Association for Emissions Control by Catalyst AISBL

AECC CONTRIBUTION TO THE CARS 21 PROCESS ON COMPETITIVENESS AND THE SUSTAINABLE GROWTH OF THE AUTOMOTIVE INDUSTRY IN THE EUROPEAN UNION

EXECUTIVE SUMMARY

AECC[*], the Association for Emissions Control by Catalyst, strongly believes that the development in Europe of technological solutions for future clean, efficient vehicles and mobile machinery, including the continued development of internal combustion (IC) engines and emissions control technology, is the key requisite for the competitiveness and sustainable growth of the automotive industry in the European Union.

Such development will form the cornerstone of the European automotive industry's competitiveness in, and hence trade with, global markets. It will maintain and enhance the innovative capabilities of the automotive manufacturers themselves and of the supply chain industries on which they depend for key developments. This will, in turn, maximise both facility utilisation and employment in both the automotive industry directly and in the supplier chain.

To support this development, challenging technology-neutral legislation based on health and environmental needs is essential to ensure that the European industry remains at the forefront of technologies that will be accepted and adopted worldwide. To underpin this, research and development must continue to support a broad range of technologies. This must particularly bear in mind that for the foreseeable future, internal combustion engines, and particularly diesel engines, will remain the core technology for many applications such as long-haul transport, as well as providing the underlying power units for hybridisation. In addition, there are substantial regions of the world where it can be expected that IC engines will remain the only viable power source for a considerable period of time.

AECC therefore sees the key issues for CARS 21 as being:

- ***technological neutrality in defining and supporting clean vehicles for the future;***
- ***ensuring that harmonised test procedures, such as the future WLTP, provide a sound basis for good emissions performance***;
- ***improving harmonisation without diluting EU performance standards;*** and
- ***Type Approval figures reflecting real-life performance, with good market surveillance***.

With this technical report, AECC is providing detailed comments on those issues raised in the CARS 21 process that are of particular relevance and importance to the competitiveness and sustainable growth of the European emissions control and automotive industries.

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[*] *AECC is an international non-profit scientific association of European companies engaged in the development, production and testing of catalyst and filter based technologies for vehicle and engine emissions control. This includes the research, development, testing and manufacture of autocatalysts, ceramic and metallic substrates and speciality materials incorporated into the catalytic converter and filter and catalyst based technologies to control engine emissions (especially particulates and nitrogen oxides). Members' technology is incorporated in the exhaust emission control systems on new cars commercial vehicles, buses, non-road mobile machinery and motorcycles in Europe.*

More information on AECC can be found at www.aecc.eu. Information on emissions control retrofit for existing heavy-duty vehicles and non-road machinery can also be found at www.dieselretrofit.eu. AECC's members are: BASF Catalysts Germany GmbH, Germany; Corning GmbH, Germany; Emitec Gesellschaft für Emissionstechnologie mbH, Germany; Ibiden Deutschland GmbH, Germany; Johnson Matthey PLC, United Kingdom; NGK Europe GmbH, Germany; Rhodia Operations, France and Umicore AG & Co. KG, Germany.

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a) Clean Vehicles for Future and Technological Neutrality

The European automotive manufacturing industry is widely recognised as the leader in the technology and application of diesel engines. The EU has a high proportion of diesel cars that are gaining global acceptance for their combination of fuel efficiency, driveability and refinement. This is supported by the European supply chain that is providing the enabling technologies for clean vehicles, such as Diesel Particulate Filters (DPF) to reduce particulate matter and ultrafine particles, and Selective Catalytic Reduction (SCR) and NOx traps to limit emissions from nitrogen oxides. These emission reduction technologies allow diesel engines to meet the most stringent emissions legislation (Euro 6), needed to minimise the health effects and the environmental results of emissions, with minimal impact on fuel efficiency.

Diesel engines are, of course, globally used for commercial haulage and utility vehicles, for a wide variety of non-road mobile machinery (NRMM) and for passenger service vehicles because of their power and fuel-efficiency. The same emissions control technologies are available for these.

Spark-ignition engines should not be ignored as they provide the main power source not only for the majority of cars sold worldwide, but also for mopeds, motorcycles, recreational craft and small machinery. Conventional port-injection petrol engines are now being supplemented by an increasing number of Direct Injection petrol engines. Emissions control technologies for such engines are available in addition to ‘conventional’ three-way catalysts. Should they be needed for the future, particulate filters for petrol DI engines have also been developed.

Emissions and CO_2 legislation are critical drivers for the future development of automotive technology. As such the legislation needs to continue to be technology neutral, permitting the development of those technologies best suited to the particular applications. Specifically, it needs to ensure a level playing field for all powertrain options to ensure the development of the most appropriate and cost-effective systems. It is not valid to consider only tailpipe emissions if some technologies, such as plug-in electric vehicles, rely on the generation of emissions elsewhere to achieve low or zero tailpipe emissions.

In addition, European emissions legislation needs to remain a template that can be used by other countries, such as already occurs through the adoption of EU Regulations into the UNECE framework. To maintain Europe’s competitive advantage, emissions legislation needs to continue to be class-leading and challenging in the future, helping both the EU and other nations to provide improved air quality for their citizens.

The continued development of both IC engine technologies and the supporting component technologies (including emissions control) remains a significant objective for the industries concerned. It is therefore vital that neither legislation nor innovation policies discriminate against the continued development of internal combustion engines and of the key enabling technology of emissions control systems. IC engines and their associated emissions controls will continue to be required for many years to come even in Europe, and will remain essential for many applications and territories. It is crucial that the development of low-emissions IC-engine systems is not excluded from research and development programmes.

b) Development of the World-harmonised Light-duty Test Procedure (WLTP)

An important issue for light-duty vehicles in the near- to mid-term future is the World-harmonised Light-duty Test Procedure (WLTP); this process needs to not only provide improvements in the determination of fuel economy but also to improve air quality through control of regulated emissions, especially NO_2. The development work must clearly ensure that this new cycle provides the EU’s initial target of a more real-life cycle (particularly for CO_2/fuel consumption measurements). But it must also support the EU industry’s leading position in light-duty diesel vehicles whilst still ensuring effective emissions control of all light-duty vehicle powertrains. It is essential that this global cycle does not ‘smooth out’ the key parameters that ensure effective control of emissions and so dilute the levels achieved by the Euro 6 standards. Starting from ambient soak conditions should exhibit realistic warm-up procedures to demonstrate that they will operate effectively in real service. The cycle should provide a better representation of transient conditions than the current cycle so as to ensure proper control of such real-life driving patterns and should provide sufficiently high speeds to properly represent European driving conditions, again so as to ensure proper emissions control under normal European driving conditions.

The differences apparent in test data from the current (NEDC) test and transient cycles such as the Artemis suite (CADC) highlight the need to ensure that the test cycle covers the critical parameters for good control of regulated emissions. Control of these aspects should ensure that EU emissions regulations remain a benchmark for use in other parts of the world, thus giving EU manufacturers a broad base in export markets. Nevertheless, the Commission has already recognised that conventional test cycles do not always offer sufficient control of emissions in real driving. AECC is participating in the Commission's working group (RDE-LDV) on this aspect and notes that this work on Off-Cycle Emissions could form a basis for one of the future parts of the WLTP development.

c) UNECE Regulations and Harmonisation

The EU has already provided a lead for the utilisation of world-harmonised test cycles and procedures by the adoption into EU legislation of the cycles for motorcycles (WMTC), heavy-duty engines (WHDC) and NRMM engines (NRTC). It is expected that in due course the development of WLTP for light-duty vehicles will also lead to its adoption into EU legislation. Europe has also taken a position at the forefront of the development of new methodologies, notably the Particle Measurement Procedure (PMP) to count emissions of ultrafine particles that are dangerous to health. Following the development of that procedure, Europe's adoption of PMP for improved particulates measurement and limitation through the Euro 6 and Euro VI legislation has provided an important precedent for other nations.

The uptake in other regions of UNECE Regulations based on those developed in Europe provides a strong basis for the European automotive and components industries, including the emissions control industry, to offer class-leading technology to other regions of the world. The efforts of the Commission to encourage such uptake are therefore of benefit to the industry as a whole. To maximise the benefits, it is essential that the EU Regulations for cars and for heavy-duty engines continue to ensure that engine and emissions control technologies remain at the forefront of global development. Those for NRMM, tractors and powered two-wheelers will need to reach the same level of development and environmental protection as do those for light-duty vehicles and heavy-duty engines.

Whilst the benefits of this leading position are important, it is also essential to ensure that efforts towards global harmonisation do not lead to a dilution of European ambition levels for environmental performance. The EU, with the co-operation of organisations such as the United Nations Environment Programme (UNEP) and the World Health organisation (WHO), will have to seek to ensure that other regions of the world ultimately strive to reach the same health- and environment-based targets as the European Community.

The recent proposal for emissions limits in gtr no.2, the World-harmonised Motorcycle Test Procedure (WMTC) go some way towards this in setting a globally accepted set of limit values, thus permitting manufacturers to offer the best available technology in global markets. However, the option for secondary national/regional limit values leaves the door open for some fragmentation of markets and may put 'global' products at a cost disadvantage regionally, thus forcing manufacturers to develop solutions with low costs and performance, and hence losing some of the potential benefits of scale. This also needs to be borne in mind when considering the further development of the other existing world-harmonised procedures for heavy-duty vehicles (gtr no.4; WHDC) and Non-Road Mobile Machinery (gtr no. 11; NRTC), as well as the on-going development of the light-duty procedure (WLTP).

d) Real Driving Emissions (RDE)

AECC supports the need to ensure that real driving emissions and fuel consumption are properly represented by the results of Type Approval tests and supports the work of the Commission's RDE-LDV group on this topic. Clearly the objective of emissions control legislation is to ensure improvement of ambient air quality which is in turn linked to the aims to minimise the health effects of vehicle operation. As such, the measurement not only of real-life emissions but especially of actual air quality is an important factor in assessing the level of emissions control that will be needed in the future. A critical assessment of the changes in air quality and the performance of vehicles to date will be needed to help gauge the level of future performance needs. The anticipated 2013 review of the Air Quality and National Emissions Ceilings Directives will therefore form an important input to any future stages of emissions legislation.

The development of the new WLTP cycle offers a step towards a more realistic cycle for Type Approval, but at the same time it is necessary to ensure that the Euro 6 levels of emissions control performance are maintained by the new cycle (as discussed above). WLTP should also provide the basis for further reductions in emissions if supported by cost-benefit analysis.

One of the issues currently under discussion is the need for additional control of engine/vehicle NO_2 emissions as a result of concerns over exceedances of the NO_2 limits for local ambient air quality. In part these stem from the historical setting of vehicle emissions limits as NOx (on the basis that all NO emissions are oxidised to NO_2 over a period of time) and partly to the emissions legislation setting targets for control of other pollutants without significantly strengthening NOx requirements. Ultimately, the best method to ensure good control of NO_2 is to ensure good control of NOx, such as is anticipated for Euro 6 and VI. However, if it is felt necessary to have an additional limit for NO_2, then this should be done as an absolute (mg/km or mg/kWh) limit to ensure that the best technologies are used. Euro 6/VI will reduce ambient NOx and NO_2 levels and the introduction of the WLTP for regulated emissions will further reduce the real world passenger car contribution, particularly from diesels. It is important that these measures are taken as soon as is practicable and that there is no dilution of the Euro 6 regulated emission requirements when the new (WLTP) cycle is introduced.

In conclusion, AECC supports the continued development of technology-neutral emissions regulations linked to air quality, health protection and real-use emissions of all classes of vehicle and machinery. This route provides a method for the European automotive industry to continue to develop and apply class-leading technologies. The transposition of European legislation into global terms offers the potential for global acceptance of those technologies, opening world markets to European industries. European innovation and development strategies need to ensure that the European Community’s lead in internal combustion engine and emissions control technologies is maintained whilst still providing improved emissions performance and CO_2/ fuel consumption measured on a basis which gives a level playing field for all technologies.

It is essential that for the future the Type Approval values for both greenhouse gases and regulated emissions properly reflect in-use emissions, and the current process to achieve this is fully supported. But care must be taken to avoid dilution of current measures to limit vehicle emissions through unintended legislative loop-holes arising as new procedures are introduced, particularly for vehicles with combined or fully electric power sources, as this could cause considerable market distortion. In particular, incentives based on tailpipe CO_2 alone would distort the market away from the clean and efficient internal combustion engine technologies in which European industries currently have a leading position.

CONTENTS

FIGURES

INTRODUCTION

AECC, the Association for Emissions Control by Catalyst, would like to provide comments on the issues raised in the CARS 21 process that are of particular relevance to the competitiveness and sustainable growth of the European emissions control industry.

AECC strongly believes that a competitive and sustainable European supply industry is essential for a strong European automotive industry that is competitive in a global industry environment and allows for sustainable growth.

Given that for the foreseeable future the global market will include clean and fuel efficient internal combustion engines, this also requires that the European emissions control industry remains innovative, competitive and is able to deliver the products demanded to improve our living environment and the air that we all breathe.

1. INTERNAL MARKET, EMISSIONS AND CO_2 POLICIES (WG4)

1.1. Emissions, Air Quality and Noise

For the foreseeable future, internal combustion (IC) engines will continue to be required for long-distance heavy-haul operations, for use in many types of mobile machinery, and for direct or hybrid application in light-duty vehicles. There will also be many parts of the world where there is no or limited access to power grids, thus resulting in a continuing and important export market for European OEMs capable of supplying vehicles with IC engines providing good fuel efficiency in combination with low pollutant emissions. A number of authoritative reports recognise that internal combustion engines will continue to play a significant role in transport for the foreseeable future. The report of the European Expert Group on Future Transport Fuels[1], for instance, records that although road transport could be powered by electricity for short distances, hydrogen and methane are possible fuels up to medium distance, and biofuels/synthetic fuels, LNG and LPG up to long distance and that waterborne transport could be supplied by biofuels, hydrogen, LPG and LNG.

The European Commission's Roadmap to a low-carbon economy for 2050[2] confirms that technological innovation can help the transition to a more efficient and sustainable European transport system by acting on 3 main factors: vehicle efficiency through new engines, materials and design; cleaner energy use through new fuels and propulsion systems; and better use of networks and safer and more secure operation through information and communication systems.

1.1.1. Clean Vehicles for the Future

The European automotive manufacturing industry is widely recognised as the leader in the technology and application of diesel engines. This is supported by the European supply chain that is providing the enabling technologies for clean vehicles, such as Diesel Particulate Filters (DPF) to reduce particulate matter and ultrafine particles, and Selective Catalytic Reduction (SCR) and NOx traps to limit emissions from nitrogen oxides. These emission reduction technologies allow diesel engines to meet the most stringent emissions legislation, needed to minimise the health effects and the environmental results of emissions, with minimal impact on fuel efficiency. Spark-ignition engines, both conventional port-injection and Direct Injection, remain equally important as they provide the main power source for the majority of cars sold worldwide as well as for mopeds, motorcycles, recreational craft and small machinery. Emissions control technologies for such engines are available in addition to 'conventional' three-way catalysts. Should they be needed for the future, particulate filters for petrol DI engines have also been developed.

Emissions and CO_2 legislation are critical drivers for the future development of automotive technology. As such the legislation needs to continue to be technology neutral, permitting and supporting the development of those technologies best suited to the particular applications. Specifically, it needs to ensure a level playing field for all powertrain options to ensure the development of the most appropriate and cost-effective systems. It is not valid to consider only tailpipe emissions if some technologies, such as plug-in electric vehicles, rely on the generation of emissions elsewhere to achieve low or zero tailpipe emissions. This applies not only to research and development programmes and to legislative texts, but especially to the issue of incentives for the uptake of clean and efficient vehicles.

If such incentives are based solely on tailpipe CO_2 emissions without considering greenhouse gas emissions in the production of electricity used for external charging, for instance, this will not only grossly underestimate the total CO_2 contribution to the global issue of greenhouse gas emissions but will clearly penalise clean and efficient Internal Combustion Engines.

The recent study for the European Commission by CE Delft, ICF and Ecologic[3] highlights the importance of considering both CO_2 and regulated pollutant emissions on a well-to-wheel basis. In particular, this report identifies the potential impact of conventional and electric vehicles on total NOx emissions. It shows that substantial reductions in vehicle tailpipe NOx emissions are expected, as shown in Figure 1.

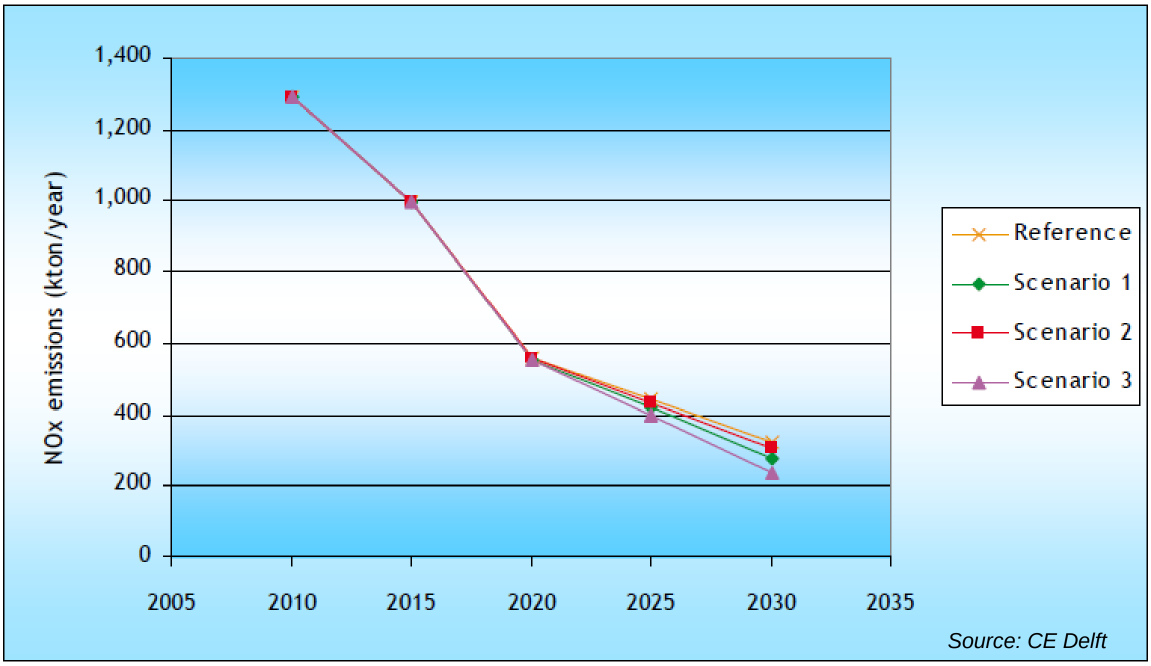


Figure 1: Projected NOx emissions of European vehicles (tailpipe emissions only).

The scenarios shown here are:
Reference: No electric vehicles (EV) until 2030.
Scenario 1: “most likely” EU development of EVs – 3 million in 2020, 50 million in 2030
Scenario 2: technology breakthrough for IC engines; 2 million EVs in 2020, 20 million in 2030.
Scenario 3: EV breakthrough: almost 6 million EVs in 2020 and 93 million in 2030.

However, the report then considers ‘well-to-wheel’ NOx emissions showing that in all scenarios, the additional NOx emissions from power production are higher than the emissions reduced by the reduced use of IC-engined vehicles. In these scenarios, the net effect of the electric vehicles is therefore an increase of overall NOx emissions in the EU, of about 150, 50 and 240 k-tonnes NOx in 2030, for the three scenarios respectively, compared to the baseline projection without EVs, as shown in Figure 2.

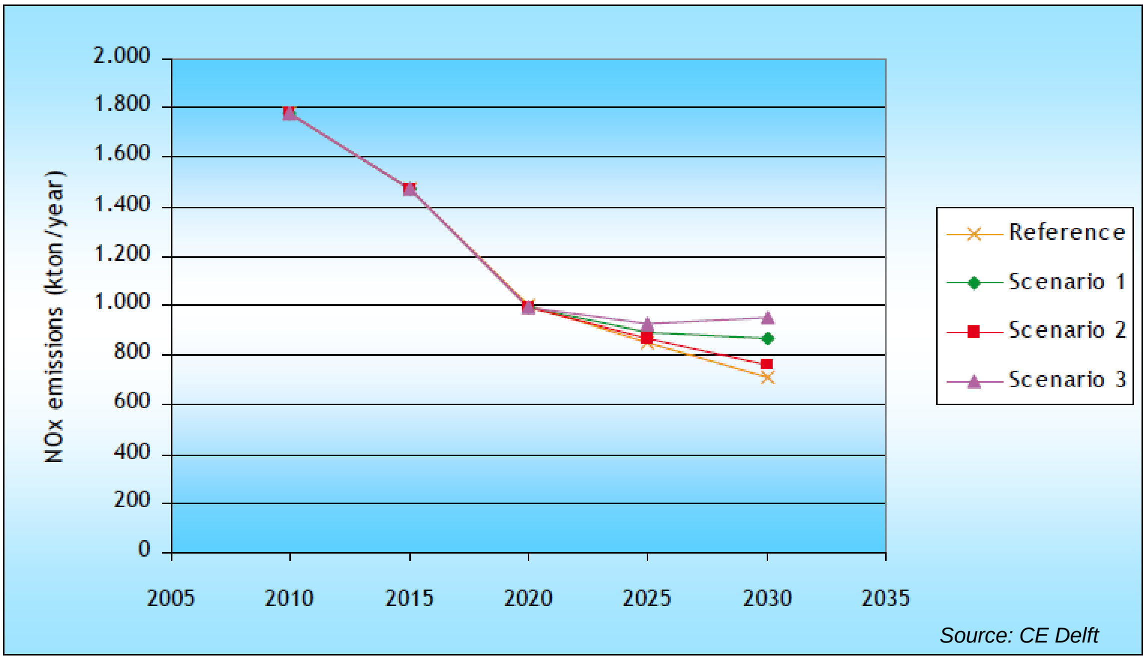


Figure 2: Projected NOx emissions of European vehicles (well-to-wheel excl. mining and gas production).

Most automotive consultancies and OEMs are working on technologies to provide both improved emissions and fuel consumption. Figure 3 from the UK's Society of Motor Manufacturers and Traders[4] shows clearly that although work is under way on fuel cell and electric vehicles, the continued development of innovative solutions for IC engines will remain a significant part of the industry's technology roadmap for several decades. The SMMT roadmap shows that medium-term work in industry and universities (7 to 15 years from production) covers topics such as higher efficiency IC engines, optimised range extender engines and heat energy recovery, whilst longer term research in Universities includes targeting new IC engines with 70+% thermal efficiency and advanced heat recovery.

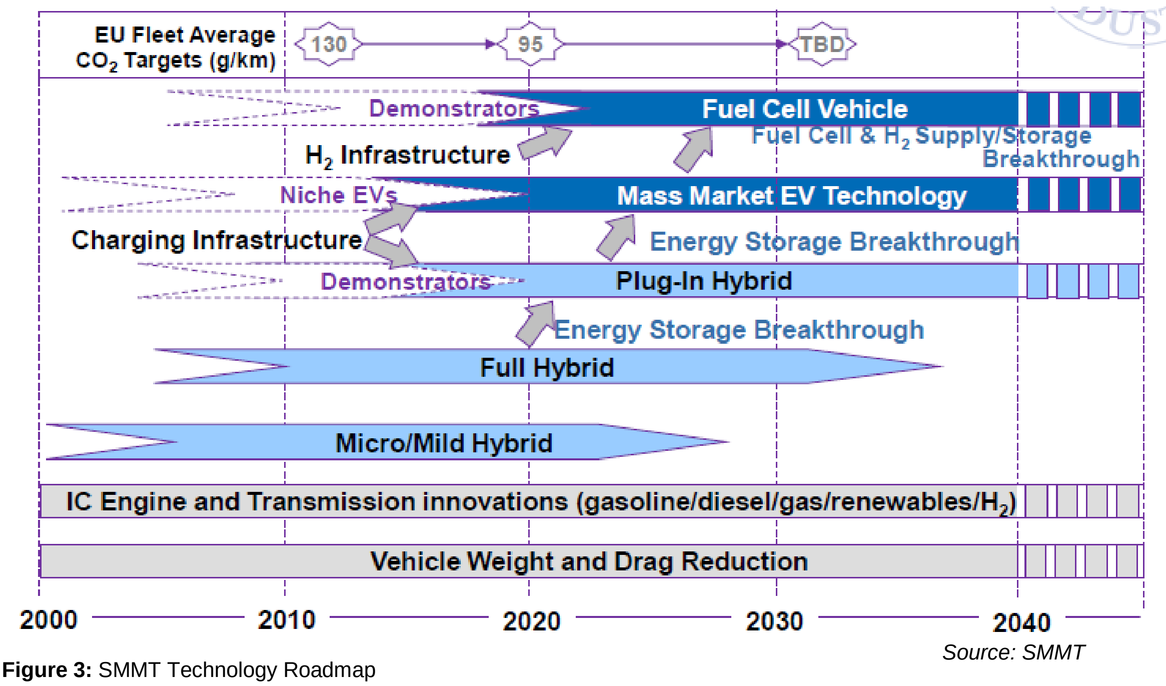


Figure 3: SMMT Technology Roadmap

Input from automotive engineering companies and research centres shows the broad range of developments that are envisaged for the continued development of IC engines. Figure 4 for instance, shows a synthesis of concepts for improvement of IC engines under development, with work on the direct enhancement of engine systems and components as well as hybridization and application of alternative fuels. Approaches for further NOx and PM reduction being developed include fuel injection aspects, charge motion, boost pressures, EGR developments and homogenous charge compression ignition (HCCI) and hybridisation. These will be complemented by further improvements in the various emissions control technologies suitable for the broad range of applications of IC engines.

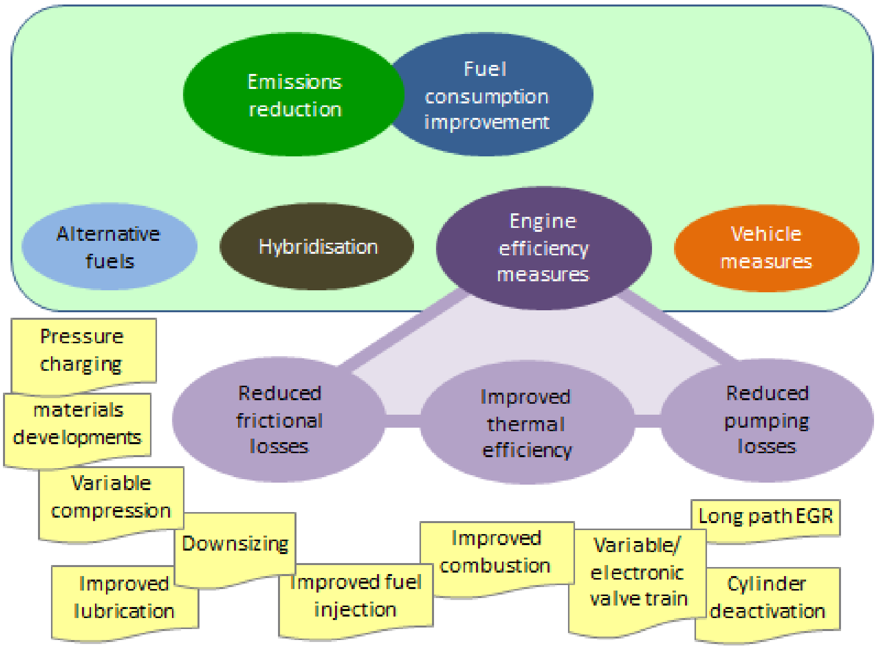


Figure 4: Concepts for IC engine improvements.

Throughout several test programmes run over the last decade, AECC has consistently demonstrated the technical feasibility of future and more stringent emissions limits, including durability aspects. The tests, using state-of-the-art engines and emissions control systems, have regularly shown the potential for further emissions improvement.

Passenger cars

In 2005, emissions from a production Euro 4 diesel passenger car fitted with a particulate filter were measured after de-greening at 4000 km and re-measured after the vehicle was subjected to an on-road durability driving of 160 000 km[5]. Not only did the vehicle meet the Euro 4 emissions limits throughout the whole durability exercise but it also met the Euro 5 standards for all emissions at the start of the programme. After 160 000 km of on-road durability running it met the Euro 5 standard in all respects except NOx emissions, where the average emissions were slightly above the standard (+13%, 204 mg/km against a standard of 180 mg/km) even without specific NOx aftertreatment emissions control.

Later, between 2008 and 2010, a selection of 'state of the art' light-duty vehicles from Euro 3 to Euro 6, equipped with SI and CI engines, was tested on the current European test cycle (NEDC) and the more transient CADC (Common Artemis Driving Cycles including urban, road and motorway driving patterns)[6,7]. The results reinforce the existing data on the effectiveness of diesel particulate filters on controlling both particulate mass and particle number emissions under a wide variety of different driving conditions. They also showed the effectiveness that can be achieved with advanced NOx control systems for Euro 6 and beyond.

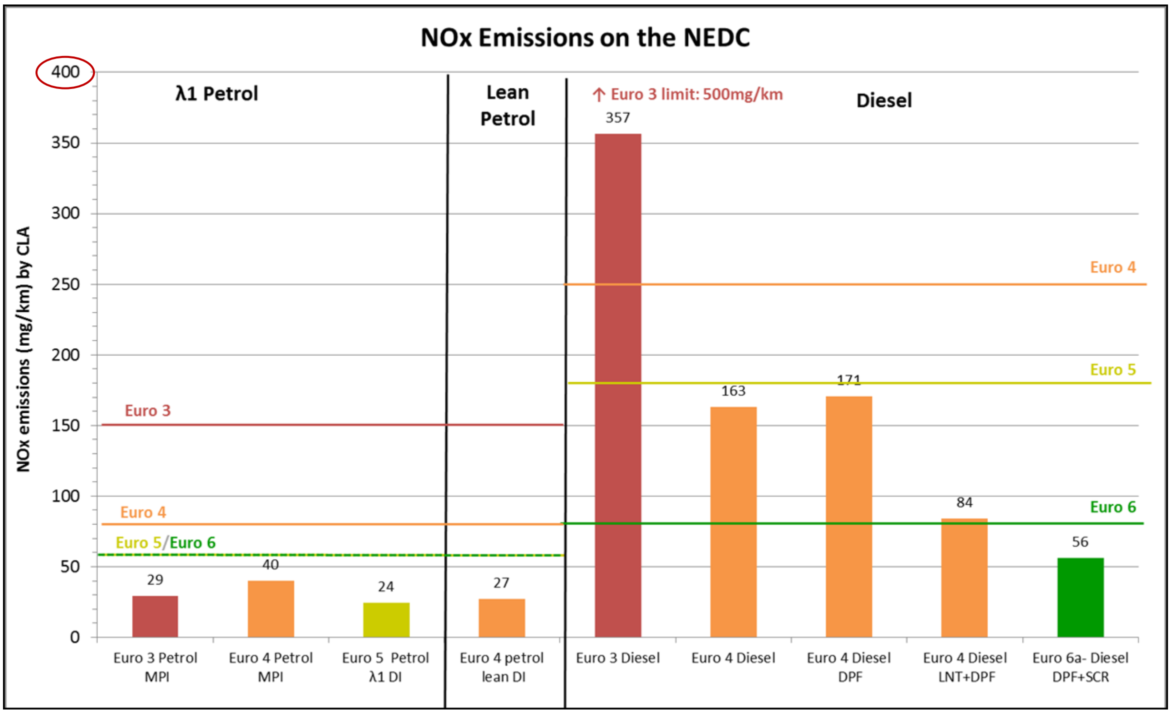


Figure 5: NOx emissions of Euro 3, 4, 5 and 6 vehicles on the NEDC

Source: AECC data presented at CARS 21 WG4 meeting, 15/04/2011

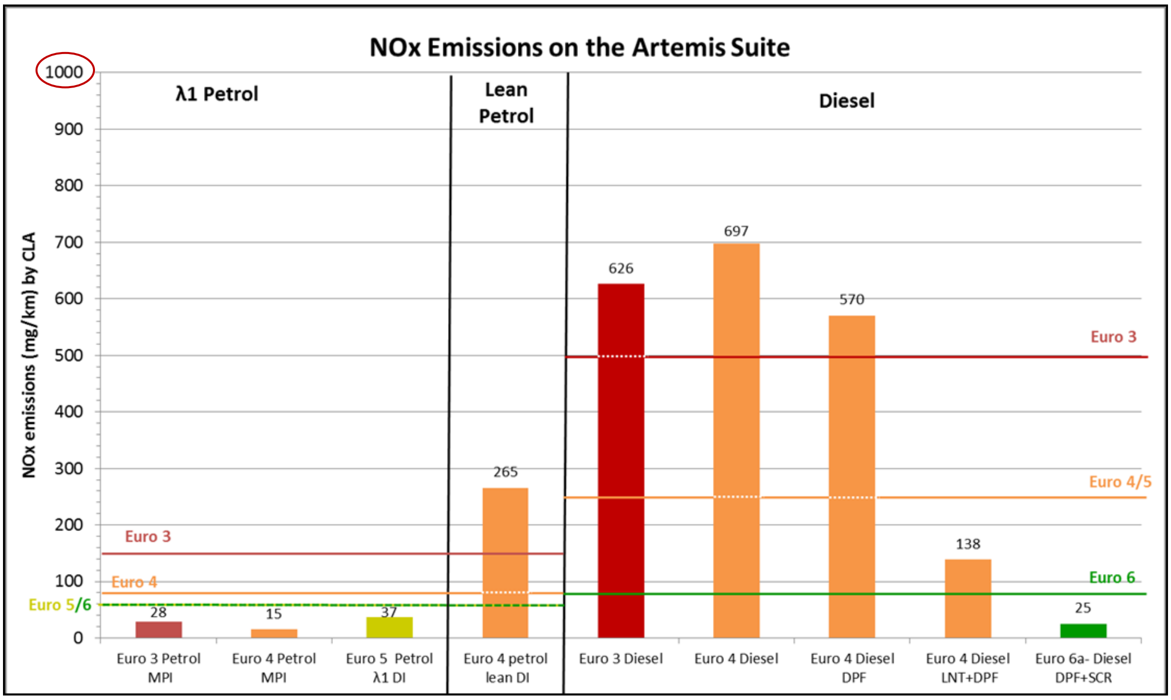


Figure 6: NOx emissions of Euro 3, 4, 5 and 6 vehicles on the Artemis suite of cycles

AECC Members have also conducted tests on currently available US production vehicles. When tested on the European legislative driving cycle (NEDC) these petrol-engined vehicles met the CO, THC, NMHC and NOx emissions limits for Euro 6 with margins of more than 50% - both vehicles tested gave NOx emissions below 20 mg/km, one-third of the Euro 6 standard. Note that there were no PMP measurements made during these vehicle tests.

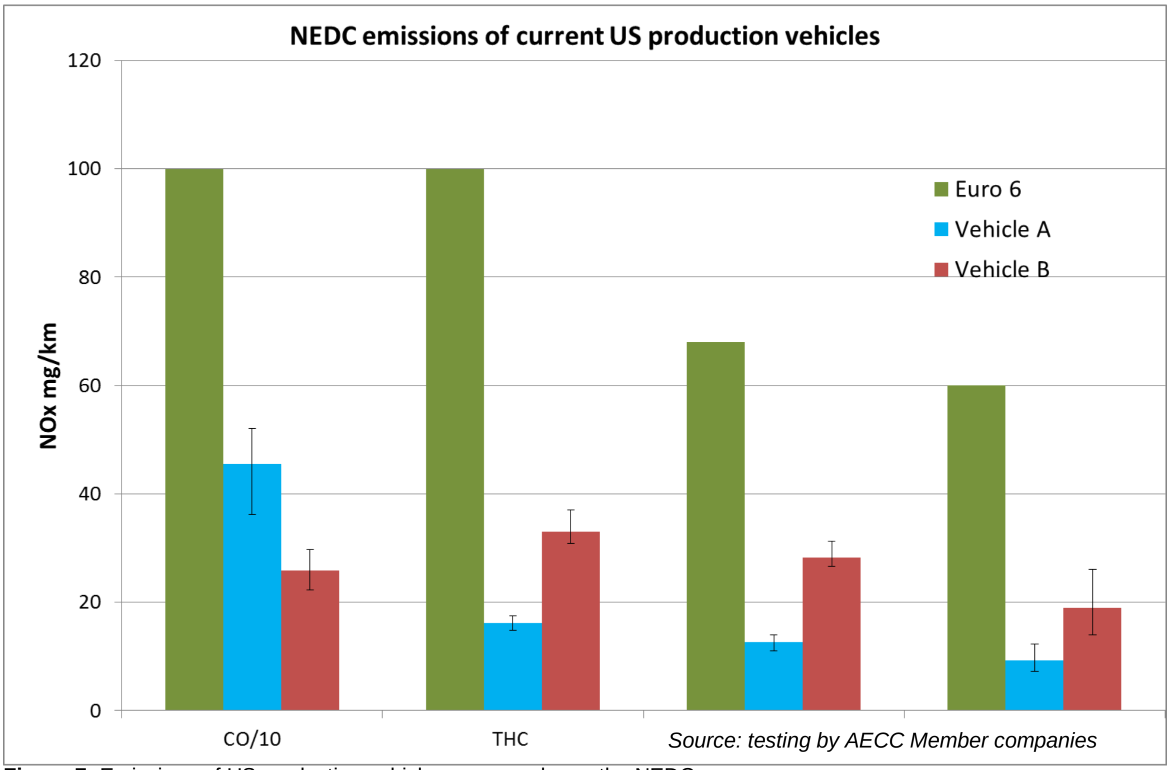


Figure 7: Emissions of US production vehicles measured over the NEDC

Heavy-duty Euro VI

In 2007, prior to the definition of Euro VI, an existing medium heavy-duty "world" engine with low engine-out NOx emissions was fitted with an emissions control system comprising a diesel oxidation catalyst (DOC) and catalysed diesel particulate filter (C-DPF), an airless urea dosing system, a Selective Catalytic Reduction (SCR) catalyst and an Ammonia Slip Catalyst (ASC)[8].

The urea dosing system was calibrated to provide good performance over the European steady-state and transient emissions test cycles (ESC and ETC) as well as the World Harmonised Transient Cycle (WHTC) without modification of the existing engine calibration.

Tailpipe WHDC composite NOx emissions with the 10% cold weighting expected at that time was 340 mg/kWh (10 minutes soak period), 74% of the Euro VI limit. Using the 14% cold-start 86% hot-start weighing that has now been agreed for the WHTC test, applied to NOx emissions gives 400 mg/kWh, 87% of the Euro VI limit. The integrated SCR system reduced all nitrogen species to low levels over the various cycles tested. NO_2 reduction efficiency of the SCR was over 80%.

PM conversion efficiencies were more than 99.5% over the WHTC, resulting in PM tailpipe levels lower than 2 mg/kWh, so less than 20% of the Euro VI limit. The PMP particle number method proved very reliable even at near-ambient particle emissions levels. Engine-out particle number data were in the range of 2.5 to 5×10^{14}/kWh. Particle numbers were essentially cycle-independent. The catalyst system reduced elemental carbon emissions by more than 99%. WHTC cycle data showed tailpipe particle number emissions of 4.8×10^{11}/kWh, 80% of the Euro VI limit.

Measurements of emissions over the ESC test were made using B30 biodiesel to investigate the effects of possible future higher levels of biodiesel use. Compared with mineral diesel, the emissions control system efficiencies on B30 biodiesel were the same for CO, slightly reduced for NOx and HC, and slightly higher for PM. Comparing B30 and diesel, there was no significant difference in particle numbers.

Previously, in 2002, the emissions control system (C-DPF + SCR + ASC) applied to an unmodified heavy-duty Euro III series production engine enabled Euro V emissions limits to be achieved with a margin of more than 50% after 1000 h ageing[9]. For an on-highway application, 1000h engine ageing on the test bed was designed to be representative of about 250 000 km of real-world driving. There was even no deterioration in emissions after ageing for 1000 h using a cycle typical of severe continuous on-road operation with 100h high sulfur fuel misfuelling. After 1000 h ageing, the tailpipe NOx level corresponded to a reduction of 85%; particulate mass emissions were reduced by about 85% on both ETC and ESC tests and particle numbers were reduced by about two orders of magnitude over a size range from 10 to >100 nm.

Non-Road Mobile Machinery (NRMM)

In 2010, a state-of-the-art engine system comprising a low emissions industrial engine designed for Stage IIIB and an Emissions Control System comprising a DOC, C-DPF, SCR and ASC, all hydrothermally aged for 200 h, produced substantial reductions in all regulated pollutants over a range of test cycles[10]. The engine system was not fully optimized; there was no thermal management to assist with warm-up from cold starts. Nevertheless, Stage IV emissions limits were met with an engineering margin of more than 50%.

NOx conversion efficiencies were 95% and 92% over the NRTC and NRSC C1 cycles respectively, resulting in tailpipe NOx levels of 169 and 216 mg/kWh compared to the NRMM Stage IV limit of 400 mg/kWh. Tailpipe NO_2 levels were 50% or less of engine-out.

PM conversion efficiencies[11] were 96% and 97% over the NRTC and NRSC C1 cycles respectively, resulting in tailpipe PM levels of 1 to 2 mg/kWh (partial flow method). ECS efficiency for PMP Particle Numbers was >99.8% for all transient and steady state cycles with engine-out PN from all cycles ranging from ~6 x 10^{13} to ~3 x 10^{14}/kWh and particle numbers at tailpipe for all cycles in the range of ~10^{10} to <1.8 x 10^{12}/kWh.

Motorcycles

In 2008, the emissions performance evaluation of five state-of-the-art motorcycles showed that all Euro 3 certified models could meet both the ECE-cycle and WMTC limits for Euro 3 when tested in relatively new condition[12]. Comparison to a previous test programme[13] showed that significant improvements have been made to emissions between equivalent models of Euro 2 to Euro 3 bikes. The motorcycle emissions results were close to Euro 5 passenger car limits at the mileages tested and indicated the potential to move towards the future emissions limits proposed for Euro 4, 5, 6. Indeed the Kraftfahrt-Bundesamt (KBA) data[14] shows that a number of motorcycles are already capable of meeting the proposed future emissions levels.

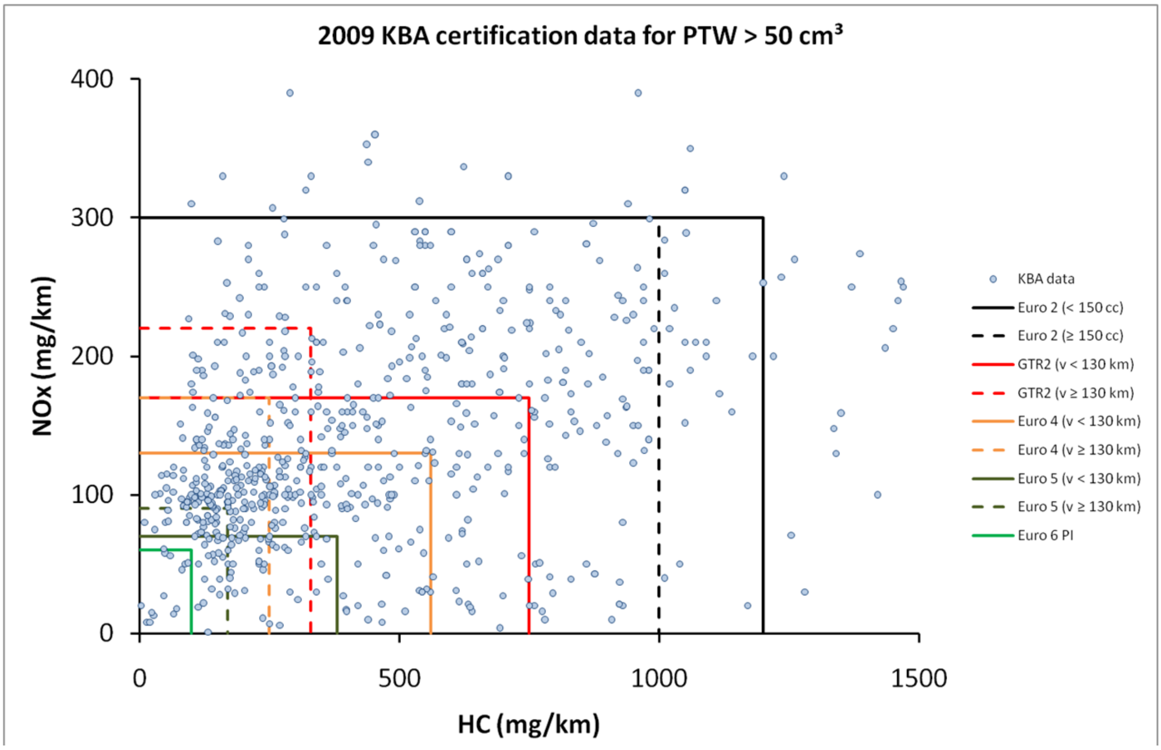


Figure 8: Type approval data for motorcycles

Source: KBA

Particle mass levels below the Euro 5 diesel limit of 4.5 mg/km were measured on all bikes and lambda 1 bikes demonstrated similar particle number emissions to DPF equipped diesel passenger cars over the New European Driving Cycle (NEDC).

Mopeds

In 2010, exhaust emissions of five European mopeds were evaluated on the regulatory ECE R47 cycle and on the WMTC test cycle[15,16]. One standard production moped, homologated to Euro 2, did not meet Euro 2 emissions limits; this reinforces the need for market surveillance for all types of applications. Overall, the test results inductee that current vehicles appear to be calibrated for fuel economy and performance, to the detriment of emissions. However, they also show that technologies are available to permit 2-stroke engines to meet anticipated Euro 3 (and even Euro 4) limits. Proper control of air-fuel ratio is nevertheless a pre-requisite for effective application of catalysts to 4-stroke mopeds.

This programme also measured particulate mass and particle number emissions. Of the 5 mopeds tested, only the 4-stroke EFI machine would have met the proposed PM limit for Euro 5 (4.5 mg/km). For mopeds, solid (PMP) particle number emissions were found to be at a similar level to diesel cars without DPFs.

1.1.2. Development of the World-harmonised Light-duty Test Procedure

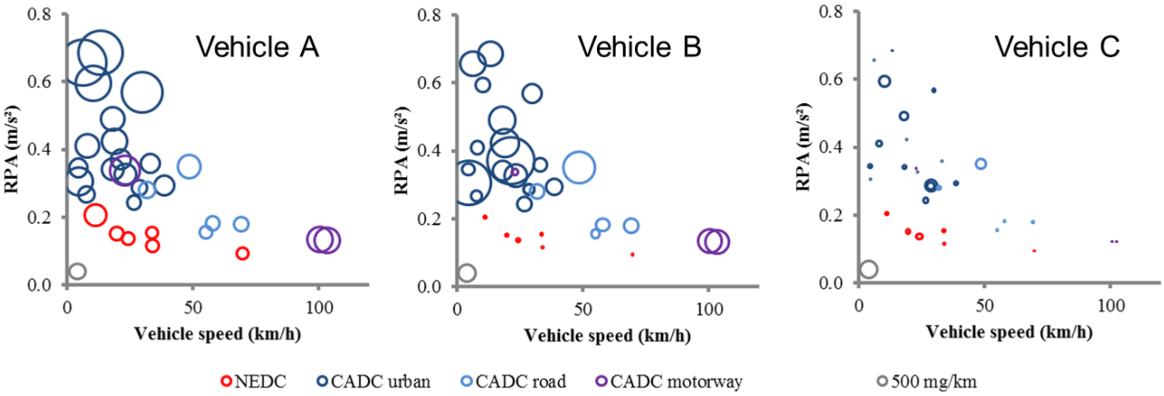
World-harmonised cycles and Regulations must maintain the EU's lead in clean vehicle technology (especially for diesels) and must provide a platform for challenging and class-leading EU legislation to be adopted worldwide for the benefit of the EU automotive industry as a whole.

The current development of the internationally harmonised procedure for light-duty vehicles (WLTP) needs to not only provide improvements in the determination of fuel economy but also to improve air quality through control of regulated emissions, especially NO_2. To do this, it has to be recognised that the ultimate procedure as a whole involves not only the important aspect of the development of a test cycle representative of a broad range of real world driving conditions – it has to ultimately produce a whole procedure encompassing different elements, including both on- and off-cycle emissions. The highly stylised nature of the current (NEDC) test cycle particularly lacks the elements of transient operating conditions in both urban and high-speed driving that are necessary to ensure good control of emissions.

The development work must clearly ensure that this new cycle provides the EU's initial target of a more real-life cycle (particularly for CO_2/fuel consumption measurements). But it must also support the EU industry's leading position in light-duty diesel vehicles whilst still ensuring effective emissions control of all light-duty vehicle powertrains. It is essential that this global cycle does not 'smooth out' the key parameters that ensure effective control of emissions and so dilute the levels achieved by the Euro 6 standards. Starting from ambient soak conditions should exhibit realistic warm-up procedures to demonstrate effective operation in real service. The cycle should provide a better representation of transient conditions than the current cycle so as to ensure proper control of such real-life driving patterns and should provide sufficiently high speeds to properly represent European driving conditions, again so as to ensure proper emissions control under normal European driving conditions. The Commission has already recognised that conventional test cycles do not always offer sufficient control of emissions in real driving. AECC is participating in the Commission's working group (RDE-LDV) on this aspect and notes that this work on Off-Cycle Emissions could form a basis for one of the future parts of the WLTP development.

Nevertheless, the differences apparent in test data from the current (NEDC) emissions test and transient cycles such as the Artemis (CADC) suite (such as that from AECC light-duty test programmes described in section 1.1.1) highlight the need to ensure that the test cycle itself covers the critical parameters for good control of regulated emissions. Control of these aspects should ensure that EU emissions regulations remain a benchmark for use in other parts of the world, thus giving EU manufacturers a broad base in export markets.

In the context of the development of the new World-harmonised Light-duty Test Cycle (WLTC), AECC and the University of Ghent[17] have used two approaches with the data from the AECC light-duty test programmes to visualize the operating zones with the highest emissions. First, the different trips (in between two idling periods) of the test cycles were analyzed for their contribution to the emissions by calculating trip values in mg/km. These values were then plotted on bubble charts of RPA (Relative Positive Acceleration) vs. vehicle speed. The results, reproduced in Figure 9, showed that the trips with the highest NOx emissions differed from vehicle to vehicle.



Source: AECC/Gent University data presented at CARS 21 WG4 meeting, 15/04/2011

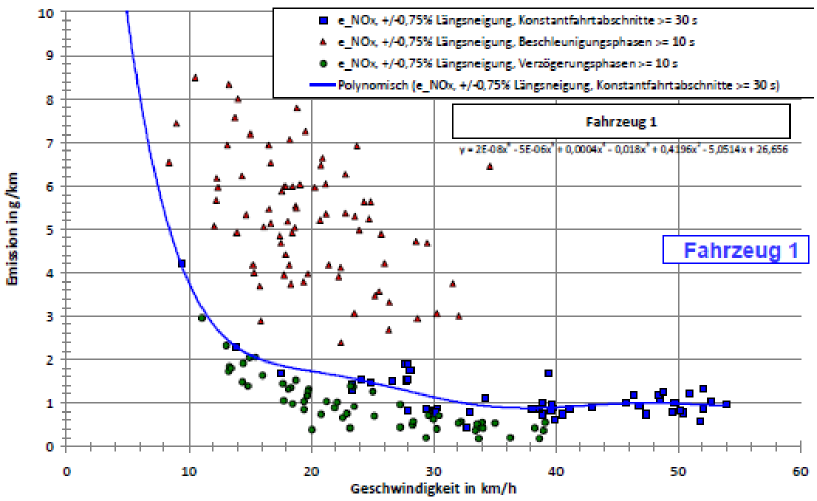
Figure 9: Bubble charts of NOx emissions for 3 different diesel vehicles

This first approach was also used to demonstrate the effect of a cold start on emissions. It showed that significant tailpipe CO emissions only occur during cold start phases. The second approach, with contour plots of NOx emissions for acceleration vs. vehicle speed confirmed that the zones with high emissions differ from vehicle to vehicle. The key points to ensure that WLTP is representative of real-world emissions are therefore the inclusion of appropriate transient conditions and maximum speeds together with a cold-start with the immediately-following conditions being representative of warm-up under normal operating conditions.

1.1.3. Real Driving Emissions

The emissions figures obtained for Type Approval must reflect the real-life performance of vehicles. The development of the new WLTC offers a step towards a more realistic cycle for Type Approval, but at the same time it is necessary to ensure that the Euro 6 levels of emissions control performance are maintained by the new cycle.

The short-trip analysis of the NEDC and CADC data gives a good indication of the range of operating modes that need to be covered by the WLTC, but those data are reinforced by the ability to now measure real-life emissions performance using PEMS data in light-duty vehicles, as well as the existing applications of PEMS to heavy-duty and NRMM engines. Work by TÜV Nord with LUBW (Landesanstalt für Umwelt, Messungen and naturschutz Baden-Württemberg – the Baden-Württemberg State environmental research centre)[18] shows the dependence of NOx emissions on vehicle operating conditions in real world driving. The chart reproduced as Figure 10 indicates the velocity dependence of NOx emissions for one test vehicle, differentiated by acceleration, deceleration and constant-speed operating modes.



Source: LUBW/TÜV Nord, 2011

Figure 10: Real driving NOx emissions differentiated by driving conditions (accel., decel., steady state)

DG-JRC's report on light-duty PEMS measurements[19] shows that the real-world short trips on four different PEMS routes are not well represented by the relative positive acceleration vs. average speed points that characterise the current NEDC test procedure. In particular the JRC's test routes, typifying a range of real operating conditions, included a larger share of high-speed driving than the NEDC. Vehicle testing on the four test routes also covered a substantially larger range of the RPA-speed spectrum than does the conventional NEDC testing, much more similar to the CADC characteristics shown in Figure 9 than to the NEDC cycle.

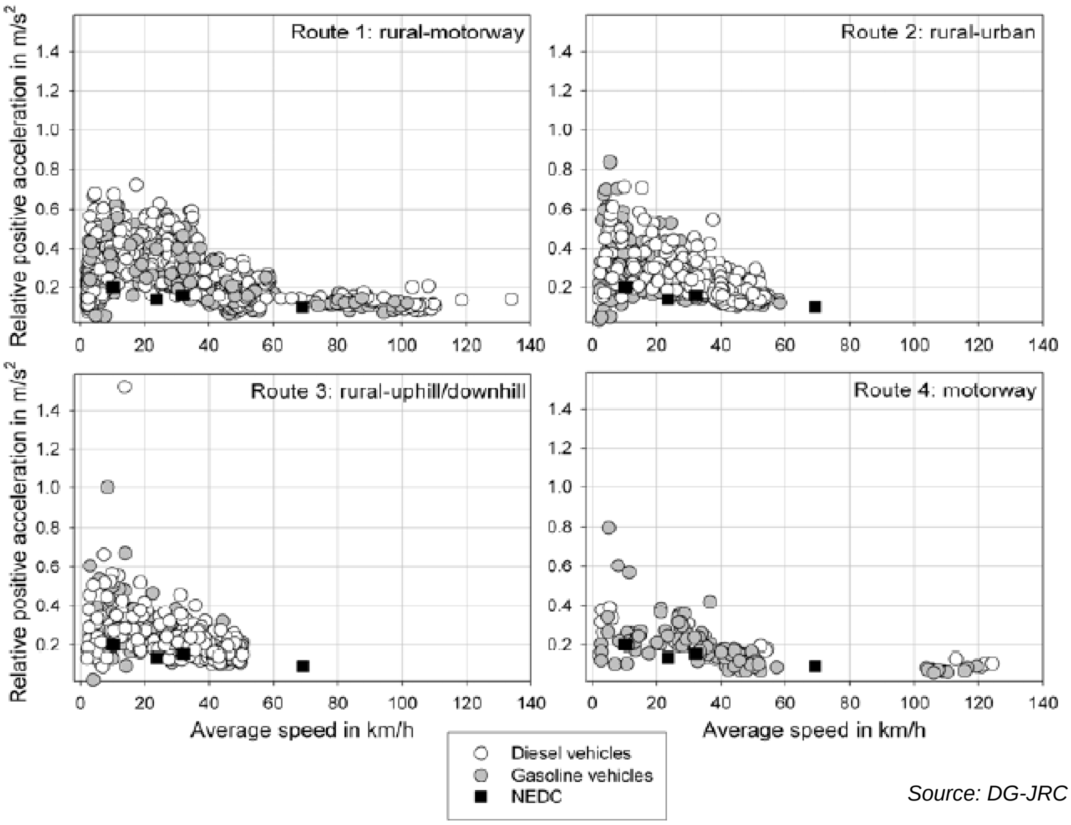
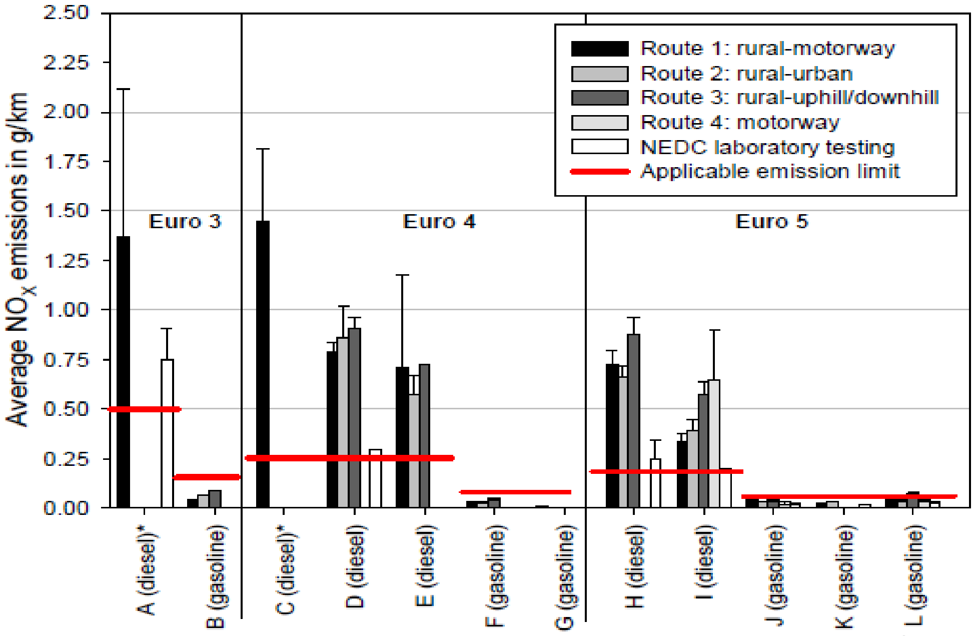


Figure 11: PEMS sub-trips vs. NEDC

The JRC report states that although on-road NOx emissions of petrol-engined vehicles generally stayed within the respective Euro 3 to 5 emissions limits, the average NOx emissions of diesel vehicles in real usage substantially exceed their respective emission limits. The observed deviations range from a factor of 4 to 7 for average NOx emissions over entire test routes up to a factor of 14 for NOx emissions of individual averaging windows. In line with the analysis of test cycle data in section 1.1.2, the magnitude of on-road emissions was found to vary depending on the vehicle type, operation mode, route characteristics, and ambient conditions. (see Figure 12). Cold-start emissions of both diesel and gasoline vehicles were found to span a wide range; NOx emissions exceeded Euro 3 to 5 emission limits by a factor 2-14.

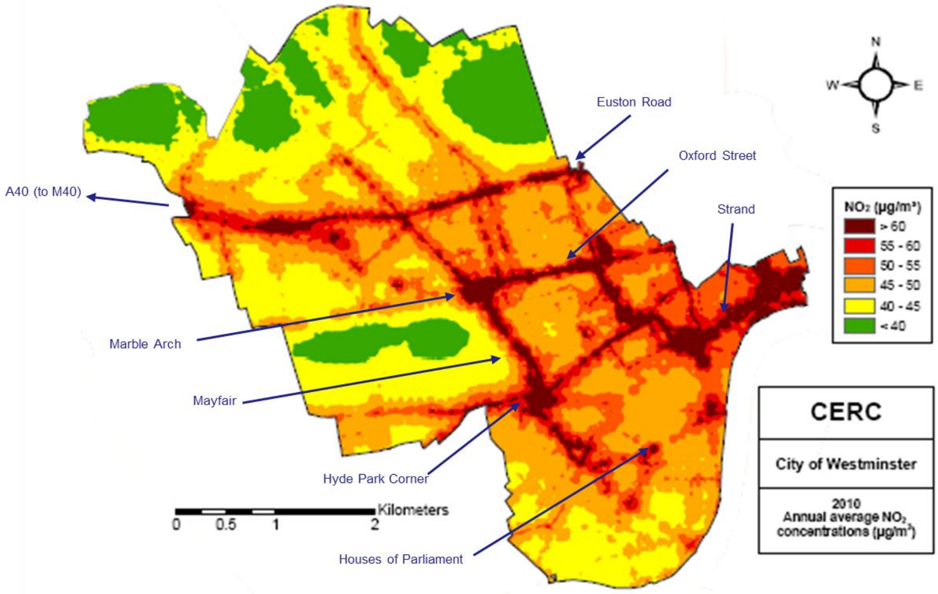
Whilst the development of the WLTC must attempt to cover as broad a range of operating conditions as possible, it is also clear that a fixed cycle cannot encompass all possible situations within a reasonable test time. There will also be need in the eventual WLTP procedures to ensure that the complete set of requirements address the issues of both on-cycle and off-cycle emissions. AECC supports the work of the Commission's RDE-LDV group on the latter issue. With such requirements in place the WLTP as a whole should also provide the basis for further reductions in emissions if supported by cost-benefit analysis. This would not only address the health and environmental benefits potential of low emissions vehicles but would assist in keeping European vehicles at the forefront of technology with consequent benefits in providing a lead for other worldwide markets.



Source: DG-JRC

Figure 12: NOx emissions on PEMS routes and the NEDC

One of the issues currently under discussion in the EU is the need for additional control of engine/vehicle NO_2 emissions as a result of concerns over exceedances of the NO_2 limits for local ambient air quality, particularly in 'hot spots'. In part these stem from the historical setting of vehicle emissions limits as NOx (on the basis that all NO emissions are oxidised to NO_2 over a period of time) and partly to the emissions legislation setting targets for control of other pollutants without significantly strengthening NOx requirements. However, concerns over the influence of real driving direct NO_2 emissions - particularly their very local effect in urban hotspots, such as is indicated in Figure 13 for the City of Westminster[20] (London) UK –have resulted in a re-appraisal of direct NO_2 emissions. DG-JRC's PEMS work, for instance, has shown that the share of NO_2 in the total NOx emissions reaches 60% for diesel vehicles but is substantially lower for gasoline vehicles (0-30%).



Source: Westminster City Council

Figure 13: Map of NO_2 concentrations, City of Westminster

Ultimately, the best method to ensure good control of NO_2 is to ensure good control of NOx, such as is anticipated for Euro 6 and VI. Figure 14 shows the NO and NO_2 emissions over the Artemis cycles for the diesel vehicles tested in the AECC light duty programme (for which total NOx results were shown in Figure 6). This demonstrates the potential for good control of both NOx and NO_2 through the careful application of NOx emissions control systems at Euro 6. However, if it is felt necessary to have an additional limit for NO_2, then this should be done as an absolute (mg/km or mg/kWh) limit to ensure that the best technologies are used. Euro 6/VI will reduce ambient NOx and NO_2 levels and the introduction of the WLTP for regulated emissions will further reduce the real world passenger car contribution, particularly from diesels. It is important that these measures are taken as soon as is practicable and that there is no dilution of the Euro 6 regulated emission requirements when the new (WLTP) cycle is introduced.

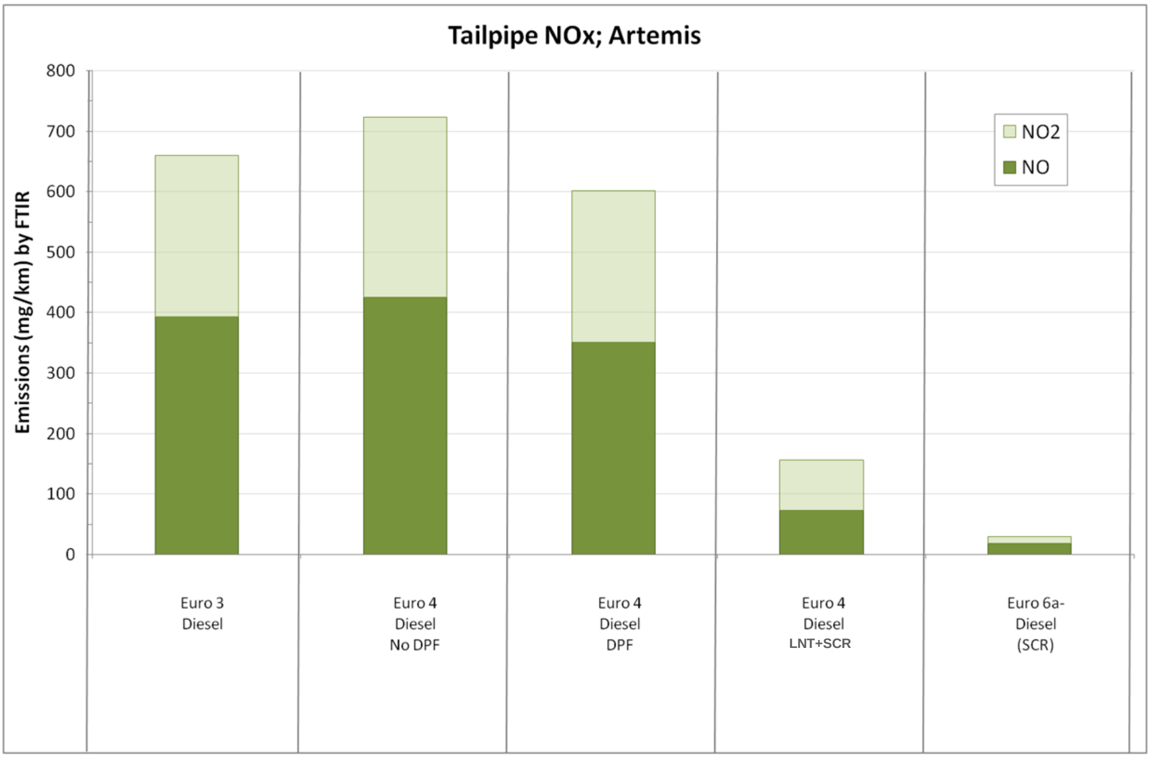


Figure 14: NO and NO_2 emissions from diesel vehicles *Source: AECC test programmes at TÜV Nord, 2008-2010*

One issue that will need to be addressed in considering real driving emissions is the situation of hybrids where the combustion engine operates for only parts of the cycle. In such cases emissions are measured over the whole cycle, but the result is that the emissions of the engine during the time that it is actually operating can be significantly higher than for a comparable engine operating in a conventional vehicle. The net result of this may thus be that emissions of a hybrid in pollution hot spots may be higher than a conventional vehicle – indeed could be comparable to a vehicle without emissions control. It may therefore be appropriate to consider whether hybrids should have to meet some emissions limits during its periods of operation.

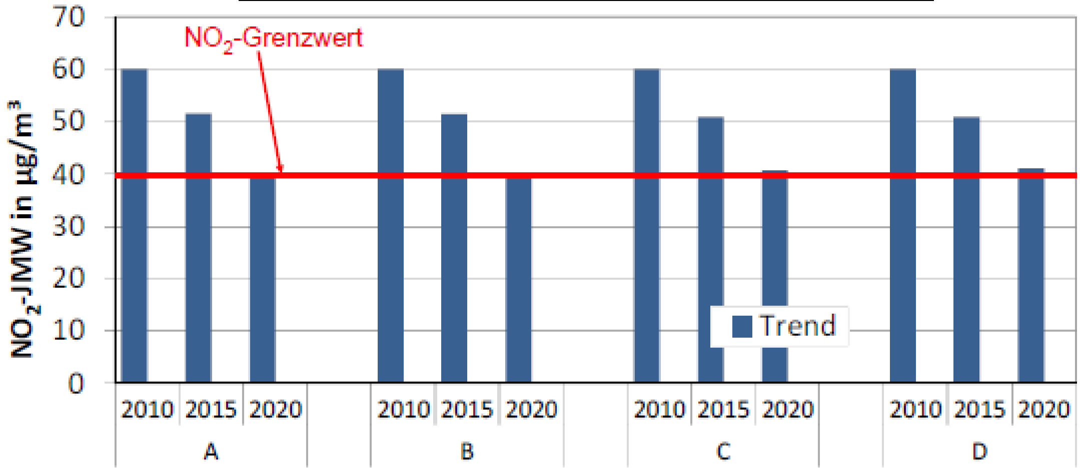
1.1.4. Ambient Air Quality

The object of the regulations on vehicle and machinery emissions is, of course, to ensure that those sources of emissions play an appropriate, proportional and cost-effective effective part in meeting the air quality ambition levels set in the Thematic Strategy on Air Pollution[21]. The strategy aims to attain "levels of air quality that do not give rise to significant negative impacts on, and risks to human health and environment".

The measurement not only of real-life emissions but especially of actual air quality is therefore an important factor in assessing both the impacts of those emissions stages that have been set and the level of any emissions control that will be needed in the future. Figure 15 shows the anticipated trends in NO_2 immissions, including the impact of Euro 6 and Euro VI legislation, for various scenarios of urban background and proportions of primary NO_2 emitted locally[22]. However, the validity of such assessments will depend upon the uptake of low emissions vehicles as well as influence of local traffic patterns and volumes, and the rate of reduction can be assisted by incentives for the uptake and use of clean vehicles in critical areas such as NOx hotspots.

A thorough and critical assessment of the changes in air quality and the performance of vehicles to date will be needed to help gauge the level of future performance needs. The anticipated 2013 review of the Air Quality and National Emissions Ceilings Directives will therefore form an important input to any future stages of emissions legislation.

		Urban background	
	proportion of local primary NO_2	Low (20 µg/m³)	High (30 µg/m³)
Local situation	High: 60%	A	C
	Average: 50%	B	D



Source: IFEU

Figure 15: Anticipated trends in NO_2 immissions, including introduction of Euro 6/VI

1.1.5. Real-world Durability and Market Surveillance

If vehicles and machinery are to meet the levels of emissions reduction that are expected of them, then not only must they meet the required emissions levels at Type Approval. Production models must meet the required limits and durability of the systems must meet the requirements of the legislation. Whilst the vast majority of European machines and vehicles do indeed meet those requirements, there is also evidence that good market surveillance is essential to ensure that all products entering the EU market actually deliver the stated emissions performance.

The AECC motorcycles and mopeds test programmes described previously, highlighted the need for future emissions legislation on L-category vehicles to incorporate good controls on the maintenance of emissions in use (including use of OBD systems and durability requirements) and for good market surveillance.

Firstly, one standard production moped, homologated to Euro 2, did not meet Euro 2 emissions limits for CO by a substantial margin, giving emissions some 6 times the limit value; this further reinforces the need for market surveillance for all types of applications. One of the motorcycles (tested at 8000 km after being received from a dealership) also initially failed the emissions tests. On examination it was found that in this case the oxygen sensor leads for the two banks of the engine were crossed, leading to the air-fuel-ratio not being controlled, with the vehicle not running closed-loop at any point in the cycle. This type of fault should have been detected by OBD.

The second area of concern was that when initially tested on the ECE Reg. 40 cycle, an Asian scooter (homologated to Euro 3) failed to meet the emissions limits and was found to be running with closed-loop fuelling only during the extra-urban (EUDC) part of the test cycle. On the urban portions it ran considerably richer. A second example of the same type of scooter performed similarly. Following discussions with the importer and on instruction from the manufacturer, the test laboratory conducted a specific pre-conditioning of 5 km at 120 km/h followed by switching off before the soak period for each test. The bike would only meet the Euro 3 limit requirements when using reference fuel and after this specific preconditioning. Even after the preconditioning, tests on pump fuel (10 ppm S) failed CO limits.

This scooter used for this part of the test programme was also subjected to durability tests. The durability exercise demonstrated that a certified Euro 3 motorcycle could have emissions exceeding the limits after only 2000 km; NOx emissions increased continually through the test programme and reached double the Euro 3 limit by 20000 km. This indicates the need for improved durability requirements in future legislation for L-category vehicles, but also highlights the more general issue of the need for strong market surveillance to ensure that products meet their stated level of performance.

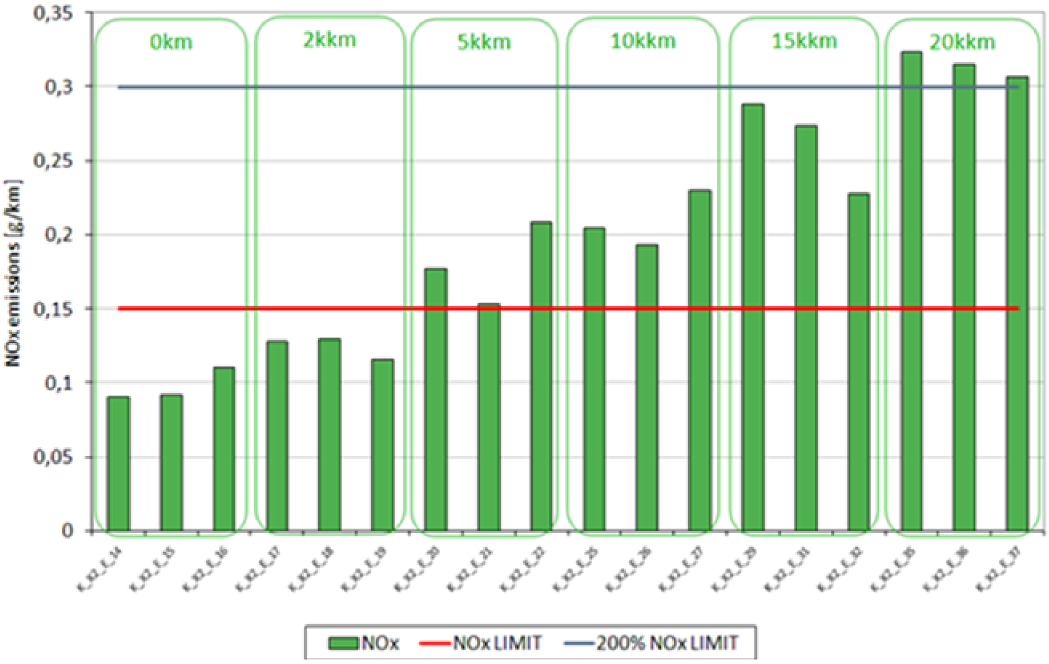


Figure 16: NOx emissions - motorcycle durability test *Source: AECC, SAE 2009-01-1841*

1.1.6. Replacements and Retrofits

Replacement Pollution Control Devices

The emissions control catalysts and filters used by OEMs have good durability performance both at Type Approval and in real use. Nevertheless, replacement units are sometimes needed, for example due to accident damage. In this respect there are still some significant gaps in EU legislation. There are, for instance, currently no requirements for replacement catalysts in current heavy-duty (Euro V) and NRMM legislation. Even for light-duty vehicles, the current legislation[23,24] only addresses durability to a limited extent, in that it permits the use of assigned deterioration factors with no requirement for demonstration of actual durability performance. In the case of motorcycles and mopeds[25] there are no durability requirements. The analysis of the failed catalyst from the Asian scooter in AECC motorcycle durability test programme indicates the pitfalls that can be introduced if there are not good durability and market surveillance. This unit showed mechanical and thermal deterioration, loss of washcoat and agglomeration of materials.

The Euro VI heavy-duty emissions legislation is showing the way forward to ensure good quality, durable replacement units, by incorporating a positive demonstration of durable emissions performance. This approach should be extended to other applications (light-duty, motorcycles, NRMM) once completed. But even that approach needs good market surveillance to be an effective tool to maintain the emissions performance of in-use vehicles.

Retrofit Emissions Controls (REC)

Retrofitting of emissions control devices and systems offers a way to upgrade the performance of existing vehicles. It is not a substitute for new vehicles meeting the latest emissions limits, but can offer a way of upgrading the emissions performance of older vehicles in regard to one or sometimes two pollutants. It must be understood that in most cases this does not constitute a full upgrading from one Euro Stage to the next.

Nevertheless, retrofitting can assist in reducing emissions of particulate matter and/or NOx, primarily for heavy-duty and NRMM engines. In Belgium, bus company De Lijn has retrofitted a substantial number of older buses with either particulate filters or, more recently, combined PM and NOx reduction systems. The Flemish Institute for Technological Research, VITO, conducted a real-life evaluation of a DPF-equipped bus[26] and showed a reduction of PM emissions of over 90% in on-the-road conditions. PEMS data from TÜV Nord[27] has demonstrated that the application and operating conditions need to be carefully evaluated (see Figure 17), but the well-considered application of appropriate retrofit systems can show significant emissions benefits. This in turn can contribute to the reduction of air quality exceedances, especially in combination with Low Emission Zones and with financial or other encouragement for their fitting.

AECC is therefore actively supporting the development of retrofit requirements for heavy-duty and NRMM engines as a UNECE (REC)[28] activity.

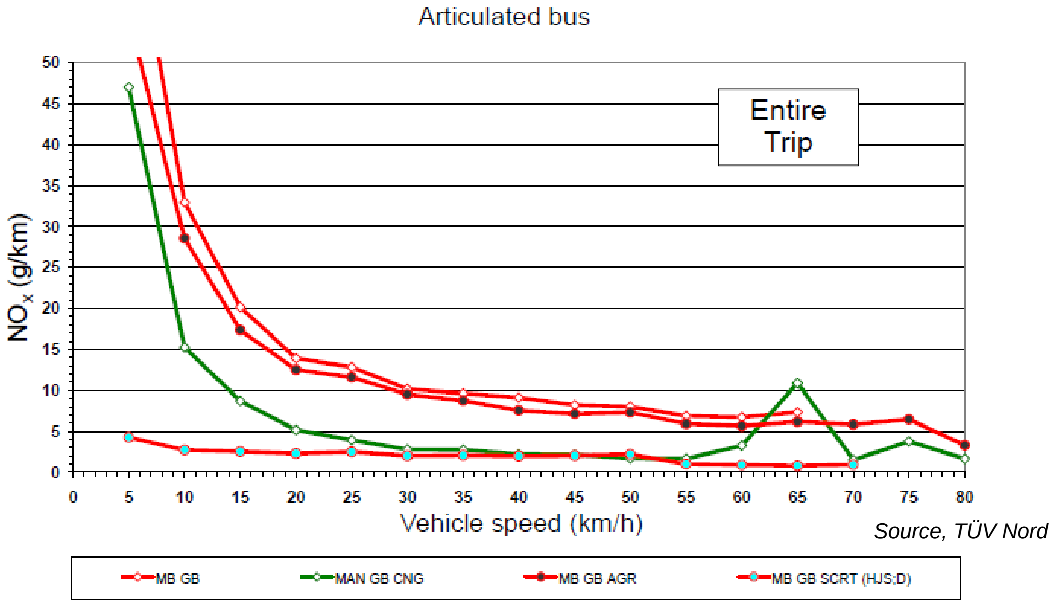


Figure 17: PEMS NO_2 data: standard bus diesel, CNG, retrofit EGR, and retrofit PM and NOx control (SCRT)

1.2. CO_2 Policy – Supply Side

AECC is following with interest the Commission's work on CO_2 requirements for cars and light commercial vehicles and the current examination of options for heavy-duty vehicles, together with the introduction of CO_2 measurement requirements into L-category and heavy-duty engine emissions legislation.

In addition to reducing vehicle mass, rolling resistance and aerodynamic drag, part of an effective CO_2 reduction strategy involves improving engine efficiency. OEMs, suppliers, automotive consultancies and research institutions are all working on the continued improvement of the CO_2 emissions of internal combustion engines, as was indicated in Figure 3. One supplier's view of potential areas for engine improvements[29], including reducing component mass, reducing frictional losses or creating a gain in engine conversion efficiency is shown in Figures 18 and 19, whilst Figure 20 provides an overview from an automotive consultancy[30] of the potential for CO_2 reduction of a 1250 kg inertia weight class vehicle whilst maintaining constant (65 kW) engine performance.

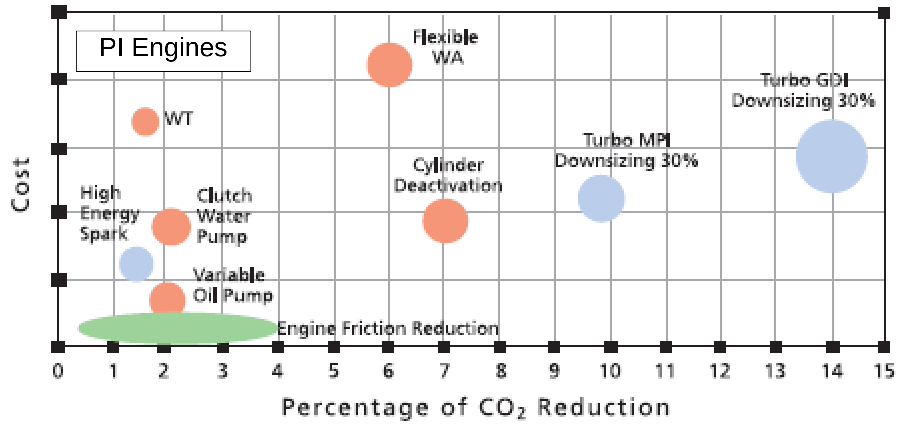
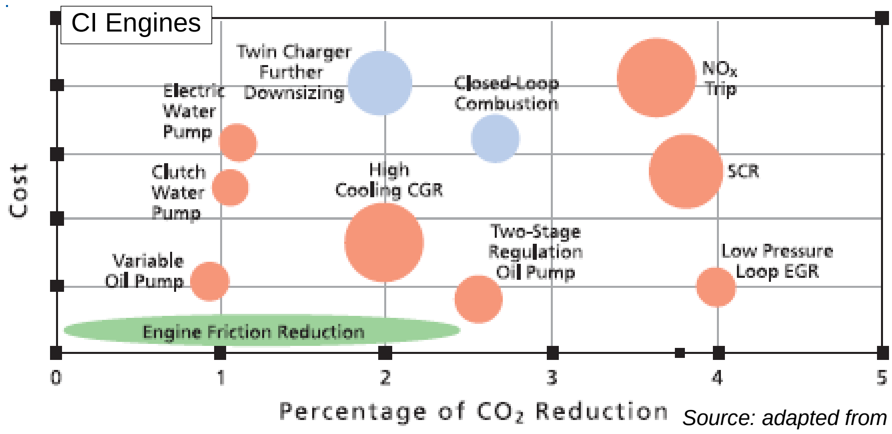
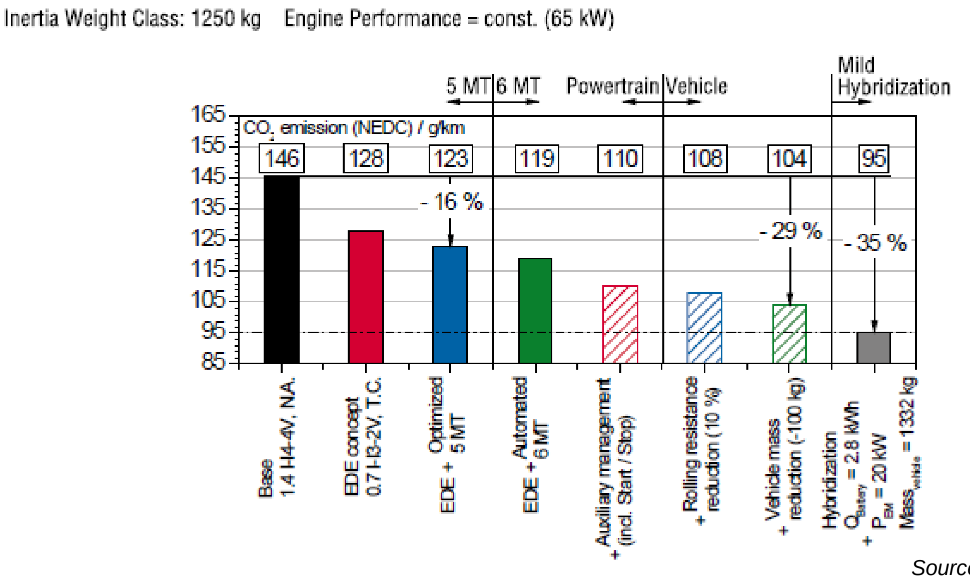


Figure 18: Potential fuel-efficiency improvements for PI engines *Source: adapted from Federal-Mogul*



Source: adapted from Federal-Mogul

Figure 19: Potential fuel-efficiency improvements for CI engines



Source: FEV

Figure 20: CO_2 emissions reduction potential through engine development

These developments demonstrate the potential for continued improvements in both petrol and diesel engine efficiency whilst maintaining or improving emissions performance. Although the specific examples given refer to light-duty vehicles, progress in IC engine technology will similarly benefit heavy-duty vehicles, NRMM and motorcycles. They are a key part of ensuring that the European automotive industry as a whole remains competitive in clean, fuel-efficient internal combustion engine technology to serve the needs of the global market.

Although CO_2 is the prime greenhouse gas of concern for vehicle emissions, the Commission has recognised that other emissions are also relevant. One proposal currently under discussion is to remove methane form consideration as a pollutant, due to its low ozone potential, but to consider it with CO_2 as a global warmer, with an appropriate factor for its higher global warming potential.

One aspect that AECC has examined is the effect of Black Carbon (BC) as a short-term global warmer. Although IPCC has not yet been able to provide a definitive Global Warming Potential for BC, a number of respected authorities on the subject have recommended figures, and current advice[31] is that the 100-year Global Warming Potential should be considered as between 350 and 1500 times that of CO_2, depending on the study and region of emission. The UNECE Executive Body for the Convention on Long-range Transboundary Air Pollution set up an Expert Group on Black Carbon. Their report[32] resulted in the decision by the UN Working Group on Strategies and Review in April 2011 to target the reduction of Black Carbon through a revision of the Gothenburg Protocol. The Expert Group notes that BC emissions in the UNECE region are expected to decline between 2000 and 2020 by about one third as a result of current emission control legislation, primarily in the transport sector. The group sees some of the key target areas for the future as stationary diesel engines and non-road mobile machinery (including the marine sector), high-emitting on-road vehicles, and the accelerated introduction of particle traps (DPF) for light duty and heavy duty vehicles, as well as retrofitting of existing vehicles.

Their report comments that “Emissions could be further reduced through accelerated introduction of particle traps (DPF) for new machinery and retrofitting of existing machinery with DPFs. This could be implemented by mandating that all non-road diesel engines comply with emission standards similar to heavy duty vehicles, i.e., the upcoming Euro VI standard. Eliminating high emitting vehicles and enforcing Euro-VI standards (where applicable) accounts for nearly 20 per cent of the total reduction potential in the region.”

AECC has, in its test programmes, examined the impact that DPFs can have on BC emissions and hence the effect on a vehicle or engine’s effect on overall climate change emissions[33]. Figure 21 shows the relative CO_2-equivalent global warming figures for a range of light-duty vehicles, both petrol and diesel.

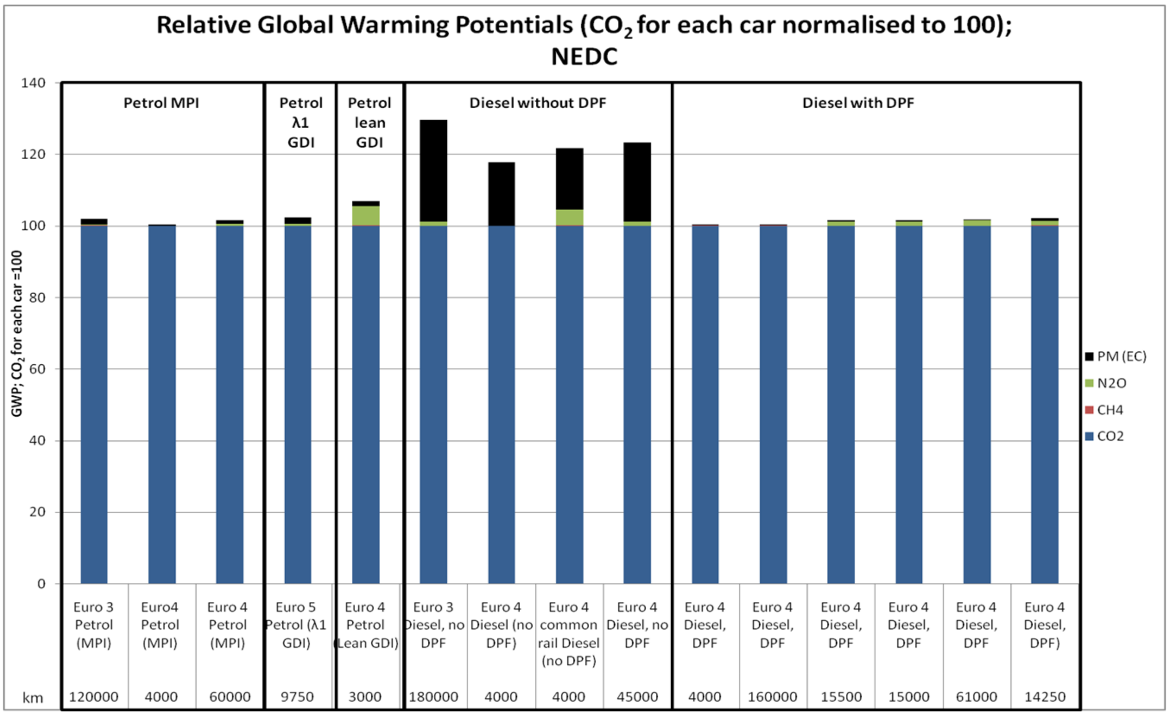


Figure 21: Climate Change-relevant emissions from light-duty vehicles

Source: AECC test programmes at TÜV Nord

The high GWP of 1500 for BC is used in this chart and, to allow comparison of different vehicles, the data is based on normalising the CO_2 figure for each car to 100. The difference between diesels without diesel particulate filters (DPF) and those with DPFs is clearly visible.

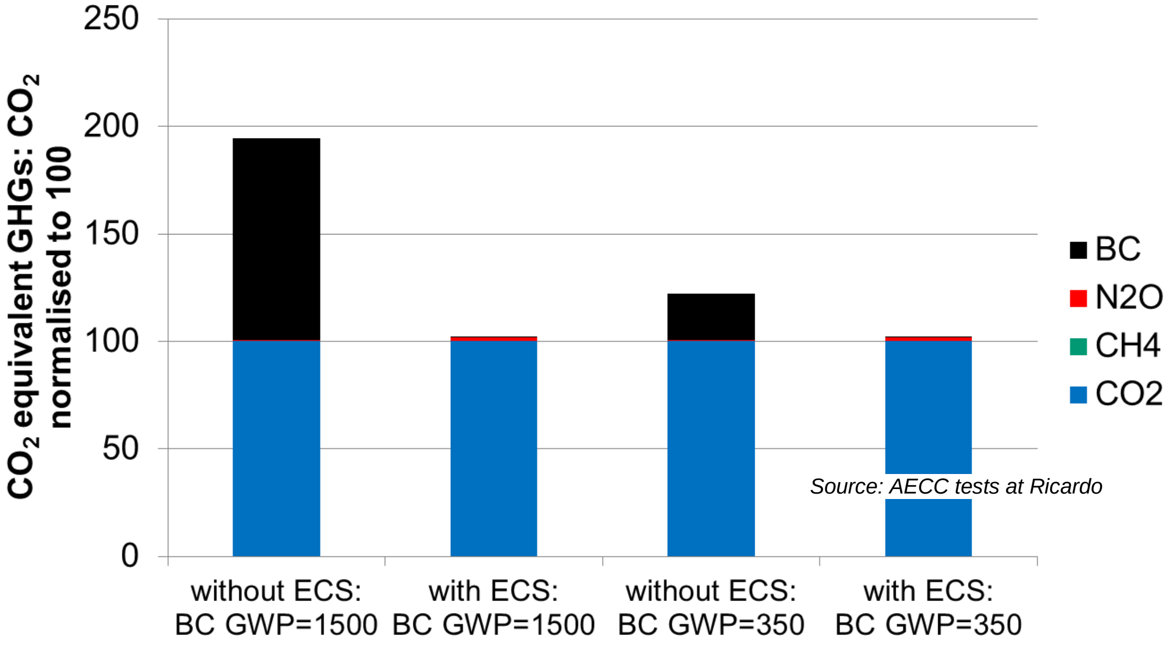


Figure 22: Climate Change-relevant emissions from a heavy-duty engine

Similarly Figure 22 shows the effect of fitting a complete emissions control system, including DPF, to a heavy-duty diesel engine as a demonstrator for Euro VI technology. In this case data is shown for both a BC GWP of 350 and one of 1500. The effect of the DPF is clearly visible for both cases.

1.3. CO_2 Policy – Demand Side

Fuel efficiency is a major operating cost for heavy-duty vehicles and so is a core consideration in the purchase of new heavy-duty vehicles. But it is not yet the major consideration for other vehicles. A range of policies is available to reduce CO_2 based on demand-side activities. These include driver training, on-board information and vehicle efficiency labelling as well as taxation, incentives and 'bonus-malus' schemes for the purchase or use of low-CO_2 vehicles. The heavy-duty vehicle industry has helped pioneer the development of eco-driving skills amongst commercial vehicle drivers, for instance. Nevertheless, analysis of data from the ODYSSEE MURE[34] (Mesures d'Utilisation Rationalle de l'Énergie) Project by ADEME[35] shows that for cars, incentives are the most prevalent of these options in the EU.

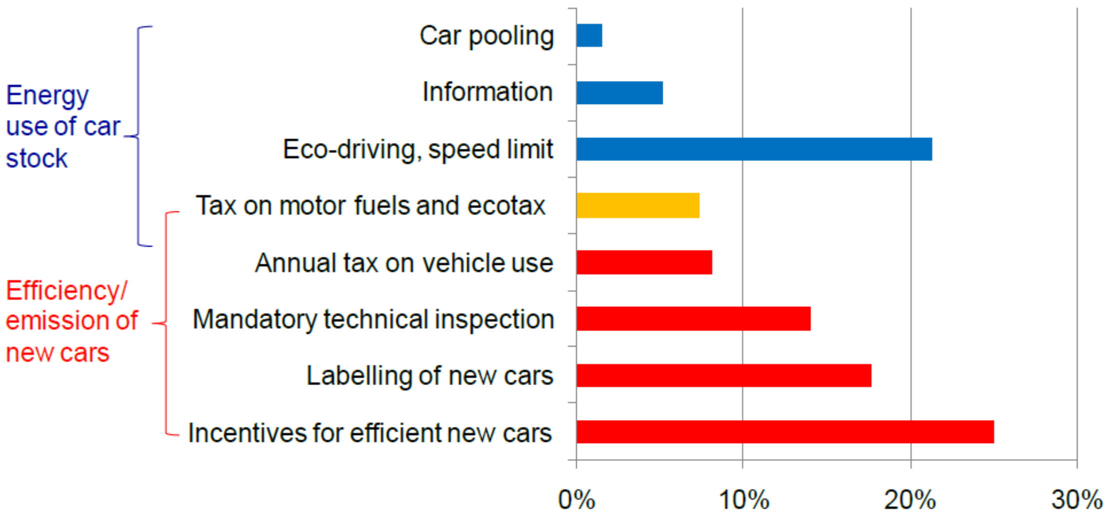


Figure 23: Overview of CO_2-reduction policies in the EU *Source: ADEME*

A particular area of concern for AECC and its Members is that there have been suggestions that CO_2 should be considered only on the basis of tailpipe emissions. A critical point in this is that in the draft CARS 21 consensus paper on 'Guidance on Financial Incentives for Clean & Energy Efficient Vehicles', recommendation no. 4 says that "the CO_2 figure from type-approval seems for light-duty vehicles the most appropriate measure of performance to be used for granting financial incentives". AECC cannot agree with this approach, which is clearly not technology neutral and unjustifiably penalises low-emission internal combustion-engined vehicles. Greenhouse gas emissions are a global, rather than local or national, issue and hence actions to reduce their emissions need to be considered in terms of the overall effect from the use of vehicles. We recognise the dependency of well-to-wheel greenhouse gas/ CO_2 emissions for electric vehicles on the efficiency of the local power generation mixture, and the difficulty this causes in assessing well-to-wheel emissions. But the proposal to use only the Type Approval CO_2 figures would substantially underestimate the true global effect of the power used in such vehicles. It would also potentially lead to gross distortions in the market. Under this proposal, for instance, a large highly-inefficient pure electric vehicle would have a 0 g/km CO_2 figure at tailpipe and hence be eligible for incentives, whilst a clean and highly-efficient vehicle with an IC engine would not.

One option to provide an appropriate CO_2 figure could be to adopt an approach analogous to that used for the current measurement of vehicle CO_2 emissions. In that the vehicle is tested on a representative reference fuel – the reported CO_2 emissions are based upon the test figure achieved with that fuel, regardless of the energy content and refinery energy efficiency for the fuel that any given customer will actually use. It might therefore, be possible to use an appropriate 'reference energy source' to give CO_2 figures for the electric power usage of externally-charged vehicles.

1.4. Internal Market, including Vehicle Safety

The results from the AECC test programmes discussed in section 1.1.5. highlight the need to improve surveillance of the quality and conformity of products placed on the market in the EU. AECC recognises that the overwhelming majority of vehicle and machinery producers go to great lengths to ensure that their products meet legislative requirements both at Type Approval and in-service, but the examples discussed above indicate the need to ensure that all manufacturers adhere to these standards if EU targets for emissions and air quality are to be met. This must include surveillance of aftermarket replacement catalysts and pollution control devices as well as new vehicles and machinery.

For vehicles in use, the requirements on OBD that are now being applied to an increasing number of vehicle categories offer perhaps the best option to ensure that vehicles (and machinery) remain in compliance with emissions performance requirements during use. Nevertheless, the roadworthiness requirements that ensure that vehicles receive a regular check on (amongst other things) emissions performance, also provide a valuable tool to ensure that equipment continues to operate correctly. At present, EU-wide requirements to not apply to all categories (for instance NRMM) and their inclusion could provide valuable additional controls on real in-use emissions.

The internal market also needs to ensure control of devices and services (such as 'chipping') that can have a deleterious effect on the engine and emissions control system.

2. INNOVATION, INFRASTRUCTURE ENERGY SUPPLY AND USE (WG1)

2.1. Innovation and R&D

Whilst recognising the likely future importance of electric vehicles (EVs), AECC also feels strongly that there will be a continuing need for conventional IC engines in powertrains for light-duty vehicles, many commercial vehicles (especially for long-haul applications) and Non-Road Mobile Machinery applications until such time as electric drivetrain technologies and EVs are established and accepted[36,37].

AECC also recognises that other parts of the world may continue to require a range of vehicles and machinery using IC engines. To maintain Europe's competitiveness, research should not solely focus on EVs but should also maintain momentum on conventional engines, including their application in novel systems.

EVs are not predicted to substantially replace IC engines in the short term. Research and development needs to be directed in a balanced manner to both further improving internal combustion engines to provide continued benefits in the short to medium term as well as new fuels, infrastructure and powertrains for the longer term.

The current and future use of legislation to drive GHG reduction from internal combustion engines should be supported by appropriate R&D funding to drive further innovation in IC engine efficiency.

AECC Members make substantial up-front investment in the technologies that allow reduced emissions from vehicles with internal combustion engines and so contribute to the development of cleaner and more fuel-efficient conventional vehicles and to the technologies that enable legislation to enforce tightened and improved emissions values.

New powertrains have many unknowns associated with, for example, cost, performance, infrastructure requirements and recyclability. Internal combustions engine powertrains are better understood but require further investment on new fuels and further efficiency and emission improvements. A balanced R&D portfolio is required across these sectors which balances risk and reward and short and longer term aspirations for air quality, GHG emissions and vehicle cost.

2.2. Energy Sources and Infrastructure

The report of the Commission's European Expert Group on Future Transport Fuels[1] indicates the breadth of the range of fuels that can and will be considered for future use in internal combustion engines. In considering such alternatives, (including electrical energy) it is necessary to consider the full 'well-to-wheels' impact, not only 'tank-to-wheels'. In addition, although there have been a number of reports examining the 'well-to-wheels' CO_2/ energy impacts of a range of fuels[38,39], few studies have also considered the impact of alternative fuels on criteria pollutants and on other climate change-relevant emissions. In any true consideration of alternative fuels, these impacts should also be examined, as was done in the USA's Argonne National Laboratory with its GREET model for Greenhouse gases, Regulated Emissions, and Energy use in Transportation[40].

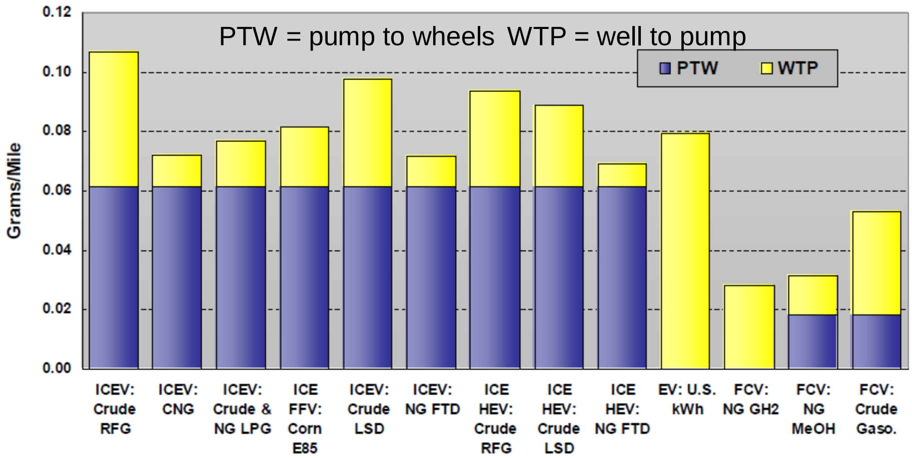


Figure 24: Well-to-wheel NOx emissions for fuel and vehicle technologies *Source: Argonne National Laboratory*

This study is for a particularly American context and only covers a limited number of alternative fuels, but nevertheless indicates the need to consider the complete picture including pollutant emissions, as exemplified by Figure 24 showing 'Well-to-pump' (WTP) and 'pump-to-wheel' emissions of NOx.

Regarding the control of pollutant emissions from IC engines fuelled with alternative fuels, the technologies in use for current petrol and diesel engines – catalysts and particulate filters – are equally applicable, providing that the engine system is properly designed and calibrated to run on those fuels. As an example, Figure 25 shows the results of running the engine from the AECC heavy-duty Euro VI test programme on B30 (30% biodiesel).

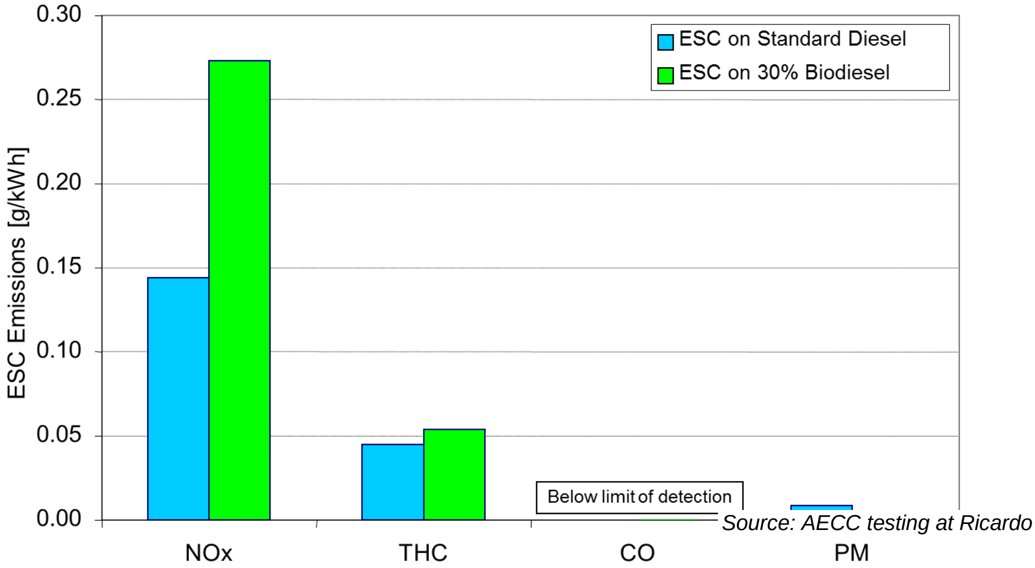


Figure 25: Comparison of standard diesel and B30 emissions for a heavy-duty engine equipped to meet Euro VI

The engine was not designed or calibrated for this fuel, so unfortunately it proved impossible to run the transient cycle properly, but it was possible to run the steady state cycle and, even without the emissions control system being calibrated for B30, good emissions performance was achieved, meeting the Euro VI levels (as originally proposed on the ESC).

2.3. Road Safety and Intelligent Transport Systems

The development of Intelligent Transport Systems might offer some potential to assist in the reduction of emissions at urban 'hot spots', perhaps through either guiding driver behaviours or by helping exclude inappropriate vehicles from Low Emission Zones. Such a development would reinforce the need for the harmonised standards for retrofit systems being developed by UNECE in order for them to meet the requirements of LEZs, as discussed previously.

3. TRADE AND INTERNATIONAL HARMONISATION (WG2)

3.1. Multilateral and bilateral Trade Negotiations

As already mentioned, the internal combustion engine will be the major engine for mobile sources for quite some time, especially in developing countries, where the infrastructure for electric cars will have to be developed. In developing multilateral and bilateral trade agreements, it is essential that the removal of trade barriers for clean and efficient vehicles (and machinery) does not exclude IC engines. Trade agreements need to result in a level playing field, not only for vehicles and mobile machinery, but also for components, replacement parts such as pollution control devices or systems and retrofit systems. They need to also ensure the continued quality and performance of all these through good market surveillance and roadworthiness requirements. European legislation can provide a lead on this, to the benefit of consumers and air quality as well as industry.

Trade negotiations covering only electrical cars as "clean vehicles" would be negative for the European industry as the European car and truck industry is leading the development of new engines. Even most of the IC engines developed for cars in other parts of the world originate from European based engineering companies. The potential of emission reduction of combustion engines, which is e.g. demonstrated by PZEV cars for the Californian market, should be considered.

Another important issue in reducing trade barriers is equivalent emission legislations. European emission legislation is used in many places in the world. The development of the WLTP should have an even bigger distribution over the world. But the contrary could be seen for the legislation of mopeds and motorcycles. The European emission legislation was not demanding enough for countries with a larger population of motorcycles and several markets such as India and Taiwan have developed their own emission legislation as a result. As long as the European emission legislation is the world leading one there is a significant chance that most parts of the world will follow the European model.

In addition, the previously mentioned AECC test programs for motorcycles and mopeds showed that the durability, OBD and in use compliance testing are an important part of the emission legislation as otherwise there is the possibility that real world emissions over the life cycle are significantly worse than expected by legislation. This has to be considered for the certification of replacement emission systems.

Concerning the basic design of free trade agreements we see the already finalized FTA with South Korea as a good starting point for future FTAs.

3.2. Framework conditions for Trade for Clean and Safe Vehicles and Development of new Technologies

The internal combustion engine will play an important role, even if electrical engines will be installed in cars. The driving range of electrical cars will not be sufficient for many applications and hybrid systems will be required to extend the operation range of cars. Long haul trucks will mainly be operated with IC engines. In many developing countries the mobility of the people is still limited and they will look for cheap solutions to improve mobility. If the electrical drive train will not offer a sufficient driving distance, they will opt for IC engines, which should clearly be optimised for lowest environmental impact. The infrastructure to support hydrogen in IC engines will not easily be developed. For fuel cell cars it is still a point of discussion if the hydrogen will be stored at filling stations or if it is to be produced by a refining system on the car e.g. from natural gas. The use of diesel engines for heavy-duty applications seems to be without doubt, while for the use in passenger cars the fuel quality is a key item. Clean sulfur free fuel is required for clean diesel passenger car engines. Clean IC engines should be included in the definition of clean vehicles.

A clean vehicle should be clean over the whole life time. The emissions of IC engines and their emission control system have to be proven and monitored. This is not only valid for the OEM equipment. If for some reasons parts have to be replaced, they should have equivalent performance as the OEM part. The relevant UNECE Regulation 103 needs to be updated and extended to replacement parts for all types of IC engine use; besides Light-duty it should cover Heavy-duty, motorcycles and Non-Road Mobile Machinery.

Another trade barrier has some effect on the emissions control industry as well as the automotive industry as a whole. The recently reduced export quota of rare earth materials from China led to significant increase of prices and shortages in production of catalysts, where for example ceria is used as an oxygen storage material in catalysts for gasoline engines. International trade negotiations should ensure that export quotas of raw materials provide sufficient lead time for the development of alternatives. In the case of rare earth elements, this would mean to develop mines in other parts of the world or to install recycling systems e.g. from spent catalysts.

One example where recycling is already playing an important role is in the recovery of the precious metals used for catalysts[41,42]. But the recycling rate of PGM and rare earth materials could be improved significantly if catalysts could be traced in a better way. The current trend of exporting used cars to parts of the world where recycling is not state of the art leads to a significant loss of precious metal. A general overview of the supply and demand situation including recycling rate is given by public information of the precious metal supplying companies[43] and an overview of platinum recycling against demand for its use in autocatalysts is shown in Figure 26.

Platinum Demand: Autocatalyst '000 oz						
	Gross		Recycling		Net	
	2009	2010	2009	2010	2009	2010
Europe	970	1,415	(290)	(375)	680	1,040
Japan	395	535	(50)	(60)	345	475
North America	370	430	(425)	(590)	(55)	(160)
China	85	115	(20)	(20)	65	95
Rest of the World	365	490	(45)	(50)	320	440
Total	**2,185**	**2,985**	**(830)**	**(1,095)**	**1,355**	**1,890**

Figure 26: Pt demand for autocatalysts and platinum from recycling *Source: Johnson Matthey*

3.3. Regulatory Cooperation

Provided that the modernisation of the UN 1958 agreement increases the use of UNECE Regulations without resulting in a 'lowest common denominator' approach, this will inherently be a positive development for the European industry, allowing technologies developed to meet European applications to be sold in a much wider market.

The uptake in other regions of UNECE Regulations based on those developed in Europe provides a strong basis for the European automotive and components industries, including the emissions control industry, to offer class-leading technology to other regions of the world. The efforts of the Commission to encourage such uptake are therefore of benefit to the industry as a whole. To maximise the benefits, it is essential that the EU Regulations for cars and for heavy-duty engines continue to ensure that engine and emissions control technologies remain at the forefront of global development. Those for NRMM, tractors and powered two-wheelers will need to reach the same level of development and environmental protection as do those for light-duty vehicles and heavy-duty engines.

One specific area that needs to be addressed in the UNECE Regulations is that of Regulation 103. This currently covers only replacement catalytic converters and includes minimal durability requirements, allowing assigned deterioration factors to be used without any demonstration of real durability. In addition, as the requirements are written around a basis of UNECE Regulation 83, they are generally taken as referring only to light-duty vehicles. The Regulation needs a thorough updating so as to apply to all categories of vehicle and machinery and to a cover pollution control devices of all types (including DPFs, SCR etc.), rather than only catalysts. Such an update would be of benefit to both Europe and other countries adopting UNECE Regulations, as well as assisting in keeping non-durable products off the market.

An important part of the regulatory developments by the UNECE working party on pollution and energy (GRPE) is that of harmonised test procedures. Important steps have already been taken with the WMTC, WHDC and the harmonisation of legislation for NRMM. The EU has already provided a lead for the utilisation of these world-harmonised test cycles and procedures by the adoption into EU legislation of the cycles for motorcycles (WMTC), heavy-duty engines (WHDC) and NRMM engines (NRTC). It is expected that in due course the development of WLTP for light-duty vehicles will also lead to its adoption into EU legislation. Europe has also taken a position at the forefront of the development of new methodologies, notably the PMP procedure to count emissions of ultrafine particles that are dangerous to health. Following the development of that procedure, Europe's adoption of it for improved particulates measurement and limitation through the Euro 6 and Euro VI legislation has provided an important precedent for other nations.

GRPE is developing the world-harmonised test procedure for cars (WLTP), which is an important step for the certification of cars and should be a significant move to avoid loop holes in the emission legislation. Care should be taken to cover the real driving behaviour to avoid that more stringent emission standards have no effect on real world emissions of cars. This should be verified in the process by scientific statistical analysis comparing real driving patterns with the new test cycle. The development of WLTP under the 1998 agreement could be key advance, but must eventually provide a complete package of measures to ensure both on- and off-cycle performance, with no relaxation of European performance requirements.

Whilst the benefits of such a leading position are important, it is also essential to ensure that efforts towards global harmonisation do not lead to a dilution of European ambition levels for environmental performance. The EU, with the co-operation of organisations such as the United Nations Environment Programme (UNEP) and the World Health organisation (WHO), will have to seek to ensure that other regions of the world ultimately strive to reach the same health- and environment-based targets as the European Community.

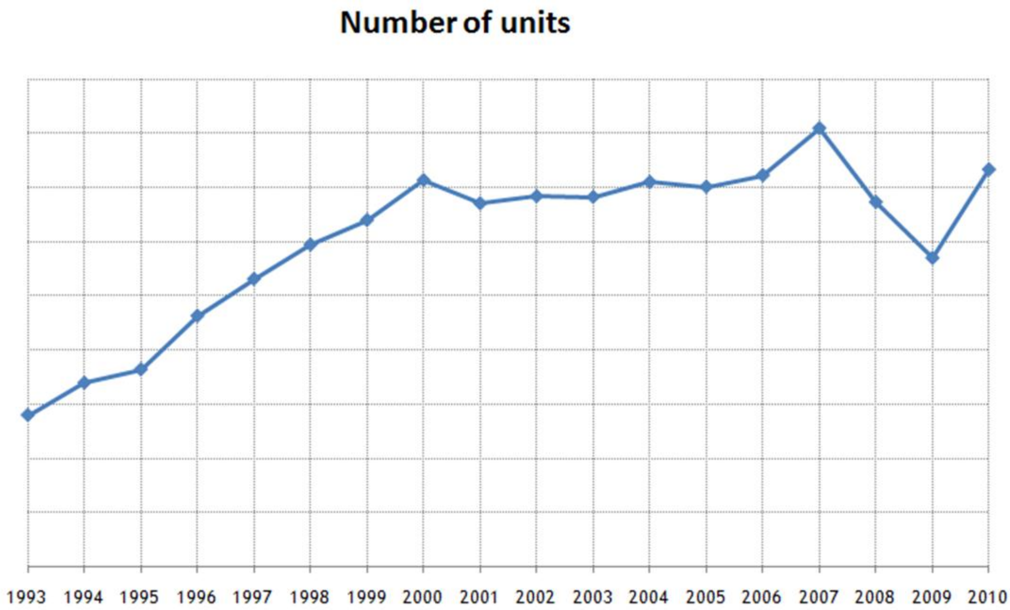
But there are still differences which lead to different emission systems for different markets. Even inside markets there are sometimes different emission standards for different regions including different fuel qualities. As mobile sources can be operated in both areas where such a situation exists, the emission system has to be able to operate and be durable with both fuel qualities. Here full harmonisation would be of help. Even if countries are following the EU legislation, there is quite often a delay in introducing it, which leads to different developments for several markets.

The recent proposal for emissions limits in gtr n° 2, the World-harmonised Motorcycle Test Cycle (WMTC) go some way towards true harmonisation this in setting a globally accepted set of limit values, thus permitting manufacturers to offer the best available technology in global markets. However, the option for secondary national/regional limit values leaves the door open for some fragmentation of markets and may put ‘global’ products at a cost disadvantage regionally, thus forcing manufacturers to develop solutions with low costs and performance, and hence losing some of the potential benefits of scale. This also needs to be borne in mind when considering the further development of the other existing world-harmonised procedures for heavy-duty vehicles (gtr n° 4; WHDC) and Non-Road Mobile Machinery (gtr n° 11; NRTC), as well as the on-going development of the light-duty procedure (WLTP).

4. INDUSTRIAL, SOCIAL AND TERRITORIAL ASPECTS OF COMPETITIVENESS (WG3)

4.1. Impact of the Crisis and Recovery Measures

The European emissions control industry has been affected by the economic crisis in much the same way as the automotive industry as a whole. As can be seen in Figure 27, the industry’s annual sales statistics mirror those we have seen for the auto industry. These data are collected by CEFIC (the European Chemical Industry Council) of which AECC is an affiliated member.



Source: CEFIC

Figure 27: Emission control industry annual sales 1993-2010

One matter that is currently of particular concern to AECC is the proposals to increase the flexibility provisions for tractors and NRMM and to delay emissions implementation for certain categories of tractor. The increased flexibility provisions were intended to alleviate the effects on machinery of the economic crisis, but are already far too late to achieve this aim. They do, though, have an unintended consequence on the upstream supply chain. The emissions control industry has, like other parts of the supply chain, had to invest heavily to develop solutions that could be applied to equipment by the due dates for the relevant stages of the emissions regulations. As these dates and emissions limits were known many years in advance, machinery manufacturers should also have been preparing to meet them. That investment has already been made by the emissions control industry and solutions are available. The increased flexibility provisions will mean that the uptake of those solutions will be significantly lower than expected, thus both substantially delaying the return on that investment and diluting it through lower production levels resulting in lower cost efficiency.

4.2. Current Situation of the Automotive Manufacturing Base in Europe and Future Trends

As discussed in previous sections, one of the consequences of the use of UNECE Regulations in the rest of the world is the benefit it offers to European OEMs and component manufacturers, providing European legislation remains at the forefront of technology-neutral emissions and safety requirements. UNECE and globally harmonised legislation needs to strive to maintain and improve on current legislative standards, but it is important that the European automotive industry's investment in class-leading technologies is not harmed by backing off severity either in the elaboration of globally-harmonised legislative requirements or at a late stage after investment has been made.

4.3. How to tackle in Optimum Way the Social and Territorial Consequences of the future Evolutions of Market and Technology

The continuing need for internal combustion engines and the related components and emissions control systems must not be ignored. The European Community needs to maintain a strong EU emissions control industry if it is to retain EU leadership in technologies and applications with skills and equipment that will be applied worldwide. As part of this it is essential that R&D expertise and application knowledge of the industry is retained and supported in Europe.

5. LIST OF ABBREVIATIONS

ADEME	Agence de l'Environnement et de la Maîtrise de l'Energie (France)
AECC	Association for Emissions Control by Catalyst AISBL (Brussels, Belgium)
ASC	Ammonia Slip Catalyst
B30	Diesel fuel containing 30% biodiesel (Fatty Acid Methyl Ester)
BC	Black Carbon
CADC	Common Artemis Driving Cycle
CARS 21	Competitive Automotive Regulatory System for the 21st Century
C-DPF	Catalysed Diesel Particulate Filter
CEFIC	European Chemical Industry Council
CH_4	Methane
CI	Compression Ignition (Diesel)
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DI	Direct Injection
DG-JRC	European Commission Directorate General – Joint Research Centre
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter
ECE	Economic Commission for Europe of United Nations (also ECE urban test cycle)
ECS	Emissions Control System
EFI	Electronic Fuel Injection
EGR	Exhaust Gas Recirculation
ESC	European Steady State Cycle (Heavy Duty)
ETC	European Transient Cycle (Heavy Duty)
EU	European Union
EUDC	Extra Urban Driving Cycle (EU) – part of the European emissions test cycle
EV	Electric Vehicle
FFV	Flexible-Fuel Vehicle
FTA	Free Trade Agreement
GHG	Green House gas
GPF	Gasoline Particulate Filter
GWP	Global Warming Potential
H_2	Hydrogen
HC	Hydrocarbon(s)
HCCI	Homogeneous Charge Combustion Ignition
HD	Heavy-duty
HEV	Hybrid Electric Vehicle
IC	Internal Combustion
ICE	Internal Combustion Engine
KBA	Kraftfahrt-Bundesamt (Germany)
LEZ	Low Emissions Zone
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LUBW	Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg (Germany)
N_2O	Nitrous oxide
NEDC	New European Driving Cycle
NMHC	Non-methane Hydrocarbons
NO	Nitric Oxide
NO_2	Nitrogen dioxide
NOx	Oxides of nitrogen (primarily NO + NO_2)
NRMM	Non-Road Mobile Machinery
NRSC	Non-road Steady-state Cycle (UNECE)
NRTC	Non-Road Transient Cycle (UNECE
OBD	On-Board Diagnostics
OEM	Original Equipment Manufacturer
PEMS	Portable Emissions Measurement System

PI	Positive Ignition
PGM	Platinum Group Metals (Pt, Pd, Rh, Ir, Ru, Os)
PM	Particulate Matter
PMP	Particulate Measurement Program (UNECE)
PN	Particle Number
PTW	Pump-to-Wheels (also Powered Two-Wheeler - motorcycle or moped)
PZEV	Partial Zero Emissions Vehicle (California)
R&D	Research & Development
REC	Retrofit Emissions Controls (UNECE)
RDE-LDV	Real Driving Emissions – Light Duty Vehicles
RFG	Reformulated Gasoline
RPA	Relative Positive Acceleration
S	Sulfur
SCR	Selective Catalytic Reduction
SI	Spark Ignition (Otto)
SMMT	Society of Motor Manufacturers & Traders (UK)
THC	Total Hydrocarbons
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
VITO	Vlaamse Instelling voor Technologisch Onderzoek (Belgium)
WHDC	World-Harmonized Heavy-duty Test Procedure (UNECE)
WHO	World Health Organisation
WHSC	World-Harmonized Steady-state Cycle (UNECE)
WHTC	World-Harmonized Transient Cycle (UNECE)
WLTC	World-Harmonized Light-duty Test Cycle (UNECE)
WLTP	World-Harmonized Light-duty Test Procedure (UNECE)
WMTC	World-wide Motorcycle Test Procedure (UNECE)
WTP	Well-to-pump
WTW	Well-to-wheels
λ1	Stoichiometric air-fuel ratio

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