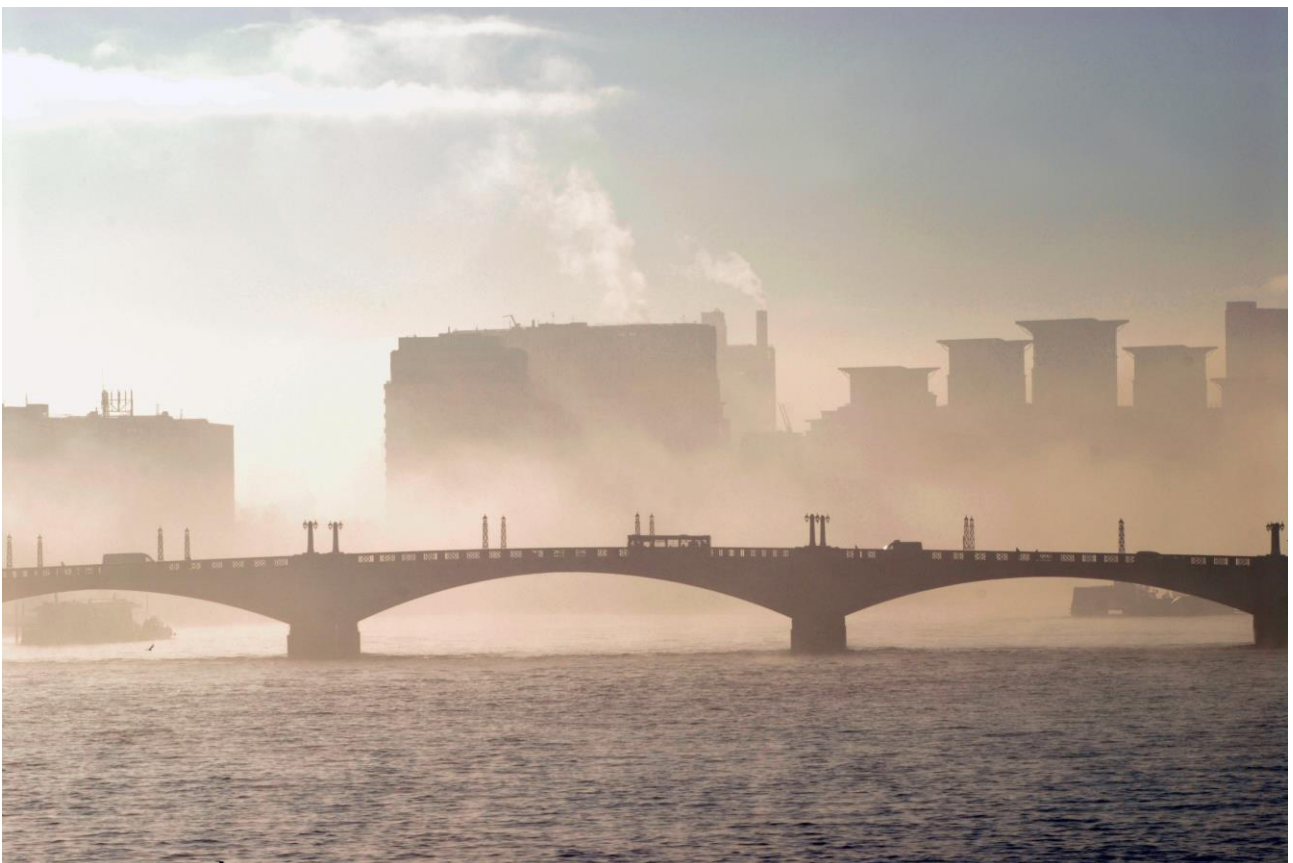


PM_{2.5} in London: Roadmap to meeting World Health Organization guidelines by 2030

October 2019



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**Greater London Authority
October 2019**

Published by
Greater London Authority
City Hall
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More London
London SE1 2AA

www.london.gov.uk

enquiries 020 7983 4000

minicom 020 7983 4458

ISBN

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Executive Summary

The Mayor of London commissioned the Environmental Research Group (ERG) at King's College London to model PM_{2.5} concentrations in London in 2030. This report outlines the assumptions and results of this modelling. Key findings of the report are:

- Although recent trends in PM_{2.5} (in London and across Europe) have been better than anticipated, the latest Londonwide modelling for 2016 found nowhere in London met the World Health Organization (WHO) guideline limit for the protection of human health
 - New modelling confirms that without the additional powers and measures outlined in this report, London will not meet its target of compliance with WHO limits for PM_{2.5} by 2030
 - As Parliament now considers a new Environment Bill, it is essential that the additional powers set out in this report are included in that legislation if the health of Londoners is to be protected
 - However, with the additional powers and measures, London is capable of meeting its target (as demonstrated in Figure 1), fulfilling the commitment the Mayor of London has made in the London Environment Strategy and as part of the Breathe Life campaign
 - The UK Government should follow in London's footsteps and adopt the WHO guideline limit for PM_{2.5} by 2030 as a legally-binding target
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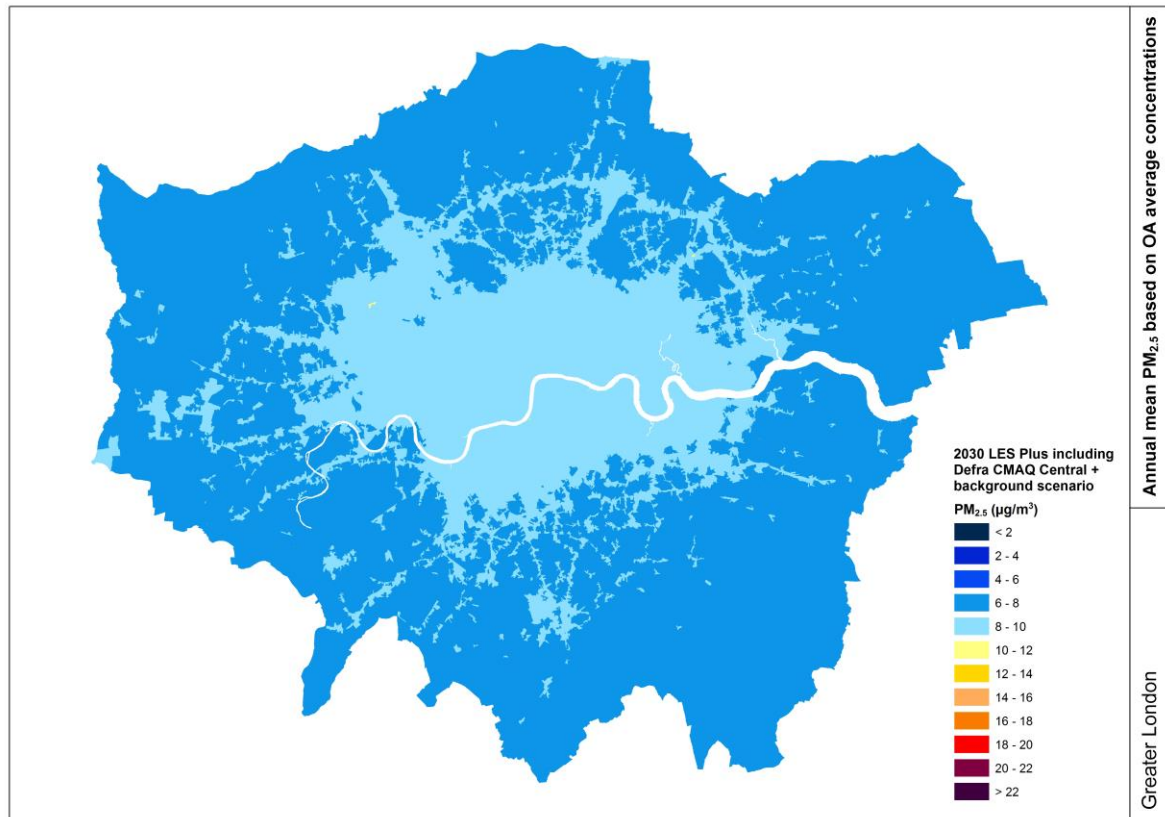


Figure 1: Annual average PM_{2.5} in 2030 with additional measures

Introduction

In October 2017 London was the first world megacity to sign up to the World Health Organization's (WHO) "Breathe Life" campaign. The campaign asks cities to commit to meeting the WHO recommended guideline limit for PM_{2.5} by 2030. This pledge was subsequently adopted in the statutory London Environment Strategy¹ published in May 2018.

The UK Government has now published its draft Environment Bill, which does not yet include the legally binding WHO based PM_{2.5} limits needed for the protection of human health. Nor does it include the new powers for London and other UK cities needed to achieve them.

However, as Parliament now considers the Government's draft bill, this report demonstrates how, with the necessary action at a regional and national level supported by new powers, London can achieve the WHO guideline limit for PM_{2.5} by 2030.

What is PM_{2.5}?

PM_{2.5}, also known as fine particulate matter, refers to particles or liquid droplets in the air that have a diameter less than 2.5 micrometres across (that's one 400th of a millimetre, about 3 per cent of the diameter of a human hair). Some PM_{2.5} is naturally occurring, such as dust and sea salt, and some is manmade, such as particulates from vehicle exhausts.

Based on current evidence PM_{2.5} is thought to be the air pollutant which has the greatest impact on human health. Both short and long-term exposure to PM_{2.5} increases the risk of mortality from lung and heart diseases as well as increased hospital admissions. Children growing up exposed to PM_{2.5} are more likely to have reduced lung function and develop asthma. The UK government's Committee on the Medical Effects of Air Pollution (COMEAP) estimate exposure to PM_{2.5} attributes to 29,000 premature deaths in the UK every year².

¹ London Environment Strategy, Greater London Authority, 2018

² The Mortality Effects of Long-Term Exposure to Particulate Air Pollution in the United Kingdom, COMEAP, 2010

Targets and Limits

The World Health Organization acknowledges that current evidence suggests no safe level for PM_{2.5}. However, the WHO set a guideline limit which reflects the level at which increased mortality from exposure to PM_{2.5} is likely. This recommended guideline limit is an annual mean concentration of 10 micrograms per cubic metre of air ($\mu\text{g m}^{-3}$)³.

In the European Union (EU), the legal annual mean air quality limit value (the “legal limit”) for PM_{2.5} is 25 $\mu\text{g m}^{-3}$. This limit has been transposed into UK law. The Mayor does not think this limit goes far enough for the protection of human health. That is why in the London Environment Strategy the Mayor set out the ambition that all of London will have concentrations of PM_{2.5} within the World Health Organization guideline limit by 2030.

Many regions containing large urbanised areas that are similar to London, such as California, Scotland and Japan, have already set more ambitious limit values for PM_{2.5}. The Breathe Life network now includes 63 regions, cities and countries with a combined population of 271 million people.

London currently meets the legal limits for both PM_{2.5} and PM₁₀ (also known as coarse particulate matter). London was able to meet the PM₁₀ limit for the first time in 2011, in part due to an extra £5 million in funding from the UK Government to create a London Clean Air Fund. This highlights that improvement in air quality is helped by Government support and funding.

UK Government analysis on PM_{2.5} compliance

In July 2019 the UK Department for Environment Food and Rural Affairs (Defra) published a report assessing the UK’s capability to meet the WHO guideline target for PM_{2.5} by 2030⁴. The report combined analysis from Imperial College London and King’s College London. Their modelling showed that 95 per cent of the UK would meet the WHO limit by 2030.

Defra’s modelling indicated areas in central London were still likely to exceed WHO guidelines in 2030. However, they did not take into account recent action London has taken to improve air quality, including introducing the world’s first Ultra Low Emission Zone (ULEZ). In addition, Defra did not take into account London’s future committed policies (as outlined in the London Environment Strategy) including tightening the standards of the Londonwide Low Emission Zone for heavy vehicles and expanding the central London ULEZ to the North South Circular roads.

³ WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide, WHO, 2005

⁴ Assessing progress towards WHO guideline levels of PM_{2.5} in the UK, Defra, 2019

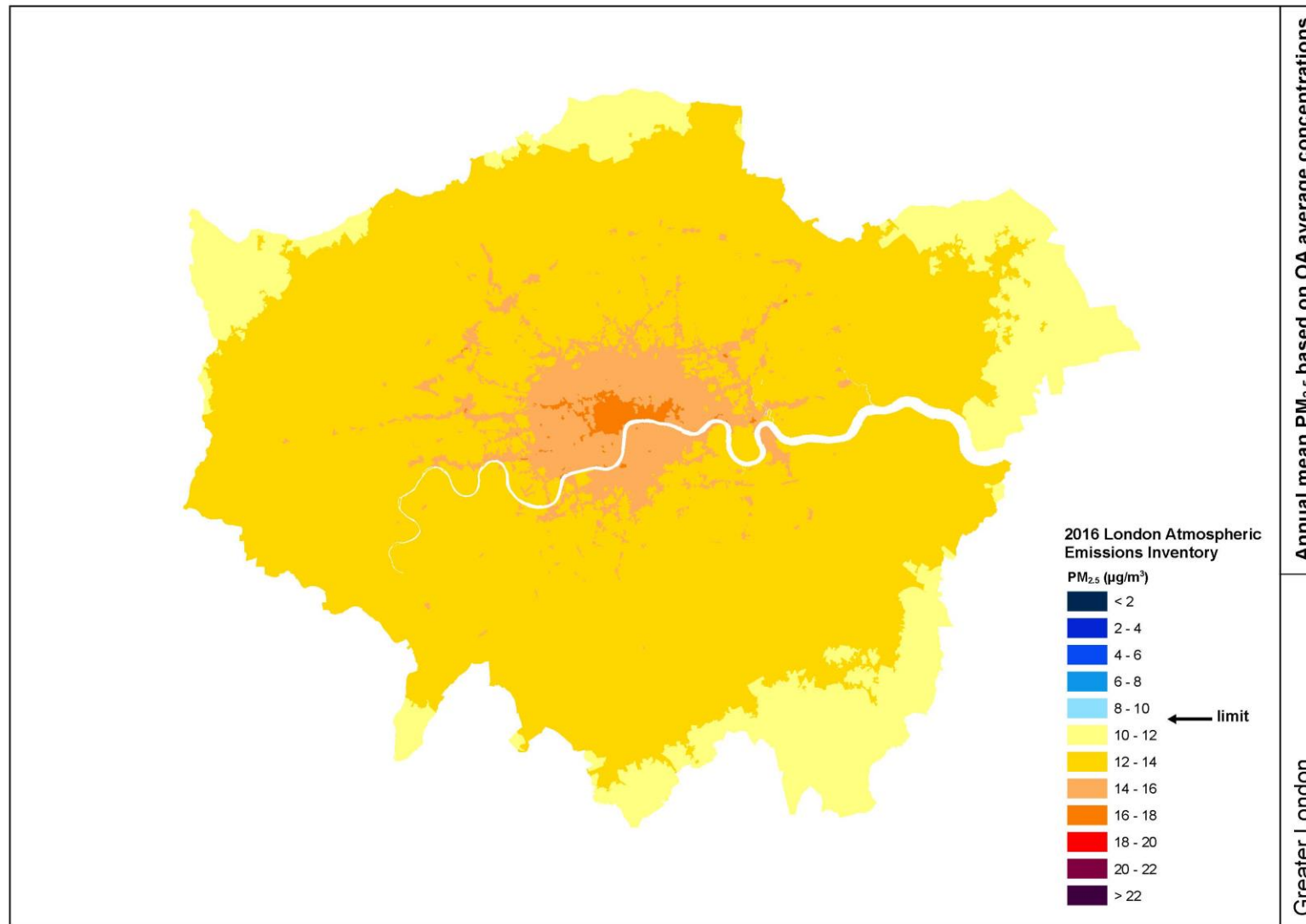


Figure 2: Annual mean PM_{2.5} in London in 2016 (Source: LAEI, 2016)

This report builds on Defra's modelling to show what reductions in PM_{2.5} are achievable once London's committed action, as well as additional powers and action requested by the Mayor, is taken into account.

Concentrations of PM_{2.5} in London

Figure 2 shows the annual mean concentrations of PM_{2.5} in London in 2016. The map has been produced by a model called the London Atmospheric Emissions Inventory (LAEI) produced by Environmental Research Group (ERG) at King's College London, Transport for London and the Greater London Authority⁵ and using the London Toolkit operated by King's College London. The LAEI is a bottom-up inventory of emissions across London, including all the major sources such as: transport; construction; and industry. These local London emissions are then modelled and dispersed over a background concentration with a large regional contribution from outside of London. The average PM_{2.5} concentration in London was 13.3 µg m⁻³ and there were no areas in London within the WHO guideline limit. Areas in light yellow had concentrations of PM_{2.5} between 10 – 12 µg m⁻³, this covers a small area at the very outskirts of the city which is home to 3 per cent of the population. The other parts of the map (in dark yellow, orange and red) are home to the remaining population of London.

Sources of PM_{2.5} in London

Unlike other pollutants, such as nitrogen dioxide, a big proportion of PM_{2.5} in London comes from regional, and often transboundary (non-UK) sources. In 2016 the estimated background concentration for PM_{2.5} was 10.2 µg m⁻³, meaning the external contribution to London's PM_{2.5} levels alone were above the WHO guideline of 10 µg m⁻³. Much of this background contribution comes from areas outside of London and the powers to tackle these emissions lie elsewhere within the UK and with other European governments. This is why, in addition to local action, London needs national, European and international action if it is to meet the WHO 2030 target.

The Mayor will work with European institutions, other European cities and city networks on efforts to minimise transboundary pollution. As noted above, the challenge of cleaning London's air is made tougher because nearly half of the PM_{2.5} pollution experienced is not created here. This is why close working with European partners through sharing best practice and coordinated action is required. This will help drive reductions in emissions across the continent and accelerate delivery of the National Emissions Ceiling Directive (NECD). Tighter NECD standards should be adopted to help cities like London achieve WHO air quality guidelines, particularly for PM_{2.5}. The Mayor will work with European institutions, other European cities and city networks to ensure that transboundary pollution affecting London is minimised and ensuring strong source control measures and regulations are adopted at EU level. This includes for real-world driving emissions testing,

⁵ [London Atmospheric Emission Inventory, 2016](#)

type-approval process arrangements, tyre and brake wear, and new emission standards (for example Euro 7).

Road transport is the largest individual source of PM_{2.5} in London, accounting for 30 per cent of local emissions. The introduction of the central London Ultra Low Emission Zone and cleaning up the bus and taxi fleets are expected to reduce PM_{2.5} emissions coming from road transport. However, a growing proportion of road transport emissions are now non-exhaust emissions including road wear, resuspension of particles and tyre and brake wear. Therefore, it is also essential to reduce the number of trips made by road and encourage walking, cycling and public transport where possible, as laid out in the Mayor's Transport Strategy.⁶

Biomass burning (including domestic woodburning) is the second largest source of PM_{2.5} in London, accounting for 16 per cent of local PM_{2.5} emissions. Construction, which includes emissions from Non-Road Mobile Machinery, is the next largest source making up 15 per cent of local emissions. The next largest individual source is cooking (including commercial cooking) which contributes 13 per cent of local emissions.

Together road transport, biomass burning, construction and cooking make up around three quarters of all local emissions of PM_{2.5} in London.

The Mayor of London has many of the powers required to tackle road transport emissions. The London Environment Strategy and Mayor's Transport Strategy include policies such as:

- Introducing the world's first Ultra Low Emission Zone (ULEZ) in April 2019
- Expanding the Ultra Low Emission Zone in 2021 to the North and South Circulars for all vehicles and London wide for lorries, coaches and buses from 2020;
- Transforming the whole of London's bus fleet by phasing out of pure diesel buses and purchasing only hybrid or zero-emission double decker buses from 2018, with the entire fleet becoming 'zero emission' by 2037 at the latest;
- No longer licensing new diesel taxis from 2018 and supporting the trade to upgrade to much cleaner 'zero emission capable' vehicles;
- Reducing traffic volumes by encouraging mode shift from travelling by car to walking, cycling and using public transport so that 80 per cent of all trips in London to be made on foot, by cycle or using public transport by 2041.

These policies will greatly reduce PM_{2.5} emissions from road transport.

⁶ [Mayor's Transport Strategy, Transport for London, 2018](#)

However, as a result of this powerful action, the emissions from non-transport sources will increase as a proportion of London's total emissions. The Mayor has much weaker – and often no – powers to tackle these sources. The London Environment Strategy laid out the additional powers required by the Mayor to tackle non-transport sources to achieve WHO recommended guidelines, including:

- Introduce a powerful new twenty-first century Clean Air Act to entrench citizens' right to breathe clean air and tackle pollution in London once and for all;
- Revitalise smoke control zones by making it easier to declare them, strengthening and bringing up to date local authority enforcement powers and conferring the ability to create zero emission zones where no combustion is allowed on certain, time limited occasions. This should include new powers to require appropriate abatement of significant combustion related sources of PM_{2.5} in London;
- Address wood burner emissions through a new fit-for-purpose testing regime and information on appropriate technology/ fuels for smoke control zones at point of sale as well as new powers for the Mayor to set tighter minimum emission standards for new wood burning stoves sold in London (for example, eco-design standard), or other standards based on contemporary understanding of pollutants such as PM_{2.5}, rather than “dark smoke” or “grit and dust”;
- Provide new powers for regional and local authorities to control emissions from Non Road Mobile Machinery (NRMM). This includes stronger enforcement powers to secure improved regulation of NRMM, including for auxiliary power and refrigeration units on vehicles and trailers, construction, road works, events and industrial sites; and
- Provide new powers and improved coordination for river and maritime vessels, including having a single regulatory authority for the Thames and London tributaries and introduce minimum emissions standards.

In addition, the Government should take a lead on working with industry and other partners to seek solutions to reduce emissions from tyre and brake wear alongside the other measures in the Clean Air Strategy.

Modelling

This section provides an overview of the method and assumptions for the latest PM_{2.5} modelling and how this differs from previous work. The key comparison is with modelling undertaken for the London Environment Strategy (LES) in May 2018. All modelling has been undertaken by the ERG at King’s College London in collaboration with Transport for London and the Greater London Authority.

London Environment Strategy (LES) model

The London Environment Strategy included PM_{2.5} forecasts for London for 2020, 2025, 2030 and 2050. The map for 2030 is presented in the Strategy document and discussed in greater detail in the evidence base⁷.

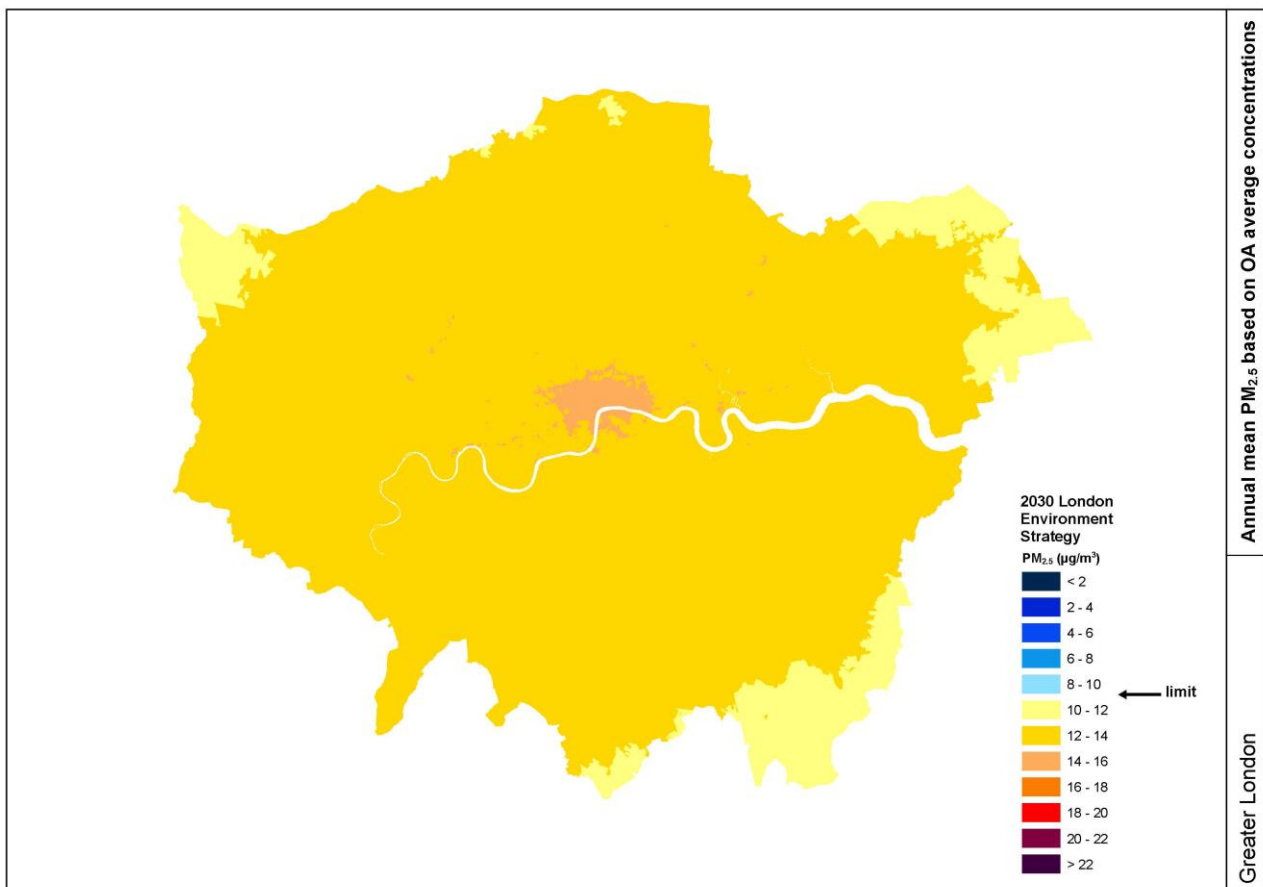


Figure 3: Annual mean PM_{2.5} in London in 2030 (Source: LES, 2018)

⁷ London Environment Strategy Evidence Base, Greater London Authority, 2018

The modelling showed, that despite a substantial improvement at all locations, all of London would continue to exceed the WHO guideline limit of 10 µg m⁻³ partly due to transboundary pollution causing high regional background concentrations.

However, the LES modelling did not take into account the additional powers and action by the UK government called for by the Mayor within the Strategy. This is a key difference between the previous and current modelling. The LES model was limited to modelling the impact of policies committed to be delivered directly by the Mayor in the London Environment Strategy and Mayor's Transport Strategy.

Updated “LES+” model

Additional measures

The “LES+” modelling presented in this report uses the same methodology as the LES model but is updated to include additional measures not currently in the Mayor of London's power to deliver or which would need to be delivered by the Government. These include additional action on:

- Woodburning
- Commercial cooking
- Shipping
- Domestic and industrial combustion of coal and oil

More detail on the additional action or support requested from Government is set out above and is included in the [London Environment Strategy](#) from page 100.

Updated base year

The LES model used 2013 as a base year to project to 2030, the LES+ model uses 2016, this update means LES+ reflects the recent improvements in PM_{2.5}.

Air pollution concentrations are highly sensitive to the prevailing meteorology within a year, such as wind speed, wind direction, precipitation and temperature, as well as the associated long-range transport of pollutants from outside London during the year. This is particularly the case for PM_{2.5} where the imported contribution is much larger.

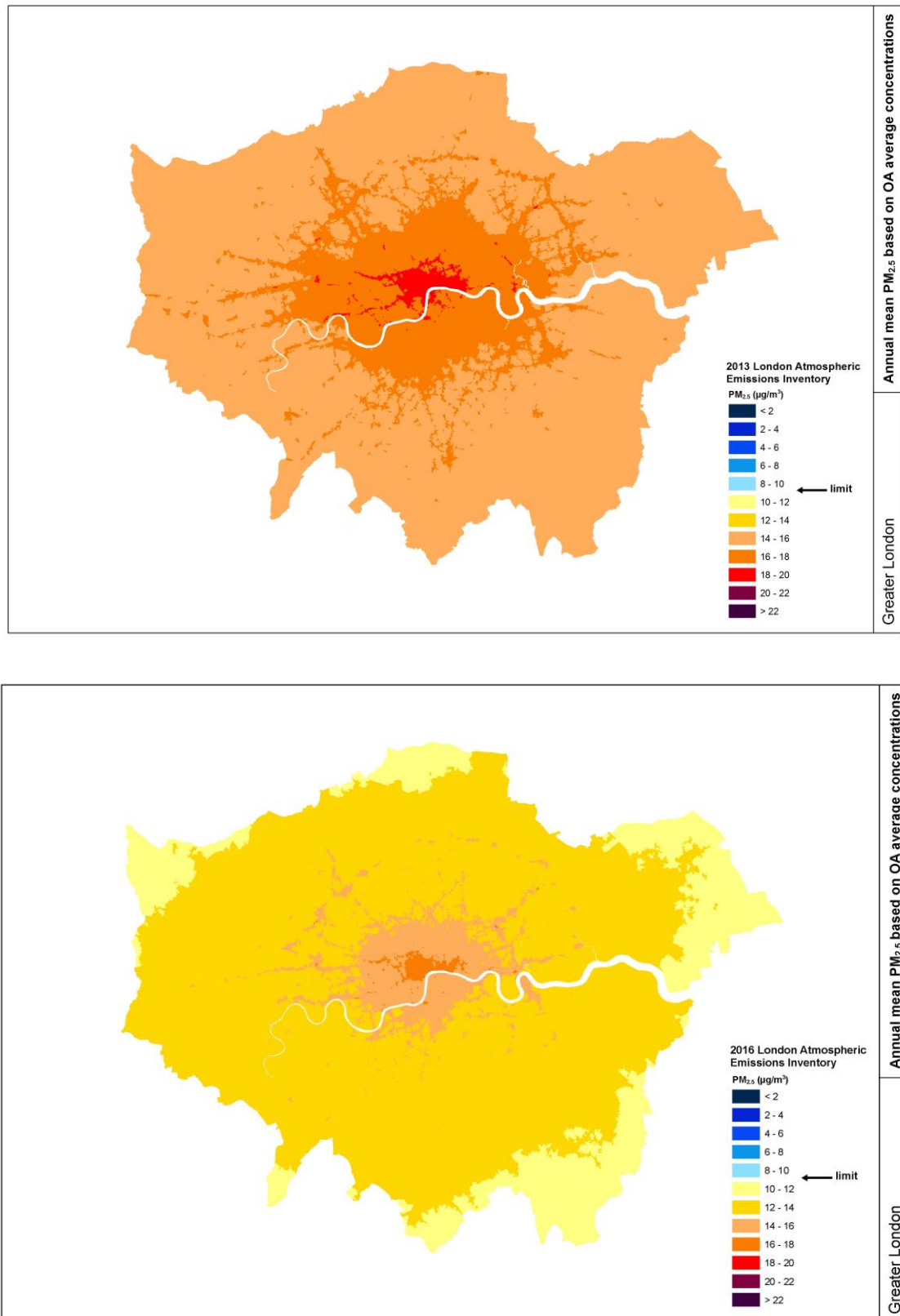


Figure 4: Annual mean PM_{2.5} in London from LAEI 2013 (top) to LAEI 2016 (bottom)

Figure 4 shows the annual mean PM_{2.5} concentrations from LAEI 2013 (top) and LAEI 2016 (bottom). Unlike nitrogen dioxide (for which there was little change over this period) there was a significant reduction in PM_{2.5} from 2013 to 2016. As a large proportion of PM_{2.5} comes from outside London much of this improvement can be attributed to changes outside of London; indeed, similar reductions have been reported across Europe.⁸ In contrast NO₂ concentrations are dominated by local activity, which is why the trends differ between the two.

To ensure that the reduction in PM_{2.5} from 2013 to 2016 is representative of a wider trend, and not a result of the natural inter annual variability described above it is important to look at the longer-term year on year trends.

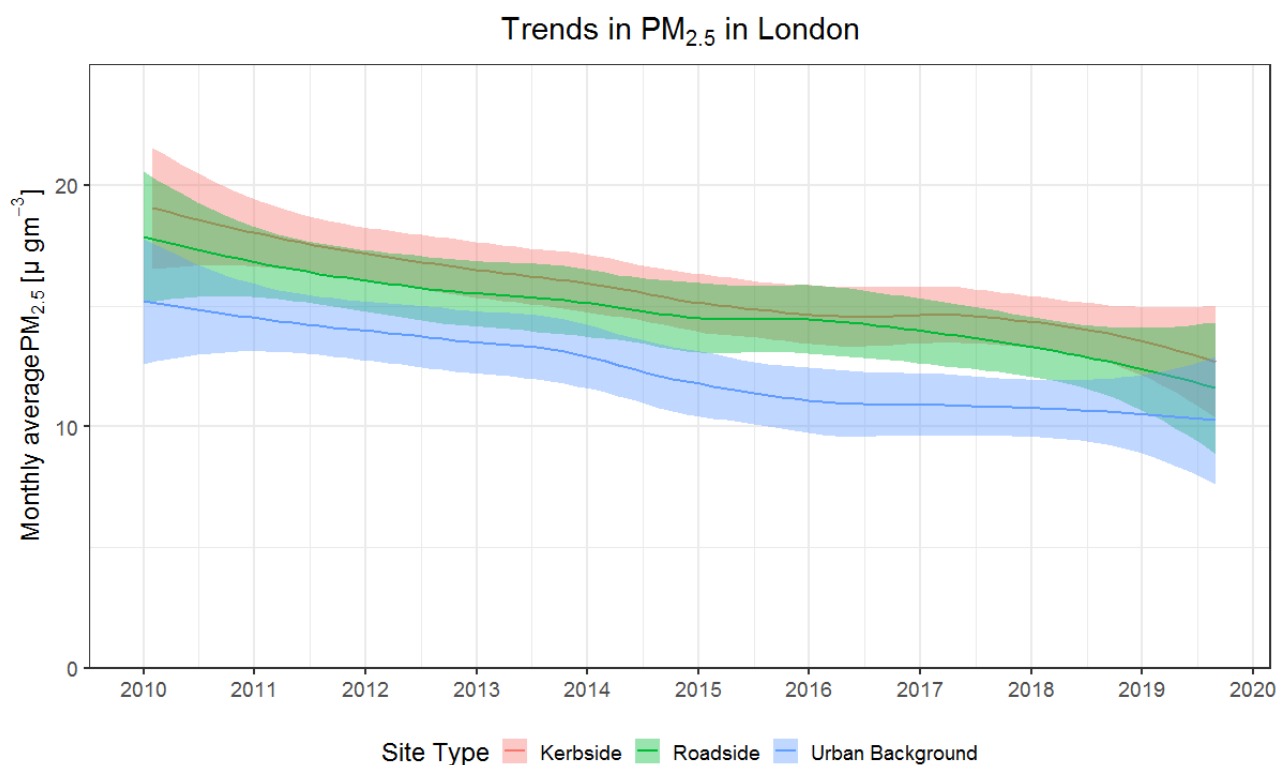


Figure 5: Monthly average PM_{2.5} in London

Figure 5 shows the monthly average PM_{2.5} from 2010 to 2019. There was a reduction between 2013 and 2016 for all site types. From 2016 onwards this slight downward trend continues, indicating the reduction between 2013 and 2016 was part of a wider trend, our modelling has been updated to reflect this. This updated base year with lower annual PM_{2.5} means less reduction is required to meet the 10 µg m⁻³ limit.

⁸ Air Quality in Europe – 2018 report, European Environment Agency, 2018

Updated regional background trend

An essential part of forecast modelling is projecting the trend of future reductions (or increases) in concentrations. For both the LAEI, LES and LES+ models the trend in regional background concentrations is calculated by the Community Multiscale Air Quality Modelling System (CMAQ) model. This is the part of the projection that reflects changes on a UK national and EU regional scale.

The UK Government Department for Environment Food and Rural Affairs (Defra) have worked with Wood Plc, Imperial College London and King's College London to model a CMAQ scenario which includes measures beyond those needed to attain the UK emission ceilings specified in the National Emissions Ceilings Directive. This scenario formed the basis for Defra's National Air Pollution Control Plan⁹ reporting. This scenario explored what additional reductions in PM_{2.5} could be achieved if a wider range of measures were implemented. For the latest LES+ modelling Defra have shared this scenario, reflecting the modelling in their National Air Pollution Control Plan.

⁹ National Air Pollution Control Plan, Department of Environment Food and Rural Affairs, 2019

Results

Figure 6 shows the annual average PM_{2.5} concentrations in each Output Area (OA) in London. Output areas are the lowest geographical level at which census data is provided and it is the best estimate for population exposure. An Output Area includes around 125 households.

As Figure 6 shows, with powers and resources provided by the Government, outlined in the previous section, London is capable of meeting the World Health Organization guideline limit for PM_{2.5} by 2030, with an average concentration of 8.0 $\mu\text{g m}^{-3}$. However, this also underlines that without these additional powers and measures London will not meet the WHO guideline limit by 2030.

Table 1: Annual average PM_{2.5} in 2030 population exposure

Concentration [$\mu\text{g m}^{-3}$]	Proportion of population [%]
6 – 8	50.6
8 – 10	49.9
10 – 10.6	<0.1

Table 1 lists the proportion of the population that fell within each concentration band. The dark blue area including most of Outer London represents 6 – 8 $\mu\text{g m}^{-3}$ and includes 50.6 per cent of London's population. The light blue area in Central and Inner London represents concentrations of between 8 – 10 $\mu\text{g m}^{-3}$ and includes 49.3 per cent of London's population. There are three small yellow areas which represent concentrations between 10 – 12 $\mu\text{g m}^{-3}$, these include less than 0.1 per cent of London's population. At these locations the highest concentration was 10.6 $\mu\text{g m}^{-3}$.

Based on the previous experience of achieving legal compliance with PM₁₀ legal limits in 2011, where a number of hotspots were effectively 'mopped up' with local measures, the modelling results provide an effective basis to be able to say with confidence that WHO recommended guidelines could be achieved across the whole of London by 2030 with the additional powers requested, as well as action and support from the Government. The Environment Bill is a crucial opportunity to ensuring that the additional powers the Mayor requires are provided. Without these it is unlikely that WHO recommended guidelines will be achieved, with corresponding and ongoing negative health impacts attributing to thousands of premature deaths.

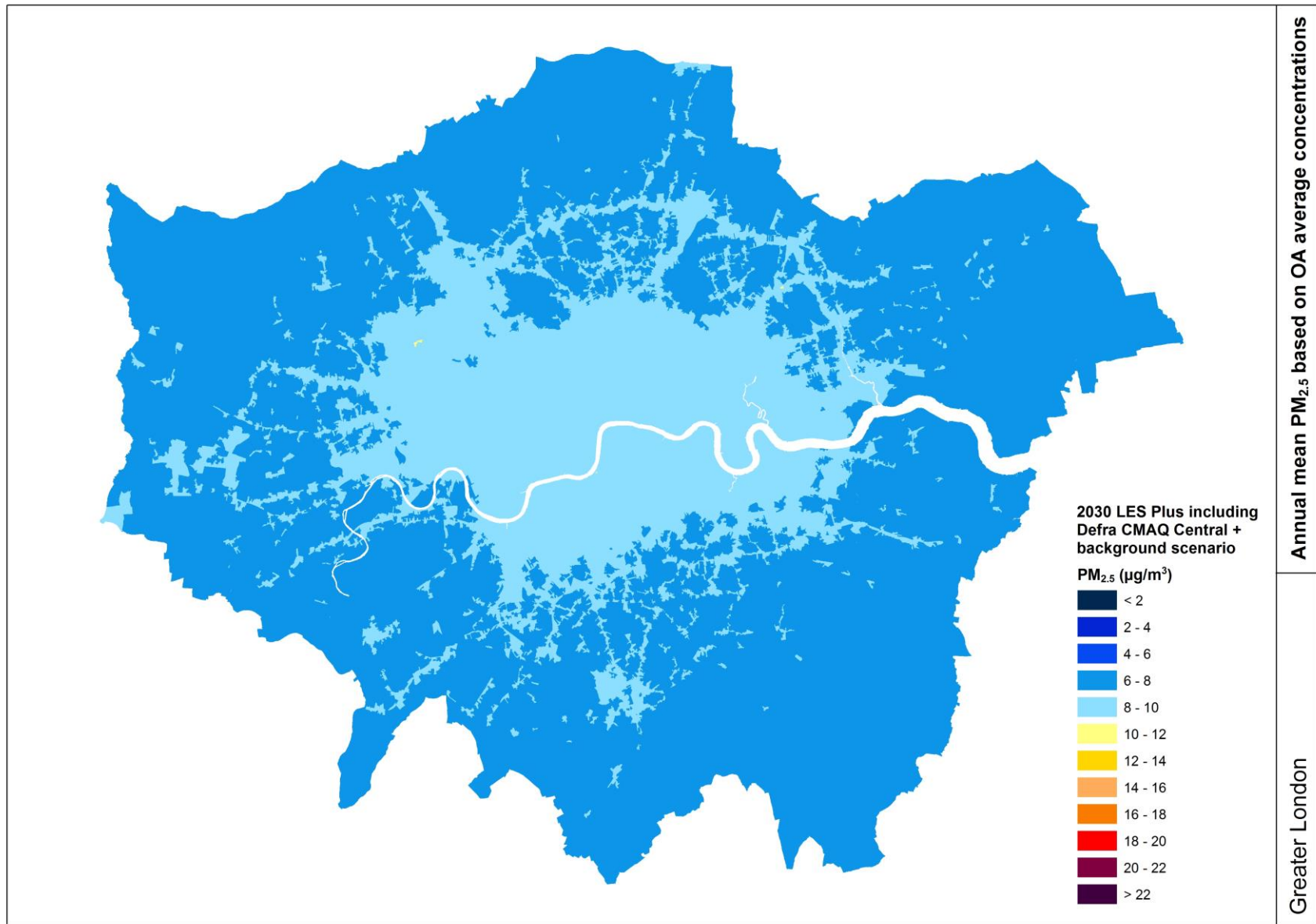


Figure 6: Annual average PM_{2.5} in 2030 with additional measures and updated background

Summary

The Mayor of London commissioned Environmental Research Group (ERG) at King's College London to produce an updated projection for PM_{2.5} in London for 2030. The aim was to evaluate if recent reductions in PM_{2.5} combined with additional powers for London and action at a national level would enable London to achieve its target of meeting World Health Organization limits for PM_{2.5} by 2030.

The new "LES+" model takes into account additional action on top of that included in the London Environment Strategy (LES) modelling. This includes additional powers and supporting action from Government for the Mayor to tackle emissions from woodburning, commercial cooking, shipping and the domestic and industrial combustion of coal and oil. In addition, greater reductions in regional background PM_{2.5} were assumed to reflect the delivery of a significantly greater level of ambition from the UK Government based on the commitments set out in their own Clean Air Strategy.

Modelling showed that, without the additional powers and measures outlined in this report, London will not meet its target of compliance with World Health Organization limits for PM_{2.5} by 2030. However, with the additional powers and measures, London is capable of meeting its target, fulfilling the commitment the Mayor of London has made in the London Environment Strategy and as part of the Breathe Life campaign.

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