >=5yr/241400 km, or if typically driven over 161000km /yr & has < 483000km when installed 2yrs unlimited mileage	3 levels. Level 1 25% PM reduction Level 2 : 50% PM reduction Level 3 >=85% PM reduction or PM <=0.01 g/bhp-hr. Level 3 tested during regen.	NO_2 <20 % increase, NOx on mass basis report total PM, CO_2 can ask for extra tests. NH_3 <25ppm. CO < current limits for new diesel, NMVOC , NO_x incr <10% or prove widespread use will not incr O_3.	In emission & durability test, backpressure within OEMs specified limits, or will not result in any engine damage. If gets gradual buildup, state how to reduce. Incl. backpressure monitor to inform operator	Must be safe to use alone. Monitor shut off additive if problem. Submit env, toxicological, epidem. data every 2yrs. Run with >50 ppm or x10 usual rate			Same as before	State maintenance requirements. Label system. Controls relying on fuel changes i.e. additives / alternative diesel fuels must evaluate multimedia effects. Owners manual required & content specified, incl. maintenance. Specifies fuel. Not test extreme DPF conditions i.e. highest space velocity.
CARB NOx	2 hot-start tests + cycle that gives sig. periods of elevated NOx. Cycle must be representative.	Rest as above									
USEPA	Dyno cycle on under load, 40 CFR Part 86 Subpart N after device run-in. Min 3 hot start and 1 cold tests with 95% confidence interval. Additional tests required if confidence interval too large. If include periodic regen., sufficient test cycles until include regen event. Multi-family applications, test with one engine, use sizing charts for relevance on different engines if verified on an engine at most challenging end of applicability. Also requires field tests. Reports to USEPA from approved lab.	No annual test. After 500 units sold testing at 25% and 75% of mileage or hours meet 75% of verified level.	Real world operation to 33% of full-life (5yrs or 100khrs), and accelerated bench testing 33% of full-life. operating new device under conditions that cause normal wear equiv. >= 33% of min required by CARB	No particular requirement, states what emissions reduction device gives	NOx, PM, HCs, CO, CO_2 & other FTP specified emissions.	Not exceed backpressure. DPF inlet/outlet temp and pressure during tests must be reported.			Maintain physical integrity		Same appearance and location as large muffler. State if OEM warrantee given or not. Quality assessment. Maintenance procedure submitted. Specifies fuel. SCR, NOx control technologies, fuels, fuel additives, reformulated fuels, and lubricants specifically excluded.

CARB alternative diesel fuel test for fuels to reduce PM and NOx, e.g. water-diesel emulsified, biodiesel, ethanol-diesel-emulsified and Fischer Tropsch fuels. The interim procedure specifically does not verify the appropriate use of alternative diesel fuels or possible impacts on engine durability and performance.

The procedure compares the NOx and PM emissions from a 10 percent aromatic California diesel reference fuel to the emissions from the alternative diesel fuel. It specifies the required emissions tests and analytical methods to conduct the assessment. In addition to NOx and PM emissions, it requires an assessment of toxics and hydrocarbon emissions - no increase in toxicity shall result from an alternative diesel fuel. Hydrocarbon emissions shall be at least 25 percent lower than any applicable diesel vehicle emission standard. No increase in toxic or potentially toxic compounds. Can agree with CARB different parameters if make sense. Additional requirements may be added.
Specifies test procedures, analysers. Hot and cold tests (or sometimes only hot), durability similar to retrofit plus doesn't harm engine

The applicant shall initially submit a proposed test protocol to the executive officer or designee. The proposed test protocol shall include:

- criteria pollutant and toxic emissions sampling and analysis consistent with the requirements of the procedure;
- test data showing that the candidate alternative diesel fuel parameters as shown below;
- test data showing that the fuel to be used as the reference fuel meets the appropriate specifications;
- the identity of the entity proposed to conduct the tests;
- reasonably adequate quality assurance and quality control procedures

References criteria pollutants and sampling methods consistent with retrofit test
Describe the applicability
General description of fuel characteristics, properties, formulation and chemical composition. Including:

1. Identity, chemical composition, and concentration of fuel additives
2. Sulphur content
3. Total aromatic content
4. Total polycyclic aromatic hydrocarbon content
5. Nitrogen content
6. API gravity (density)
7. Distillation temperature distribution information, initial boiling point (IBP),
8. 10% recovered (REC), 5O% REC, 90% REC, and end point (EP)

Info on how may affect engine performance, wear, and safety must be provided. Must specify the following:

1. Viscosity (engine performance)
2. Fuel volatility (engine performance)
3. Ignition quality (engine performance)
4. Fuel operating temperatures (engine performance)
5. Engine wear tendencies (engine wear)
6. Corrosion (engine wear)
7. Lubricity (engine wear)
8. Fuel flash point (safety)
9. Compare with selection of reference fuels.