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Road transport and air pollution – where are we now?

Hitchcock and Carslaw
Ricardo Energy & Environment
December 2016

The Royal Automobile Club Foundation for Motoring Ltd is a transport policy and research organisation which explores the economic, mobility, safety and environmental issues relating to roads and their users. The Foundation publishes independent and authoritative research with which it promotes informed debate and advocates policy in the interest of the responsible motorist.

RAC Foundation
89–91 Pall Mall
London
SW1Y 5HS

Tel no: 020 7747 3445
www.racfoundation.org

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About the Authors

Guy Hitchcock is a knowledge leader on low emission cities at Ricardo Energy & Environment with over 20 years' experience of transport and environmental issues. He has worked in both consultancy and academia and his expertise includes vehicle emissions modelling, low-emission vehicle technology, local air quality management and carbon reduction policy. Guy has worked on a range of national and international studies on transport technology and emissions, in relation to air quality and climate change policies. He is currently working with a number of local authorities on Low Emission Zones and Strategies, and for the European Commission on tools to support cities develop sustainable transport policies. Previously he has carried out air quality and carbon assessments of local transport plans, supported Defra in the review of local Air Quality Action Plans and helped develop the concept of Low Emission Zones in the UK.

David Carslaw is an air pollution scientist at Ricardo Energy & Environment with a joint position in the Department of Chemistry at the University of York. His main area of expertise is in understanding the impact transport sources have on urban air quality. These interests include the measurement of vehicle emissions using remote sensing and the analysis of ambient air quality data to better understand the contribution made by different source types to air quality impacts. He was the first to identify that directly emitted NO_2 from diesel vehicles was increasing and that these increases made an important contribution to ambient concentrations of NO_2. David has published widely in academic literature.

Disclaimer

This report has been prepared for the RAC Foundation by Guy Hitchcock and David Carslaw (Ricardo Energy & Environment). Any errors or omissions are the authors' sole responsibility. The report content reflects the views of the authors and not necessarily those of the RAC Foundation.

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List of Abbreviations

AQAP	Air Quality Action Plan
AQD	Air Quality Directive
AQMA	Air Quality Management Area
AURN	Automatic Urban and Rural Network
CAZ	Clean Air Zone
CF	conformity factor
CO_2	carbon dioxide
COMEAP	Committee on the Medical Effects of Air Pollutants
COPERT	Computer Program to calculate Emissions from Road Transport
DECC	Department of Energy & Climate Change
Defra	Department for Environment, Food & Rural Affairs
DfT	Department for Transport
DPF	diesel particulate filter
EEA	European Environment Agency
EV	electric vehicle
HGV	heavy goods vehicle
LAQM	local air quality management
LEV	low-emission vehicle
LEZ	Low Emission Zone
LTP	local transport plan
NAEI	National Atmospheric Emissions Inventory
NEDC	New European Drive Cycle
NICE	National Institute for Health and Care Excellence
NO	nitrogen monoxide
NO_2	nitrogen dioxide
NO_x	nitrogen oxide
PEMS	portable emissions measurement system
PM	particulate matter
$PM_{2.5}$	particulate matter of median diameter 2.5 microns or less: fine particulate matter
PM_{10}	particulate matter of median diameter 10 microns or less: coarse particulate matter
RDE	Real Driving Emissions
SCR	selective catalytic reduction
TfL	Transport for London
TRO	traffic regulation order
ULEV	ultra-low-emission vehicle
ULEZ	Ultra Low Emission Zone
WHO	World Health Organization
WLTP	Worldwide harmonized Light vehicles Test Procedure

Foreword

It is only two years since we published a major report conducted for us by experts at Ricardo Energy & Environment exploring the issues of air quality and vehicle emissions.

It was a comprehensive analysis of the air quality challenge and its causes.

But much has happened in those two years.

Whilst work was being taken forward to tighten emissions standards and the vehicle testing regime, the VW scandal fuelled public concern both about the need for action and the pace of change. Government has continued to encourage the take-up of low and zero emission vehicles, just recently extending its suite of grant schemes to include motorcycles and scooters, and has brought forward plans to establish Clean Air Zones. And London's new Mayor is exploring the options for accelerating and broadening the London Ultra-Low Emission Zone.

So, with Government now consulting on its proposed statutory framework for Clean Air Zones it was timely for us to commission Ricardo Energy & Environment to revisit their earlier work; not to carry out a full reworking of the original report, but to look at what has been happening since 2014 and what that means for policy makers, manufacturers and motorists.

Three things stand out from the analysis:

- the medical evidence for the harmful health impacts of poor air quality has hardened still further;
- the case for swift implementation of a new, trusted, real-world vehicle testing regime is stronger than ever; and
- as motorists we need the automotive industry to redouble its efforts to develop and bring cleaner, greener, affordable models to market.

We will draw from this work in our response to the Clean Air Zone consultation. We hope others will find it to be useful insight into an issue that should concern us all.

Steve Gooding

Director, RAC Foundation

The **Real Driving Emissions** (RDE) on-road test is due to be introduced in September **2017 for new car types** and in September **2019 for all new cars.**

In-service conformity testing for heavy goods vehicles came into force in 2012.

Years of life lost *per annum* in the UK due to exposure to NO_2 and PM: **534,000.**

The new **Worldwide harmonized Light vehicles Test Procedure** (WLTP), a laboratory test for cars and light goods vehicles, is due to be introduced over a **similar timescale as RDE.**

The WLTP is due to replace the current New European Drive Cycle (NEDC), as a laboratory test more representative of real-world driving.

According to DVLA records, there were **11.9 million diesel cars** and **3.6 million diesel light goods vehicles** licensed in the UK in 2015.

1. Introduction

"Air pollution is a major cause of disease and death… When dirty air blankets our cities, the most vulnerable urban populations – the youngest, oldest and poorest – are the most impacted."[1]

Air pollution is recognised as a major health concern in cities around the world. The latest World Health Organization (WHO) data estimates that over 80% of people living in urban areas where air pollution is monitored are exposed to air pollution levels that exceed WHO limits (WHO, 2016). In Europe, air quality limits have been set,[2] through European Directives, that all countries need to achieve to protect public health. However, although improvements have been made, these limits are still being widely breached. In the UK, compliance is assessed nationally in relation to 43 zones across the country (Hitchcock et al., 2014: 12); if anywhere within a zone exceeds the limits then that zone is deemed in breach of the Directive. The latest compliance data, based on 2013 observations, showed that 31 zones are still in breach of the limit values.

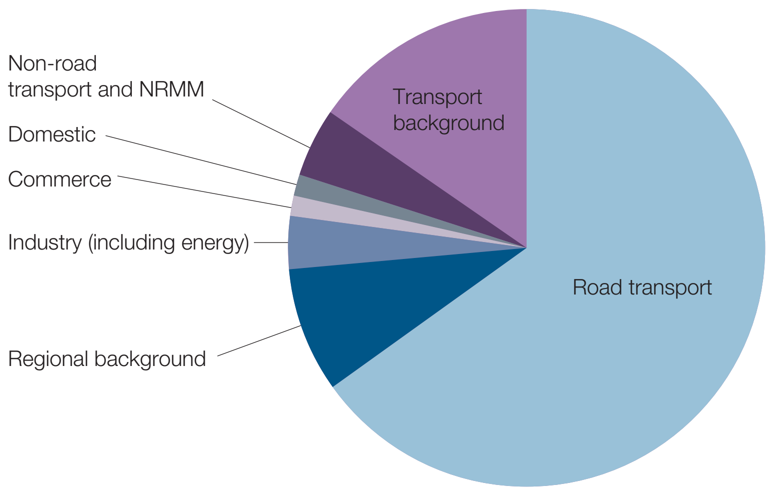
In parallel to the European Directive, there is a system of local air quality management designed to identify air pollution hotspots in our towns and cities

1 Dr Flavia Bustreo, WHO Assistant-Director General for Family, Women and Children's Health, 12 May 2016 (www.who.int/mediacentre/news/releases/2016/air-pollution-rising/en/).
2 See Box 2 in Chapter 4.

and mitigate the situation in those locations. Local authorities have a duty to assess air quality in detail and to identify areas where exceedances of the European limit values occur and there is population exposure. These areas are known as Air Quality Management Areas (AQMAs) and cover specific areas where air quality limits are exceeded. AQMA's are different from the compliance zones used in the European Directive. These compliance zones are a set geographical areas that cover the UK and if any point within a zone is assessed as being over the limits set out in the European Directive then the whole zone is classified as non-compliant. In terms of AQMAs, despite the achievement of significant improvements in air quality, there are still over 600 identified areas where people are exposed to pollution levels that are above these health-based limits, largely in our towns and cities (Defra, 2016). In the majority of cases, the limit value exceedances are in relation to nitrogen dioxide (NO_2), with a few cases related to coarse particulate matter (PM_{10}) and a very few to sulphur dioxide.

In 2014, the RAC Foundation published an evidence review setting out the current understanding of the level of air pollution in the UK and the contribution of transport activity to it (Hitchcock et al., 2014). This report concluded that transport, and particularly road transport, was the main source of pollutants in these areas of poor air quality, as is confirmed in Figure 1.1, which charts figures from the UK Department for Environment, Food & Rural Affairs (Defra). This shows the direct sources of nitrogen oxide (NO_x) emissions, a combination NO (nitrogen monoxide) and NO_2, that contribute on average to road links where measured NO_2 concentrations exceed the European limit value (see Box 1 for the relationship between NO_x and NO_2).

Figure 1.1: Average of nitrogen oxide (NO_x) source apportionment on UK road links outside London exceeding the nitrogen dioxide (NO_2) limit value in 2013



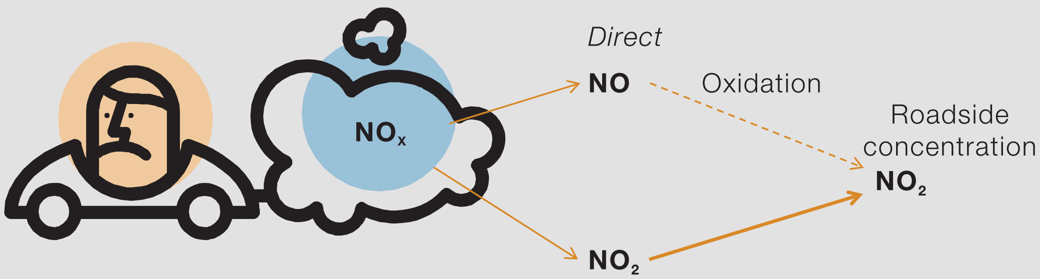
Source: Defra (2015a: 2, Figure 1)

Note: NRMM stands for non-road mobile machinery

On average, 80% of NO_x emissions in areas of exceedance were related to transport. Most of this related to direct emissions from road transport at the measurement site, but also represented were wider background sources of transport emissions such as those carried over from road traffic in other areas and from rail. It was also concluded that diesel vehicles were the major cause of these traffic emissions in relation to NO_2 and PM – the pollutants most strongly related to health impacts.

Box 1 The relationship between NO_x and NO_2

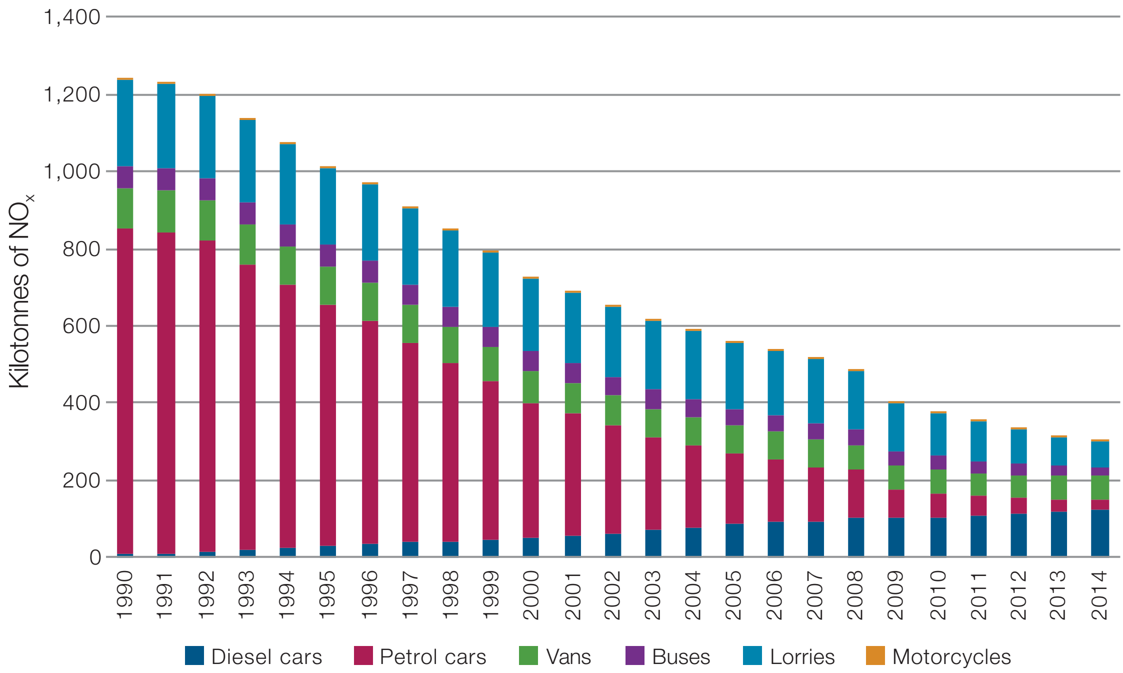
Nitrogen oxide (NO_x) is a combination of nitrogen monoxide (NO) and nitrogen dioxide (NO_2), and is generally what is measured and modelled in terms of direct emissions from combustion processes such as those found in diesel vehicles and industrial processes. The concentration of NO_2 is what is measured at roadsides and at other locations when investigating air pollution. The NO_x emitted from vehicles will undergo chemical reaction and dispersion to form the NO_2 concentrations measured at roadside, as illustrated below.



Emission limits for vehicles are then set in terms of NO_x emissions, and the health-based air quality limits are set in terms of NO_2 concentrations.

One of the key findings of the 2014 report was that while emissions from petrol vehicles in real-world conditions had reduced in line with emission regulations, those from diesel vehicles had not. This was particularly the case with emissions of NO_x, in which there had been little apparent improvement over the last decade. The difference between legislated emissions (i.e. as recorded in type-approval laboratory testing), which have been reducing, and real-world emissions was especially prominent in urban areas, where the worst levels of air pollution occur. The problem had been exacerbated by the recent growth in the number of diesel cars, which to some extent had been driven by policies to reduce carbon dioxide (CO_2) emissions, as diesel vehicles are more fuel-efficient than their petrol counterparts. The growth in the number of diesel vans, stimulated by online shopping and home deliveries, has also been a factor. Despite the reductions in road transport emissions of NO_x as shown in Figure 1.2, there has been a dramatic increase in the proportion of NO_x emissions from the diesel car fleet, with diesel vehicles making virtually no contribution in 1990, rising to 40% of total NO_x emissions by 2014. During the same period, the proportion of emissions from the petrol cars dropped from nearly 70% to less than 10% as the number of petrol cars reduced and their emissions performance improved significantly. The chart also shows the growing prevalence of vans, and the improving situation with emissions from lorries.

Figure 1.2: National road transport emissions of nitrogen oxide (NO_x) by vehicle type



Source: based on data from NAEI (2015)

Since the 2014 report, a number of key developments have occurred:

- The evidence base on the health impacts of air pollution has continued to build, especially in relation to NO_2, increasing the need for action.
- The discrepancy between quoted and real-world performance of diesel vehicles, which we had identified, has been brought under a brighter spotlight consequent on the Volkswagen Group (VW) 'dieselgate' scandal.
- The UK Government has been forced to set out more stringent plans to tackle air quality, in response to the failure to comply with EU air quality limits across much of the UK.

In this paper we explore these issues further and consider the implications for transport users and policymakers.

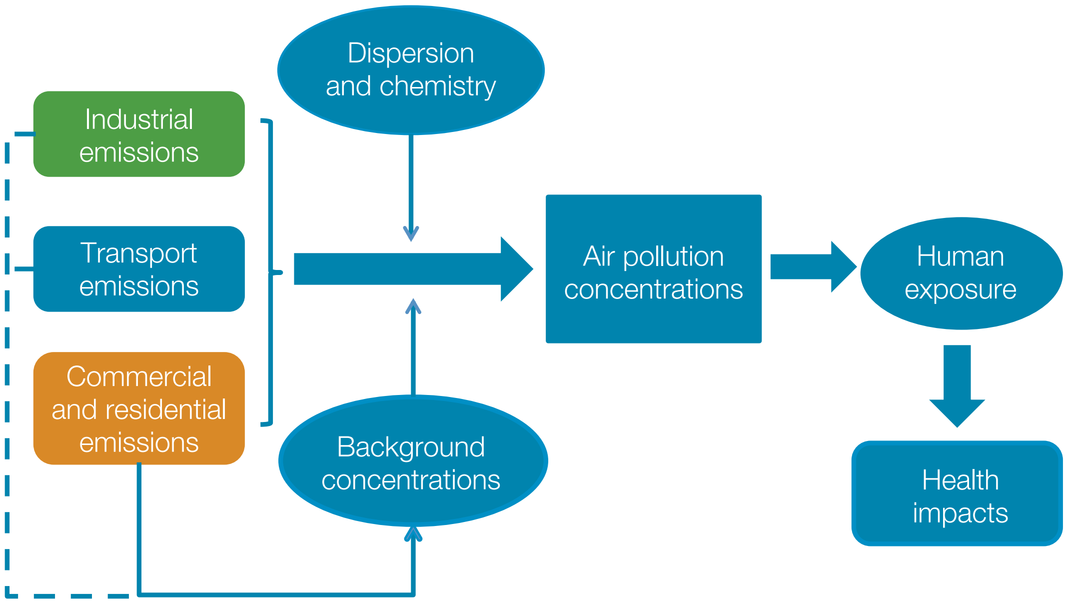
2. Health and Air Quality

In exploring health impacts, it is important to understand the relationship between three things: emission-generating activity, the resulting air pollution concentrations, and their health impact, as illustrated in Figure 2.1. Emissions are generated from transport activity and are dispersed and combined with other emissions, giving rise to pollutant concentrations in the air. When people are exposed to this pollution over a period of time, health impacts result.

The quantification of the health impacts of air pollution has traditionally focused on the impacts of particulate matter (PM[3]), in particular the fine fraction $PM_{2.5}$, in line with the strongest evidence. Hence the focus of the health debate relating to air quality has been on PM, whereas the wider air quality debate has focused on NO_2 because of the compliance problems. Although the two are related, this has led to something of a mismatch between the public health and the environmental agendas, despite the overall goal of improving air quality being improved public health.

3 Particulate matter is subdivided in terms of particle size measured in micrometres (μm): the key sizes for air quality are the coarse fraction of size 10μm (PM_{10}) and 2.5 μm ($PM_{2.5}$), fine particulate matter.

Figure 2.1: The relationship between emissions, concentrations and health impacts



Source: Hitchcock et al. (2014: 4, Figure 1.1)

2.1 The latest health evidence

Since the 2014 report, the evidence for the health impacts of NO_2 has increased significantly. The Committee on the Medical Effects of Air Pollutants (COMEAP) concluded in 2015 (COMEAP, 2015: 1):

> "Evidence associating NO_2 with health effects has strengthened substantially in recent years. This increase in evidence has led to interest in estimating the mortality effects associated with long-term average concentrations of NO_2."

Building on this, COMEAP provided an interim recommendation to Defra on the quantification of the health impacts of NO_2 on the basis of a coefficient of exposure of 1.025 per 10 μg/m^3 in relation to all-cause mortality (Defra, 2015: 3). Put plainly, this means that statistically the estimated rate of mortality (deaths) increases by 2.5% for every 10 μg/m^3 increase in NO_2 concentrations.

Using this interim data from COMEAP and average population exposure to NO_2, Defra estimated that exposure to NO_2 resulted in annual mortality rates that were 4.3% higher across the UK than would otherwise be the case. This means 23,500 deaths annually – 4.3% of total UK deaths – relate to NO_2 pollution, burdening the country with an estimated social cost of £13.3 billion annually. Combined by simple addition with the estimate of annual deaths attributable to PM exposure of 29,000 deaths, this gave a total of 52,500 deaths annually attributable jointly to both NO_2 and PM air pollution, valued at £29.7 billion annually. However, COMEAP noted that there was likely to be an overlap between the estimate of deaths related to NO_2 and PM of up to 33%, as exposure to both pollutants was strongly correlated (both being dominated by roadside transport emissions). Therefore, the combined effect of NO_2 and PM air pollution is likely to be of the order of 44,750 deaths annually, valued at £25.3 billion.

At around 64%, the increase in the estimated health impact of air pollution in terms of all-cause mortality generated by this new evidence, compared to the previous PM-only estimates, is significant.

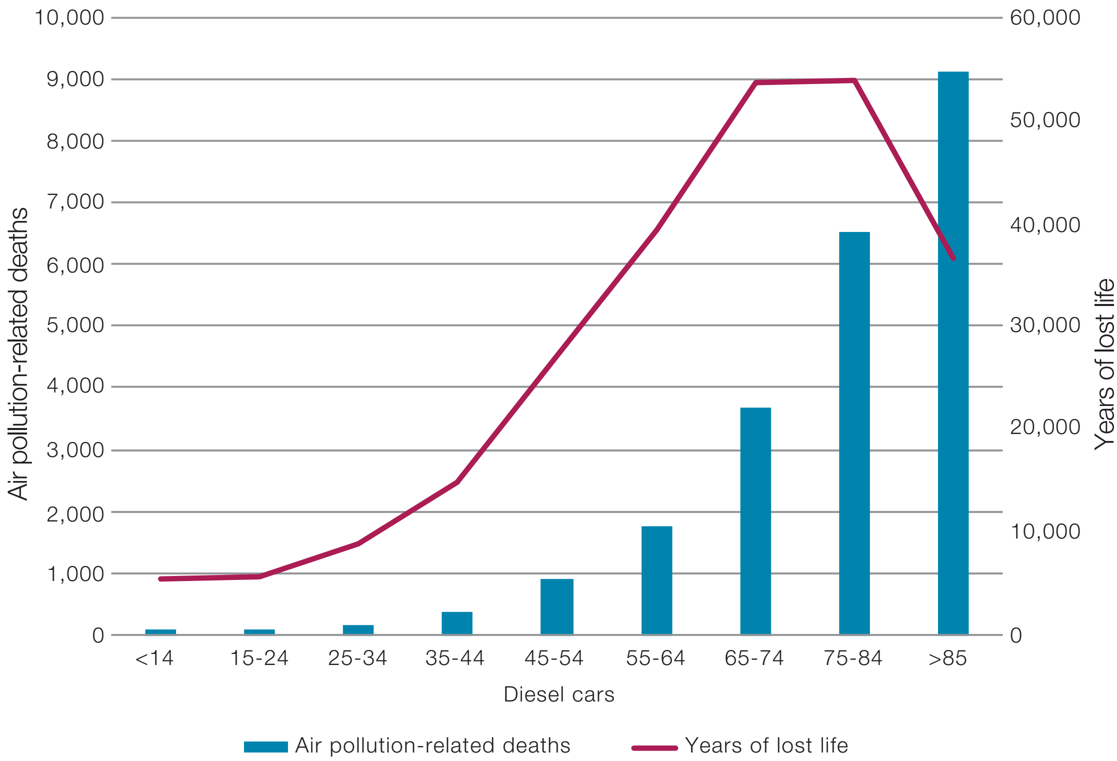
2.2 Understanding the impact on health and costs to society

This evidence is stark, but what does it actually mean, and how does it compare with other public health issues? Firstly, deaths related to NO_2 and PM pollution are *indirect* rather than *direct*: in the case of road accidents or heart attacks, deaths can be attributed directly to the cause, whereas air pollution exacerbates or increases more direct health effects such as respiratory disease or cardiovascular disease, thus increasing the risk of mortality. In this case, the analysis is carried out on a statistical basis, whereby changes in all-cause mortality (i.e. all deaths) are related to differences in long-term exposure to air pollution. The assessment carried out by COMEAP reviewed a large range of studies and concluded that there was a 95% confidence level in relation to their previously mentioned recommended quantification of health impacts, that mortality rates increase by 2.5% for every 10 μg/m^3 change in average NO_2 pollution exposure levels. This is then applied to average population exposure to varying concentrations of pollution, and average mortality rates, to obtain an estimate of deaths attributable to air pollution. The same approach is used for both NO_2 and the fine fraction $PM_{2.5}$. This assessment is also based on total NO_2 and PM air pollution from all sources, but as noted above in urban areas where the majority of exposure occurs this pollution is dominated by traffic emissions.

One associated measure of health impact that is often quoted is 'years of life lost'. Mortality statistics are provided by age group, hence the number of deaths attributable to pollution can be related to these different age groups. The number of years of life lost is then, essentially, the number of attributable deaths in each age group multiplied by the expected remaining year of life of that age group (i.e. how many years early a person has died). This is then summed over all the age groups to give a total of life-years lost. This is illustrated in Figure 2.2, with deaths shown in the columns for each age group and the years of life lost shown as the red line. The area under the line represents the total years of life lost. COMEAP suggests that a reasonable estimate of this can be provided by simply multiplying attributable deaths by an average loss of life of 12 years.[4] So combining average loss of life with annual attributable deaths associated with PM and NO_2 pollution gives an estimated 534,000 years of life lost per year in a population of some 65 million.

4 This average derives from a national assessment carried out by COMEAP in 2010 (COMEAP, 2010) and relates to the average loss of life across all age groups and associated rates of death.

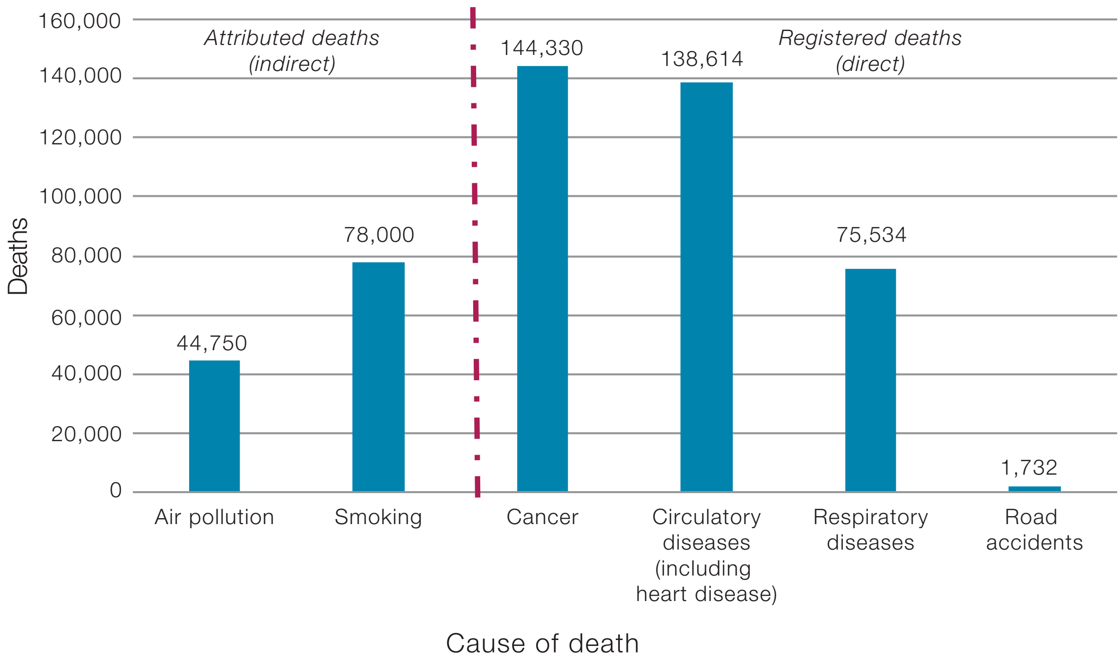
Figure 2.2: Estimate of deaths and years of life lost attributable to air pollution in the UK in 2015



Source: calculated from 2015 registered deaths and life expectancy statistics (ONS, 2016)

To put the annual deaths attributed to air pollution into context, the annual deaths attributed to smoking are estimated to total 78,000 per year (Health & Social Care Information Centre, 2016: 2), nearly double that from air pollution (44,750). These can in turn be compared with the registered causes of death (ONS, 2016), which show that the greatest direct cause of deaths is cancer, followed by heart disease and respiratory disease, as shown in Figure 2.3. This also shows that the number of road traffic deaths are several orders of magnitude lower than those associated with air pollution.

Figure 2.3: Attributed and registered deaths per year in the UK in 2015

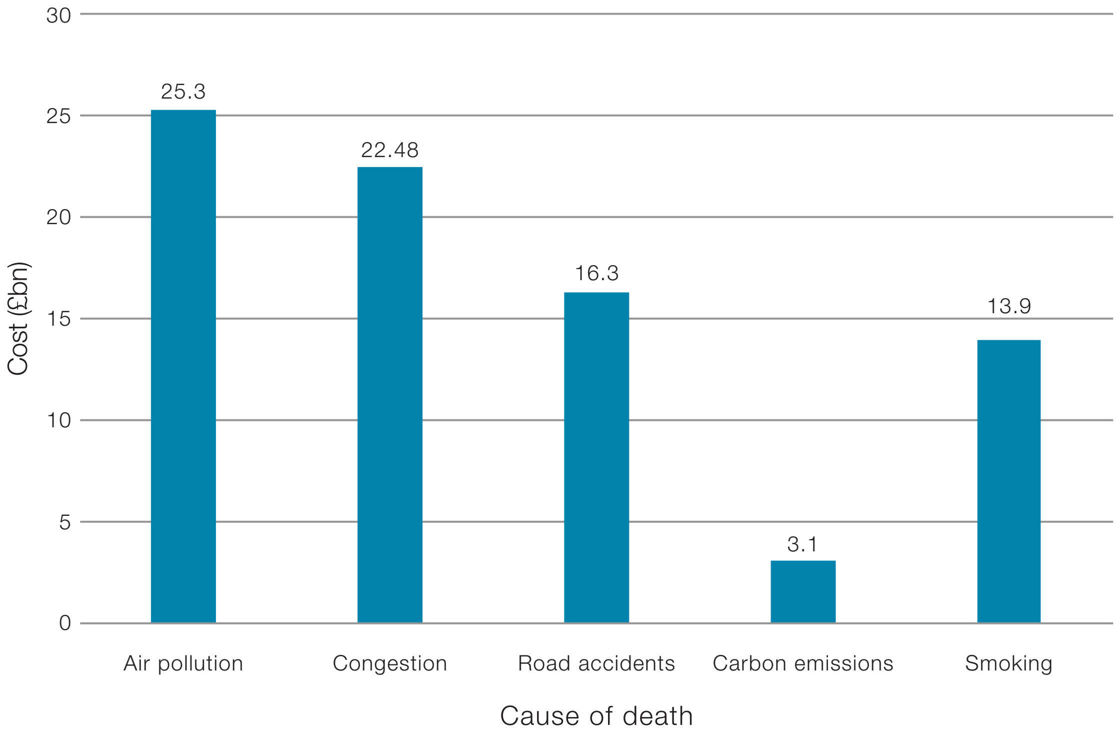


Source: Air pollution: Defra (2015: 9, Table 5)
Smoking: Health & Social Care Information Centre (2016: 2)
Registered deaths: ONS (2015, Table 2)
Road accidents: DfT (2015: 57)

Note: the figure for road accident fatalities has been adjusted by DfT to allow for annual variations in temperature and rainfall.

In terms of costs to society, air pollution is also significant when compared to the other impacts of transport such as congestion and road accidents, and also other health and environmental issues such as smoking and overall carbon emissions, as illustrated in Figure 2.4. Clearly there are differences in how these costs are estimated. For example, the costs of air pollution cover mortality, morbidity and damage to buildings and crops, whereas the costs of smoking do not cover direct mortality costs but do cover other social costs such as health-care costs, loss of productivity and smoking-related sick days. Similarly, the congestion costs are based on time delay costs, road accidents include deaths and serious injuries with a value needing to be placed on human life and able-bodiedness, and costs of carbon emissions are based on the traded values of carbon. However, they do give an indication of the relative costs to society of these various aspects of modern life.

Figure 2.4: Costs to society of various UK transport, environmental and health issues (£ billion)



Source: Air pollution: Defra (2015: 9, Table 5)
Congestion: European Commission (2016)
Road accidents: DfT (2015: 14)[5]
Carbon emissions: Author calculation based on DECC (2015) and DECC (2016)
Smoking: Action on Smoking and Health (2015)

Key messages

This latest evidence strengthens the case for action on air pollution. First, it aligns the focus for air quality compliance and public health concern – both particulate matter and nitrogen dioxide are estimated to have similar health impacts. Second, in the context of other public health issues, air pollution is responsible for a number of deaths equivalent to 60% of that associated with smoking, with a potentially higher societal cost. Third, the cost of air pollution is at least equivalent, if not considerably greater, than other negative impacts of transport such as congestion and road accidents, both of which have historically generated more attention from the transport community.

5 From 2016 DfT includes an additional measure to estimate the cost to society of unreported road accidents, resulting in a higher road accident costs.

3. Vehicle Emissions in the Real World

Managing and reducing emissions from transport is the central challenge in tackling air pollution and a key part to improving public health. In addressing this, the 2014 report identified the apparent mismatch between legislated emission limits (the Euro standards) and real-world vehicle performance as a key problem. Inasmuch as legislation was not delivering the necessary improvements in the real world, we asked why, and how this situation could be improved.

3.1 The challenge of vehicle emission in real-world conditions

Understanding and quantifying emissions from vehicles under actual driving conditions is a uniquely challenging problem. There are about 37.1 million road vehicles in the UK covering a diverse range of vehicle types, vehicle ages, fuel types, engine sizes and technologies. Additionally, these vehicles are driven and maintained differently, and their emissions also depend on environmental factors such as ambient temperature and road gradient. Moreover, the emissions themselves vary over both space and time, making their robust quantification very challenging.

In particular, we need to consider the difference between light-duty vehicles (cars and vans) and heavy-duty vehicles (buses and lorries). The emission legislation for these type groups of vehicles is somewhat different. Light-duty vehicles are subject to whole-vehicle tests and the relevant Euro standards are denoted by Arabic numerals (i.e. Euro 1 to 6), whereas heavy-duty vehicles are subject to engine tests, with the standards denoted by roman numerals (Euro I to VI). There are also slight differences between the dates of introduction of the emission standards for light- and heavy-duty vehicles.[6]

Since the 2014 report, interest in vehicle emissions, and in particular emissions of NO_x from diesel cars, has grown following the revelations about the use of emissions test ‘defeat’ devices by VW (and potentially other manufactures). The so-called dieselgate scandal has highlighted many of the known deficiencies in the vehicle emissions testing regime, including the way the legislation is interpreted, and has led to calls for planned improvements in the regime to be accelerated.

Over the next few years, as the latest Euro 6/VI vehicles are introduced, considerable changes to vehicle emission legislation and emission measurement will take place. These include the introduction of the new more stringent laboratory test procedures and on-road real-world testing. There is considerable interest in whether these new testing regimes, combined with the more widespread introduction of technologies such as selective catalytic reduction (SCR) and lean NO_x traps, will deliver the substantial reductions in NO_x required to improve ambient NO_2 concentrations.

3.2 Emission regulation and real-world emissions

The new testing regime for vehicle emissions includes on-road tests known as RDE, or Real Driving Emissions for light-duty vehicles (Euro 6), and in-service conformity for heavy-duty vehicles (Euro VI). These real-world tests represent a major shift in how vehicle emissions are quantified for type approval. The tests are in addition to the laboratory tests that take place over a new more stringent test cycle – the ‘Worldwide harmonized Light vehicles Test Procedure’ (WLTP) and its equivalent for heavy vehicles. The RDE and in-service conformity tests take place on real roads, with exhaust emissions measured using portable emission measurement systems (PEMS). While these tests can never be expected to cover the full range of actual driving conditions – which could, for example, include extremes of temperature and road gradient – they are designed as far as possible to represent the average driving conditions of the vast majority of drivers.

The Euro VI tests for new heavy-duty vehicles, including in-service conformity, came into force at the end of 2012. However, for light-duty vehicles the EU has adopted a staged approach to introducing Euro 6. The initial introduction of the new emission limits came in during 2014 for cars and in 2015 for vans. The RDE test (known as Euro 6c) is being implemented from September 2017 for new types of cars, and for all new registrations from September 2019. The details of the introduction of the WLTP test are still being finalised, but the proposal is for this to take place over the same timescale as that governing RDE tests.

6 The emissions legislation also has test procedures which differ for light- and heavy-duty vehicles. Similarly, there is separate legislation for motorcycles and off-road vehicles.

In relation to the real-world tests, the new legislation has also introduced the idea of 'conformity factors' (CFs). The idea of a CF is to have a 'not to exceed limit' with a value of 1, meaning the Euro 6 NO_x limit of 80 mg/km must be met over an RDE test. In practice it is not possible to ensure the equivalence of laboratory and real-road conditions, for a wide range of reasons – for example, PEMS readings are not as accurate as laboratory measurements. Because of these statistical and technical uncertainties, an allowance is made permitting the emissions measured over the RDE to be *higher* by up to a certain factor (the CF) than the emissions measured under laboratory conditions. For heavy-duty vehicles the CF has been set at 1.5, but for light-duty vehicles it is being phased in with an initial CF of 2.1 to be reduced to 1.5 by 2020 (European Parliament, 2016). In other words, even at the point when the RDE regulation – Euro 6c – is fully phased in, diesel passenger cars will be allowed to emit up to 50% more NO_x in a real-world test than the Euro 6 laboratory-based limit.

There is likely to be a lot of discussion over CFs in the coming years, focusing in particular on whether they are sufficiently stringent, particularly for light-duty vehicles. However, it is important to note that even with the CFs in place as currently planned, actual real-world driving emissions will be substantially reduced from those of Euro 5/V vehicles – and results obtained so far suggest that this seems to be the case, going on the measurements of emissions from Euro 6/VI vehicles which have already been designed to meet the new legislation. Additionally, it would be prudent for car manufacturers to set their design objectives comfortably below the legal limit in order to be certain of complying. The expectation is therefore that as manufacturers increasingly introduce RDE-compliant vehicles, the real-world emissions performance of vehicles will improve considerably.

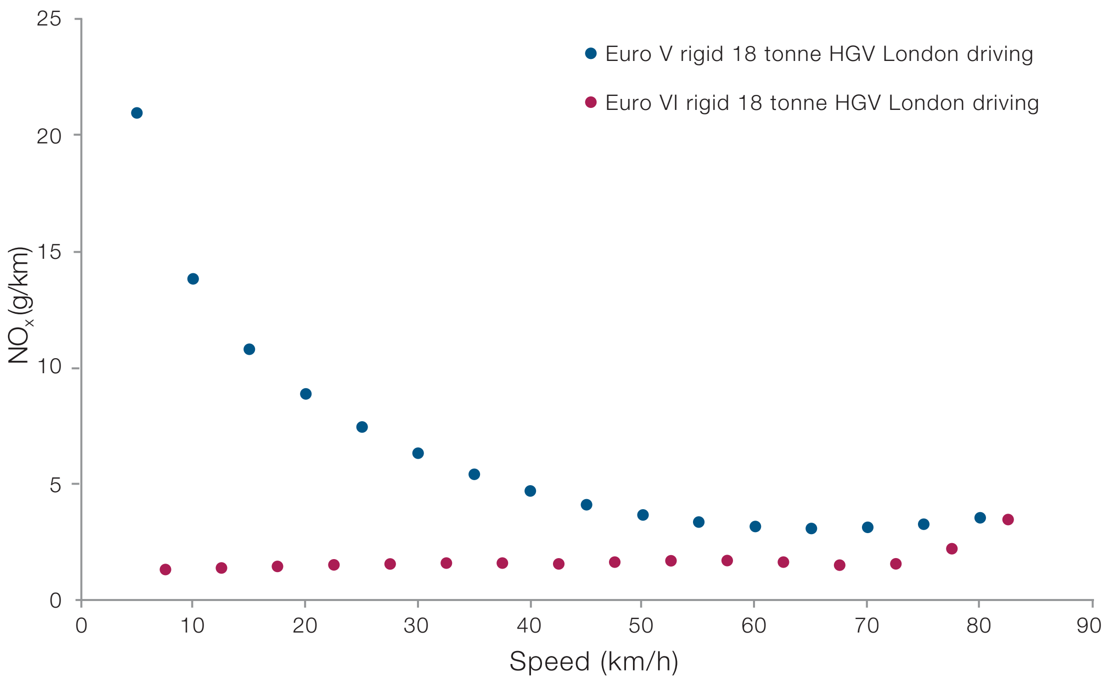
3.3 The latest evidence on real-world performance

It has been known for many years that there has been a mismatch between emissions from diesel vehicles over test-cycle laboratory conditions and those actually produced under real-world driving conditions. An increasing amount of work published has shown that the emissions of NO_x from diesel vehicles has not reduced by the amounts expected in line with changes in emission legislation. The lack of reduction in NO_x emissions from Euro 5 diesel passenger cars has been a particular focus and is now well established. There is therefore now an increased focus on measuring Euro 6/VI diesel NO_x and NO_2 emissions, to establish whether the new legislation really is closing the gap between test-cycle emissions and real-world emissions.

In relation to heavy-duty vehicles – lorries and buses – the evidence is that Euro VI, with its in-service conformity tests, has significantly improved real-world performance of these vehicles. Transport for London (TfL) has commissioned real-world testing on a London drive cycle for both buses and lorries (TfL, 2015). This showed that there was significant improvement of the Euro VI vehicles over the Euro V vehicles, as illustrated in Figure 3.1. This difference was most significant at lower speeds, indicating the improvement in operating in low-speed conditions typical of urban operation. A study by the Dutch research centre TNO (Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek – the Netherlands Organisation for Applied Scientific Research) (Vermeulen et al., 2014) showed similar improvements over Euro V vehicles. This study also included in-service conformity tests which showed CFs ranging from 1.5 up to 5 for Euro V vehicles compared to CFs of less than 1 achieved by the Euro VI vehicles. This indicates that the Euro VI vehicles are capable of very low real-world emissions, in line with or better than the legislated limits.

The main concern picked up in these tests with heavy-duty vehicles was some significant variation relating to engine load, with lightly loaded vehicles producing higher NO_x emissions than more heavily loaded vehicles. Although this is counter-intuitive, it is likely that the more heavily loaded vehicles are generating higher exhaust temperatures and so the emission control equipment (such as SCR) is working more effectively. There are also still some concerns about primary NO_2 as a proportion of NO_x, which can be as high as 40% but is very variable. However, given the very low levels of NO_x overall, the new regime should still deliver a very low emission of primary NO_2.

Figure 3.1: Comparison of Euro V and Euro VI 18-tonne rigid lorry on London Roads



Source: TfL (2015)
Note: Results are for 100% payload.

In terms of light-duty vehicles, as noted previously, the differences between legislated and real-world emissions have been brought into sharp focus over the revelation that VW was involved in the use of so-called defeat devices in some of their vehicles. Various governments, regulatory bodies and NGOs have conducted vehicle emissions tests, which have been reported over the past few months, in part as a response to the VW issue and a desire to better understand the levels of emissions from diesel passenger cars under a wider range of driving conditions. These tests have included those in the UK, France and Germany. The tests have focused for the most part on how emissions of NO_x vary when tested over the current NEDC (New European Drive Cycle) conditions and similar drive cycle patterns with different ambient and engine temperatures, and have involved a range of Euro 5 and Euro 6 vehicles.

The tests carried out recently by the Department for Transport (DfT, 2016) have been widely reported in the media and elsewhere, and have specifically investigated the evidence for defeat devices on a range of vehicles types. The DfT work confirmed the use of defeat device software in VW Group diesel cars (a Skoda), but found no evidence of similar practices being used by other manufacturers. The analysis of on-road emissions for Euro 5 vehicles showed that emissions of NO_x were about five times higher than those over the NEDC (i.e. in agreement with many other studies) and that the defeat-device vehicle was not the highest-emitting vehicle – pointing towards other more general causes for high on-road emissions.

Further vehicle emission remote-sensing measurements have also been reported, and are based on work carried out for Defra (Carslaw & Priestman, 2015). That work provided some of the first Euro 6 real-world emission measurements for diesel cars and showed that NO_x emissions were down by 40% compared with Euro 5. These results were, however, based on relatively few measurements (85 exhaust plume measurements) and were for Euro 6 cars that were introduced to the market early, i.e. before the date required by Euro 6 legislation. The Defra remote-sensing work also made comprehensive measurements of the TfL retrofitted optimised (low-NO_2) SCR Euro III buses in London (Carslaw et al., 2015a). The results showed that NO_x emissions were on average 45% less than those of similar buses without the optimised SCR systems, and – importantly – that direct emissions of NO_2 were 60% less. These reductions are encouraging, and would be expected to make significant contributions to vehicle emissions NO_x reduction in London.

So for light-duty diesel vehicles (cars and vans), the picture has been encouraging, if not as positive as for heavy-duty vehicles. These initial results from real-world emissions testing of early Euro 6 vehicles show that their real-world emissions performance for NO_x is typically about half that of Euro 5 vehicles; nevertheless, this is still some four times the legislated limit. However, as the Euro 6 legislation is phased in over the next few years (see Section 3.2) it is expected that Euro 6 vehicles – constrained by the Euro 6c (RDE) standard – will display much-improved real-world emissions performance.

In terms of how the recent emissions tests affect commonly used emission factors used in the compilation of local and national emission inventories, Ntziachristos et al. (2016) provide some up-to-date comparisons between real-world PEMS results and the emission factors used in the COPERT model.[7] The COPERT model forms the basis of vehicle emission factors used in the UK National Atmospheric Emissions Inventory (NAEI), part of the national air quality compliance assessment model, and Defra's Emissions Factors Toolkit used

7 COPERT (COmputer Program to calculate Emissions from Road Transport) is a road transport emissions calculation tool. Its development is co-ordinated by the European Environment Agency (EEA) and it is part of the EEA 'Air pollutant emission inventory guidebook'.

by local authorities in modelling air quality. Hence COPERT's ability to realistically predict real-world emissions is critical to the robustness of modelled air quality results, at both the national and local level.

The study came to several key conclusions. The first of these was that for Euro 5 diesel cars, existing emission factors used in COPERT are in good agreement with recent PEMS measurements, and that the COPERT emission factors for NO_x are already a factor of 4 to 5 higher than the legislative limit of 0.18 g/km. Second, the evidence does suggest, however, that the COPERT emission factors for Euro 6 diesel passenger cars and Euro 5 light-duty commercial diesel vehicles underestimate NO_x emissions by around a factor of two. Third, the study indicates that the emissions of NO_x for the current Euro 6 diesel cars can be highly variable, which is consistent with other evidence reporting the real-world driving emissions of NO_x from Euro 6 vehicles at the current time.

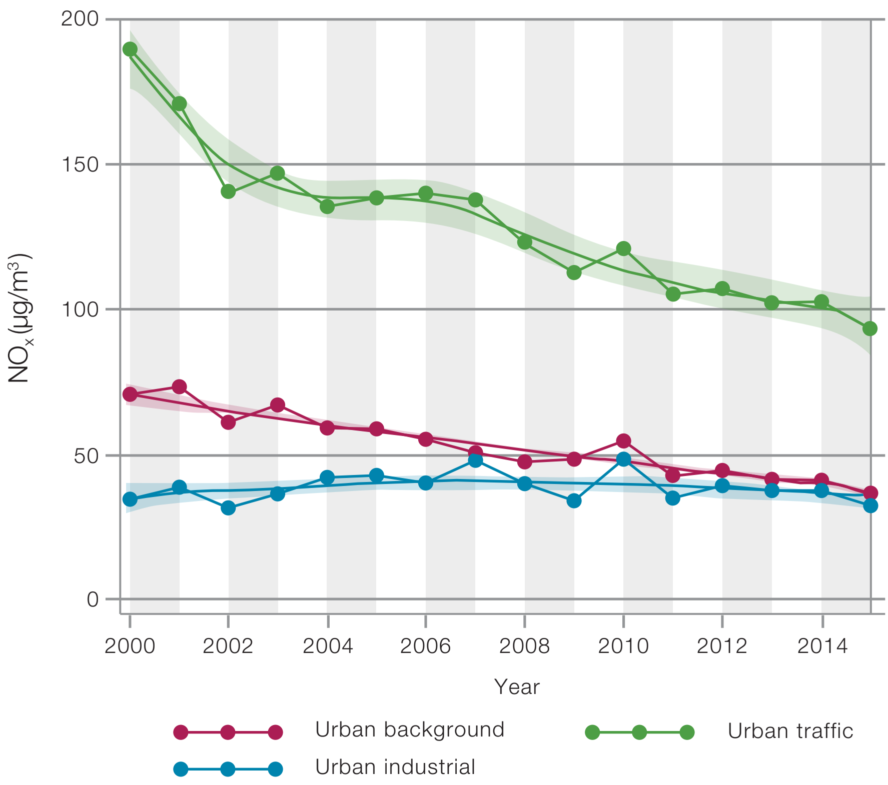
These results imply some uncertainly about the future projections of air quality in relation to the introduction of Euro 6 cars and vans, suggesting that emissions from these vehicles is being underestimated. In the light of this, further revisions to the emission factors model are needed, building on the real-world emissions data from a wide range of vehicle manufacturers and technologies that is becoming increasingly available. In relation to COPERT, a revised version is expected by the end of 2016.

3.4 The impact on pollution concentrations

Trends in air pollution provide the truth on the ground and the strongest evidence as to whether changes in vehicle emissions have had an appreciable impact on measured concentrations. Therefore it is important to understand the way that air pollution trends, specifically NO_x and NO_2 concentrations, are affected by changes in vehicle emissions over time. Both NO_x (combined NO and NO_2) and NO_2 need to be considered: NO_x is what is measured in terms of vehicle emission regulations and NO_2 is the pollutant for which health-based concentration limits are set. These pollutants are both measured by a network of national monitoring stations – the Automatic Urban and Rural Network (AURN). The AURN consists of over 100 sites in the UK covering suburban background sites, urban background sites, urban industrial sites and urban traffic sites.

Figure 3.2 shows the trends in concentrations of NO_x across the 119 AURN sites where data was available over the period 2000 to 2014. The trends have been averaged across each site type and provide an indication of the general change in concentrations of NO_x over the past 15 years for sites with at least five years of data. The plot shows that concentrations of NO_x have been steadily decreasing at urban traffic sites over the past five years but that there have also been periods where concentrations of NO_x have been stable, for example 2002–7 and 2011–14.

Figure 3.2: Trends in nitrogen oxide (NO_x) concentrations 2000–15 in the UK at AURN sites

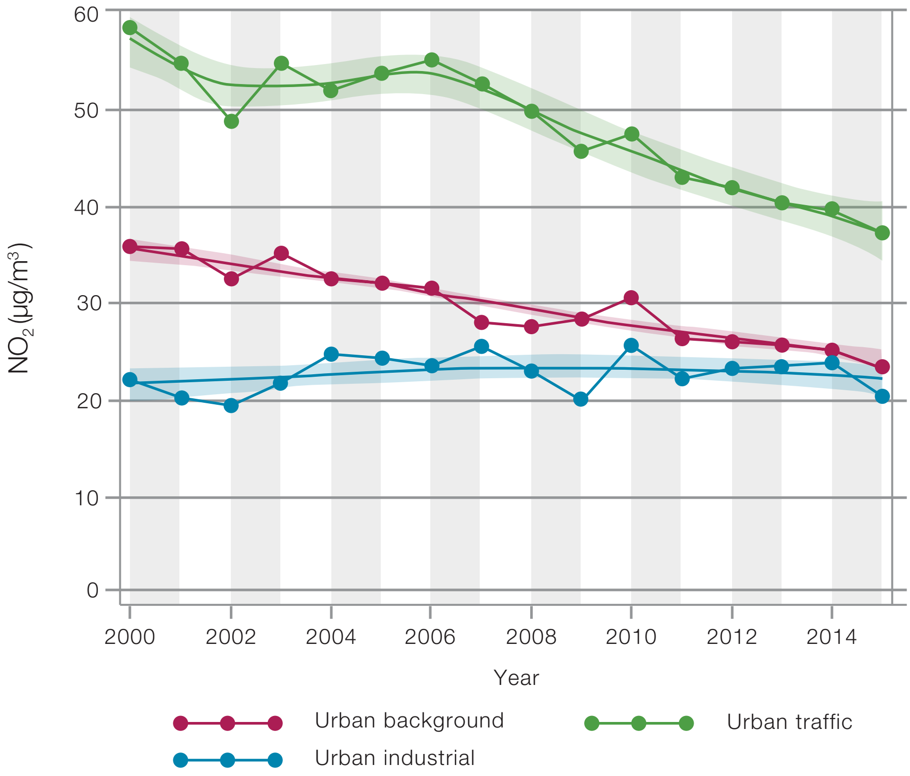


Source: based on data from AURN (2016)

The trends in concentrations of NO_2 (shown in Figure 3.3) differ from NO_x in that concentrations did not decrease by much between 2002 and 2010. The reason for a lack of decrease in NO_2 concentrations relative to NO_x over this period is very likely related to increased volumes of NO_2 emitted directly from diesel vehicles. However, since 2010 the data for urban traffic sites has shown consistent year-on-year decreases, suggesting reductions in both total NO_x and NO_2. In fact, the average NO_2 concentration at the roadside sites has decreased from well above 50µ/m³ in 2000 to just under 40µ/m³ (which is the European air quality limit for NO_2) in 2014, so the metrics are definitely moving in the right direction. However, it should be noted that these plots provide a broad overview by site type, and that there is considerable site-to-site variation, which reflects differing vehicle fleets and other influences. It is expected that the recent introduction of Euro 6/VI vehicles will become apparent in the NO_x and NO_2 trend data when data for 2016 is available and there are sufficient numbers of these vehicles in the parc.

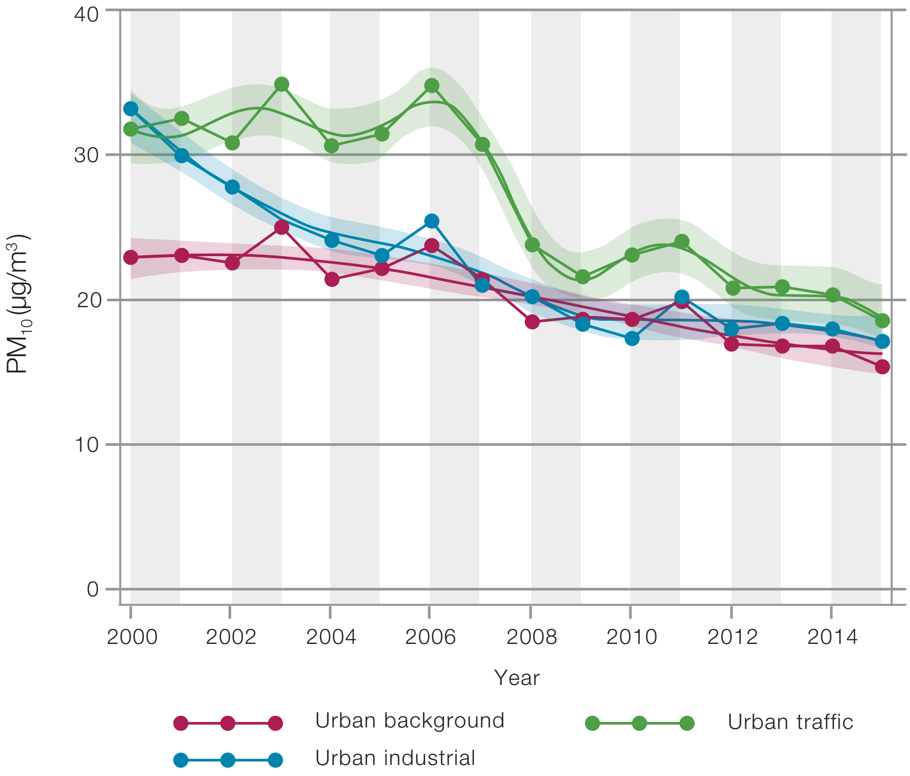
For completeness Figure 3.4 provides the data for coarse particulate matter (PM_{10}), which shows quite a different picture. In this case there is marked decrease in roadside concentration from 2006 to 2010, which most likely coincides with the introduction of diesel particulate filters (DPFs), initially in heavy-duty vehicles and then in light-duty cars and vans. This indicates that DPFs have been much more successful in reducing real-world PM emissions than technologies such as SCR have been in reducing NO_x emissions.

Figure 3.3: Trends in nitrogen dioxide (NO_2) concentrations 2000–15 in the UK at AURN sites



Source: based on data from AURN (2016)

Figure 3.4: Trends in coarse particulate matter (PM_{10}) concentrations 2000–2015 in the UK at AURN sites



Source: based on data from AURN (2016)

The other aspect to note for all air pollution trend plots for NO_x, NO_2 and PM_{10} is that there is convergence between the traffic site concentrations and urban background concentrations. This is most marked for coarse particulate matter, PM_{10}, where all sites are now averaging at a similar level. In other words, as the measured level of pollutants in the background measurements have continued to fall, the levels where road traffic is concentrated have been falling rapidly and are now at or around the same level as the general background, demonstrating that in general vehicle emissions are decreasing.

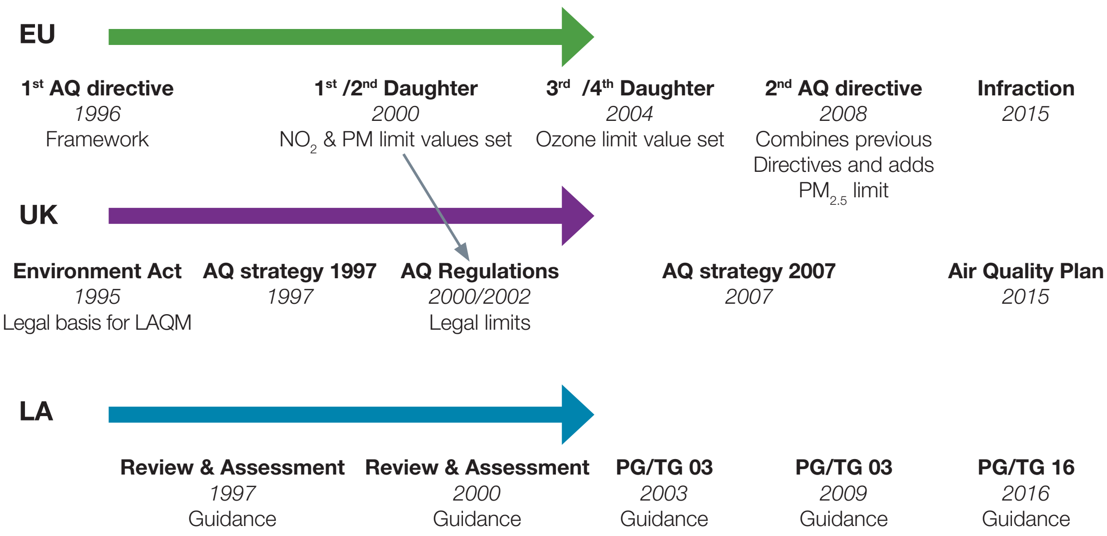
Key messages

There has been a gap between emission legislation and the real-world performance of vehicles, which is one of the reasons why air pollution levels have remained higher than expected in our towns and cities. The issue has related to diesel vehicles, and particularly diesel cars. To tackle this problem, new test procedures are being introduced which include real-world emissions tests. The benefits of this are already being seen in the case of heavy-duty vehicles. With light-duty vehicles the new test procedures are being phased in more slowly, with the full real-world tests not coming into force until 2020. Thus it is not until 2020 that we would expect all new diesel vehicles to be producing emissions in real-world conditions that match the legislated limits. The good news is that although improvements in air quality are happening more slowly than expected, the metrics are definitely moving in the right direction.

4. The Government's Approach to Tackling Air Pollution and Improving Health

The UK government's history in development of policies and regulations to tackle air pollution and related health issues goes back to the Clean Air Act 1956 (which is still in place today). The current air quality regulations and the health-based air quality limits have been in place since the mid-1990s. The development of these policies and regulations in the UK has gone hand in hand with those at the European level, as illustrated in Figure 4.1. The health-based air quality limits have been developed through the European Air Quality Directives (AQDs) and transposed into the UK regulations (see Box 2). Alongside this, the UK's Environment Act 1995 provides the basis for air quality action in the UK and places the requirement on local authorities to manage air quality in their areas.

Figure 4.1: Development of air quality regulation in the EU and UK



Source: Author's own

Note: PG – Policy Guidance; TG – Technical Guidance.

Box 2 Air quality limit values

Health-based air quality limits have been established for the EU, and are closely related to the recommendations by WHO.

Pollutant	Averaging period	Concentration	
		EU limit	WHO guidelines*
PM_{10}	24-hour mean	50 µg/m³	50 µg/m³
	Annual mean	40 µg/m³	20 µg/m³
$PM_{2.5}$	Annual mean	25 µg/m³ **	10 µg/m³
Ozone	Daily 8-hour mean	120 µg/m³	100 µg/m³
Nitrogen dioxide (NO_2)	Hourly mean	200 µg/m³	200 µg/m³
	Annual mean	40 µg/m³	40 µg/m³

Source: European Commission (2008)

Notes:

* WHO (2005)

** The $PM_{2.5}$ value is introduced in the new directive and is based on the average exposure indicator (AEI).

Progress has been made on reducing air pollution over the two decades since the regulations were introduced, but the UK is still failing to meet legally binding air quality limits in many areas. The UK's compliance with the European AQD is assessed by monitoring and modelling air pollution in each of the 43 zones covering the country (Hitchcock et al., 2014a; 12). If any areas or roads in the zone have air pollution levels higher than the limit values, then the zone is deemed to in breach of the Directive. The latest compliance assessment showed that 31 zones failed to meet the assessment criteria in 2013 in relation to NO_2, based on measured and modelled data. What is more, future national modelling results suggested that eight zones will still fail to comply by 2020 (Defra, 2015a: 10 para 42). This is against a requirement to comply with the Directive by 2010, subsequently extended to 2015.

In response to the failure to meet the requirements of the European AQD, an environmental lobby group, Client Earth, took independent legal action against the Government in 2015. This resulted in judgment at the Supreme Court against the Secretary of State for the Environment, ruling that new air quality plans be produced to bring air pollution down to legal levels in the “shortest possible time”. In addition, the European Commission also started infraction proceedings against the UK Government in relation to the AQD and required that a new plan of action be submitted no later than the end of 2015. This led the Government to set out a new air quality plan, focused on meeting NO_2 limits, that was released at the end of last year (2015). Alongside this, the Government has also been updating its approach to working with local authorities and managing air quality at the local level – the Local Air Quality Management (LAQM) regime.

4.1 The new National Air Quality Plan

The National Air Quality Plan is targeted at NO_2 compliance in relation to the EU’s AQD, and sets out existing and additional measures to bring non-compliant zones below the limit values by 2020. The exception is in London, where compliance is not expected until 2025. The plan focuses in particular on the areas of non-compliance covering the cities of Birmingham, Leeds, Southampton, Nottingham and Derby. These cities will be required to introduce Clean Air Zones (CAZs) designed to discourage the most polluting vehicles from entering the cities.

CAZs will essentially comprise two components: a charging component that will provide the ability to levy a charge on vehicles for entering the city if they do not meet specific emission levels; and a non-charging component consisting of a wider package of measures to promote ultra-low and zero emission vehicles. The legal basis for introducing a charging CAZ is set out in the Transport Act 2000. Part III of the Act empowers local authorities (as “charging authorities”) to make a local charging scheme in respect of the use or keeping of motor vehicles on roads. Draft secondary legislation has been prepared by the Government to support the use of charging powers in relation to meeting air quality objectives (Defra, 2016b).

The minimum vehicle standards for charging CAZs have been set in relation to the European Vehicle Emission standards (Euro standards): Euro VI for buses, coaches and heavy goods vehicles (HGVs) and either Euro 6 diesel or Euro 4 petrol for cars and vans. The distinction between diesel and petrol for cars and vans reflect the fact that the Euro 4 NO_x limits for petrol are as low as the Euro 6 limits for diesel. The charging CAZs have also been defined in term of classes in respect of which vehicle types are covered, as shown in Table 4.1, with each successive class of zone applying to all vehicle types covered by the previously defined class plus one more type. Hence, only a Class D CAZ would apply restrictions to cars.

The formal requirements will be for Derby, Nottingham and Southampton to implement class B charging CAZs and Birmingham and Leeds to implement class C charging CAZs. London is already committed to its Ultra Low Emission Zone (ULEZ), which is essentially a Class D charging CAZ. In addition, the framework for CAZs can be adopted by any city in the UK, either as a charging or non-charging although there is no obligation or requirement for them to do so.

It is important to note that none of the cities, except London, are required to implement a Class D CAZ which would cover passenger cars, although they do have the flexibility to do this if they wish. For this reason it is likely that all the CAZs outside London will target commercial vehicles rather than private vehicles. This is principally a pragmatic approach, since although diesel cars are an equal part of the problem, they are practically and politically harder to tackle. It is easier to deal with buses and taxis first, as local authorities have most control over these (for example through taxi licensing powers); then HGVs, as there are fewer of them, and most of them will meet the standards anyway by 2020, meaning that it is just the 'rump' that remains to be tackled; and lastly vans and cars, many of which are owned by a large number of small business or individuals. In most cases it is likely that the air pollution limit values can be achieved by taking on no more than the first two or three groups (i.e. by instituting class A, B and C CAZs) without having to consider cars (Class D zones).

Table 4.1: Clean Air Zone Classes

Clean Air Zone Class	Vehicles included	Emission standards	Cities affected
A	Buses, coaches and taxis	Euro VI standard	(none)
B	Buses, coaches, taxis and HGVs	As above but taxis either Euro 6 for diesel or Euro 4 for petrol	Derby, Nottingham, Southampton
C	Buses, coaches, taxis, HGVs and vans	As above but vans either Euro 6 for diesel or Euro 4 for petrol	Birmingham, Leeds
D	Buses, coaches, taxis, HGVs, vans and cars	As above but cars either Euro 6 for diesel or Euro 4 for petrol	The London ULEZ

Source: based on Defra (2015a)

Those cities which are not formally required to implement CAZs will have the flexibility to do so nevertheless, primarily as a non-charged scheme focusing on measures to promote ultra-low emission vehicles but also potentially as a more formal charged scheme given secretary of state approval. However, any local authority that is considering a non-charged scheme is encouraged to use existing powers such taxi licencing, road traffic regulation orders or differential parking charges within the CAZ to discourage vehicles that do not meet the CAZ standards set out in Table 4.1 above. This has already been done by some authorities, for example in Oxford and Brighton in relation to bus Low Emission Zones. Further details on such vehicle-restricted areas were set out in section 4.3.2 on Low Emission Zones (LEZs) in the 2014 report (Hitchcock et al., 2014: 82–84).

Currently the definition of CAZs in relation to taxis and cars does not take into account the phased implementation of Euro 6 in terms of RDE compliance (as described in Chapter 3). This means that the full benefit of Euro 6 regulations, in relation to CAZs, will not been seen until new diesel cars compliant with Euro 6c (the RDE test) enter service around 2020 and fully penetrate the car parc approximately ten years after this.

Lastly, even the charging CAZs are expected to comprise more than merely the establishment of a defined area which vehicles are levied a charge to enter, with the clear expectation being that there will be a suite of complementary measures to ensure good accessibility and a thriving economy, as well as supporting the wider uptake of ULEVs. This might include recharging infrastructure for electric vehicles (EVs), planning conditions which promote the use of LEVs in new developments, reducing parking charges for LEVs, and improvements designed to encourage walking, cycling and public transport use.

4.2 Managing air quality at the local level

The LAQM regime, as set out in the Environment Act 1995, focuses on local hotspots – local authorities have the duty to assess air quality in these areas using both monitoring and modelling tools. Where breaches of the air quality limit values are identified, they must declare an AQMA and put in place an Air Quality Action Plan (AQAP) targeted at reducing air pollution in the AQMA. The AQMAs differ from the compliance zones defined in relation to the European Directive (see the start of this chapter) in that they cover *only* the specific very local areas where the air quality limits are exceeded. Currently there are some 600 AQMAs defined across our towns and cities in the UK (Defra, 2016). The majority of these have been defined because of breaches of the NO_2 limit, with the main source of contributing emissions being identified as road traffic.

Government has been reviewing and consulting on improving the approach to LAQM. With LAQM in place for some 20 years now, it is considered that the principal areas where air quality problems exist have, by now, all been identified and assessed. Therefore, the main focus for the future is to support local authorities in taking effective action to tackle the problem of improving local air quality, whilst supporting wider compliance with the European Directive.

After a lengthy consultation process, the final updated guidance to local authorities on LAQM was issued earlier in 2016. The key changes to the guidance covered:

- focusing activity on actions rather than monitoring and assessment;
- a greater emphasis on involvement from all local government departments to support action;
- a new objective in relation to the fine fraction $PM_{2.5}$ in order to build stronger links with public health priorities; and
- streamlined reporting, focused on action and aligning with EU reporting requirements.

The first two of these are perhaps the most significant, recognising firstly that many air quality problems are locally specific and need local solutions, albeit support by national action, and secondly that while the air quality duty (in relation to the Environment Act 1995) sits with environmental health departments, the solutions sit with transport, planning and other departments. Air quality thus needs to be embedded as a consideration in all areas of council policy, especially those relating to transport and public health.

The inclusion of the new $PM_{2.5}$ objective in the LAQM guidance helps to further link the air quality and public health debates. In recognition of this, the Department of Health has asked the National Institute for Health and Care Excellence (NICE) to produce guidance on how local authorities can reduce exposure to air pollution from road traffic. This guidance will also be used to develop a NICE quality standard on air pollution.

In terms of action at the local level, the guidance provided by Defra (2016b: 24, para 8.5) sets out three core groups of measures that can be developed by local authorities to reduce transport emissions:

- **reducing traffic levels** – through investment in and promotion of alternatives to the car such as walking, cycling and public transport;
- **improving traffic flows** – using traffic management techniques, road layout and design, and technology such as intelligent transport systems; and
- **promoting LEVs** – through investment in infrastructure and vehicles, and incentives such as reduced parking tariffs and promotional activities.

The guidance states that the bulk of these measures should be delivered through and integrated with the local transport plan (LTP) that sets out transport objectives and spending at the local level. The first two groups of measures already sit comfortably in the LTP being measures that align with other transport objectives such as tackling congestion and improving accessibility. The last group might not have featured traditionally in plans focused on accessibility, but can be supported through complementary policies in areas such as planning and local development, for example requiring a certain level of EV recharging infrastructure in new developments.

DfT and Defra have established a single combined unit to focus on air quality, with links to the initiatives promoted by the joint Office for Low Emission Vehicles aimed at supporting the uptake of low and ultra-low-emission vehicles (ULEVs). To date there have been a number of different funding streams available to local authorities to help fund measures to reduce emissions from vehicles, such as the Green Bus Fund. Most recently, the Government has provided funding to four cities to act as exemplar low-emission cities. The four core Go Ultra Low cities are London, Milton Keynes, Bristol and Nottingham. Some £25 million has been allocated to these cities to support investment in EV recharging infrastructure, low-emission parking and priority schemes, with the remainder of the £40 million total going to fund promotional activities such as the opening of an ‘Electric Vehicle Experience Centre’ (which will extend its activities to loaning ULEVs) in Milton Keynes, which also intends to make mass provision of free parking for EVs and give them many of the privileges of buses (DfT, 2016a).

4.3 Developments in London

London has the worst air quality in the UK, and arguably some of the worst air in Europe. The London Assembly estimates that 9,500 people die prematurely from air pollution in the capital each year and that the cost of air pollution to the city's economy is potentially as much as £3.7 billion annually (Walton et al., 2015: 8). Being in such an unenviable position, the city has led the way in terms of measures to tackle air pollution. The key actions in hand to reduce emissions from transport include:

- the introduction of the London LEZ in 2008, which was the first in the UK and one of the first in Europe – this has subsequently been developed, and the city is now committed to the introduction of a ULEZ (equivalent to a Class D CAZ) in 2020;
- making significant investment in improving the bus fleet to reduce emissions, which includes:
  - retrofitting older buses with NO_x reduction technology (SCR) and particulate filters;
  - investing in hybrid buses, setting a target of 1,700 such buses (some 20% of the fleet) by the end of 2016; and
  - commitment to providing 300 zero-emission electric or hydrogen buses by 2020;
- establishing age limits for all taxis in London, and requiring that all new taxis from 2018 be zero-emission capable; and
- providing support for low- and zero-emission vehicles, principally in the form of EV recharging infrastructure, through the ULEV delivery plan.

The new Mayor of London, elected in 2016, set out proposals for further action on air pollution in July 2016. The most significant elements of his proposals were:

- expanding the ULEZ beyond central London and implementing it a year earlier than required by the previous commitment, in 2019;
- introducing an emissions surcharge for pre-Euro 4 vehicles entering the central London Congestion Charging zone from 2017 onwards, as an interim step before the ULEZ is introduced – this would be a £10 additional charge on top of the existing Congestion Charge; and
- considering a diesel scrappage scheme for older diesel vehicles, within a national scheme.

The aim of these new measures is to bring forward the expected compliance date for NO_2 concentrations and achieve this ahead of the Government's estimated date of 2025.

The RAC Foundation (Lawson & Gomm, 2016) has considered the potential of a national diesel scrappage scheme. The authors concluded that the costs involved in a scheme that would secure a significant decrease in NO_2 emissions would be substantial, and certainly more than those of the 2009–10 scrappage scheme introduced to support the automotive industry. They also queried whether a nationwide scheme would be able to effectively target those cars travelling high mileages in areas of poor air quality and whether it would be practical, or even possible, to maximise NO_2 reduction by ensuring replacement vehicles were zero-emission.

Key messages

Taking action to improve air quality in the UK is a growing political imperative, one that is driven by the recognition of slower-than-expected progress over the last two decades and further compounded by direct legal challenges from the European Commission and lobby groups such as Client Earth. A crucial element of the Government's approach to meeting air quality limits is the introduction of Clean Air Zones in five cities across the UK by 2020. These zones will focus on commercial vehicles (buses, lorries and taxis) and will levy a charge on vehicles not meeting the Euro 6/VI emission standard for entering the zone. Passenger cars will be unaffected except in London, where the Ultra Low Emission Zone is being introduced. Other cities will also be taking action, but this is likely to focus on measures to encourage the use of low- and zero-emission vehicles and reduce reliance on car use, rather than seeking to restrict access to pre-Euro 6 passenger cars.

5. What This Means for the Motorist

So where are we now, and what does this mean for the individual motorist?

In essence, the main problems relating to air pollution and transport remain as set out in the 2014 report. Since then, significant attention has been generated by the dieselgate scandal, raising awareness about how manufacturers have interpreted the existing regulations, and the question of whether more could be done – more quickly – in the face of recent improved understanding of the health implications of poor air quality. This, combined with the legal challenges emanating from the European Commission and Client Earth, is driving changes within both public policy and industry that will have an impact on the vehicles we buy and on the air we breathe.

Emissions from road transport are still the primary cause of air pollution in our towns and cities, and whilst the situation is improving, it is not doing so as quickly as legislators had hoped. Unsurprisingly, exposure to poor air quality is highest where traffic density is high, in particular in congested town and city centres, but also where there are high traffic volumes on through routes.

One of the main reasons that air quality has improved more slowly than expected is that vehicle emissions have not reduced as much in real-world conditions as they have over the legislated test cycle. This is specifically the case for NO_x emissions from diesel vehicles. However, changes to the type-approval testing regime for HGVs appear to be delivering good results for the latest Euro VI vehicles. The regime for cars is also changing, but more slowly: the introduction of RDE tests will not be fully implemented for new cars until 2020. At the average rate of turnover of the vehicle parc, this means that the full benefits of the new regime will not be fully felt for another ten years or so after 2020.

The goal of much of national policy is therefore to remove as quickly as possible from the vehicle parc the older more-polluting diesel vehicles, and to replace them with new low- or zero-emission vehicles. This is the aim of the proposed CAZs. Charging CAZs will only be formally required in five cities, and are targeted at commercial vehicles rather than the private motorist. The exception to this is the ULEZ in London, which will also tackle private cars and likely to be extended beyond the current Congestion Charging Zone.

Alongside these charging based schemes, we will see additional actions from both government and local authorities to encourage drivers to adopt low- and zero-emission vehicles. Financial incentives already exist, for example in the form of plug-in vehicle grants to encourage the uptake of EVs. There is also considerable investment taking place in the expansion and improvement of EV recharging infrastructure. We are also likely to see more incentive schemes such as reduced parking rates for ULEVs, ULEV lanes and promotional activities being developed in cities across the country.

5.1 Choosing the right vehicle

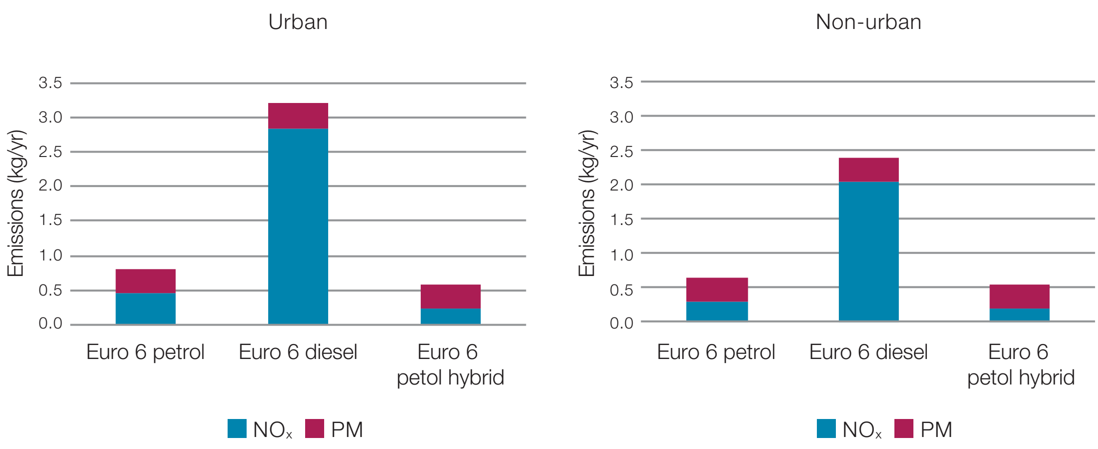
In relation to this policy direction, the greatest pressure will be on commercial fleets to review their purchase decisions and move to low- and zero-emission vehicles. In areas where charges may apply – such as the London ULEZ and the CAZs – there will be a direct financial incentive to populate these fleets with newer LEVs. For private motorists, measures from national and local government to encourage change will be more indirect, but will include provision of a range of incentives and information for them to consider when choosing a vehicle.

When it comes to petrol and diesel cars, there is clearly a difference in emissions and also in the associated cost of the respective health impacts (the 'damage costs') of these emissions as illustrated, for cars, in Figure 5.1 and Figure 5.2. The estimated combined NO_x and PM emissions (in urban conditions) of a diesel car bought today is likely to be three times higher than the figure for a new petrol car, with the biggest difference being in terms of NO_x emissions. Converting these to damage costs using Defra's latest damage cost data yields a social cost for driving a typical petrol car in urban conditions of around £40 per year, compared to £120 per year for a diesel car. The petrol hybrid car provides a further benefit in emissions over the diesel.

In non-urban conditions, emissions are slightly less than in urban driving, but damage costs are significantly less. The reduction in these costs is due to lower levels of human exposure resulting from the emissions being generated in areas of less dense population. Further, in non-urban areas the benefits of hybrids are less marked.

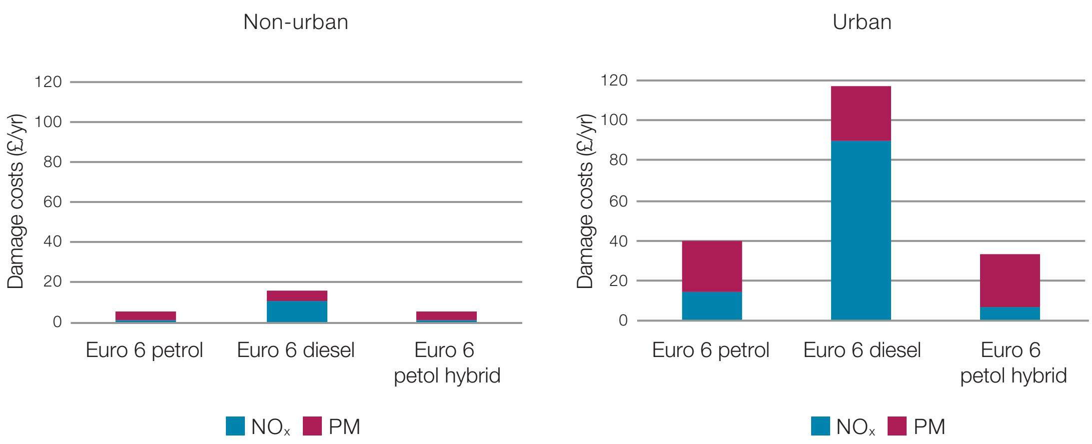
Looking ahead to 2020, the relative difference between new petrol and diesel cars will reduce as the RDE regulations come into play. However, even then, because of the allowances of the CF, a diesel car is likely to produce around twice the level of NO_x and PM emissions as a petrol car.

Figure 5.1: Estimated annual emissions for new petrol and diesel cars in the UK



Source: Ricardo Energy & Environment calculations based on COPERT 4.11 emission factors, with urban speeds at 30 km/h and non-urban speeds at 60 km/h, and 12,000 km per year

Figure 5.2: Estimated annual damage costs for new petrol and diesel cars in the UK



Source: Ricardo Energy & Environment calculations based on emission data in Figure 5.1 and Defra NO_x and PM damage costs for a big urban area and rural areas

The key message from this is that when driving principally in urban areas and agglomerations, the use of petrol cars – and particularly hybrids – rather than diesel cars will generate significant air quality benefits. However, where driving activities are undertaken in non-urban conditions, for example rural or motorway settings, then the benefits of diesel cars, such as improved fuel economy and towing ability, can outweigh their air quality disbenefits. As already noted, the issue is not just *what* pollutants are being emitted, but *where* this is occurring – a vehicle largely used in a rural environment is unlikely to be contributing in any significant way to a deterioration in air quality that would have an impact on human health.

The main alternative to petrol and diesel vehicles that is being promoted, particularly in urban areas, is the battery electric vehicle. There is now a wide variety of models available, and their range between charges is increasingly making them appropriate for many peoples' day-to-day journeys. In addition, there has been significant investment in the EV recharging infrastructure both by national and local government, providing the opportunity to charge EVs at a much wider range of locations. And with existing grants, such as the government's Plug-in Car Grant (and Plug-in Van Grant), taken with zero-rated Vehicle Excise Duty, they are becoming cost effective when compared with conventional petrol and diesel vehicles. Figures produced for the Government's Go Ultra Low initiative estimate that over a three-year ownership period an EV will cost the same as a petrol or diesel vehicle when upfront and running costs are taken into consideration.[8] With a battery lease option for an EV, they can work out even cheaper than a petrol or diesel vehicle.

Where range is more of a concern, for example in the case of long trips, then plug-in hybrid or range-extended electric vehicles, which combine an electric and international combustion engine power train, can be considered. These vehicles are currently more expensive than conventionally powered ones, but can provide the best of both worlds: zero-emission operation where necessary, coupled with the confidence of the additional range provided by a combustion engine.

5.2 Responsible vehicle ownership

Complementing the efforts to promote the use of low- and zero-emission vehicles is the need to use vehicles responsibly and appropriately. Driving vehicles efficiently and reducing their use by exploiting other modes such as walking, cycling and public transport will have multiple benefits: reduced emissions, reduced congestion and improved physical activity/health. Local authorities are working to improve the infrastructure that supports these alternative modes and to provide information so that people can make informed decisions about their travel choices.

Whatever the vehicle in question, driving it in the most efficient enables the user to reduce its emissions and fuel use, and save some money at the same time. Better driving styles can also reduce other aspects of a vehicle's running cost, and contribute to improved safety

8 https://www.goultralow.com/wp-content/uploads/2014/01/cost_comparison_table.pdf

on our roads. The Energy Saving Trust provides an abundance of useful information to help motorists and fleets make the most of their vehicles (see Box 3). This topic is also explored in an RAC Foundation report on eco-driving (Wengraf, 2012).

Box 3 Smarter driving tips

- *Switch off your engine* – Many newer cars automatically turn off when stationary in neutral. If yours doesn't, turn off your engine when you've stopped for a minute or so to save fuel.
- *Higher gear* – Driving at lower revs reduces fuel consumption, so change up a gear at around 2,000 rpm.
- *Drive smoothly* – Assess the road ahead as much as possible to avoid unnecessary braking and acceleration, which increases the amount of fuel you use.
- Slow down – Your fuel costs will increase the faster you drive, so keep speeds reasonable.
- *Windows vs air conditioning* – If you are travelling at low speed, opening the windows is more efficient. If travelling at 60 mph or above, closing the windows and using the air con will save you more.
- *Tyre pressures* – Under-inflated tyres increase your fuel consumption and can be dangerous on the road, so check them once a month and before long journeys.
- Roof racks/boxes – Having these attached to your car when they're not being used will increase drag and increase your fuel costs.
- *Lighten your load* – Remove excess items from your car before travelling to reduce weight.

Source: www.energysavingtrust.org.uk/travel/driving-advice

We also need to bear in mind that few motorists restrict themselves to that mode of transport – many will also walk, cycle and/or use public transport. There can be a tendency to 'hop in the car' too readily without thinking, when upon consideration other options may be more practical or appropriate. In urban areas at peak times, particularly over relatively short distances, the car will generally be the most *inefficient* transport mode, using more fuel and generating more emissions per passenger-kilometre, not to mention its much smaller capacity than public transport (European Commission, 2016). However, in off-peak times or in suburban areas, when demand for mobility is much lower (and hence congestion less severe), and where public transport services are typically less regular, then passenger cars have a role to play in an effective urban transport system.

When it comes to many of the shortest trips, walking and cycling can be the most practical option for those who are still physically active – and these 'active travel' modes also contribute to improved health. This is another area where the public health and the air quality agendas are aligned, along with other transport objectives such as congestion reduction. Joint working to support walking and cycling is now increasingly common between public health, transport and air quality departments.

The ‘aggregation of marginal gains’ applies in this instance – small changes by individuals and fleets, all taken together, can add up to a large overall effect Reducing air pollution, emissions, or any other statistic in this field by 20% would be considered a significant achievement, but it is worth reflecting that this is the gain obtained by anyone who manages to use a zero-emission mode of transport, such as walking or cycling, for just one of their five working days every week. Improved driving techniques have been shown, moreover, to reduce average car fuel use and associated costs by as much as 8% (EST, 2012: 8).

Key messages

It makes sense to think about both the vehicles that we choose to buy, and the way in which we then choose to use them. More information is now becoming available about the real-world performance of different models, even before the significant improvements in standards and testing cycles that will come with the introduction of Euro 6c. The perceived fuel economy benefits of the diesel engine warrant a closer look – the payback period might be longer than at first apparent; that said, for certain patterns of driving such as long distances at motorway speeds or hauling heavy loads, the diesel might still offer an advantage. Meanwhile, electric and hybrid vehicles are becoming more widely available, the range of battery vehicles is extending, and the network for recharging is becoming more comprehensive.

For many people, access to a car means access to employment opportunities and to retail and other services. On the other hand, much work is being done to make the alternatives attractive for at least some kinds of trips: improvements in public transport information, secure cycle parking, and better provision for pedestrians, to name but three.

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RAC Foundation
89–91 Pall Mall
London
SW1Y 5HS

Tel no: 020 7747 3445
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