SMMT
DRIVING THE MOTOR INDUSTRY

SEPTEMBER 2015

AIR QUALITY: THE AUTOMOTIVE INDUSTRY CONTRIBUTION

THE SOCIETY OF MOTOR MANUFACTURERS AND TRADERS LIMITED

FOREWORD

"NOx emissions from road transport have halved in the UK since 1990. Nevertheless, we recognise that air quality remains a critical and complex challenge"

Air quality has dominated news and political agendas in recent times, and understandably so. Air pollution levels in some urban centres are exceeding EU limits, and governments across the world are coming under increasing pressure to take action.

Taking action is exactly what the automotive industry has been doing – and not just recently. Over the past two decades and more, manufacturers have been investing heavily in new, innovative technologies that have driven down emissions of all types.

It's important to remember that air quality is better now than it has been for centuries. Levels of particulate matter (PM) have been in decline for decades, and emissions of nitrogen oxides (NOx) from road transport alone have halved since 1990 *(Source: DEFRA)*. Nevertheless, industry recognises that air quality remains a critical and complex challenge, one which must be addressed.

Since the early 1990s, guided by the Euro Standards emissions programme, industry has delivered huge reductions in pollutant emissions from new vehicles. Each EU standard has required even more stringent limits, and the latest and toughest stage in the programme, known as Euro-6, is being introduced now. Not only does Euro-6 set the strictest NOx and PM emissions limits yet, it also requires – for the first time – on-road testing to prove new cars can deliver low emissions in the real world.

Meeting the strict requirements demanded by Euro-6 has required huge investment by industry. In fact, it has been estimated it costs EU car manufacturers an extra £1,500 for every car produced *(Source: ACEA)*. At the same time, billions of pounds are being invested in vehicle safety, autonomous drive technologies and high-tech in-car convenience features now demanded by consumers, as well as more efficient powertrains that deliver important and ongoing reductions in fuel consumption and the CO_2 emissions that contribute to climate change.

The internal combustion engine has undergone vast transformation, and ongoing improvements will ensure this continues into the future. Alongside this, industry is investing heavily in alternative powertrains, including ultra low and zero-tailpipe emission hybrid and pure electric vehicles, and even those powered by hydrogen.

Although demand has increased exponentially, a volume alternative-fuel vehicle market is still some way off. In the short and medium term, the modern internal combustion engine represents our best chance to make the most meaningful improvements to air quality. However, vehicle technology cannot do the job on its own. The challenge now is to get these new vehicles replacing the old ones – and to do this support from government will be vital.

Air quality is a local issue, and therefore technology must be underpinned by nationally-led policies, supported at a local level; policies that consider traffic flow, congestion and infrastructure, and encourage optimal driver and fleet behaviour. Engines operate at peak efficiency when vehicles are on the move, not stuck in traffic, and UK drivers spend more time at a standstill than those in Belgium, France, Germany, Luxembourg or the Netherlands *(Source: INRIX)*.

Air pollution is a problem that will not be solved overnight and there is still much work to be done. However, vehicle manufacturers are tackling it head on. As the following pages set out, modern vehicles are light years away from the polluters of the past. The automotive industry has made extraordinary technological progress – and in doing so has demonstrated its vital contribution to air quality improvement.

Mike Hawes
Chief Executive, SMMT

EMISSIONS REGULATION AND TECHNOLOGY: THE STORY SO FAR

According to government calculations, it would take 50 new cars to produce the same amount of pollutant emissions as one vehicle built in 1970. Driven by EU regulation, this remarkable achievement is ultimately thanks to industry's continual investment in ever more advanced vehicle technology.

How emissions limits have been cut:

PM (since 1993)
▼96% (diesel)
NOx (since 2001)
▼84% (diesel) ▼84% (petrol)
CO (since 1993)
▼82% (diesel) ▼63% (petrol)
HC (since 2001)
▼50% (petrol)

The automotive industry has been working hard to drive down vehicle emissions of all types for many years. Reductions of carbon monoxide (CO), hydrocarbons (HC), sulphur dioxide (SO_2), nitrogen oxides (NOx) and particulate matter (PM) are linked to EU regulation that has set a programme of Euro Standards to lower emissions in stages as technology develops. It's a step-by-step process, and since 1993 when the first standard came into force, we have benefited from vastly reduced tailpipe emissions over six increasingly strict stages.

Euro-6: the cleanest cars in history

The latest stage arrived in September 2015: Euro-6. It imposes the toughest vehicle emissions limits yet, and has the potential to all but eliminate exhaust pollutants that impact air quality.

The previous Euro-5 standard, introduced in 2011, focused on PM (or soot) from diesel cars, requiring an 80% reduction in these emissions. Diesel particulate filters (DPFs) that capture 99% of all PM were developed to meet this, and are now fitted to every new car. Today, PM from cars meeting Euro-5 is equivalent to just one single grain of sand per kilometre driven.

With Euro-6, the emphasis has shifted to NOx, reflecting concerns about the emerging science connecting these emissions with respiratory problems. This latest standard mandates a 56% cut in diesel NOx emissions compared with Euro-5.

Industry has responded by developing sophisticated after-treatment systems, which mop up engine emissions before they leave the exhaust. From 1 September 2015, all new cars are fitted with one of two NOx neutralising systems: selective catalytic reduction (SCR), which uses a urea-based additive called AdBlue to convert NOx into harmless nitrogen and water; or a Lean NOx Trap, which absorbs NOx and reduces it to nitrogen.

Meeting the EU's 2020 challenge

Compared with Euro-1, diesel emissions at Euro-6 have been cut by 92% and 96% for NOx and PM respectively, contributing to an overall reduction of both in the UK. According to the European Environment Agency's Emissions Inventory Report 2014, UK NOx emissions fell faster than any other European member state, except the Czech Republic from 1990 to 2012 with an overall reduction of 63%. Nevertheless, with the UK just one of 22 member states currently exceeding the EU annual average limit for NO_2 (one of the major constituents of NOx), there is still more to do. To realise the European Commission's aim for Euro-6 to deliver on air quality targets by 2020, a second stage will follow. Stage two is significant because it introduces standardised emissions testing that will be conducted outside of the lab, on the road. Real Driving Emissions (RDE) will represent an important air quality breakthrough, ensuring not only that modern cars are ultra-low in emissions, but that they deliver in the real world.

EU LIGHT VEHICLE EMISSIONS LIMITS: 1993-2015 *(Source: ACEA/SMMT)*

Stage	Petrol emission limits (g/km)				Diesel emission limits (g/km)				Petrol and diesel
	CO	HC	NOx	PM	CO	HC	NOx	PM	No. of ultra-fine particles per km
Euro-1 1993	2.72	-	0.97[1]	-	2.72	-	0.97[1]	0.14	-
Euro-2 1997	2.2	-	0.5[1]	-	1.0	-	0.9[1]	0.1	-
Euro-3 2001	2.3	0.2	0.15	-	0.64	-	0.5	0.05	-
Euro-4 2006	1.0	0.1	0.08	-	0.5	-	0.25	0.025	-
Euro-5 2011	1.0	0.1	0.06	0.045[2]	0.5	-	0.18	0.045	6×10^{11} [3]
Euro-6 2015	1.0	0.1	0.06	0.045[2]	0.5	-	0.08	0.045	6×10^{11} [4][5]

(1) Expressed as HC & NOx
(2) Applicable to direct injection petrol engines
(3) Applicable to diesel engines only
(4) Limit of 6×10^{12} in the case of direct injection petrol engines
(5) Common limit of 6×10^{11} for direct injection petrol engines and diesel engines from September 2017/September 2018

TECHNOLOGY TIMELINE 1986-2020

1986 1990
First petrol and diesel oxidation catalytic converters introduced ahead of Euro-1

1993
EURO 1 EMISSIONS LIMITS
First limits for pollutant emissions introduced for petrol and diesel cars

1996
First diesel with high-pressure direct injection launched

1997
First petrol/electric hybrid launched

1997
First common-rail diesel car launched

1997
EURO 2 EMISSIONS LIMITS
Limits are tightened for all regulated emissions, with individual caps set for diesel and petrol and a particular focus on carbon monoxide reduction

Diesel: CO -63%

Petrol: CO -19%

2001
EURO 3 EMISSIONS LIMITS
Focus shifts to NOx with specific limits imposed for the first time. Particulate emissions must be cut in half

Diesel: PM -50%

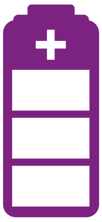
2006
EURO 4 EMISSIONS LIMITS
Standards get tougher on NOx as limits for both diesel and petrol are halved. Diesel PM limits also fall by **50%**

Diesel:
NOx -50%, PM -50%

Petrol:
NOx -47%, HC -50%

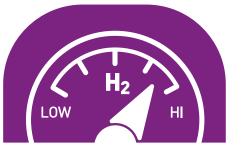
2009
Diesel particulate filters (DPFs) that capture 99% of soot particles become ubiquitous for diesel cars to help meet strict Euro-5 limits

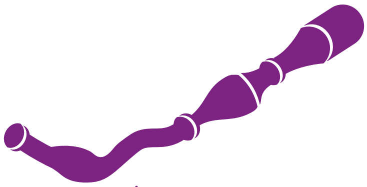
201
NO
NOx emissions from cars now **81%** lower than 1990 levels, even as average mileage has increased 19%
[Source: DEFRA]



2011

The world's first mass produced 100% electric plug-in car goes on sale in Europe – and it's built in the UK





2015

The first production hydrogen fuel cell car goes on sale in the UK

Selective Catalytic Reduction (SCR) and/or Lean NOx Traps (LNT) become standard fitment on new cars to meet the strictest-yet limits set by Euro-6

CAR MANUFACTURER MILESTONES

EU EMISSIONS LEGISLATION

WHAT'S NEXT?

2011

EURO 5 EMISSIONS LIMITS

Emphasis shifts to PM, with petrol emissions limited for the first time and a massive 80% cut required for new diesels, now fitted with DPFs. New limits on particulate numbers as well as weight are imposed

Diesel:
PM -80%, NOx -28%

Petrol:
NOx -25%

2015

EURO 6 EMISSIONS LIMITS

Diesel NOx is now the focus, with further sizeable cuts required. PM emissions from diesel and petrol cars are now comparable, and at trace quantity levels. The new standard paves the way for more robust emissions testing, to be conducted on the road for the first time

Diesel:
NOx -56%

2017

Proposed introduction of European Real Driving Emissions (RDE) test cycle & World Harmonised Light Vehicles Test Cycle (WLTC)

2020

Introduction of London Ultra Low Emission Zone (ULEZ). Euro-6 vehicles will be able to enter without charge

THE EVOLUTION OF DIESEL TECHNOLOGY

Under Euro-6, diesel cars are the cleanest in history. Nitrogen oxides (NOx) and particulate matter (PM) emissions have been cut significantly in recent years, thanks to sophisticated exhaust after-treatments and advanced engine design. Here are some of the key technologies that have made it happen.

Common rail
In combustion, the higher the pressure at which fuel is injected into the cylinder, the cleaner and more efficiently the fuel is burnt. A common rail is a high-pressure fuel reservoir which supplies the injectors with fuel in a sequence of pulses, fractions of a second apart at pressures even higher than those found on the seabed in the deepest of oceans.

Turbocharger
The turbocharger increases an internal combustion engine's efficiency and power output by forcing extra air into the combustion chamber.

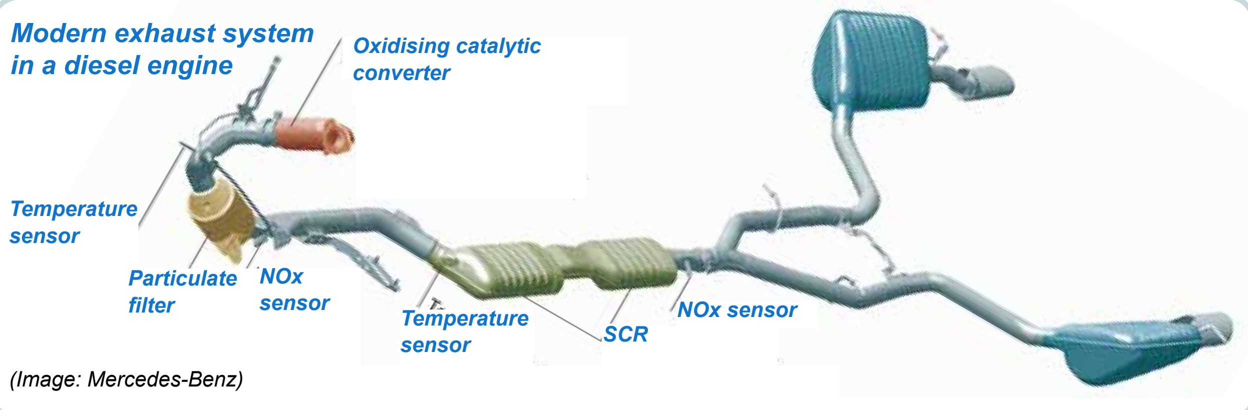
Exhaust gas recirculation (EGR)
The higher the temperature in the cylinder, the more NOx is produced. EGR controls NOx emissions by recirculating a small amount of inert exhaust gas back through the engine to reduce the engine temperature and therefore lower NOx emissions.

Variable exhaust cam timing
Exhaust cam timing ensures the exhaust catalytic converters reach optimum temperature as quickly as possible, improving efficiency and optimising emissions reduction.

Intercooler
The intercooler cools the air from the turbocharger so that more air can be forced into the engine, promoting more efficient combustion.

A Euro-6 diesel engine explained
(Image: Jaguar Land Rover)

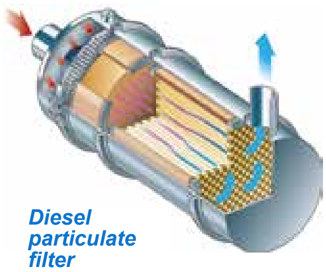
Exhaust out to DPF, SCR or LNT systems (see page 7)



(Image: Mercedes-Benz)

A Euro-6 exhaust system explained

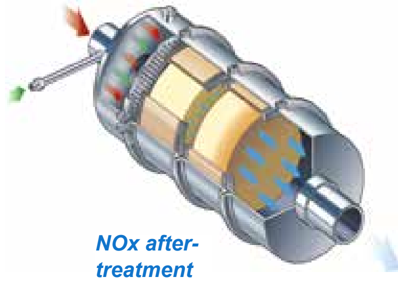
Diesel particulate filter



Diesel particulate filter

The DPF passes the exhaust gas through ceramic and metal honeycomb plates, filtering the deposits rather than releasing them into the atmosphere. The particles burn to ash to keep the filter clear. This important development has helped reduce PM emissions by more than 90% since its introduction in 2000.

Selective Catalytic Reduction (SCR)



NOx after-treatment with SCR (Images: Johnson Matthey)

This specialist diesel catalytic converter uses a urea additive called AdBlue, which is stored in a tank and injected into the hot exhaust manifold. NOx is converted into harmless nitrogen and water.

Lean NOx catalyst

A lean NOx catalyst can be used instead of SCR to store NOx and then convert it by reacting it with HC in the exhaust. It does not need a urea solution.

THE EVOLUTION OF PETROL TECHNOLOGY

Continuous advances in vehicle technology have ensured the petrol-driven cars we use today are unrecognisable compared with those we relied on even just 10 years ago. Massive investment has resulted in an evolution of the combustion engine, and vastly reduced tailpipe emissions.

Electronic control unit (ECU)

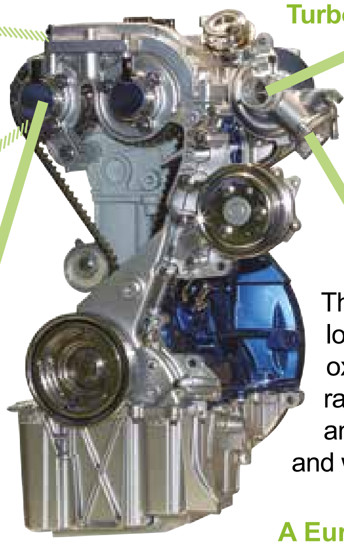
The ECU keeps the engine in tune, ensures smoother running so emissions are controlled, and prevents over-revving.

Direct fuel injection

Injects the fuel accurately to ensure it burns more efficiently.

Variable valve timing (VVT)

VVT changes the amount each valve is opened by a small degree to optimise engine efficiency and reduce NOx and CO_2 emissions.



Turbocharger

The turbocharger increases an internal combustion engine's efficiency and power output by forcing extra air into the combustion chamber..

Output to three-way catalytic converter

The three-way cat operates in a closed-loop system, including a lambda or oxygen sensor to regulate the air to fuel ratio. It converts around 90% of NOx and HC emissions to harmless nitrogen and water, and CO to CO_2.

A Euro-6 petrol engine explained
(Image: Ford)

Spot the difference: In terms of emissions, a 1976 Ford Fiesta is virtually unrecognisable to the modern-day 2015 model

THEN

1976 Ford Fiesta 1.0-litre

Pre-Euro Standard: Carburettor, mechanical control, leaded petrol, oxidation catalytic converter
NOx: 1.72g/km
HC: 2.513g/km
CO: 18.311g/km
MPG: 30.2
CO_2: 150g/km
PM: N/A
Kerb weight: 800kg

NOW

2015 Fiesta Zetec 1.0T EcoBoost 100PS Start/Stop

Euro-6: Fuel injection, electronic control, three-way catalytic converter, turbocharger, variable valve timing
NOx: 0.0341g/km (98% reduction)
HC: 0.069g/km (97% reduction)
CO: 0.558g/km (97% reduction)
MPG: 65.7 (118% improvement)
CO_2: 99g/km (34% reduction)
PM: N/A
Kerb weight: 1,025kg (28% increase)

(Source: Data is model specific where available, Ford, VCA)

THE EVOLUTION OF ALTERNATIVE FUEL VEHICLES

While manufacturers are investing heavily in low emission internal combustion technologies, they are simultaneously committing huge funds to the development of alternative-fuel vehicles, many of which are already delivering zero exhaust emission motoring to the consumer.

Alternatively-fuelled vehicles (AFV), which include everything from pure-electric vehicles and plug-in hybrids, to range extenders and even hydrogen-powered vehicles, have the potential to make a particular difference in towns and cities where air quality problems are most acute.

Until recently, AFVs have remained a niche choice but now we are seeing a rapid increase in uptake as manufacturers introduce new models, consumers become more aware of their benefits and infrastructure develops. British car buyers now have well over 20 plug-in cars to choose from, up from just six in 2011. The UK is currently the fastest-growing market for plug-in cars in Europe, while it is also home to a dedicated battery manufacturing plant and produces the world's best-selling all-electric car.

Pure electric vehicles

Pure electric vehicles (EVs) date back as far as the car itself: one of the first land-speed records was set by an electric car in 1899. Powered solely by batteries, they use an electric motor to turn the wheels, and produce zero emissions from the tailpipe.

Pure EVs are becoming increasingly viable for an ever-growing number of people. One of the major investment areas by manufacturers is increasing the distance between charges, resulting in a range of up to 100 miles for the majority of EVs – a favourable comparison with the average car journey in the UK, which is less than 10 miles *(Source: DFT National Travel Survey 2013).*

Hybrids, plug-in hybrids and range extenders

Many AFVs employ both a small internal combustion engine and an electric motor to deliver combined benefits. These can offer additional range over a pure electric vehicle while still delivering significant emission and cost benefits.

In a full hybrid, either the engine or the electric motor can power the wheels – and this will change depending on the charge of the battery as well as the amount of power required at a given moment.

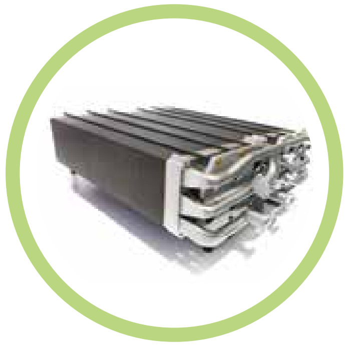
A plug-in hybrid works in the same way, but the battery can also be recharged via an electric chargepoint – giving greater potential for zero-emission driving. Range extenders feature a small-capacity internal combustion generator to provide 'on-the-go' recharge if necessary.

Hydrogen fuel cell vehicles

Hydrogen fuel cell vehicles are zero-emission electric vehicles, which use hydrogen fuel cells to generate power. Hydrogen – stored in an on-board fuel tank – is combined with oxygen in the fuel cell, and the only outputs are electricity, heat and water.

A number of manufacturers are investing heavily in this technology, and in 2015 the first full-production hydrogen fuel cell vehicle went on sale in the UK.

Further uptake will require support in developing the refuelling infrastructure.



Biofuels

Biofuels deliver the simultaneous advantages of using renewable energy and enabling the reduction of some pollutant emissions, including particulate matter. Significant research and development is taking place into a range of different biofuels, including ethanol, biodiesel and natural gas.

Petrol and diesel sold in the UK already contains some biofuel: the former with up to 5% ethanol, and the latter with up to 7% biodiesel. As further advances are made in this area, it is expected that biofuels will become more prevalent in motoring and other road transport.

THE EVOLUTION OF EMISSIONS TESTING

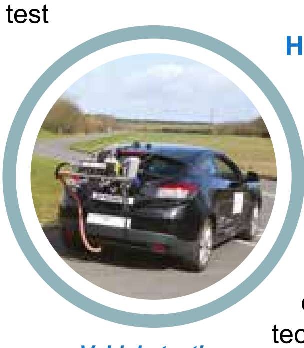
Euro-6 introduces not just the toughest limits for pollutant tailpipe emissions, it also heralds a radical transformation of the way we measure them. Real Driving Emissions will be the most demanding test ever developed – and will ensure modern cars deliver benefits on-road as well as in the lab.

Vehicle testing in the lab (Images: Milbrook)

The move from Euro-5 to Euro-6 involves a mandatory 56% cut in NOx emissions from new diesel cars, which will help the UK meet EU NO_2 limits. An EU policy review in 2013 confirmed Euro-6 will deliver key air quality objectives by 2020 – achieved via a multi-stage strategy that focuses on emissions limits and the measurement of them. Measurement is a vital part of emissions reduction, proving vehicles deliver against the required limits, and ensuring each car in the EU meets the same standards. Equally important is the benchmark it provides for consumers.

A real driving revolution

Currently, both pollutant and CO_2 emissions linked to fuel consumption are tested in the laboratory. However, a second stage of Euro-6, which will come on stream in 2017, is proposed to coincide with the introduction of an additional Real world Driving Emissions (RDE) test for regulated pollutant emissions, including NOx and PM.
RDE will be carried out on the road, instead of the lab, and will use a portable emissions measurement system (PEMS), which is a mobile laboratory that measures and analyses tailpipe emissions on the move.



Vehicle testing on the road

RDE represents an important breakthrough for the automotive industry – and is perhaps the biggest revolution in vehicle emissions measurement since testing first began. Until now, robust and standardised on-road testing has not been possible because equipment to measure the particles with sufficient accuracy was not available. Variations in weather conditions, road profile, vehicle load and the challenge of determining 'real world' driving behaviour, have meant that, unlike in the laboratory, tests could not be reliably repeated to provide comparable results. It has taken years and considerable investment to design and test equipment that can accurately and consistently measure trace quantities of emissions outside of the lab.

New European Driving Cycle

Simultaneously, measurement of CO_2 emissions and fuel consumption is also undergoing radical change. The current emissions test cycle, known as the New European Driving Cycle (NEDC), is carried out in a laboratory on a rolling road under controlled conditions. In the UK, tests are carried out under rigorous conditions witnessed by a government-appointed agency to ensure strict European standards are met.
They are conducted in a controlled temperature of 20-30°centigrade, and the car must be calibrated as per the manufacturer's on-road specification. Tyre pressures, fluid levels and other equipment must all be as standard, while random testing of vehicles off the production line ensures production vehicles meet the laboratory test results.

Harmonised light vehicle testing

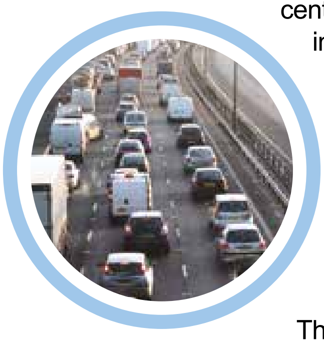
The NEDC, which has its roots in the 1970s, has been criticised for delivering fuel consumption figures that are difficult for drivers to match. This is due to discrepancies between controlled lab conditions and the variables of real on road driving conditions and behaviour. Also, modern technology such as heated windscreens, air-con, heated seats, sat navs and tyre pressure monitoring systems, which draws energy from the vehicle, was not available when the test cycle was developed.

A new test is planned that is more representative of 'real world' driving and the complexities of modern vehicle technology.

The World harmonised Light vehicles Test Cycle (WLTC) and Procedure (WLTP) will replace NEDC, and is proposed for implementation from 1 September 2017. The WLTP is developed using globally sourced driving data, and the cycle is more dynamic, with changes including more acceleration and braking, different speeds and standstill times.

PUTTING ROAD TRANSPORT INTO CONTEXT

Advanced vehicle technology has the power to make a dramatic improvement to air quality – but it cannot do the job on its own. The most meaningful benefits will be achieved by an integrated approach involving industry, government, local authorities and road users.



Road transport may currently be the biggest single source of roadside air pollution in urban centres, but it is important to put it into context. Society – and the economy – is dependent on cars and commercial vehicles to get us to work and deliver our essential goods and services. Trucks and buses in particular offer an opportunity to reduce pollution on a major scale.

The heavy duty sector has been regulated by an equivalent Euro Standard to cars – Euro VI – since 2014, and it's already proving itself. Transport for London tests using the London 159 bus route show a 95% reduction in NOx over the previous Euro-V standard. But, as with Euro-6 for cars, the technology doesn't come cheap and to speed up fleet replacement, government support at all levels to promote business certainty and encourage uptake is critical.

Congestion control

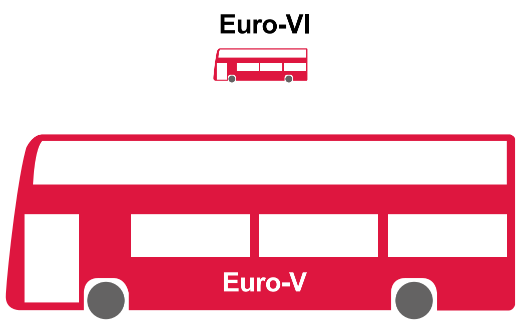
Reducing congestion and unnecessary journeys as well as encouraging more efficient driving are also important. Engines are at their least efficient when in stop-start traffic and keeping them moving will make a serious impact not only on air quality, but business productivity, too. The cost to the economy of congestion is estimated at £307 billion between 2013 and 2030, with motorists stuck in traffic for 18 working days on average *(Source: INRIX 2014)*. In some urban areas, anti-idling campaigns have been introduced to encourage drivers to turn off engines while waiting or parked. Action at local level to encourage more efficient driving behaviour would build on vehicle technology to reduce emissions further.

Traffic management

Managing traffic to smooth its flow can significantly reduce air pollution. Intelligent traffic systems such as motorway speed regulation schemes, smarter traffic sequencing and intelligent road design in urban areas help reduce stopping and starting and improve air quality in hotspots. Out of hours deliveries also reduce congestion and emissions at peak times, while 'last mile' delivery schemes and urban freight consolidation may be appropriate in cities where low or ultra-low emission vehicles can complete the final stage of distribution. Planning policies, which recognise changing mobility trends in urban areas and offer an integrated range of choices to suit journey needs, including cycling, walking, car sharing and public transport, will also be paramount, and must keep traffic moving.

Essential maintenance

Regular maintenance is essential to keeping emissions in check, and motorists and fleet managers have a responsibility to adhere to recommended manufacturer service intervals to ensure engine and after-treatment systems are optimised. These systems are critical to the emissions performance of modern vehicles. For example, removal of diesel particulate filters, which is an offence, will greatly increase emissions of PM. Selective catalytic reduction systems, meanwhile, require regular top-ups of AdBlue. In most cases, these are carried out during standard servicing when other lubricants are replenished. Finally, we must not forget other contributors of pollutant emissions, including rail, domestic and commercial heating and electricity generation, and even construction machinery in urban areas. All of these sources will also need to be addressed.



A Euro-VI bus emits 95% less NOx than a Euro-V bus

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