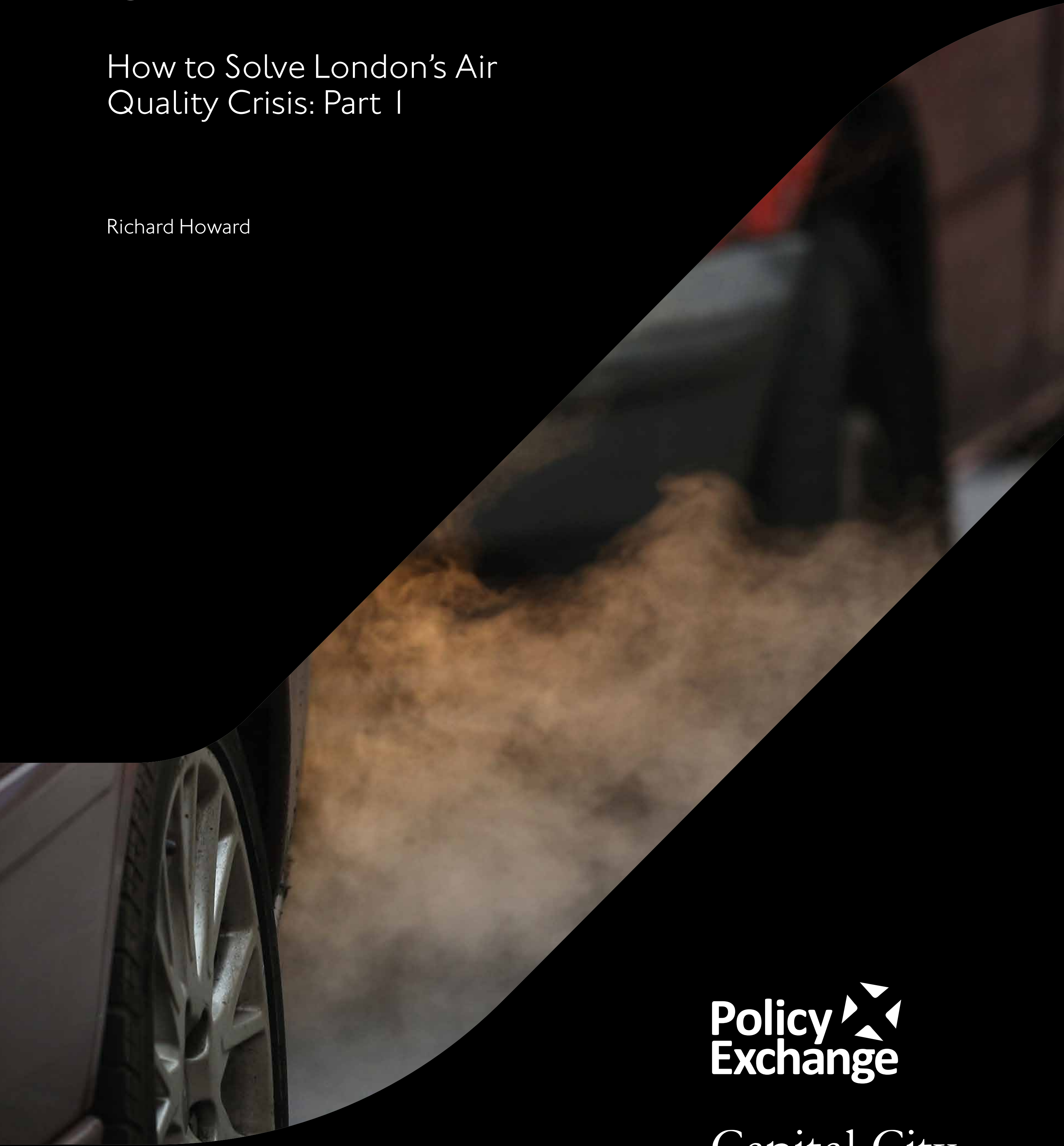
UP IN THE AIR

How to Solve London's Air Quality Crisis: Part 1

Richard Howard



Policy Exchange

Capital City Foundation

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Acknowledgements

This report was produced by Policy Exchange in partnership with King's College London. We would like to thank Drs Sean Beevers, David Dajnak and Heather Walton and Professor Frank Kelly at King's College London for their substantial input into this project. We would also like to thank Trust for London, Bloomberg Philanthropies, City of London Corporation, the Liebreich Foundation, and Calor Gas Ltd for their generous support for this research.

Thanks also go to Simon Birkett (Clean Air in London) and Ruth Calderwood (City of London Corporation), who kindly reviewed and commented on this report, as well as all of those who gave their time and expertise to inform this research.

Any errors that remain, and the conclusions of the report, are the author's own.

Executive Summary

In simple terms, London's air is unhealthy to breathe, and more needs to be done about it. Air pollution is arguably the most significant environmental issue facing London, as well as one of the most significant public health issues. It is consistently identified by Londoners as one of their top environmental concerns,[1] and over two thirds (69%) of Londoners think that the government is not doing enough to tackle it.[2]

Air pollution is an enormously challenging issue, and has vexed policymakers in London for centuries. As early as 1285, fumes from coal burning in London were considered so serious that the world's first air pollution commission was created. Fast forward to the 1950s, and London was experiencing regular "pea soupers", with the Great Smog of 1952 killing around 4,000 people.[3] London's air pollution problem is less visible than in the past, and the nature of the problem has changed, with the coal smoke of the past being replaced by nitrogen oxides from diesel fumes, gas boilers, and other sources.

There has been an increasing focus on the issue of air pollution by successive London Mayors as well as Central Government. London is already taking action to tackle air pollution on a number of fronts, for example through the Low Emission Zone and Congestion Charge Zone, investments in the bus fleet, restrictions on older taxis, investment in public transport, and regulations to address emissions from construction sites and new developments. Recently, the Mayor of London has also proposed the introduction of an Ultra Low Emission Zone (ULEZ) in 2020, covering all vehicles in Central London. However, air pollution in London remains well above legal limits (UK and European) and gives rise to significant health impacts. There is a recognition that more needs to be done to tackle the issue, and air pollution is becoming one of the key issues in the run up to the London Mayoral elections in 2016.

This report, the first in a series of two reports on air pollution in London, considers the moral, legal and economic case for doing more to tackle air pollution. We show that despite the growing focus on the issue in recent years, current and planned policies are unlikely to deliver compliance with air quality limits in London until at least 2025. We also outline the health and economic benefits of taking further steps to tackle air pollution. Our next report will consider specific policy proposals in more detail.

The Case for Improving Air Quality in London

Levels of nitrogen dioxide (NO_2) are well above European legal limits in large parts of London, as well as many other parts of the UK. NO_2, which arises from the combustion of fossil fuels, causes lung irritation and increases the chance of respiratory infections, and long term exposure has been linked to premature death.

London also has high levels of particulate matter (PM), which comprises fine particles of dust, soot and other materials. PM levels in London are now within European legal limits, but are still above World Health Organisation (WHO) guideline levels in most of Greater London. Exposure to PM pollution is linked to asthma, lung cancer, and respiratory and cardiovascular diseases.

Research by King's College London estimated that air pollution was **responsible for up to 141,000 life years lost or the equivalent of up to 9,400 deaths in London in 2010, as well as over 3,400 hospital admissions**.[4] The total economic cost associated with this was estimated at £3.7 billion. The scope for improving public health through improving air quality is enormous: far greater than for reducing passive smoking or eliminating road traffic accidents.[5] **Our analysis suggests that if current and planned policies deliver estimated air quality benefits in full, this would increase the average life expectancy in London by 6 months**.[6]

Children are particularly susceptible to the effects of air pollution. Analysis by Policy Exchange has shown that **328,000 children attend schools in London where NO_2 concentrations exceed the legal limit and healthy limit, representing nearly 25% of all pupils in London**. The most polluted schools in London experience NO_2 concentrations of nearly twice the limit. Although working age adults are less vulnerable in their *response* to air pollution, their *exposure* can be extremely high. **Our analysis indicates that 3.8 million people work in parts of London which are above legal limits for NO_2 pollution,** representing 44% of London's workday population. More deprived parts of London generally experience higher levels of air pollution, although there is considerable variation. Overall the moral case for tackling air pollution is very clear.

There is also a legal imperative to fix London's air quality. European legislation (the Air Quality Framework Directive) sets legal limits for key pollutants such as NO_2 and PM, based on WHO guidance. Greater London is one of 38 "zones" across the UK that are currently in breach of NO_2 limits. Failure to comply with the limits has resulted in two court cases against the UK. In the first case, the European Court of Justice ruled that the UK must put in place a plan to achieve air quality standards in the "shortest time possible." Subsequently, in April 2015, the UK Supreme Court ordered the Government to redraft the national action plan to ensure compliance with legal NO_2 limits as soon as possible.

In response to this, Defra recently consulted on a draft plan to improve NO_2. Defra modelling, published as part of the consultation, indicates that Greater London will not achieve compliance until 2025, although their earlier modelling suggested that compliance would not be reached until at least 2030. It is unclear how compliance will be accelerated, particularly since the main proposal in the document to create a number of Clean Air Zones across the UK is already being taken forward in London. It is clear that additional steps will be required in order to meet the requirement of achieving air quality standards in the "shortest time possible."

London's Air Quality Challenge

London's air pollution problem is still far from solved. Progress has been made on some pollutants, for example levels of carbon monoxide and sulphur dioxide in London have dropped by 80% since 1996.[7] There has been some progress in reducing PM and NO_2 pollution, but levels still remain high. Analysis by Policy Exchange of data from air quality monitoring sites shows that the most polluted parts of London have levels of NO_2 nearly four times the legal limit. It is also estimated that over 12% of London's area was in breach of NO_2 limits in 2010, with the most affected areas being Central London, the area around Heathrow airport, and other major transport routes.[8]

There has been limited progress in reducing NO_x levels since the early 2000s, both in London and in the UK generally.[9] The failure to control NO_x emissions is largely due to the growth in the number of diesel vehicles, combined with the failure of vehicle emissions standards to control emissions from diesels. Diesel cars now make up over 50% of all new cars sold in the UK, and 36% of the total car fleet (up from 7% in 1994), as well as being almost ubiquitous in the van, truck and bus fleet.[10] Government policy has created incentives for people to switch to diesel, based on the CO_2 advantage of diesel vehicles compared to petrol (albeit that this advantage has now been eroded). **However, diesels emit much higher quantities of local pollutants than petrol vehicles.** Research shows that despite the introduction of progressively tighter vehicle standards ("Euro standards"), there has been limited improvement in NO_x emissions from diesels over the last 20 years.[11] The latest Euro 6 diesel cars show some improvement on previous models, but there is still a gulf between how they perform on the road and the official Euro 6 standards. A range of studies have shown that real world NO_x emissions from the latest Euro 6 diesel cars are some 2.5 to 7 times the legal limits.[12] The ongoing saga concerning Volkswagen's use of illegal "cheat devices" during vehicle emissions tests is an exemplar of the failure of emissions standards. However, whilst other manufacturers have not used cheat devices, the vast majority of diesel cars still fail to match up to emissions standards on the road, particularly in urban driving conditions. By contrast, the evidence suggests that the latest Euro VI standard for heavy goods vehicles and buses has led to a significant reduction in NO_x emissions.[13]

The most recent air quality projections for London (which formed part of the evidence base for the ULEZ proposal) show that even with the current suite of policies, London is unlikely to achieve compliance with air quality limits by 2025. Indeed, the models show that 42sq km of London (an area equivalent to the size of Westminster and Camden combined) would still be above legal limits in 2025. In this scenario, the health impacts of air pollution would be significantly reduced, but not eliminated completely.

Moreover we have identified a number of risks to the current approach to modelling air quality and emissions:

- There is a risk concerning the vehicle emissions factors used in current models, in that the models may overstate the benefits of moving to Euro 6. As described above, diesel cars have failed to match up to Euro standards in practice. This is a crucial assumption, since the ULEZ policy is designed to promote a shift to low emission vehicles.
- The models also do not fully reflect the ongoing growth in decentralised power generation across London, including Combined Heat and Power (CHP). Decentralised energy is being promoted both by national government and the GLA, and there is now 195MW of CHP capacity across London (ranging from small units in homes to large units in industrial premises). Projections show that gas combustion in buildings could be responsible for 48% of NO_x emissions by 2025 in Central London.[14] There is a risk that measures to promote decentralised energy could increase local NO_x emissions.
- There are additional uncertainties relating to emissions from construction vehicles and equipment, and specialist vehicles such as refrigerated vans.

Overall this implies that current air quality projections should be treated as a best case scenario, and progress may well be slower. **A programme of additional policies will be required in order to fully address London's air pollution problem.**

Next Steps

In the next stage of this project we will consider a range of possible policy options to address London's air quality challenge. These will be modelled quantitatively, identifying the benefits in terms of reduction in emissions and improvements in air quality and health, as well as indicative costs.

01 London's Air Pollution Problem

Introduction

In 2012, Policy Exchange produced a report, *Something in the Air,*[15] on the problem of air pollution. The report highlighted the significant health effects and economic costs associated with air pollution. It recommended a range of policies to improve air quality, as follows, several of which have since been taken forward:

- Reducing or removing exemptions from the congestion charge for small diesel cars, which come under the CO_2 emissions threshold but cause local air pollution;
- Introducing a surcharge for diesel vehicles under the Vehicle Excise Duty regime;
- Ensuring that the Renewable Heat Incentive does not support the deployment of biomass technologies in cities;
- Ensuring that smoke control and air quality management rules are not weakened to promote renewable energy in homes and businesses;
- Developing a network of Low Emission Zones for locations where NO_2 limit values are being breached;
- Testing differential parking charges based on the emissions level of the vehicle;
- Carrying out further testing of pollution suppression methods;
- Retrofitting buses with pollution filtering systems, rather than replacing them;
- Introducing a Low Emission Zone around Heathrow airport.

In this follow up project we look more specifically at the problem of air quality in London, parts of which experience the worst air pollution in the UK. The project will be delivered in two stages. This first report sets out the context in terms of the scale of the air pollution problem in London, and is structured as follows:

- Chapter 1 provides an introduction and policy context;
- Chapter 2 provides information on current air quality and emissions in London, plus projections of future air quality based on current and planned policies;
- Chapter 3 sets out the case for taking action on air pollution on health and inequality grounds;
- Chapter 4 provides a summary and initial conclusions;
- Appendix 1 provides an overview of King's modelling methodology;
- Appendix 2 provides further details on the future health impacts of air pollution.

A subsequent report will consider possible policies to improve air quality in London, and their potential cost and impact. Both reports are being delivered by Policy Exchange in partnership with researchers at King's College London's Environmental Research Group.

What is Air Pollution?

"Air pollution" is an umbrella term applied to many different airborne substances, as summarised in Table 1.1. As shown, pollutants can lead to severe health and environmental effects both at a local level and over a wide area (this is explored further in Chapter 3):

Table 1.1: Local Air Pollutants[16]

Pollutant	Key sources of emissions	Health/environmental effects
Particulate matter Typically referred to as particles under 10μm in diameter (PM_{10}) and fine particles less than 2.5μm in diameter ($PM_{2.5}$)	Transport (exhaust, tyre and brake wear), combustion, industrial processes, construction and demolition, natural sources. Also created by interaction of other pollutants.	Linked to asthma, lung cancer, respiratory and cardiovascular diseases, infant mortality and low birth weight. The smallest particles are of greatest health concern (e.g. $PM_{2.5}$). PM exposure can lead to growth stunting or mortality in plants. Black carbon (a component of PM) contributes to global warming.
Nitrogen oxides (NO_x), including nitric oxide (NO) and nitrogen dioxide (NO_2)	Transport, combustion.	Exposure to NO_2 can cause lung irritation, decrease lung function, and increase chance of respiratory infections. Long term exposure is associated with low birth weight babies and excess deaths. NO and NO_2 are precursors to formation of Ozone, and acid rain. NO_x can be deposited into fresh water and land, harming biodiversity in sensitive sites.
Sulphur dioxide (SO_2)	Combustion (particularly coal) and road transport.	Causes irritation of lungs, nose and throat, and exacerbates asthma. Precursor to formation of smog. Forms acid rain, which damages freshwater environments, soils and vegetation.
Ozone (O_3)	Formed by reaction of hydrocarbons, NO_x, and Volatile Organic Compounds in sunlight.	Harms lung function and irritates respiratory system. Can increase incidence and severity of asthma and bronchitis. Long term exposure can lead to cardiorespiratory mortality. Acts as a powerful greenhouse gas. Stunts plant growth.
Carbon monoxide (CO)	Road transport (particularly petrol), combustion, industry. CO arises from incomplete combustion.	Headaches, nausea, dizziness, affects lung performance. Precursor to formation of Ozone.
Benzene (C_6H_6)	Evaporation and combustion of petroleum products.	Cancer, leukemia.
Heavy metals (e.g. arsenic, cadmium, lead, and nickel)	Combustion, industrial processes.	Nausea, diarrhoea, abdominal pain, irritation of eyes, nose, throat, and lungs, brain and kidney damage, asthma, respiratory diseases, lung cancer.

This report focuses on NO_x/NO_2 and PM pollution. As explored below, NO_2 pollution presents the greatest challenge in a London and UK context, and remains above legal and healthy limits. Historically, PM has also been a significant problem in urban areas, and whilst emissions have reduced, it still leads to significant health effects (see Chapter 3). The other pollutants listed above have historically been an issue, but emissions have now substantially reduced, and are within legal limits. For example, at UK level sulphur dioxide emissions have fallen by 94% since 1970, carbon monoxide emissions have fallen by 80% since 1970, and lead emissions have fallen by 98% since 1990.[17]

Policy Context

European and UK Air Quality Legislation

The UK is legally bound by a series of European Directives concerning air pollution and air quality. The European Commission has set an objective to "achieve levels of air quality that do not give rise to significant negative impacts on human health or the environment", and accordingly has developed a substantial body of legislation.[18] This commenced with the Air Quality Framework Directive (1996) which described how air quality should be assessed and managed. Subsequent directives established standards for a range of pollutants including nitrogen dioxide, sulphur dioxide, ozone, particulate matter, and heavy metals. The most recent directive in 2008 consolidated existing legislation into a single directive, and was transposed into English law by the Air Quality (Standards) Regulations 2010, with equivalent regulations in Scotland, Wales and Northern Ireland.

Table 1.2 Summary of Air Quality Standards in England[19,20]

Pollutant	**Concentration (limit value)**	**Averaging period**	**Introduction of limit value**	**Permitted exceedances each year**	**WHO guidelines**
Nitrogen dioxide (NO_2)	200 µg/m³	1 hour	1st January 2010	18	As per EU limit values
	40 µg/m³	1 year	1st January 2010	n/a	As per EU limit values
Particulate Matter (PM_{10})	50 µg/m³	24 hours	1st January 2005 (time extension granted to 2011)	35	As per EU limit values
	40 µg/m³	1 year	1st January 2005	n/a	20 µg/m³
Fine particles ($PM_{2.5}$)	25 µg/m³	1 year	1st January 2015	n/a	10 µg/m³
	20 µg/m³	1 year	1st January 2020	n/a	10 µg/m³

Standards are set in the form of legally binding "limit values" which Member States must comply with (Table 1.2). Standards are expressed either in the form of an annual average concentration, or as a restriction on the number of "exceedances" over shorter time periods. Crucially, compliance is only reached when the *whole of a zone* falls within the limit value.[21] Failure to comply with the air quality limits ultimately can lead to a significant fine (e.g. up to £300 million per year[22]), which in this context would be handed down from UK Government to the Greater London Authority and London Boroughs. In addition to the limit values, the EU has set an exposure reduction target for urban background $PM_{2.5}$, which translates into a target concentration of 11µg/m³ for the UK in 2020.[23]

The standards set under this legislation are largely based on health-related evidence and guidelines from the World Health Organisation (WHO).[24] It is notable that in the case of PM, the EU limit value has been set at a higher level (i.e. less stringent) than suggested in WHO guidelines, suggesting that there will be health effects even if the European limits are met.

The UK has complied with limit values for sulphur dioxide, lead, benzene and carbon monoxide for some time. In the case of PM_{10}, the UK failed to meet limit values by the original deadline of 2005, which led to the European Commission bringing forward legal action against the UK,[25] as well as the UK applying for a time-extension to 2011. Greater London was the final part of UK to achieve compliance with the daily and annual limit values for PM_{10}, which it did for the first time in 2012.[26] Greater London is compliant with the current limit value for $PM_{2.5}$, but currently looks set to breach the tighter limit value being introduced from 2020 onwards.[27]

However, the UK faces a much greater challenge in meeting limit values for NO_2. When NO_2 limits came into force in 2010, there were 40 "zones"[28] or parts of the UK which were non-compliant (one of which was Greater London). In 2011, Defra applied for a time extension to 2015 with an aim to meet NO_2 limits "as soon as possible". However, the plans drawn up at that time showed that many zones would not reach compliance until 2020 or 2025, and that Greater London (along with two other zones) would not reach compliance until at least 2030.[29] The latest data from Defra shows that 38 zones still exceeded limit values for NO_2 in 2013 (including Greater London).[30] Separately, Defra confirmed that 194 Local Authorities exceeded NO_2 limit values in 2013.[31]

The UK is not alone in failing to meet air quality standards, with more than half of the EU Member States currently under infringement procedures for at least one pollutant.[32] Research has shown that London ranks 15th out of 36 major global cities in terms of overall air quality – behind many other European cities such as Stockholm, Vienna and Berlin, but ahead of others such as Madrid, Warsaw, Rome, Munich and Milan.[33] The same study showed that relative to other cities, London has a particularly bad NO_2 problem, with similar levels of NO_2 as cities such as Shanghai and Beijing, which are amongst the worst cities globally in terms of overall air quality.

The failure to comply with NO_2 limits resulted in two court cases against the UK government concerning its air quality plans. In the first case, the European Court of Justice ruled that the UK must put in place a plan to achieve air quality standards in the "shortest time possible". Subsequently, in April 2015, the UK Supreme Court ordered the Government to redraft the national action plan for nitrogen dioxide (NO_2) by 31st December 2015, as well as zonal action plans (including for Greater London), to ensure compliance with legal NO_2 limits as soon as possible.[34]

In response to this, Defra released and consulted on a draft plan in September 2015. This outlines a package of measures including a national network of Clean Air Zones in major cities by 2020 (akin to the London Ultra Low Emissions Zone), as well as a host of local measures. The draft plan has been criticised by air quality groups such as Clean Air in London and ClientEarth for being "inadequate". A central criticism is that the document is essentially a "plan for a plan by others", passing responsibility for compliance with NO_2 limits to Local Authorities without any new powers or resources.[35] Another concern raised is the extent to which Defra's plan has met the requirement to achieve air quality standards in the "shortest time possible". Defra modelling, published as part of the consultation, indicates that most zones will not achieve compliance until 2020, and 2025 in Greater London. However, in the case of Greater London, it is unclear which of the measures identified are new, particularly given that London is already planning to introduce a "Clean Air Zone" in the form of the Ultra Low Emission Zone (discussed below). Chapter 2 of this report sets out more detailed modelling for the Greater London area (produced by TfL, GLA and King's College London) which suggests that London will fail to reach compliance by 2025 based on current and committed policies. Moreover, monitoring data shows that London roadside NO_2 levels have not improved significantly in recent years. There is a clear mismatch between this and Defra's modelling.

Either way, it appears that under current plans it will take at least 10 years to bring air quality within legal limits, and significant additional effort will be required to reach compliance "as soon as possible". Indeed, ClientEarth, who brought the Supreme Court case in the first place, are threatening new legal action unless the plan is improved.[36]

Vehicle Emissions Standards

The EU has introduced a set of emissions standards ("Euro Standards") which regulate emissions from new petrol, diesel and gas vehicles. These standards are denoted by Euro 1 – 6 for cars and light goods vehicles, and Euro I – VI for heavy duty vehicles. The standards have introduced progressively tighter limits for both PM_{10} and NO_x emissions from all vehicle types.

Table 1.3: Euro Emissions Standards[37]

	Petrol car (g/km)		Diesel car (g/km)			Heavy Duty vehicles (g/kWh)	
	NO_x	**PM_{10}**	**NO_x**	**PM_{10}**		**NO_x**	**PM_{10}**
Euro 1 (1992)	0.97*	–	0.97*	0.140	Euro I (1992)	8.00	0.36
Euro 2 (1996)	0.50*	–	0.70*	0.080	Euro II (1996)	7.00	0.25
Euro 3 (2000)	0.15	–	0.50	0.050	Euro III (2000)	5.00	0.13
Euro 4 (2005)	0.08	–	0.25	0.025	Euro IV (2005)	3.50	0.02
Euro 5 (2009)	0.06	0.005	0.18	0.005	Euro V (2008)	2.00	0.02
Euro 6 (2014)	0.06	0.005	0.08	0.005	Euro VI (2013)	0.43	0.01

* For Euro 1/2 the limit values related to NO_x + Hydrocarbon emissions (i.e. unburnt fuel).

In theory, the introduction of these limits should reduce emissions as vehicles are replaced with newer, less polluting models. However, as discussed in Chapter 2, this has not turned out to be the case to date, as "real-world" emissions have not reduced in line with standards and even the newest vehicles have emissions well above legal limits.

These standards, and their effectiveness, are particularly important in a London context, since some of the key policies being implemented in London (e.g. the Low Emission Zone and Ultra Low Emission Zone, described below), rely on this system to categorise and charge vehicles.

Greater London

Air quality in London has been a key policy issue for a very long time. As early as 1285, fumes from coal burning in London were considered so serious that the world's first air pollution commission was created. A Royal Proclamation in 1306 attempted to ban the burning of coal in London – ultimately unsuccessfully since there were no economic alternatives.[38] The health effects of smoke in London were recognised as early as the 1600s.[39] Fast forward to the 1950s, and London was experiencing regular "pea soupers", with adverse weather conditions trapping acute levels of smog in the city. It is thought that the Great Smog of 1952 may have killed 4,000 people. Again the situation was so bad that it led to new legislation, this time in the form of the 1956 Clean Air Act, which led to the phase out of burning coal in London.[40]

Much more recently, air pollution has been a significant focus of the Mayor of London under both Ken Livingstone and Boris Johnson. The Mayor has a legal responsibility under the Greater London Authority Act (1999) to develop an Air Quality Strategy to achieve European air quality standards and objectives (described above). The London Mayor has control (either directly or through London Boroughs) of many policies related to air quality, such as transport and development planning.

The first Mayor's Air Quality Strategy in 2001 introduced a raft of proposals including: the creation of the Congestion Charge Zone, a feasibility study for a Low Emission Zone, investment in public transport, grants for low emission vehicles, and measures to target emissions reductions in buses, taxis and HGVs.[41] Even so, it was clear at the time that the proposed measures would not be sufficient to meet NO_2 or PM_{10} limits.[42]

The Low Emission Zone was eventually introduced in 2008. Under the scheme, heavy duty vehicles that do not comply with certain Euro standards (Euro IV for HGVs, buses and coaches; and Euro III for vans, minibuses and pickups) must either be retrofitted to reduce emissions, or face a charge of £100–200 per day to drive in the Low Emission Zone. The scheme covers most of Greater London and operates 24 hours per day. Cars and motorbikes are not covered by the scheme.

The Mayor's Air Quality Strategy was updated in 2010 to include the following additional policies:[43]

- Support for the uptake of low emission electric and hydrogen vehicles;
- A scrappage scheme for older vehicles, and grants for retrofitting older vehicles;
- An age limit for black cabs (15 years) and private hire vehicles (10 years). This has retired more than 3,000 taxis since it was introduced in 2012;
- Investment in cleaner hybrid and hydrogen buses with 1,700 hybrids on the road by 2016;
- Retrofitting 1,000 older buses, and retiring 900 of the oldest buses and replacing them with Euro VI buses;
- Investments in public transport such as Crossrail, electrification of the rail network, tube network upgrades, Cycle Superhighways and the Cycle Hire scheme;

- Best practice guidelines to reduce emissions associated with construction and demolition sites;
- A requirement for new developments to be "air quality neutral";
- Emissions limits for biomass and Combined Heat and Power (CHP) boilers;
- The RE:NEW and RE:FIT programmes to improve energy efficiency in homes, commercial buildings and public buildings;
- Investments in "green infrastructure" including tree planting and green roofs;
- The Mayor's Clean Air Fund, with £5m of funding to target innovative pollution reduction measures, such as dust suppressants, green walls and other green infrastructure, and a no engine idling campaign across central London.

The strategy stated that the measures would be sufficient to achieve PM_{10} limit values by 2011, but that it would not deliver a sufficient improvement in NO_2 to meet legal limits. Boris Johnson has stated that he wants London to be compliant with NO_2 legal limits by 2020 at the latest,[44] and subsequently proposed two other major policies to tackle air pollution:

- A new Ultra Low Emission Zone (ULEZ) is proposed to be introduced in 2020, covering the same area as the Congestion Charge Zone, and operating 24 hours per day. All vehicles (including cars, motorcycles, buses, taxis, HGVs) will have to either comply with specific emissions standards, or pay a daily charge (in addition to charges under the Congestion Charge and the Low Emission Zone). Diesel vehicles meeting Euro 6 standards, and petrol vehicles meeting Euro 4 standards, will be exempt from the charge. There will also be an exemption for historic vehicles, plus a three year exemption for residents of the ULEZ area.
- The GLA has introduced a policy concerning Non-Road Mobile Machinery (NRMM) which comprises vehicles and equipment used on construction sites such as cranes, diggers, diesel generators, and smaller equipment such as chainsaws and hedge-trimmers.[45] NRMM is a significant source of PM_{10} and NO_x emissions. As of September 2015, NRMM equipment used in London will be required to meet specific Euro emissions standards, with tighter standards applied within a "Central Activity Zone", and less stringent standards applying to major development sites in the rest of Greater London. The policy contains exemptions in cases where equipment is only used intermittently, or where compliant equipment is not available in sufficient quantities. The standards applied in London will be tightened from 2020 onwards.

Summary

The key findings from this Chapter are as follows:

- Improving London's air quality is a significant, long-running and complex challenge.
- London is currently in breach of legal and healthy limits for NO_2 pollution, and PM_{10} and $PM_{2.5}$ levels remain above health guideline levels.
- Exposure to high levels of NO_2 and PM can cause a wide range of serious health conditions.
- London has put in place a large number of policies to address air pollution, however based on current plans it appears that air quality will not come within legal limits until at least 2025, and perhaps later.
- London has a legal duty to reach compliance with NO_2 limits in the shortest time possible.

02 Air Quality Trends

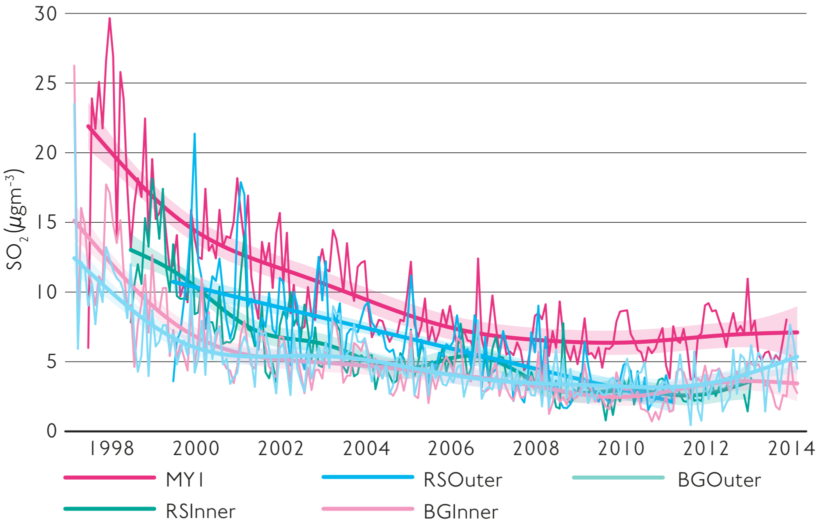
This Chapter provides a review of data on air quality in London – identifying trends for key pollutants such as NO_x and PM. This is largely based on two key sources of information:

- **Air Quality Monitoring Data.** This data is derived from the London Air Quality Network (LAQN), a network of over 100 air quality monitoring sites located around London. This is the most reliable source of information on air quality, based on actual measurements on the ground. However this dataset only provides a partial picture. By its nature it is backward looking, and is limited by the number of monitoring sites. It provides data on the overall concentration of pollution at monitoring sites, rather than emissions from individual sources.
- **London Atmospheric Emissions Inventory and Air Quality Modelling.** We also present modelled estimates for air quality and emissions in 2010, 2020 and 2025 across all of London. These estimates are taken from an interim update to the London Atmospheric Emissions Inventory, which was developed by Transport for London, GLA, and King's College London, as part of the assessment of the Ultra Low Emission Zone. This represents the most up to date set of models for air quality in London. Unlike the monitoring data, this dataset provides estimates for air quality and emissions for all locations in London (down to 20 metre by 20 metre resolution), and also provides additional information such as the emissions from different sources. The projections for 2020 and 2025 reflect the projected impact of all current and committed policies (i.e. those identified in Chapter 1). It is important to note that this information is based on modelled estimates, which whilst calibrated to current measurements, are based on a large number of assumptions. A number of issues have been identified with the projections, as discussed later in this chapter. Whilst these issues do not undermine the modelling results entirely, they do mean that the results should be interpreted with a degree of caution.

Recent Trends in Air Quality

The overall trend in air quality in London has been mixed over the past two decades, with more progress on some pollutants than others. Figure 2.1 provides summary data from the London Air Quality Network for concentrations of SO_2, for roadside locations in inner and outer London (denoted by "RSInner" and "RSOuter"), urban background readings ("BG Outer" and "BG Inner") and for the sensor at Marylebone Road ("MY1"), one of the most polluted locations in London. As shown, there has been a sharp decline in sulphur dioxide (SO_2) concentrations since 1998 at all locations (Figure 2.1).

Figure 2.1: Trend in Measured Concentrations of sulphur dioxide (SO_2)[46]



However, there has been relatively less progress in tackling NO_2 concentrations (Figure 2.2). NO_2 concentrations at roadside locations in Inner London have remained largely static since the early 2000s, and remain well above the legal limit of 40 µg/m³. This is consistent with data for the UK as a whole, which shows that there has been limited improvement in NO_2 concentrations since around 2002.[47] Whilst there has been a significant improvement in NO_2 concentrations at Marylebone Road, other locations have seen persistently high levels of NO_2. For example the average NO_2 concentration at Oxford Street in the 12 months to August 2015 was over 150 µg/m³ – nearly four times the legal limit.[48]

Levels of PM_{10} have seen some improvement since 2004, with the worst locations such as Marylebone Road coming within the European limit since 2013. However, PM_{10} concentrations are still well above WHO guideline levels (20 µg/m³) at roadside locations in London.

Figure 2.2: Trend in Measured Concentrations of nitrogen dioxide (NO_2)[49]

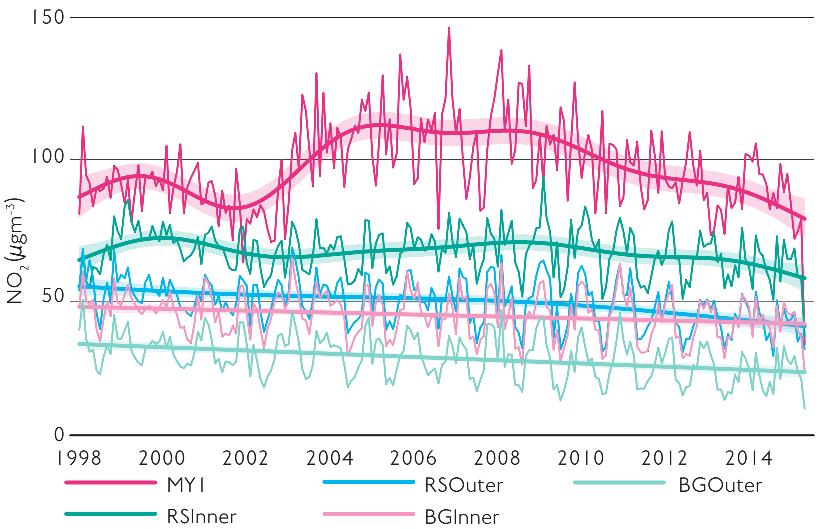
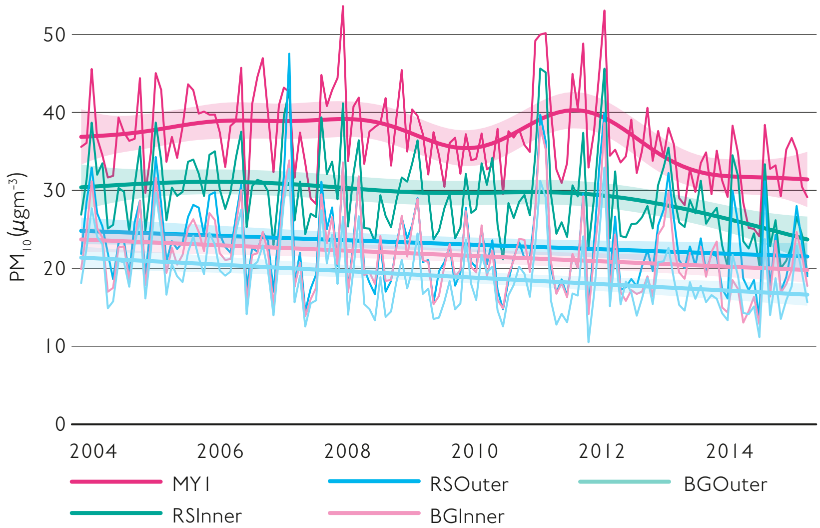


Figure 2.3: Trend in Measured Concentrations of Particulate Matter (PM_{10})[50]



The air pollution problem in London is geographically concentrated in certain areas. As shown in Figure 2.4, the annual NO_2 concentration limit of 40µg/m^3 is exceeded in most of Central London, as well as around Heathrow and major roads around London. Indeed, **Policy Exchange analysis shows that 12.5% of the total area of London[51] currently exceeds the limit value for NO_2 –** a total of 292 sq km. Within this, an area of 14 sq km exceeds the limit value by more than a factor of two (i.e. >80µg/m^3). The maps relate to the year 2010, but as shown above there has been relatively little change in pollution concentrations since this time.

Figure 2.4a: Modelled Concentrations of NO_2, 2010[52]

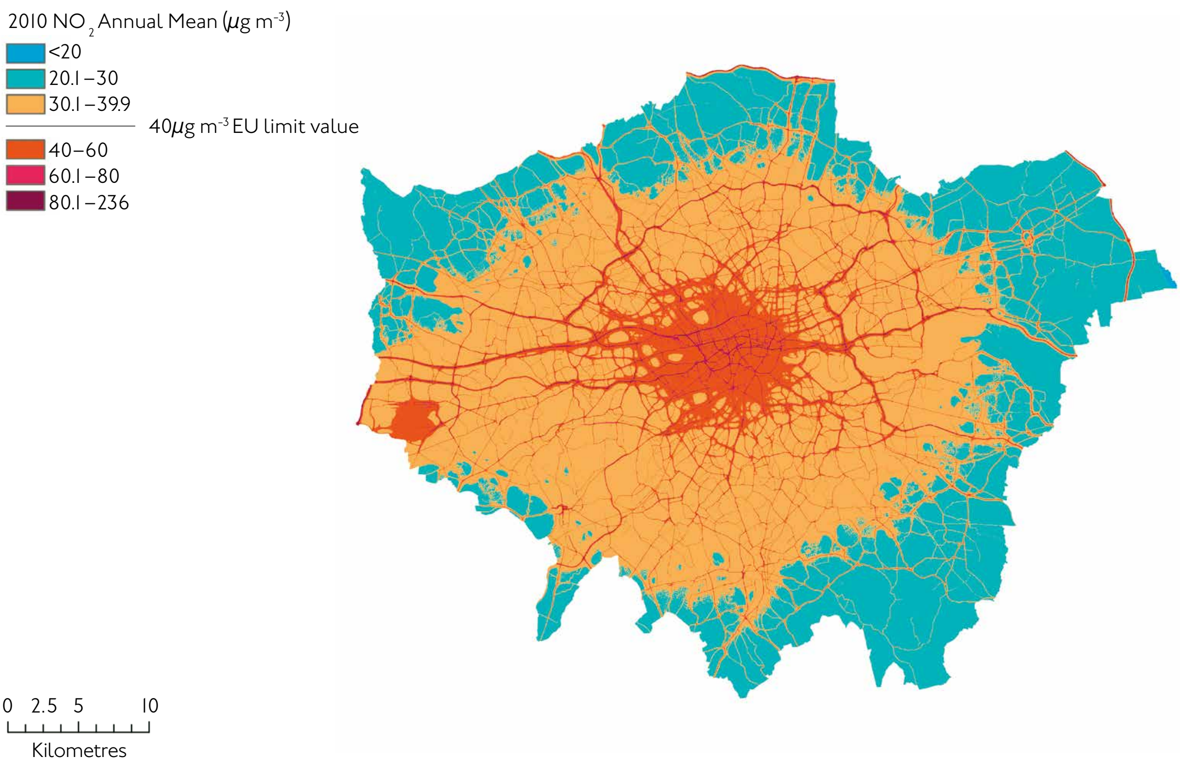
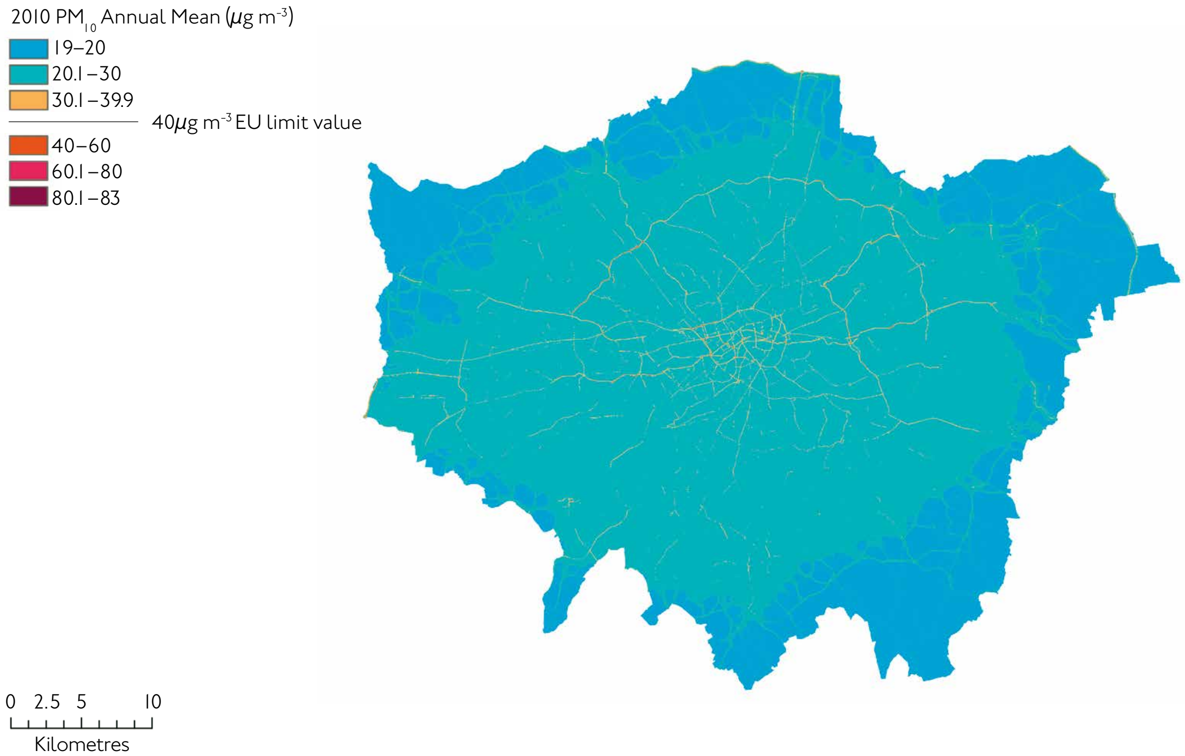


Figure 2.4b Modelled Concentrations of PM_{10}, 2010



The picture is very different in terms of PM_{10} concentrations. The majority of the Greater London area (88%) has an annual average PM_{10} concentration below the European limit value (40µg/m^3), but above WHO guideline levels (20µg/m^3), with the remaining 12% falling below WHO guideline levels. Again, the impact of road transport can be identified on the maps – with the highest concentrations found close to major roads.

Why the Lack of Progress on NO_2?

As outlined in Chapter 1, there are now numerous policies in place aimed at tackling air pollution in London. However, the data above shows that there has been limited progress on NO_2 pollution in recent years. This is due to the increasing trend towards diesel vehicles in the UK fleet; combined with the systematic underperformance of diesel vehicles against emissions performance standards.

"Dieselisation" of the Vehicle Fleet

There has been a rapid and significant shift towards diesel vehicles in the UK in recent years, as in many other European countries. In 1994, there were 1.6 million diesel cars on the road in Great Britain, making up 7% of the total fleet. Diesels increased from 18% of all new cars sold in 2001, to over 50% from 2011. There are now 10.7 million diesels on the road, making up 36% of the total fleet.[53] A similar growth in diesel vans and light goods vehicles has also taken place, where diesels went from 51% of the total fleet in 1994, to 96% in 2014.

Diesels have been promoted heavily by successive Government since the 1990s, on the basis that they achieve greater fuel efficiency and lower CO_2 emissions and are therefore preferable on climate change grounds. The greater fuel efficiency of diesels provides an economic advantage, but this has been increased further through government policy. In 2001–02 the UK began taxing vehicles according to CO_2 emission rates. Cars with lower carbon dioxide (CO_2) emissions fell into cheaper Vehicle Excise Duty (car tax) bands, which gave diesels a further cost advantage, and contributed significantly to the subsequent "dash for diesel". This incentive was effectively removed in the Summer 2015 budget, since from 2017 almost all new cars will pay a standard VED rate.

In addition, legally binding EU-wide CO_2 emission targets for manufacturers gave them added incentives to bring lower emission vehicles to the market. The combination of these factors has meant that diesels have been a more economic option overall for motorists, despite costing slightly more up front, particularly for drivers who do a lot of miles.

Whilst diesels have been favoured for CO_2 reasons, they emit far higher emissions of NO_x and PM than equivalent petrol vehicles. For example, under the Euro 3 emissions limits introduced in 2000, the limit value for diesel cars (0.5g/km) was more than three times that of petrol cars (0.15g/km), and this disparity was maintained under Euro 4 and Euro 5. Moreover, as discussed in the next section, diesel cars have systematically failed to achieve the stated emissions limits in practice, whereas petrol cars generally have not. Barry Gardiner MP, the shadow energy minister, has acknowledged that the policy to promote diesels under Gordon Brown's government was a mistake, with a lack of evidence at the time on the air quality impact of diesels.[54]

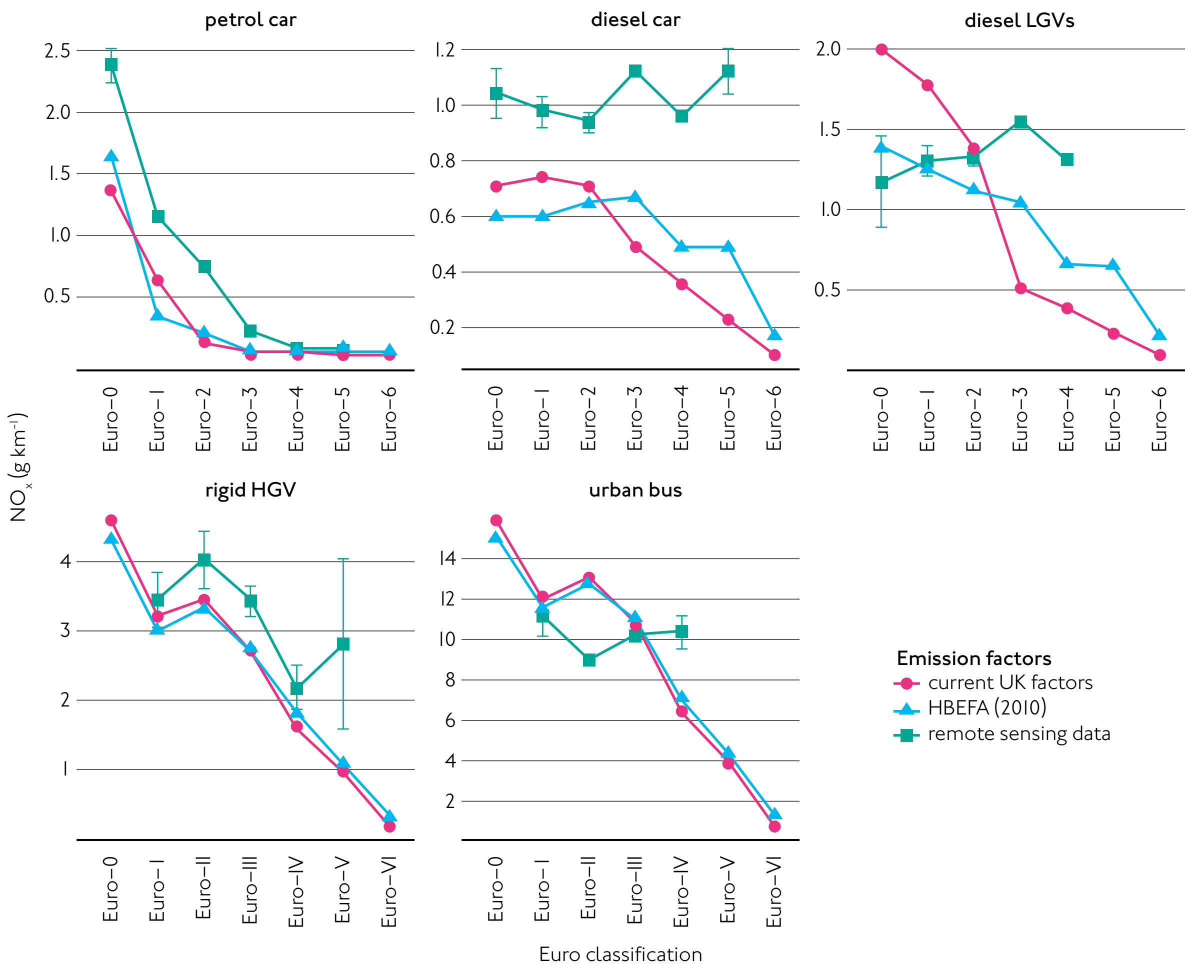
The switch to diesel has resulted in CO_2 savings. Research shows that the impact of UK consumers switching from petrol to diesel cars from 2001 onwards has been a saving of 0.4 megatons (Mt) of CO_2 and 1 million barrels of oil.[55] However, the CO_2 advantage associated with diesels has now been eroded, with diesel and petrol cars now achieving similar CO_2 emissions per km (126.5g CO_2/km for petrol, compared to 124.9g CO_2/km for diesels).[56] Therefore, the Government's original rationale for supporting diesel is no longer valid in any case. Moreover, research suggests that if the climate change impact of black carbon emissions (a component of particulate matter) from diesels is taken into account, then this more than offsets the CO_2 saving.[57]

Failing Emissions Standards

Compounding the trend of "dieselisation" of the fleet is the fact that diesel vehicles have failed to perform in line with Euro emissions standards in practice. Researchers at King's College London undertook testing of over 80,000 vehicles at roadside locations in 2011.[58] This found that there had been little or no improvement in terms of NO_x emissions from diesel cars, vans, HGVs or buses over the preceding 20 years, although it identified a significant improvement for petrol cars (see Figure 2.5, "remote sensing data"). The study estimated that Euro 5 diesel cars in practice emit over 1.1g of NO_x per km – more than five times the Euro 5 emissions limit of 0.18g/km, and more than even the Euro 1 limit of 0.97g/km.

These findings were confirmed in a more recent study by the same authors, which showed that Euro 5 diesel cars perform no better in terms of NO_x emissions than pre-Euro 1 vehicles.[59] A range of other studies have come to similar findings, for example a study by the European Joint Research Centre concluded that petrol cars largely perform within Euro emissions limits, but diesel cars have emissions 4 to 7 times higher than the limits, and showed little improvement between Euro 3 and Euro 5.[60]

Figure 2.5: Real World Performance of Vehicles, by Euro Classification[61]



NO_x emissions consist of a mix of nitrogen dioxide (NO_2) and nitrogen oxide (NO). NO_2 can lead to significant health effects, and is therefore of the greatest concern. NO itself is much less harmful but can oxidise in the air to form NO_2. Research has shown that the mix of NO_2 and NO in diesel exhaust has changed over time, with an increase in NO_2 emitted directly (known as "primary NO_2"). The proportion of NO_x which is primary NO_2 increased from 10–15% for Euro 3 vehicles, to 30% for Euro 4/5 diesels, and up to 60% for Euro 4/5 diesels with larger-engines.[62] Given that overall NO_x emissions from diesels have not reduced (up to Euro 5), this means that primary NO_2 emissions actually *increased* in practice, despite the introduction of progressively tighter Euro standards. This is consistent with the fact that roadside NO_2 concentrations have remained high, whilst urban background concentrations have decreased (see Figure 2.2).

The failure of Euro standards to control emissions is in large part due to vehicle testing regime, which has a large number of weaknesses that vehicle manufacturers have been able to exploit. Vehicle manufacturers are required to test new vehicles to demonstrate that they have met the prevailing standards. But the independence of the European testing regime has been called into question, since carmakers generally oversee and conduct the tests themselves.[63]

The tests are currently performed in laboratory conditions, and it has been argued that they do not adequately represent real world driving conditions – particularly urban driving conditions.[64] The test cycle is "unrealistic and undemanding", with cars able to accelerate slowly under relatively low engine loads, and therefore fails to represent real-world driving conditions.[65] Also, some of the main technologies used to control emissions from diesels (e.g. Diesel Particulate Filters and Selective Catalytic Reduction) are influenced by operating conditions, and perform less well in the stop-start traffic conditions found in cities. A report for the RAC Foundation, commenting on the performance of these technologies, stated that: *"in this slow speed, stop start operation, the control technology did not reach a sufficiently high temperature to operate at maximum efficiency for much of the time."*[66]

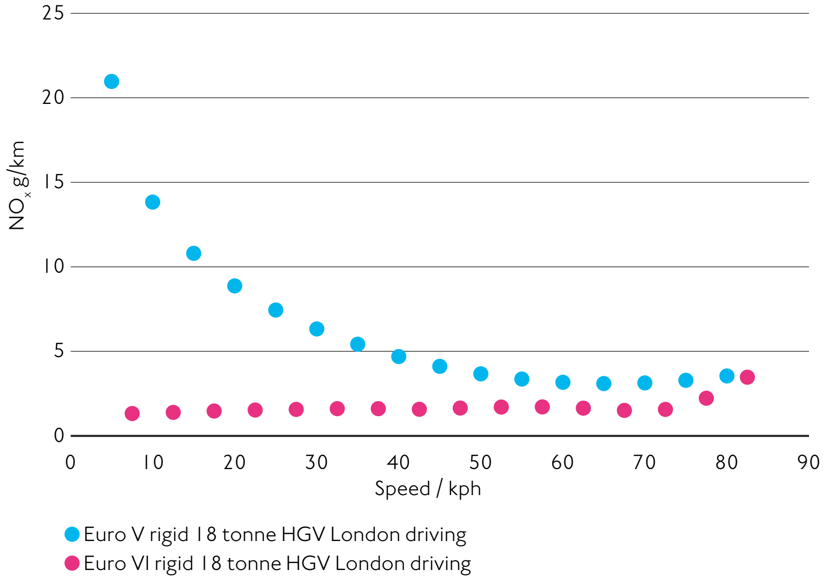
Moreover, vehicle manufacturers have employed a range of increasingly sophisticated strategies simply to pass the test itself, leading to an increasing gap between test figures and actual world performance. In the main these strategies are legal, exploiting loopholes and weaknesses in the test regime, such as disconnecting the alternator, stripping out excess weight, testing at high temperatures, and taping up seams and removing wing mirrors to improve aerodynamics.[67] However, some manufacturers have gone further still. Volkswagen has recently admitted to using *illegal* means to cheat emissions tests.[68] This relates to an engine used in 11 million diesel vehicles sold globally between 2009 and 2015, 1.2 million of which are thought to have been sold in the UK, which equates to more than 10% of the entire diesel car fleet in the UK.[69] VW has now said that all 1.2 million cars will need to be recalled,[70] although it remains unclear what impact this will have in terms of the performance or emissions of these cars.

These issues are linked to the wider issue of vehicle performance figures not matching up with reality. For example, it has been shown that in the case of fuel efficiency and CO_2 emissions, the gap between official figures and real world performance has grown from around 10% in 2002 to around 35% in 2014.[71]

A key question going forward is whether the Euro 6 standard will fare any better than previous standards. Euro 6 has a far more explicit focus on reducing NO_x than the previous Euro standards, which focused more on reducing PM emissions. Evidence on the performance of Euro 6 vehicles is relatively scarce, since the standards have only just been introduced. The evidence that exists shows that although Euro 6 has led to an improvement, NO_x emissions from Euro 6 diesels are still well above limits. For example, a study by the Transport Research Laboratory identified that a sample of Euro 6 diesels had NO_x emissions of 2.5 times the Euro 6 limit, although this was still a 65% reduction on Euro 5 performance.[72] Several other independent studies have shown that emissions from Euro 6 diesel cars are 2.5 to 7 times higher than legal limits in practice.[73] One study of Euro 6 diesel cars showed that real-world emissions of NO_x were 7 times the emissions limit for Euro 6 on average, and of the 15 cars tested only one met the Euro 6 standard.[74] In the same study, the worst performing car exceeded the Euro 6 limit by a factor of 25 times.

Whilst the performance of Euro 6 diesel cars is highly questionable, there is evidence of some improvement with Euro VI heavy duty diesel vehicles. Recent analysis by TfL showed Euro VI trucks achieving a 77% reduction in real world NO_x emissions compared to Euro V trucks, and a 98% reduction for Euro VI buses.[75] This is due to a significant improvement in NO_x emissions at lower speeds, which is particularly important in the context of urban driving conditions.[76] If the estimated savings from Euro VI are delivered in full, this would mean that new Euro VI buses and HGVs would have lower NO_x emissions than many Euro 5 diesel cars.

Figure 2.6: Comparison of Euro V versus Euro VI NO_x Emissions over a Range of Road Speeds[77]



The issues with the vehicle testing regime could potentially be overcome through the introduction of a new test protocol to better reflect real world driving conditions. The Euro 6 regulations propose the introduction of a new Real-world Driving Emissions (RDE) test, which will use a portable emissions testing system fitted to cars on the road to better simulate real world driving conditions. Until recently there was still uncertainty about when the RDE tests would be introduced, but in the wake of the Volkswagen emissions scandal, the European Parliament has decided that the RDE test will be implemented from 2017.[78] There has been an ongoing debate about the exact RDE standards that will be applied. Carmakers have been calling for a "conformity factor" of 5 to be applied, which would mean that real world emissions up to five times the legal limit would still be permissible under the new RDE test.[79] This is little better than current Euro 6 performance, hence NGOs have been calling for the original NO_x limit of 0.08g/km to be applied (i.e. a "conformity factor" of 1).[80] The European Commission recently agreed that the "conformity factor" should be set at 2.1 for new models from September 2017 (for all new vehicles by September 2019), and for this to be further tightened to a conformity factor of 1.5 for new models by January 2020 (by January 2021 for all new vehicles).[81] This means that current models, including those which do not conform to the Euro 6 standard in practice, can be sold until September 2019. This has been criticised by NGOs as still being too weak and letting car manufacturers off the hook.[82]

Sources of Air Pollution

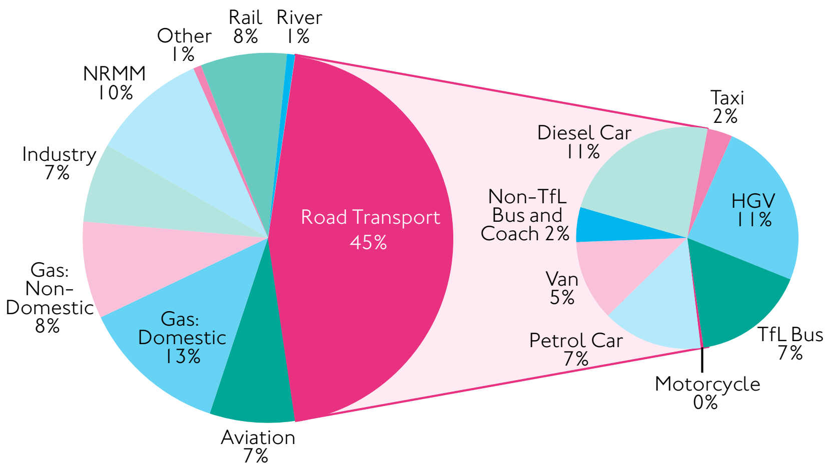
This section provides data on the key sources of emissions, which is helpful in order to further understand the air pollution problem. The following data is mainly drawn from the emissions models which underpinned the development of the ULEZ policy. Whilst this is the most detailed set of emissions models currently available for London, there are some identified issues with the modelling approach as discussed throughout this chapter, which mean that the models are likely to underplay the importance of road transport emissions.

It is worth noting first that there is a link between the emissions produced in an area and the local concentrations; however certain forms of pollution can travel greater distances than others. Analysis by the GLA suggests that 25% of PM pollution in Greater London is attributable to sources within the city, and 75% to sources outside the city. By contrast, NO_2 is a far more localised problem, with 82% of London's NO_2 pollution generated within the city and only 18% brought in from elsewhere.[83] This suggests that policies to tackle air pollution will need both a national and local focus.

Turning to emissions produced within the Greater London area, 45% of total NO_x emissions are from road transport (Figure 2.7). Within this, the principal sources are diesel cars, HGVs, petrol cars, and buses. Other important sources of NO_x emissions within London are domestic gas (13%), non-domestic gas (8%), and rail (8%). Another significant source is Non Road Mobile Machinery (NRMM) which includes vehicles and equipment used on construction sites such as cranes, diggers, diesel generators, and small equipment.

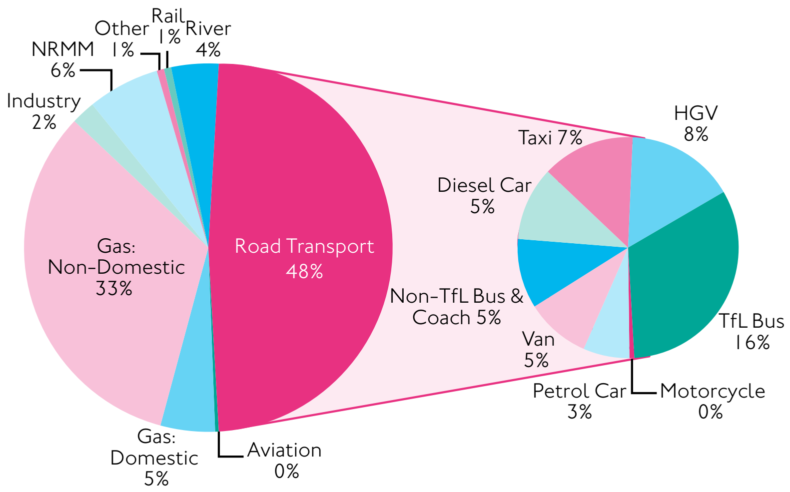
This pattern is somewhat different to the UK as a whole. Defra's recent consultation on a new air quality strategy suggests that around 80% of NO_x emissions across the UK relate to transport, and attributes one third of road transport emissions to diesel cars. This suggests that national level policies may need to be modified slightly in a London context to reflect other important sources of pollution.

Figure 2.7: Breakdown of NO_x Emissions in Greater London in 2010, by Source[84]



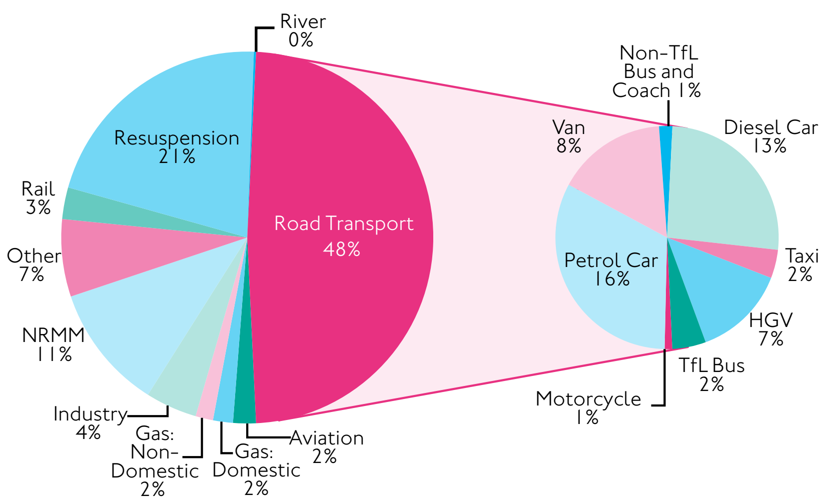
The breakdown of NO_x emitted in Central London is somewhat different to Greater London as a whole, with non-domestic gas combustion playing a far more significant role (33% of NO_x emissions in Central London as opposed to 8% in Greater London). Road transport contributes a similar proportion of overall NO_x emissions overall, although with a different mix of vehicle types: buses, coaches, HGVs and taxis[85] cause a large proportion of road emissions in Central London, whilst private cars are less important (compared to Greater London as a whole). Aviation, domestic gas, rail, and industry also play a less significant role in NO_x emissions in Central London than they do in Greater London.

Figure 2.8: Breakdown of NO_x Emissions in Central London in 2010, by Source[86]



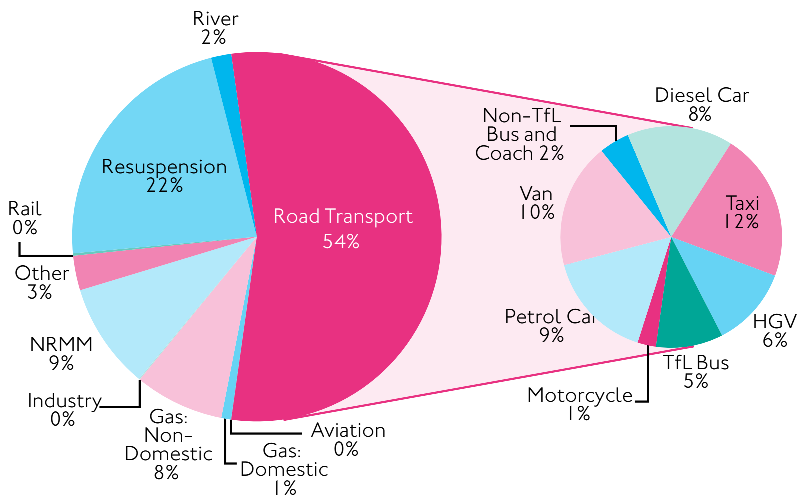
There are some similarities and some differences in the sources of PM_{10} and NO_x emissions. Road transport plays a similar role in both cases, amounting to 48% of PM_{10} emissions in Greater London, compared to 45% of NO_x emissions (Figure 2.9). However, gas combustion makes up a very small share of PM_{10} emissions (4% in total across domestic and non-domestic gas), compared to its share of NO_x emissions (21%). Other important sources of PM_{10} are resuspension (settled PM that becomes airborne again through wind or turbulence caused by vehicle movements) and NRMM. Within the "Other" category, important contributors are waste facilities, fires, and construction and demolition sites.

Figure 2.9: Breakdown of PM_{10} Emissions in Greater London in 2010, by Source[87]



Road transport is a particularly important contributor of PM_{10} emissions in Central London (54%), with taxis, vans, petrol cars, and diesel cars being the main sources (Figure 2.10). Particulates from road transport stem from a combination of exhaust (40% of the total), brakes (50%) and tyre wear (10%). This is important, since the focus of policies such as Euro vehicle standards is to reduce *exhaust*-related particulate matter, not tyre and brake related particulates. Tyre and brake related particulates can only be reduced through reducing transport movements altogether, improving traffic flow, or through technologies such as regenerative braking. This suggests that there is a limit to the impact that Euro standards will have on PM emissions.

Figure 2.10: Breakdown of PM_{10} Emissions in Central London in 2010, by Source[88]



Air Quality Projections

The discussion above has been about the trend to date in key pollutants. As discussed in Chapter 1, there are now numerous policies aimed at tackling air quality issues in London – including policies already in place, and those currently in development such as the ULEZ. Air quality models allow the potential impact of policies to be estimated, as well as assessing future compliance with air quality limits. As set out at the beginning of this chapter, the most recent projections for air quality in London were produced as part of the evidence base for the Ultra Low Emission Zone (ULEZ). These provide projections to 2025 based on all current and committed policies including the planned introduction of the ULEZ in 2020. Note that there are some issues with regard to the accuracy of the modelling, which are discussed further below, hence these trends should be treated with a degree of caution.

Notwithstanding that, the projections show that current policies could deliver a significant reduction in NO_2 and PM_{10} emissions and concentrations by 2020, and further improvements by 2025. In 2025, the model predicts that 98% of the Greater London area would fall within the EU limits for NO_2. However, this still leaves an area of 42 sq km above the legal limit (equivalent to the area of Westminster and Camden combined) and means that compliance would not have been achieved in London. The model also predicts that PM_{10} levels will continue to decline, with half of the Greater London area falling under the WHO guideline levels by 2025 (compared to only 12% in 2010).

Figure 2.11 a: NO_2 Concentrations, 2025 (with Current/Planned Policies)[89]

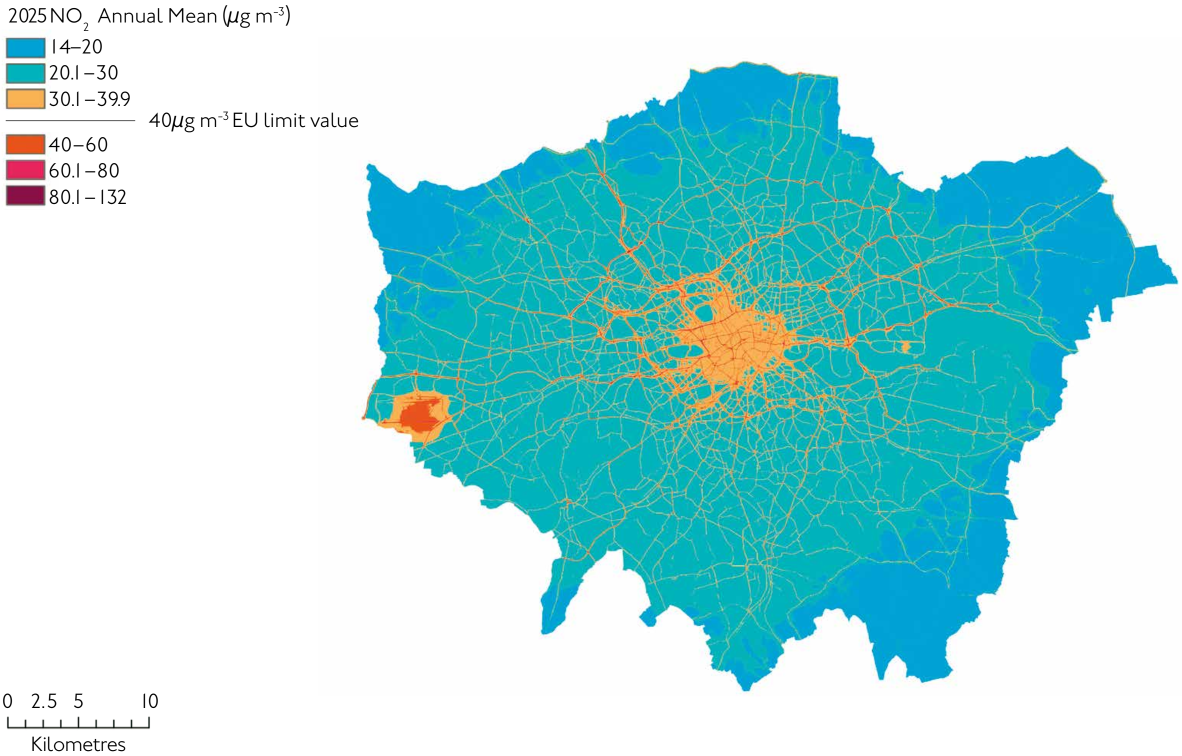
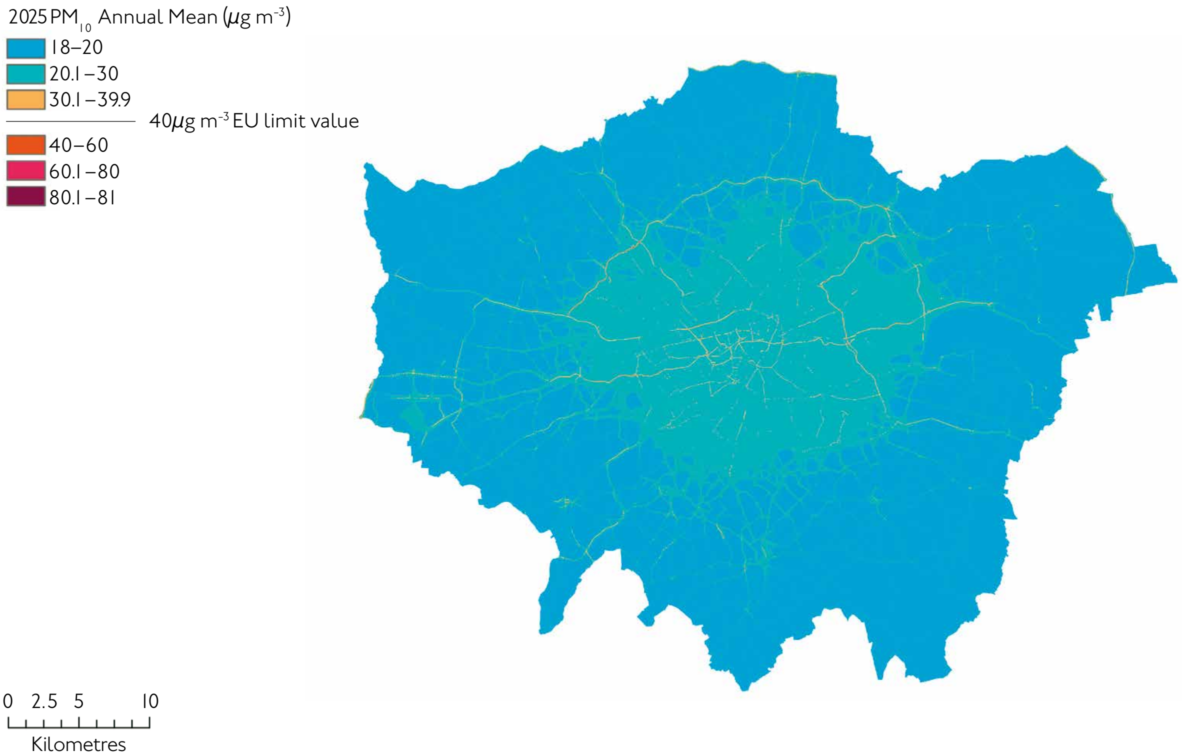


Figure 2.11 b: PM_{10} Concentrations, 2025 (with Current/Planned Policies)

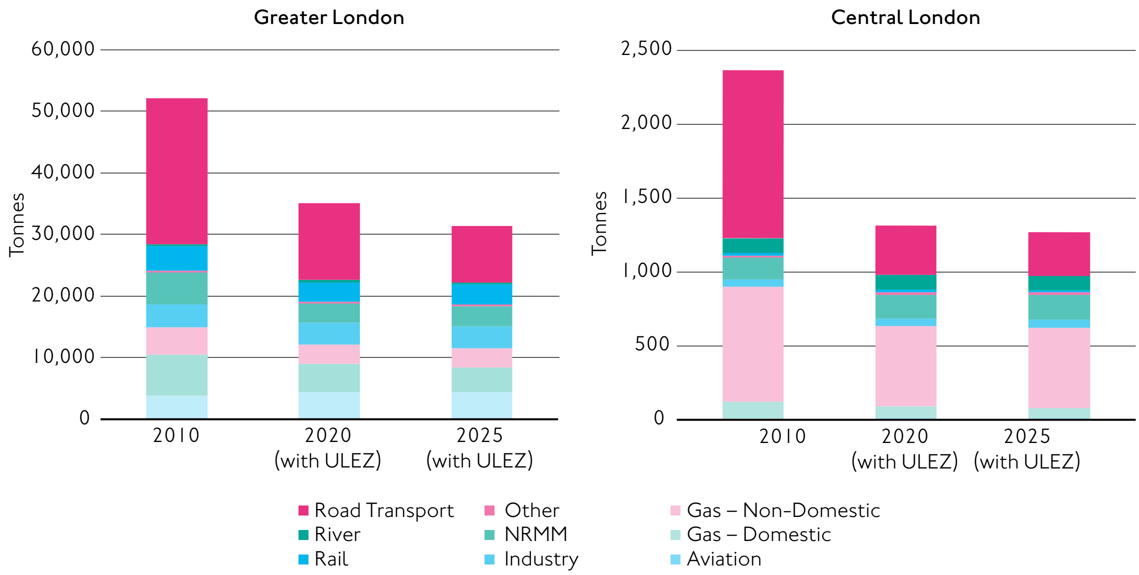


Projections also show that the current suite of policies could deliver a 40% reduction in the amount of NO_x emitted in Greater London per year between 2010 and 2025, and a 46% reduction in Central London. Much of this reduction is anticipated to be realised by 2020 with the introduction of the ULEZ, although other factors such as natural fleet turnover will result in additional reductions between 2020 and 2025.

Within the overall reductions, the projections show a significant shift in the source of emissions. For example, in Central London, road transport related NO_x emissions are projected to decrease by 74% between 2010 and 2025, whilst aviation related emissions are projected to *increase* by 77% (discussed further below). Based on these projections, road transport emissions would amount to just 23% of total NO_x emissions by 2025, down from 43% in 2010. This result relies heavily on the assumptions made about the performance of Euro 6 vehicles, as discussed above.

By contrast, the figures show that gas combustion is likely to remain a very significant source of NO_x emissions. Although NO_x emissions from gas combustion are projected to fall in absolute terms, they will increase substantially as a *share* of total NO_x emissions reaching 48% of total NO_x emissions in 2025 in Central London. **Whilst the focus of policy to date has been on road transport emissions, there are also potential reductions possible in other areas such as gas combustion which should not be overlooked.**

Figure 2.12: Trend in NO_x Emissions by Source[90]



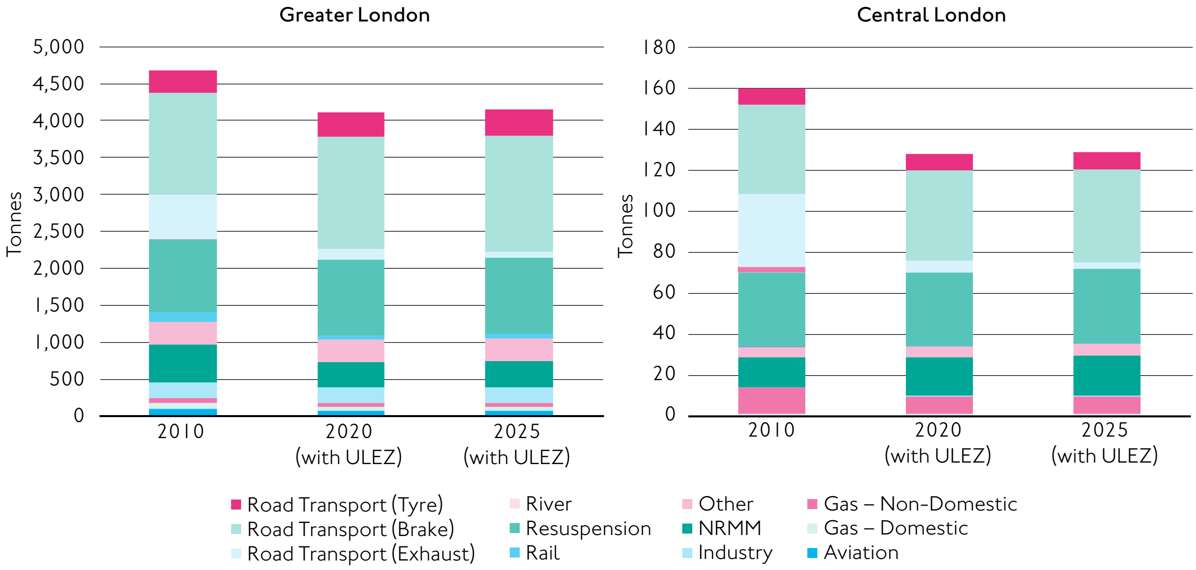
Although less significant in absolute terms, NO_x emissions from Non Road Mobile Machinery (NRMM) are projected to increase to 13% of total NO_x emissions in Central London by 2025 (up from 6% in 2010), becoming the third largest source of NO_x emissions. Whilst the GLA is already taking some action in this area through NRMM regulations (see Chapter 1), there may also be a case to strengthen policy in this area.

Another important trend is the growth in aviation related NO_x emissions in London. Aviation currently makes up 7% of total NO_x emissions in Greater London, but this could increase to 14% by 2025. Aviation emissions are forecast to increase due to a growth in air movements, whilst at the same time emissions from other sectors are decreasing.

Importantly, this does not yet factor in the impact of possible airport expansion around London. Although the Government has not yet made a decision on new airport capacity, the independent Davies Commission recommended the expansion of Heathrow airport to include a third runway.[91] This would increase the number of passengers from 70 million per year in 2011, to 104–129 million passengers per year in 2030.[92] It is beyond the scope of this report to consider the impact of Heathrow expansion on air quality in any detail (indeed our analysis only looks to 2025, whilst new airport capacity is expected by 2030). However the Davies Commission report recognised that Heathrow expansion presents "particular air quality challenges." The Commission recommended that new capacity should only be released "when it is clear that air quality around the airport will not delay compliance with EU limits." On this basis, the acceptability of Heathrow expansion in air quality terms rests not only on the extent to which air quality impacts at Heathrow can be mitigated, but also on the level of progress on air pollution in the rest of London. If pollution levels are brought within legal limits across the rest of London, then this could undermine the case for Heathrow expansion on air quality grounds.

Turning to particulate matter, the forecasts show that current policies will achieve a reduction in emissions, but not to the same extent as with NO_x. PM_{10} emissions are projected to decline by 12% between 2010 and 2020 in Greater London, and 20% in Central London. Notably, exhaust emissions are projected to decline substantially as a result of the ULEZ and tightening emissions standards (to the point of becoming negligible), whilst emissions related to brake and tyre wear are largely unaffected by these policies.

Figure 2.13 Trend in PM_{10} Emissions by Source[93]



Risks to Projections

Whilst the projections presented above are the latest and best available data, there are still a number of uncertainties relating to certain emissions sources which put the projections at risk. These issues affect all of the models currently available including the London Atmospheric Emissions Inventory, the modelling which underpins the ULEZ, and the modelling which underpins the Defra consultation on air quality.

Vehicle Emissions Factors

As discussed above, diesel vehicles have systematically underperformed against emissions standards. To an extent this is built in to emissions forecasts, for example the ULEZ modelling presented above assumes that emissions from Euro 6 diesel cars are around 3 times the stated emissions limits. This is a very important assumption which underpins the modelling of the impact of the ULEZ proposal, given that the objective of the policy is to push drivers towards adopting low emission vehicles. However, there is a degree of uncertainty and variation in the performance of Euro 6 diesel cars, with studies to date identifying real life emissions of 2.5 to 7 times the Euro 6 limit. The modelling also assumes very substantial reductions in NO_x emissions from HGVs and buses, which appears to be backed up by evidence, albeit that there is very little evidence currently available on their performance. Overall, based on current standards there is a risk that current models overstate the benefit of moving to Euro 6, although this could be mitigated if Euro 6 standards are tightened again in the future.

In addition, there are issues concerning the quantification of emissions from specialist vehicles. For example, there are a large number of refrigerated lorries on the road. Whilst the lorries themselves are regulated under Euro vehicle standards, the refrigeration units are generally powered by auxiliary engines which fall outside the regulations. Research has shown that refrigerated units emit up to six times as much NO_x as a Euro VI truck, and up to 29 times as much PM.[94] The GLA has suggested that 5–25% of heavy goods vehicles in Central London are refrigerated, and that the significant emissions associated with this are not currently included in emissions models.[95]

Decentralised Generation including CHP (Combined Heat and Power)

In the past, power generation has taken the form of large-scale centralised power stations such as coal, gas and nuclear facilities. Most large scale power stations in London have been closed down, the only exceptions being Enfield (a 400MW gas power station), and Taylors Lane (a 132MW open cycle gas turbine in North West London). However, there is now a trend towards deployment of smaller scale decentralised generation, including in cities such as London. This can take a number of forms including renewables, small scale gas and diesel generators, and Combined Heat and Power (CHP), which is a growth area. CHP units burn gas, biomass or other fuels, to simultaneously produce heat and power. They range from micro CHP units in homes (e.g. up to 5kWe), to larger units in office blocks, hotels, public buildings, and industrial premises (e.g. up to several MWs).

Decentralised generation is being encouraged through national level energy policy (by DECC), because it represents a more efficient way of delivering energy to end users than large centralised power stations, from an overall system point of view. CHP achieves very high levels of efficiency and is therefore beneficial in terms of CO_2 emissions, compared to alternatives. Decentralised energy is also being encouraged by the GLA which has a target of 25% decentralised energy by 2025. Modelling undertaken by the GLA shows that meeting this target would require around 4GW of capacity in London, including a mix of gas power stations, CHP, and energy from waste.[96] Decentralised energy is seen as playing a key role in meeting the Mayor's target to reduce carbon emissions by 60% by 2025 and 80% by 2050 (compared to 1990 levels). CHP is becoming more widespread in London, with a total of 195MWe of CHP capacity as at the end of 2014.[97]

However, there is a degree of tension between policies to promote decentralised energy, and air quality in cities. Some forms of decentralised energy are benign in terms of air quality – for example solar, fuel cells, and waste heat recovery. But other forms of decentralised energy, such as CHP, biomass, gas and diesel engines, could potentially increase local NO_x emissions, depending on what is being replaced, and the specific technologies chosen. In order to address this, the GLA has developed emissions standards for CHP, biomass and other forms of generation which are enforced through the planning system and require developers to use the best available technologies. However, the policy still allows emissions of up to 300mg/kWh for gas CHP turbines,[98] which is significantly higher than emissions from a modern heat only condensing boiler (less than 40mg per KWh).[99] The GLA has also put in place an "air quality neutral" policy which requires new developments to achieve emissions standards (per unit of floorspace) based on the average of existing buildings. However, given the pace of new development in London there is a risk that total building-related NO_x emissions could increase despite the policy.

Decentralised generation is also being promoted by DECC on the grounds that it makes a contribution to ensuring security of supply of electricity. Recent projections show that the UK is facing a very tight power capacity margin this winter of just 5%.[100] DECC has put in place a "Capacity Mechanism" which provides payments to existing and new forms of generation to ensure security of supply. However, the Capacity Mechanism does not distinguish supported power plants by their location, fuel type, or emissions, and it is therefore possible that policy is promoting new generation capacity to be built within Greater London or other cities where air quality is an issue.

National Grid holds a database of all projects supported under the Capacity Mechanism, but due to data quality issues it is difficult to identify the location of all projects. However, our review of the database suggests that *at least* 640MW of generation capacity in London has qualified for the Capacity Mechanism auction in 2015, including the existing Enfield and Taylors Lane facilities, plus a further 95MW of existing or new capacity. The true figure is likely to be higher given the gaps in the dataset. It is not yet known how much of this capacity will receive a contract through the mechanism, but there is a risk that the Capacity Mechanism is incentivising new generation to be built in cities such as London.

Our understanding is that emissions from CHP and other forms of decentralised generation are not fully reflected in current emissions models, and the models appear not to factor in any future growth in decentralised generation in the future.

Overall, without proper controls and regulations, there is a risk that deployment of fossil-fuel based decentralised energy could increase local NO_x emissions, undermining progress in reducing NO_x emissions from other sources such as road transport.

Non Road Mobile Machinery (NRMM)

There is significant uncertainty at present regarding the emissions from Non Road Mobile Machinery (NRMM) such as cranes, diggers, diesel generators, and small machinery used on construction sites. This is an area of active research, but the level of understanding is currently relatively low compared to other sources of local pollution. The estimates for NRMM emissions in current models are derived from top-down national models, and then pro-rated to local areas based on the amount of floorspace per area, as a proxy for likely levels of construction activity. The modelling methodology and figures for NRMM emissions changed significantly in the latest iteration of emissions models. The future projections for air quality assume a significant reduction in emissions from NRMM. However, the current policy in this area appears to have a number of loopholes, for example if compliant equipment is in insufficient supply, or if NRMM equipment is used temporarily on a site. Hence if the policy remains in its current form there is a risk that the actual impact will be lower. Overall, the estimates for current and future emissions from NRMM should be treated with a degree of caution.

Summary

The key findings from this chapter are:

Trends to date:

- Levels of PM pollution are now below European limits, but remain above WHO guideline levels in most of Greater London.
- NO_2 levels remain above legal limits across 12.5% of the Greater London area, in particular in Central London, and close to Heathrow and major roads.
- There has been limited progress in reducing NO_2 concentrations since the early 2000s, both in London and in the UK generally.
- This is mainly due to the growth in the number of diesel vehicles, combined with the failure of Euro emissions standards to control diesel NO_x emissions. There has been limited improvement in NO_x emissions over the last 20 years, and even the latest Euro 6 vehicles have NO_x emissions many times higher than legal limits in practice.

Key sources of air pollution:

- 82% of NO_x pollution in London is generated within London, whilst 75% of PM pollution in London comes from outside London.
- Road transport is responsible for approximately half of all NO_x and PM_{10} emissions in both Central London and Greater London. Since the models underestimate emissions from road transport, this is likely to be a minimum contribution.
- Buses, HGVs, and taxis are significant sources of NO_x in Central London, plus diesel and petrol cars in Greater London. Vans are also a significant source of PM_{10} emissions.
- Only 40% of road transport PM_{10} emissions relate to exhaust, with the remaining 60% related to tyre and brake wear.
- Non-domestic gas combustion makes up one third of NO_x emissions in Central London. Domestic gas combustion makes a significant contribution to NO_x emissions in Greater London, although less so in Central London (or in terms of PM_{10}).
- Non-road mobile machinery (NRMM) makes up 10% of NO_x emissions and 11% of PM_{10} emissions in Greater London.

Forward Projections:

- Projections show that air quality in London could improve substantially by 2020, with a 40% reduction in NO_x emissions. If the projections are realised, then 98% of Greater London would be compliant with NO_2 limits by 2025, although this would still leave an area equivalent to the size of Westminster and Camden combined (42 sq km) above air quality limits.

- However there are several risks to the current set of emissions projections. The failure of vehicle emissions standards, combined with the growth in Combined Heat and Power and other forms of decentralised generation, and uncertainty over emissions from construction vehicles and equipment, means that we cannot be certain that projected improvements in air quality will be realised. Current projections should therefore be treated as a best case.
- Further steps will be required, over and above current and planned policies, in order to improve London's air quality to the point where it is legal and healthy to breathe.
- There are examples of policies creating tradeoffs between greenhouse gas (CO_2) emissions and local air quality. The promotion of diesel cars, justified on CO_2 grounds, has had severe implications in terms of air quality. The promotion of decentralised generation could now be having a similar effect, reducing national CO_2 emissions but increasing local NO_x emissions.

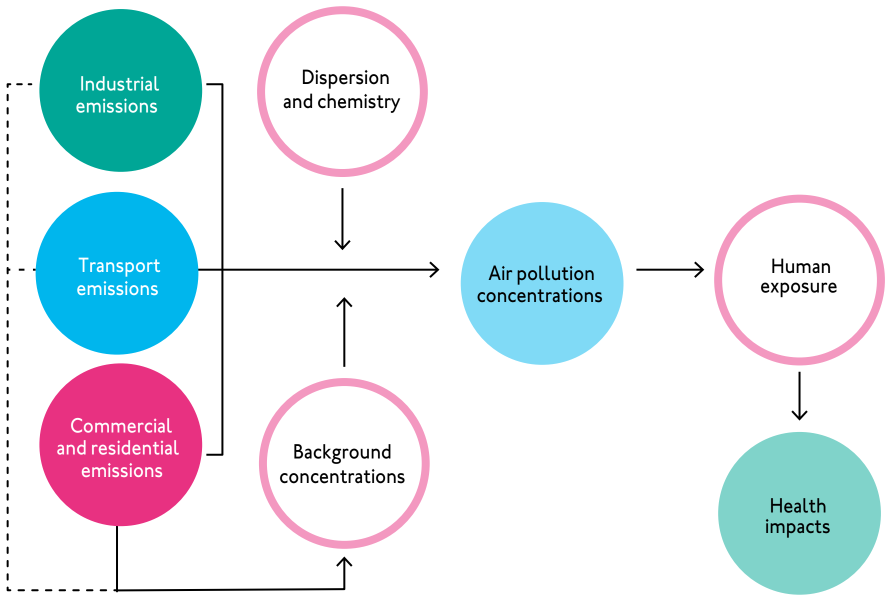
03 The Case for Action on Air Pollution

This chapter summarises the case for taking action on air pollution, on health and inequality grounds. This builds on the analysis presented in our previous report, *Something in the Air*.[101] We first consider the significant health impacts associated with air pollution in London, and the potential benefits which could be realised as pollution levels are reduced. Next we consider two specific groups of people significantly affected by air pollution – children, and working age adults. Lastly, we consider the relationship between air quality and inequality and deprivation.

Health and Wellbeing Impacts

The case for tackling air pollution in London is clear: London's air is unhealthy to breathe. There is now a significant body of research linking air pollution and ill health. Conceptually health impacts arise from human exposure to high concentrations of pollutants (Figure 3.1). Local concentrations of pollution are influenced both by emissions in the immediate vicinity, as well as emissions transported from elsewhere, and the level of human exposure depends on the extent to which high pollution areas coincide with areas where people live, work and travel.

Figure 3.1: The Relationship between Emissions, Concentrations, and Health Impacts[102]



The health impacts of particulate matter (PM) pollution have been documented for some time. The evidence base suggests that exposure to PM pollution can aggravate respiratory and cardio vascular conditions, and increase risk of death. Finer particles (often referred to as $PM_{2.5}$) can be inhaled more deeply into the lungs than coarser particles. Hence much of the health research focuses on the effects of $PM_{2.5}$ particles, although coarser particles may also have some health effects. Research on the health impacts of NO_2 pollution is still emerging but it has been shown to cause lung irritation, increase airway responsiveness in asthmatics, as well as lowering resistance to pneumonia, bronchitis and other respiratory infections.[103,104]

A 2010 study by the Committee on the Medical Effects of Air Pollutants (COMEAP) estimated that $PM_{2.5}$ pollution had an effect on mortality of 340,000 life years lost, equivalent to nearly 29,000 deaths across the UK in 2008.[105] In reality air pollution is likely to contribute a small amount to the deaths of a larger number of exposed individuals, rather than being solely responsible for the number of attributable deaths, but "equivalent deaths" is the accepted measure. Another way of expressing the impact is that it leads to a loss of life expectancy from birth of approximately 6 months across the entire population. The same study found that a reduction in $PM_{2.5}$ concentration by 1µg/m3 maintained for a lifetime would result in an increase in life expectancy of 20 days (in people born in 2008). **On this basis of these results, particulate matter pollution is second only to smoking in terms of the magnitude of its public health impact, and more significant than alcohol abuse, obesity, or drink or drug driving.[106]** Despite this, the Government spends very little on increasing public awareness of the problem.[107]

A study by King's College London provided estimates of the health impacts of air pollution in London in 2010.[108] It estimated that $PM_{2.5}$ pollution has a mortality burden of 53,000 life-years lost, equivalent to 3,500 deaths in 2010 (Table 3.1).

Table 3.1: Summary of Health Effects of Air Pollution in London[109]

Indicator	$PM_{2.5}$	NO_2	Total
Equivalent deaths at typical ages in 2010	3,500	Up to 5,900	Up to 9,400
Life years lost as a result of equivalent deaths in 2010	53,000	Up to 88,000	Up to 141,000
Average loss of life expectancy (for those born in 2010)	9.5 months (male) 9 months (female)	Up to 17 months (male) Up to 15.5 months (female)	*
Number of deaths brought forward as a result of short term exposure in 2010	787	461	1,248
Hospital admissions as a result of short term exposure in 2010	2,732	419	3,151
Monetary value of mortality burden in 2010 (2014 prices)	£1.4 billion	Up to £2.3 billion	Up to £3.7 billion

* Adding these results is not recommended as different people may be affected.

The study also, for the first time, estimated the health impact associated with NO_2 pollution in London, concluding that it has a mortality burden of up to 88,000 life-years lost, equivalent to 5,900 deaths in 2010. These figures can be added together, after accounting for some overlap between NO_2 and $PM_{2.5}$. **On this basis, the total mortality impact of $PM_{2.5}$ and NO_2 pollution has been estimated as up to 141,000 life years lost, equivalent to up to 9,400 deaths in London in 2010.**[110] Put another way, it has been calculated that $PM_{2.5}$ exposure reduces female average life expectancy by 9 months (9.5 months for males), and NO_2 pollution reduces life expectancy by up to 15.5 months (17 months for males), on average across the population of London. The same study also calculated that the mortality burden associated with poor air quality is valued at up to £3.7 billion (based on 2010 data).

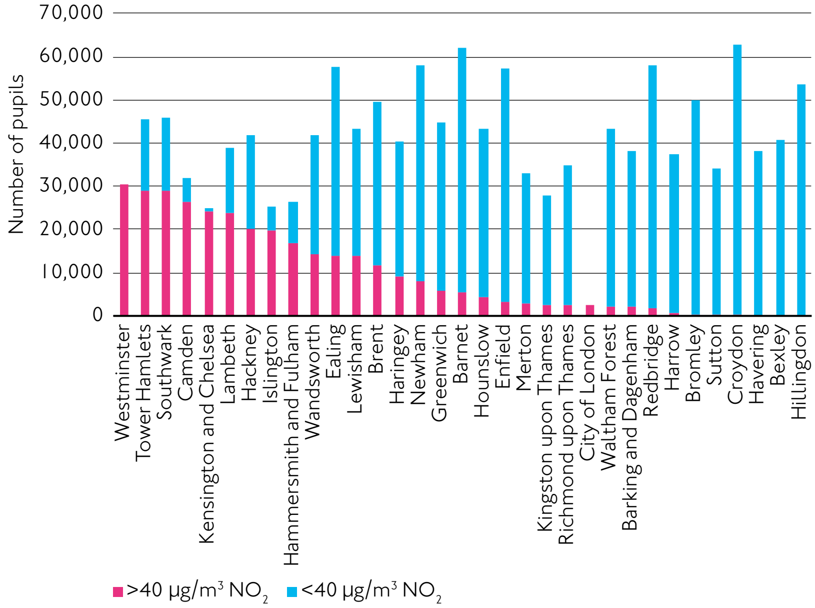
Impact on School Children

Research has found that children are particularly vulnerable to unsafe levels of air pollution – partly due to higher exposure, and partly due to children being more susceptible to the effects of air pollution[111] since they have incomplete metabolic systems, immature immune defences, and higher breathing rates than adults.[112] Evidence suggests that there is a causal relationship between air pollution and reduced lung function development, respiratory conditions, allergic sensitization, and exacerbation of asthma.[113] It is possible that air pollution plays a small part in causing asthma, particularly in those living near roads with heavy truck traffic.[114] Asthma affects approximately one million school children in the UK, and studies have shown that exposure to ambient air pollution is one of a number of factors which increase likelihood of symptoms occurring.[115] A study showed that those living near main roads in cities could account for some 15–30% of all new cases of asthma in children.[116]

It is suggested that children are likely to be disproportionately located in areas of high air pollution. This may be because, unlike adults, children have little choice about where they live or go to school.[117] It may also be because a larger proportion of this age group live in deprived areas where air pollution concentrations are highest (this is explored further below).[118]

Previous Policy Exchange research found that more than 320,000 children attend schools in London within 150 metres of a road carrying more than 10,000 vehicles per day.[119] We have conducted new analysis based on the data from the ULEZ modelling presented in Chapter 2, which shows pollution concentration levels at a very high resolution (20 metre by 20 metre grid squares). This shows that **328,000 children attend schools in London where NO_2 concentrations exceed the legal limit, representing just under 25% of the total school population in London**. These schools are predominantly located in the inner London boroughs, such as Westminster, Tower Hamlets, Southwark and Camden (Figure 3.2). 58% of pupils in Inner London Boroughs are in schools in areas with harmfully high NO_2 levels. The most polluted schools experience average NO_2 concentrations of nearly twice the legal limit.

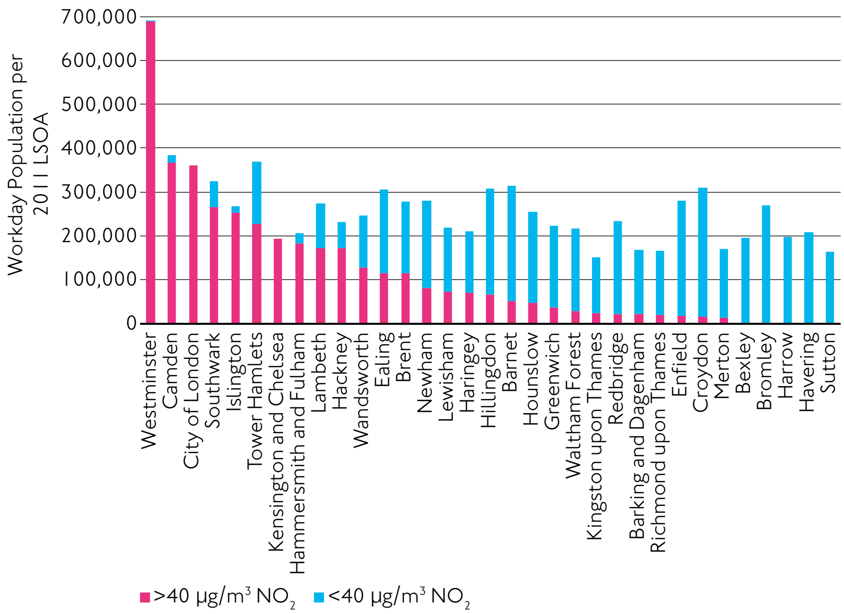
Figure 3.2: Number of Pupils Attending London Schools where Average NO_2 Concentrations within a 100 metre Radius of the School Exceed the EU Annual Limit[120]



Impact on the Working Age Population

Whilst working age adults are less vulnerable than children in their *response* to air pollution, their *exposure* can be extremely high. **Our analysis indicates that 3.8 million people work in parts of London which are above legal limits for NO_2 pollution,** representing 44% of London's workday population (Figure 3.3).[121] The problem is particularly bad in Westminster, Camden and the City of London, which have very large workday populations and high NO_2 concentrations.

Figure 3.3: Workday Population in LSOAs where the Average NO_2 Concentration is above or below EU Legal Limit[122]



Potential Health Benefits of Taking Action on Air Quality in London

As part of this study, King's College London (KCL) undertook new analysis to estimate the future health benefits from taking action on air pollution. KCL used the emissions projections presented in Chapter 2, which factor in the impact of all current and planned policies to tackle in air pollution in London, as well as growth in London's population and economic activity over time. KCL then quantified the health benefits of projected improvements in $PM_{2.5}$ and NO_2 in London, comparing the impact of being exposed to 2010 pollution levels for a lifetime, against being exposed to 2025 pollution levels for a lifetime. The following metrics were then assessed[123] (further details of the methodology can be found in Appendix 2):

- Change in average life-expectancy for those born in 2025;
- Total number of life years saved for the whole London population over time; and
- Change in economic costs associated with air pollution, annualized over time.

KCL's analysis shows that if projected improvements in air quality are realised then this would significantly improve life expectancy. If NO_2 levels stay as they are in 2010, then this would reduce life expectancy for females born in 2025 by 16 months. However, if pollution levels improve as expected to 2025 (and stay at this level), then the loss of life expectancy would be reduced to 11.5 months. In other words, **improvements in NO_2 would deliver an improvement in average female life expectancy of 4.5 months across all Londoners** (for those born in 2025). The health benefit of improving PM pollution is less significant, with an increase in life expectancy of 1 month. This is due to the fact that PM levels are already closer to health guideline levels, and that policies are projected to have less of an impact on PM than NO_2 pollution (see Chapter 2). More detailed results in terms of the life years gained for the whole population and the economic impact of these changes can be found in Appendix 2.

Table 3.2 Average Loss of Life-expectancy for those born in 2025, Exposed to 2010 and 2025 Concentrations for a Lifetime

Pollutant	Scenario	Impact on life expectancy for those born in 2025	
		Males	**Females**
NO_2	If concentrations stay as in 2010	-17.5 months*	-16 months*
	If concentrations stay as in 2025	-12.5 months*	-11.5 months*
	2025 compared with 2010	+5 months*	+4.5 months*
$PM_{2.5}$	If concentrations stay as in 2010	-9.5 months	-9 months
	If concentrations stay as in 2025	-8 months	-7.5 months
	2025 compared with 2010	+1.5 months	+1 month

* Figures shown as up to a maximum value assuming NO_2 (rather than other traffic pollutants) is responsible for all the effect. A 30% overlap with $PM_{2.5}$ is already taken into account.

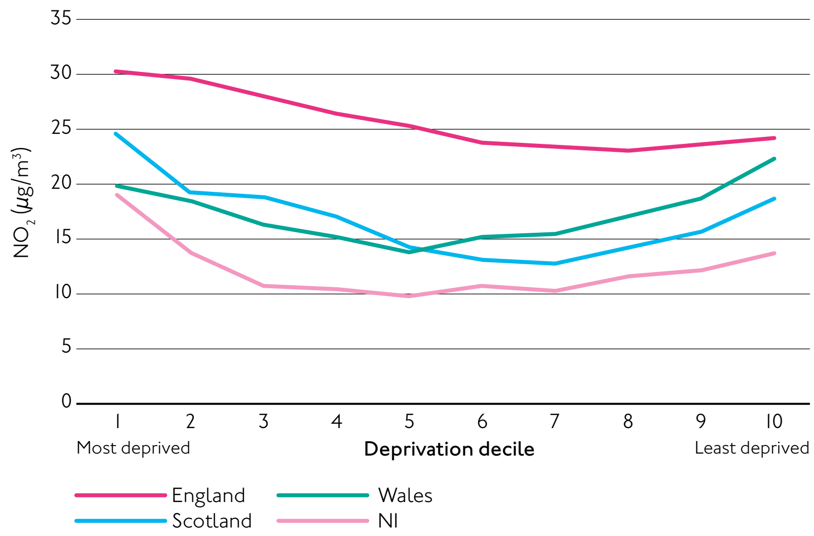
Overall it is clear that current and planned policies will materially reduce the health impact associated with air pollution in London, but not eliminate it completely.

Inequality and Air Pollution

The previous section described the health impacts that air pollution can have on people. However, pollution levels are not the same across London, or across the country, which means that some people will be exposed to higher levels of air pollution than others. Air quality is generally worse in urban areas than rural areas, and within urban areas there can also be significant variations in air quality. Various studies have considered whether deprived communities are disproportionately affected by air pollution, with mixed results.

Starting at national level, a 2006 Defra study found that England has higher levels of NO_2 and PM_{10} pollution than the remainder of the UK (Figure 3.4).[124] It also explored the link between air quality and deprivation using a modified version of the Index of Multiple Deprivation (IMD) dataset.[125] It found that the link between deprivation and air quality in the UK is not straightforward. Instead, there is a general trend of both the most and the least deprived areas suffering from above average levels of air pollution (a U-shaped distribution). This likely reflects the concentration of both deprivation and wealth in urban areas, which tend to have the highest levels of air pollution. Nevertheless, despite this U-shaped distribution, it is still generally the most deprived that experience the worst levels of air pollution. The exception is Wales, where the most deprived communities tend to be located in rural areas, which have better air quality.

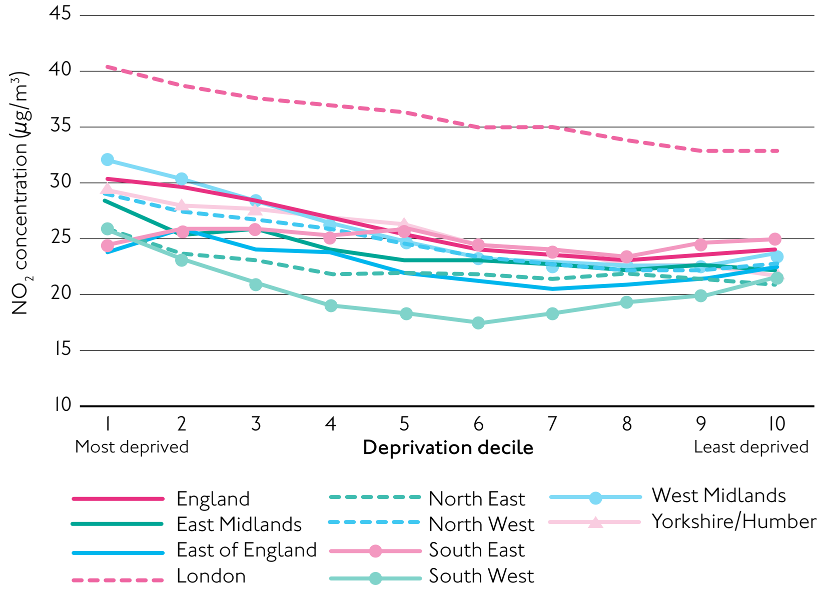
Figure 3.4: Mean Concentrations of NO_2 by Deprivation (decile) and Country in 2003[126]



Country Average µg/m³	England	Scotland	Wales	NI
	25.86	16.86	17.30	12.34

The same Defra study identified that London has much higher NO_2 and PM_{10} concentrations than all other regions of England, and that there is a more straight-forward link between deprivation and air pollution, with the most deprived areas in general experiencing the worst air pollution (Figure 3.5).

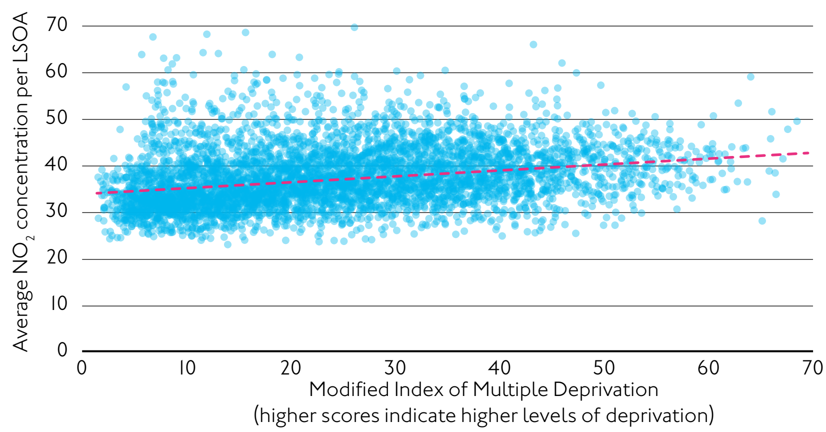
Figure 3.5: Regional Trends of Mean NO_2 Concentrations by Deprivation Decile in 2003.[127]



Air quality modelling has moved on significantly since the 2006 Defra study was published, so we have conducted new analysis of the link between air quality and deprivation in London using the latest available data. This uses data on NO_2 concentrations (in 2010) from the ULEZ modelling presented in Chapter 2. This has been summarised at Lower Super Output Area (LSOA)[128] and compared against the level of deprivation.[129]

Our analysis shows that across London as a whole, there is a weak positive relationship between deprivation and concentrations of NO_2 (Figure 3.6). More deprived areas experience higher levels of pollution in general, although there is considerable variation.

Figure 3.6: NO_2 Concentrations by Deprivation Score

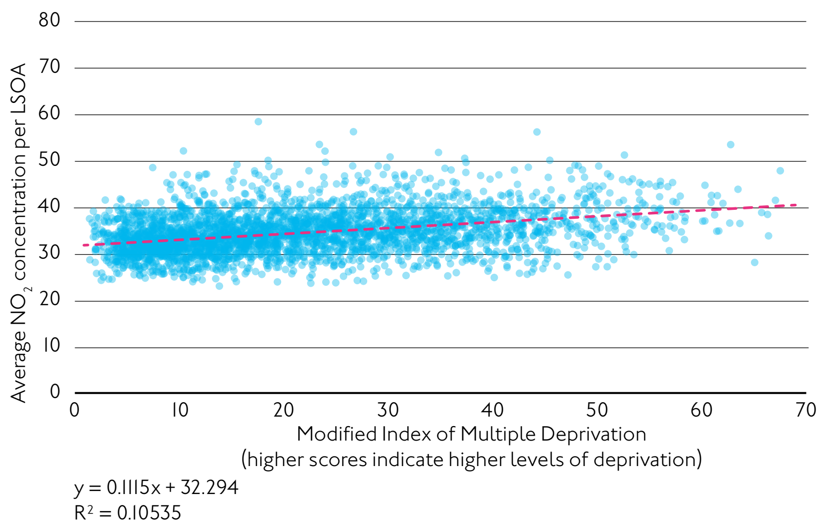


$y = 0.1253x + 34.682$
$R^2 = 0.07039$

Given that air pollution is markedly higher in Inner London, we have also analysed Inner and Outer London Boroughs separately. Our analysis shows that within Inner London there is no particular relationship between deprivation and NO_2 concentrations: air pollution within Inner London is generally high regardless of deprivation. For example, some of the highest levels of air pollution can be found in Westminster, which contains a mix of more and less deprived neighbourhoods. Overall, nearly 70% of Inner London (1,169 of 1,683 LSOAs) has an average NO_2 concentration above the 40µg/m^3 limit.

However, there is a statistically significant relationship between deprivation and NO_2 concentrations in Outer London boroughs (Figure 3.7). More deprived parts of Outer London are likely to experience higher levels of NO_2, although generally these remain below the legal limit (only 12% of Outer London LSOAs have average NO_2 concentrations above the 40µg/m^3 limit).

Figure 3.7: Outer London NO_2 Concentrations by Deprivation Score



Summary

The key findings from this Chapter are:

- Air pollution in London leads to very significant health impacts. If maintained at current levels, it would result in a loss of life expectancy across all Londoners born in 2010 of over 15 months for NO_2 pollution and 9 months for PM pollution. Exposure to air pollution in 2010 resulted in up to 141,000 life years lost, equivalent to around 9,400 deaths, for both pollutants.
- Short term exposure to pollution results in nearly 3,500 hospital admissions per year.
- The total economic cost of air pollution in London was up to £3.7 billion in 2010.
- Children are particularly susceptible to the effects of air pollution. 328,000 children attend schools in London where NO_2 concentrations exceed legal and healthy limits, making up 25% of the total school population.
- Although working age adults are less susceptible to the effects of air pollution than children, their exposure to air pollution is high. 3.8 million people work in parts of London which are above legal and healthy limits for

NO_2 pollution, with the largest numbers in Westminster, Camden, and the City of London.

- Taking action on air pollution could significantly reduce these health impacts, although not eliminate them completely. If projected improvements in air quality are realised, this would result in an improvement in life expectancy from birth in 2025 of around 6 months (5 months associated with the reduction in NO_2, and 1 month associated with PM).
- There is a complex link between air quality and inequality in London. In general, more deprived areas are likely to experience higher levels of pollution, although there is considerable variation. The link between inequality and poor air quality is stronger in Outer London than Inner London (where there are high levels of pollution in both more deprived and less deprived areas).

04 Conclusions and Next Steps

This report demonstrates the significant challenge associated with improving London's air quality. London's air is unhealthy to breathe, and this leads to significant health impacts. London is also in breach of air quality limits and has a legal duty to improve in the shortest time possible. London has already put in place a suite of policies to address air pollution, with additional policies being planned for the future. However, even if these policies deliver projected improvements in air quality (and there are several risks associated with this) then London will still fail to bring air quality within legal and healthy limits by 2025. There is a strong moral, legal and economic case for taking additional action on air pollution.

Next Steps

In the next stage of this project we will consider a range of possible policy options to address London's air quality challenge. These will be modelled quantitatively, identifying the benefits in terms of reduction in emissions and improvements in air quality, as well as indicative costs.

Policy options under consideration include:

Road transport	• Adoption of tighter Euro 6 standards (including Real Driving Emissions test) • Tightening/extending the Ultra Low Emission Zone and/or Congestion Charge Zone • Further investment in the bus fleet • Policies to encourage uptake of low emission taxis or retirement/retrofit of older taxis • Fiscal incentives to encourage a switch away from diesel
Gas combustion	• Boiler scrappage scheme • CHP regulations
Other	• Tightening NRMM standards and enforcement • Modal shift to encourage and increase in car sharing, walking, cycling • Freight consolidation • Low Emission Neighbourhoods and other measures at local level

Appendix 1: Overview of Methodology

Chapter 2 presents projections for emissions and air quality that include the Ultra Low Emission Zone (ULEZ) policy as well as all other current and committed policies. These projections were developed by TfL for use in the development of the ULEZ and were provided by TfL for use in this project.

The model used to undertake the scenario testing of ULEZ policies was based upon an updated version of the London Atmospheric Emissions Inventory 2010 (LAEI),[130] run through the London Air Quality Toolkit which is built on King's College London's modelling system, KCLurban. The KCLurban model uses a kernel modelling technique, based upon the ADMS model – a leading software for modelling air pollution.[131] The KCLUrban model estimates the contribution from each emissions source summed onto a fixed 20m x 20m grid. This is used to produce air quality maps showing the annual average concentration of nitrogen dioxide (NO_2), particles with an aerodynamic diameter less than 10 mm (PM_{10}) and particles with an aerodynamic diameter less than 2.5 mm ($PM_{2.5}$).

The model used hourly meteorological measurements from the UK Meteorological Office site at Heathrow, including measurements of temperature, wind speed, wind direction, precipitation, relative humidity and cloud cover. Sources from outside London have been represented by rural measurements of NO_x, and $PM_{10/2.5}$ from Defra's AURN (Automatic Urban and Rural Network) measurement network.[132] The KCLurban model also used road traffic emissions based upon KCL's well established emissions modelling methods, which are used for predictions within the LAEI.

Sources within the KCLurban model include: road transport (exhaust and non-exhaust), large regulated industrial processes, small regulated industrial processes, large boiler plant, gas heating (domestic and industrial-commercial), oil combustion sources (domestic and commercial), coal combustion sources (domestic and commercial), agricultural and natural sources, rail, ships, airports and others (sewage plant, fires, waste facilities etc). In modelling the emissions from large industrial processes use was made of emissions data and stack conditions (height, temperature, volume flow rate) for each source. Because emissions from biomass burning are not well represented in the London emissions inventory, an additional 1.05 $\mu g\ m^{-3}$ of $PM_{10/2.5}$ was added to the model results, and based upon the work of Fuller (2014).[133]

To predict air quality concentrations in London the KCLurban model sums together three source categories. First, for rural sources outside the model domain, use was made of rural NO_X, PM_{10}, $PM_{2.5}$ measurements taken from a combination of Harwell, Rochester Stoke and Maidstone monitoring sites, part of the UK AURN network. Second, within the model domain, but greater than 500m from a receptor location, London sources were represented as shallow volumes of 1x1 km horizontal dimension and 2m vertically for road traffic, and 50m vertically for other sources. Third, for those sources within 500m of a receptor location, a detailed treatment of road/rail/aircraft and gas combustion emissions sources was used. A complete description of the KCLurban modelling methods can be found at: http://www.kcl.ac.uk/lsm/research/divisions/aes/research/ERG/research-projects/traffic/TRAFFIC-SM-Air-pollution-Model.pdf.

Appendix 2: Modelling Future Health Impacts

Chapter 3 presents new analysis on health impacts associated with potential trajectories for air pollution in London. This Appendix provides a description of the methodology and more detailed results.

Methodology

The health impact of projected future trends in pollution was assessed by comparing two scenarios. The first scenario represented the effect of pollution remaining at 2010 levels for the next 120 years. The second assumed 2010 concentrations between 2011–19, 2020 concentrations between 2021–2024 and 2025 concentrations from 2025 until 2129. The methodology for assessing the relative risks associated with air pollution was as per previous studies[134], following COMEAP[135] and World Health Organisation (WHO) recommendations.[136]

Our approach to the calculation of future health impacts is to start with the 2010 population and mortality rates and feed in changes in the size and age structure of the population from year to year, adjusting the mortality rates according to the projected concentrations of anthropogenic $PM_{2.5}$ and NO_2 in 2020 and 2025. Essentially, this approach combines the health benefits of improvements in pollution between 2010 and 2025, with a lifetime follow-up period of 105 years, since survivors from a pollution reduction can die decades later. New births were included over time, assuming the same number of births as in 2010.

It should be noted that NO_2 is very closely correlated with other traffic pollutants, which could account for part of the results. Results are thus expressed up to a maximum, assuming NO_2 rather than other traffic pollutants is responsible for all of the effect. The results already assume a 30% overlap with $PM_{2.5}$.

Life years lost were valued using values recommended in Defra guidance[137], updated to 2014 prices. Consistent with this guidance, values for future life years lost were increased at 2% per annum, then discounted using the declining discount rate scheme in the HMT Green Book.[138] The economic impact was then annualised back to 2010, i.e. divided by the total number of years but front-loaded to take into account that benefits accrued soon are valued more than those accrued later.

Results

Life-expectancy from birth in 2025: The average loss of life expectancy for a person born in London in 2025 as a result of pollution is given in Table A1. For anthropogenic $PM_{2.5}$, it was estimated that the changes in life expectancy resulted in a gain of 42 and 38 days, respectively, for males and females born in 2025 and exposed with concentration at 2025 levels for a lifetime compared with 2010 levels for a lifetime. For NO_2 the gains are potentially larger, up to 155 and 139 days for males and females, respectively.

Table A1: Average Loss of Life-Expectancy for those born in 2025, Exposed to 2010 and 2025 Concentrations for a Lifetime

Pollutants	Scenarios	Male average loss of life expectancy	Female average loss of life expectancy
Anthropogenic $PM_{2.5}$	If concentrations stay as in 2010	~9.5 months (292 days)	~9 months (268 days)
	If concentrations stay as in 2025	~8 months (250 days)	~7.5 months (230 days)
	2025 compared with 2010	Gain of ~ 1.5 month (42 days)	Gain of ~ 1 month (38 days)
NO_2	If concentrations stay as in 2010	Up to ~ 17.5 months (534 days)[a]	Up to ~ 16 months (486 days)[a]
	If concentrations stay as in 2025	Up to ~ 12.5 months (379 days)[a]	Up to ~ 11.5 months (347 days)[a]
	2025 compared with 2010	Gain of up to ~5 months (155 days)[a]	Gain of up to ~4.5 months (139 days)[a]

[a] Figures shown as up to a maximum value assuming NO_2 (rather than other traffic pollutants) is responsible for all the effect. A 30% overlap with $PM_{2.5}$ is already taken into account.

Life years: Table A2 gives the total life years saved for the whole population over time, as a result of the improvements in pollution from 2010 to 2025. The projected changes in $PM_{2.5}$ between 2010 and 2025 result in a gain of 1.3 million life-years. For NO_2, the maximum gains were larger, up to 4.5 million life years, assuming a 30% overlap with $PM_{2.5}$.

Economic Value: Table A2 provides an estimate of the economic impact due to gains in life years as a result of the improvements in pollution from 2010 to 2025 and beyond. For $PM_{2.5}$ it is estimated to result in an annualised benefit of £0.7 billion, and for NO_2 the maximum annualised benefits are potentially larger at up to £2.5 billion (assuming a 30% overlap with $PM_{2.5}$).

Table A2: Total Life Years Saved for the Whole Population and the Annualised Economic Impact over time as a Result of the Improvements in Pollutant Concentrations from 2010 to 2025

Pollutants	Scenarios	Life Years lost	Annualised Economic impact (2010 prices)
Anthropogenic $PM_{2.5}$	Impact if concentrations stay as in 2010	9.2 million	£5.3 billion
	Impact for concentration changes 2010 to 2025	8.0 million	£4.6 billion
	2010 to 2025 compared with 2010 sustained	**Gain 1.3 million life years**	**Gain of £0.7 billion**
NO_2	Impact if concentrations stay as in 2010	Up to 16.8 million*	Up to £9.5 billion*
	Impact for concentration changes 2010 to 2025	Up to 12.2 million*	Up to £7.1 billion*
	2010 to 2025 compared with 2010 sustained	**Gain of up to 4.5 million life years***	**Gain of up to £2.5 billion***

* Figures shown as up to a maximum value assuming NO_2 (rather than other traffic pollutants) is responsible for all the effect. A 30% overlap with $PM_{2.5}$ is already taken into account.

Endnotes

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