Aether

# Air Pollution Exposure in London:

## Impact of the London Environment Strategy

**A Report for the Greater London Authority**

**January 2019**

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# Executive Summary

Poor air quality has been shown to have significant health impacts and is a policy priority for the Mayor of London, as identified by the London Environment Strategy (LES). The links between poor air quality and social inequality have also been shown in the scientific literature and elsewhere.

This report aims to identify the impact that the LES policies are predicted to have on inequalities with regard to air pollution in London, as compared to a "baseline scenario". Both scenarios include the implementation of the central London Ultra-Low Emission Zone (ULEZ-CL) as well as taking into account known future trends, such as vehicle use and performance and, to a certain extent, projected changes in the population of London. The LES scenario also includes the impact of policies and measures set out in the LES.

This report builds on previous analysis undertaken by Aether on behalf of the Greater London Authority (GLA): *Updated Analysis of Air Pollution Exposure in London* (2017) and *Analysing Air Pollution Exposure in London* (2013). Both of these previous reports focused mainly on the current air quality in London (as represented by the most up to date data available at the time), seeking to identify whether air pollution had a role in health and social inequality and the degree to which it could be quantified. However, the primary aim of this current study is to investigate the impact of future policy on inequalities in exposure.

The key outcome of the analysis is that the LES is projected to make significant progress in removing inequality associated with air quality, over and above the baseline scenario (including the central London ULEZ). More specifically:

- For $NO_2$, the difference in average concentration between the most and least deprived areas in 2013 is 7.6 µg/m$^3$, with a ratio of 0.81, which means that the average concentration in the most deprived deciles is 24% higher than the least deprived.
- The inequality in exposure across the deprivation scale is greatly reduced by 2030. For $NO_2$ the difference in average concentrations in the most to the least deprived areas goes from 7.6 µg/m$^3$ in 2013 to 3.7 in 2030 in the baseline scenario (including the ULEZ-CL) and 2.2 in the LES scenario, a reduction of 71%.
- The reduction in inequality is less marked for particulate matter but is lower than for $NO_2$ in any case. The difference for $PM_{2.5}$ goes from 0.9 µg/m$^3$ in 2013 to 0.5 in 2030 under the LES scenario, a reduction of 44%.
- Areas which have the highest numbers of mixed/multiple ethnic group residents are more likely to have the highest levels of $NO_2$ in 2013, whereas those with the highest numbers of white residents are more likely to have lower concentrations.
- This ethnicity exposure distribution does not change significantly by 2030 under either the baseline (including the ULEZ-CL) or LES scenarios, although the difference in highest concentrations for each ethnic grouping is greatly reduced
- The difference in the highest annual average concentrations of $NO_2$ across areas where non-white ethnic groups are most frequently resident (i.e. decile 10) and where they are less frequently resident reduces from 22.5 µg/m$^3$ in 2013 to 6.6 in 2030 in the baseline scenario and 3.3 in the LES scenario, a reduction of 85%.
- Out of a total of 2,367 schools analysed, 487 were shown to be in areas above the 40 µg/m$^3$ Limit Value for annual average $NO_2$ concentrations in 2013. This reduced to 15 in 2020 in the baseline scenario and 5 in the LES. Both scenarios reduce to zero in 2025 and remain at zero thereafter. However, no schools were below the WHO Guideline Value for $PM_{2.5}$ in either 2013 or 2030
- For future years (when the vast majority of schools have been brought into compliance with the legal limits for $NO_2$), no clear association was found between the level of eligibility

for free school meals (used as a metric for deprivation) and air pollution exposure at schools.

- For schools, hospitals and care homes, levels of exposure to $NO_2$ reduce over the study period, with the LES scenario significantly accelerating that improvement. Facilities closer to central London receive the greatest relative improvement in air quality

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## Common Abbreviations

| | |
|---|---|
| EEA | European Environment Agency |
| EU | European Union |
| GLA | Greater London Authority |
| IMD | Index of Multiple Deprivation |
| LAEI | London Atmospheric Emissions Inventory |
| LES | London Environment Strategy |
| LSOA | Lower Super Output Area |
| NO | Nitrogen oxide |
| $NO_2$ | Nitrogen dioxide |
| NOx | Nitrogen oxides (typically NO + $NO_2$) |
| $\mu g/m^3$ | Micrograms of a pollutant per cubic metre of air |
| OA | Output Area |
| PM | Particulate matter |
| $PM_{2.5}$ | Particulate matter less than 2.5 micrometres in diameter |
| $PM_{10}$ | Particulate matter less than 10 micrometres in diameter |
| TfL | Transport for London |
| ULEZ | Ultra-Low Emission Zone |
| ULEZ-CL | Central London Ultra-Low Emission Zone |
| WHO | World Health Organisation |

# 1 Introduction

Air quality has received increased attention in recent years and the scale of health impacts - equivalent to tens of thousands of deaths per year in the UK alone - marks it out as "the largest environmental health risk in the UK"[1]. In general, London faces the greatest air quality challenges in the UK, due to both its size and density and its proximity to continental Europe. The current Mayor of London, Sadiq Khan, has identified air quality as a priority area for policy and the London Environment Strategy (LES)[2], published in May 2018, contains a range of actions to improve air quality in London over the short, medium and longer term.

The aim of this report is to summarise the scale of the air pollution problem in London and what impacts the LES are projected to have to tackle the problem. It identifies the impact that the LES policies will have on inequalities with regard to air pollution in London, as compared to a "baseline scenario" which does not include the LES policies and measures but does take into account the central London Ultra Low Emission Zone (ULEZ-CL), as well as additional regional, national and international legislation, trends in energy use and vehicle performance and, to a certain extent, projected changes in the population of London. It builds on previous analysis undertaken by Aether on behalf of the Greater London Authority (GLA): *Updated Analysis of Air Pollution Exposure in London* (2017) and *Analysing Air Pollution Exposure in London* (2013). Both of these previous reports focused mainly on the current) air quality in London (as represented by the most up to date data available at the time, seeking to identify whether air pollution had a role in health and social inequality and the degree to which it could be quantified. However, the primary aim of this current study is to investigate the impact of future policy on inequalities in exposure.

## 1.1 Air quality inequalities

The links between exposure to poor air quality and adverse health outcomes are well established, underscored by an evidence base which is both mature and extensive. The role which exposure to poor air quality plays in health inequality is less well understood, although there is a developing literature on the issue, including the two studies mentioned above. The Centre for Research on Environment Society and Health (CRESH) published a report in 2013[3] examining the relationship between socio-economic inequality and exposure to air pollution in Europe. The study compared per capita Gross Domestic Product (GDP), as a proxy for social deprivation, with population-weighted concentration of $PM_{10}$ and Ozone within geographical units (NUTS 3 and NUTS 2 regions) across 27 EU countries, in 2006 and 2010. The study concluded that:

*"Whilst there is encouraging evidence demonstrating reductions in overall levels of air pollution across the EU the findings reveal that these advances have not been shared equally across all regions. Regional air pollution inequalities in the EU have narrowed slightly for short- and long-term $PM_{10}$, remained constant for short-term ozone, and widened for long-term ozone between 2006 and 2010. We found evidence of socioeconomic inequalities in pollution – mean $PM_{10}$ concentrations and long-term ozone concentrations were higher in the most disadvantaged areas compared to the least*

[1] Consultation draft of the Clean Air Strategy, Defra, 2018
[2] https://www.london.gov.uk/what-we-do/environment/london-environment-strategy
[3] CRESH, 2013, Geographical and Social Inequalities in Particulate Matter (PM10) and Ozone Air Pollution in the EU: 2006 to 2010, Centre for Research on Environment, Society and Health

*disadvantaged areas. This unequal burden may partially account for the well-established social gradient in health across areas and social groups in the EU".*

These findings have been confirmed in the academic literature, including for other air pollutants, and in a follow up study undertaken for the European Environment Agency (EEA) in 2018 (awaiting publication). In the original specification for this study, it was intended that data assembled for the EEA work would provide a comparison between London and other major cities in the UK and other European countries. However, different countries and cities collect different datasets to represent inequality and do so at different geographical scales. While the available data was found to be suitable for a large-scale assessment across Europe, when focusing on the city scale, a large number of anomalous results was produced. The data was not robust or comparable enough to provide useful information at the individual city scale. The results of that preliminary work have not been included in this report although will be provided separately to the GLA.

## 1.2 The London Environment Strategy

The LES, published in 2018, is London's first integrated environment strategy, bringing together approaches to every aspect of London's environment. Producing a single strategy allows the overall priories to be clarified, the interlinkage between different areas identified and the integration of actions to address them. The environmental issues addressed are:

- air quality
- green infrastructure
- climate change mitigation and energy
- waste
- adapting to climate change
- ambient noise
- low carbon circular economy

As part of the evidence base to support the strategy, Transport for London (TfL) published modelling for an assessment of future air quality in London, based on current trends and regulations and including the implementation of the ULEZ-CL. The policies and measures contained in the LES were then added to this "baseline" to produce an "LES scenario", and for each scenario a set of detailed air concentration maps were produced. This work allowed an assessment of the benefits of the LES and thus the development of a robust business case for their implementation. This work was undertaken separately from the current study although its outputs form the basis of the analysis undertaken here, as described in Section 2, below.

## 1.3 Report outline

Section 2 of this report addresses the datasets used, their origin and how they were used for the analysis. It also sets out some of the key assumptions and uncertainties regarding these datasets.

Section 3 sets out the outputs from the analysis, with the key messages detailed at the start of each subsection, which address:

- General exposure: how air quality is generally distributed across London and the changes shown over time for both the baseline and LES scenarios

- Deprivation: the relationship between projected levels of air quality and the Index of Multiple Deprivation (IMD)
- Ethnicity: how the distribution of ethnic groups across London correlates with the projected distribution of air quality
- Vulnerable receptors: how the projected air quality across London correlates with the likely location of "vulnerable receptors" as represented by schools, hospitals and care homes.

Section 4 summaries the key messages from the analysis.

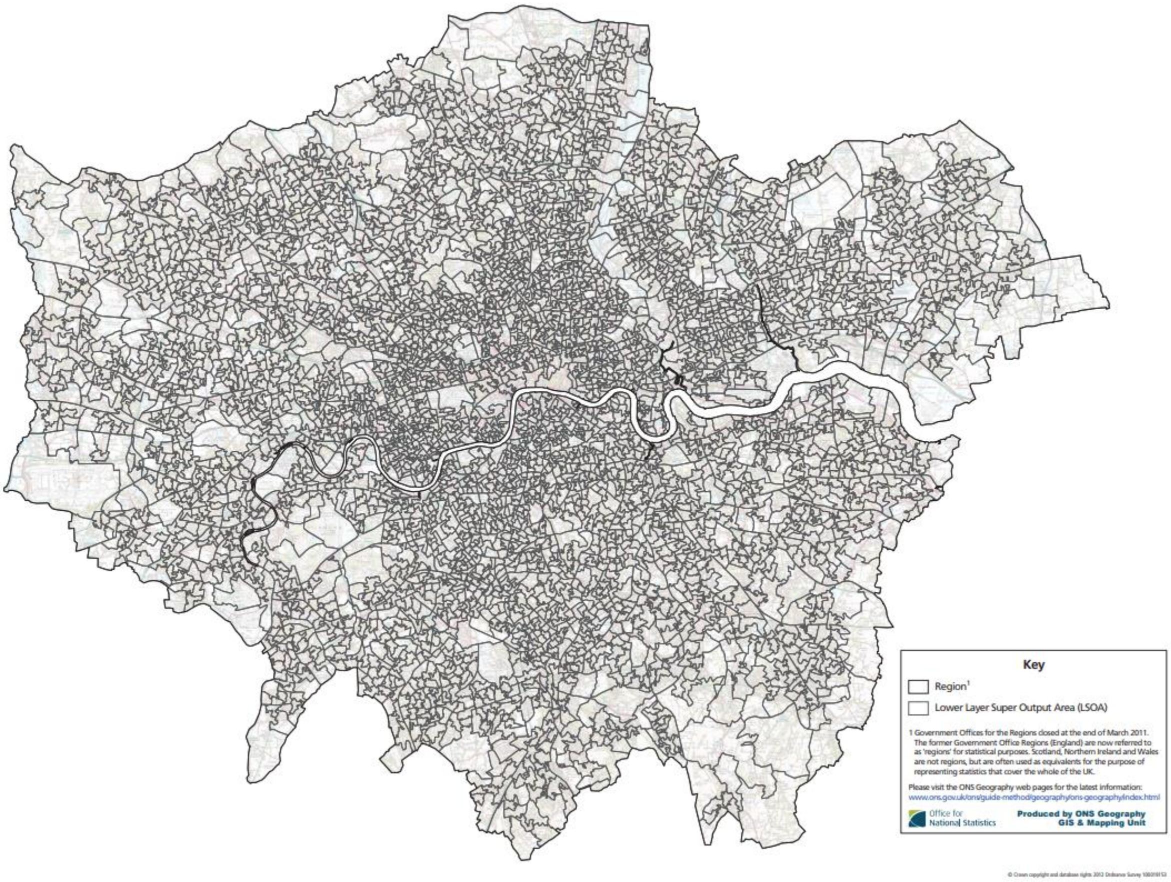
# 2 Data and Methods

Due to the complex nature of this analysis, data has been taken from a variety of different sources. This section outlines the sources of the various data required for this analysis relating to: air quality pollutants, deprivation, population, ethnicity, vulnerable receptor locations and intercity comparisons.

## 2.1 Geographical basis

The analysis used for this study is based primarily on the use of Output Areas (OAs) and Lower Super Output Areas (LSOAs). These are geographical units defined as part of the UK national census process and used as the basis for official, small area statistics. The boundaries of OAs are defined by a combination of UK postcode, ward and other electoral boundaries and the minimum size requirement, i.e. that they should have a minimum of 40 households and 100 residents, with a recommended size of 125 households. For the 2011 census, there were 181,408 OAs making up England and Wales (OAs in Scotland and Northern Ireland are defined slightly differently). LSOAs are an amalgamation of OAs aimed at improving small area statistics. In England and Wales, LSOA contain 1-2000 residents and between 400 and 1200 households. For the 2011 census, there were 34,753 LSOAs in England and Wales, of which 4829 are in London. **Figure 1** shows the 2011 LSOAs for Greater London.

*Figure 1: Lower Super Output Areas in London used for the 2011 Census*



## 2.2 Air quality pollutant concentrations

Annual average air quality concentrations of $NO_2$, $PM_{10}$ and $PM_{2.5}$ at a 20m resolution across London were obtained and supplied to Aether by TfL. The maps were calculated for concentrations in 2013 (the most recent historical year) and for 2020, 2025 and 2030. For each future year two scenarios were calculated: the LES scenario, i.e. with LES policies and measures, and the baseline scenario, i.e. without the impact of the LES but including the central London Ultra Low Emission Zone (ULEZ-CL). The concentration data are in the form of updated maps based on the latest 2013 LAEI emissions estimates[4]. It should be noted that there are significant uncertainties associated with future emission estimates, primarily due to the sensitivity of the concentration estimates to changes in base year meteorology and uncertainty in road transport emission factors, in particular the degree to which emissions test data match "real world" emissions, even with corrections.

In order to combine the pollution concentration data with population statistics, the pollution maps were aggregated to OAs and LSOAs by calculating an average air pollution concentration within each OA and LSOA based on the 20m grid squares that it covers. This analysis was undertaken by the Strategic Analysis team at TfL. The OA averages have been included in order to take into account concentration peaks at roadside locations. This data has been used to determine the air pollution exposure of the total population (see Section 3.2). However, average concentrations for LSOA have been used to compare air quality concentrations with the selected inequality indicators (see Sections 3.3 – 0) as some of indicators were only available at an LSOA level. To remain consistent, all inequality indicators have been compared against LSOA air quality concentrations.

In common with the previous report, the approach undertaken in this study considered pollutant concentrations within groups of LSOAs defined as deciles i.e. a ranked list of LSOAs divided into ten groups containing an equal number of LSOAs. Comparisons were made between the baseline scenario and the effects of implementing the LES. Average concentration data for LSOAs within deciles have been summarised as "box and whisker" plots, which are graphs that show the 2.5th, 25th, 75th and 97.5th percentiles and the maximum values within the distribution of values in each decile. This provides a very useful visual representation of the variation in pollution levels across the population variable. The change in concentrations across deciles is calculated for both the baseline and LES scenarios.

## 2.3 Index of Multiple Deprivation

The Office of National Statistics (ONS) has developed an established measure of deprivation known as the Index of Multiple Deprivation (IMD). IMD data across London for 2015 were obtained, 2015 data being available at LSOA scale[5] The IMD is made up of 7 domains of deprivation, each of which is compiled from a number of indicators. These indicators and domains are then given a weighting according to their perceived contribution to overall deprivation. These include:

- Income deprivation
- Employment deprivation
- Health deprivation

[4] https://data.london.gov.uk/dataset/london-atmospheric-emissions-inventory-2013
[5] http://data.london.gov.uk/datastore/package/indices-deprivation-2010

- Disability, education, skills and training deprivation
- Barriers to housing and services
- Crime and living environment deprivation.

The living environment includes air quality, houses without central heating and road traffic accidents involving pedestrians and cyclists. Air quality is included in the IMD, but it only makes up 1.5% of the total index and therefore it is not enough to bias the results. The overall scores for each domain are combined using the weightings to provide an overall IMD score.

For our analysis the LSOAs were ranked by IMD score and the rankings have been used to divide the LSOAs into decile (10%) ranges within which average pollution exposure and exceedances of the $NO_2$ limit value have been considered using the air concentration maps.

## 2.4 Population data and projections

Population data were obtained from the London Datastore for the population within each OA and LSOA in 2013, 2020, 2025 and 2030.

## 2.5 Ethnicity Data

Data from the 2011 Census at OA has been used to calculate the total population of the following ethnic groups within each LSOA: White, Asian/ Asian British, Black/ African/ Caribbean/ Black British, Mixed/ Multiple, and Other ethnic groups as defined in Table 1.

LSOAs were assigned a rank for each ethnic group and split into deciles according to the percentage of the population in these five groups in each LSOA. This approach provided five separate indicators of proportion of the population of each ethnic group within the LSOA, giving a metric similar to that available from the IMD and allowing the analysis techniques to be consistent.

*Table 1: The ethnic groups used and their corresponding sup-groups, taken from the 2011 census*

| Ethnic Group | Sub-groups |
|---|---|
| White | White: English/Welsh/Scottish/Northern Irish/British<br>White: Irish<br>White: Gypsy or Irish Traveller<br>White: Other White |
| Asian/Asian British | Asian/Asian British: Indian<br>Asian/Asian British: Pakistani<br>Asian/Asian British: Bangladeshi<br>Asian/Asian British: Chinese<br>Asian/Asian British: Other Asian |
| Black/African/Caribbean/Black British | Black/African/Caribbean/Black British: African<br>Black/African/Caribbean/Black British: Caribbean<br>Black/African/Caribbean/Black British: Other Black |
| Mixed/multiple | Mixed/multiple ethnic group: White and Black Caribbean<br>Mixed/multiple ethnic group: White and Black African<br>Mixed/multiple ethnic group: White and Asian<br>Mixed/multiple ethnic group: Other Mixed |
| Other ethnic groups | Other ethnic group: Arab<br>Other ethnic group: Any other ethnic group |

## 2.6 Schools, Hospital and Care Homes

The Strategic Analysis team at TfL has updated the analysis used in the previous studies of pollution concentrations within 150 m of schools using the 2013, 2020, 2025 and 2030 air pollution maps. The average $NO_2$, $PM_{10}$ and $PM_{2.5}$ concentrations within a 150 m buffer around each school was used to assess air pollution exposure. Concentration data were was also produced in the same way for a dataset of hospitals and care homes in London.

Access to free school meals was considered in the previous studies as a proxy measure of deprivation for school populations. This data was obtained for all schools in London (primary, secondary and 16+) from the London Data Store. Note that the number of schools is slightly different from the earlier studies, reflecting an updated dataset.

## 2.7 Uncertainty and assumptions

There are inherent uncertainties in the process of producing emissions estimates and in the calculation of air quality concentrations using dispersion models. These uncertainties are amplified when they are used to project into the future, with the added uncertainty of how policies and measures will be delivered and their effectiveness. However, given that these activities were undertaken outside this study, it is not intended to examine them in any detail here. It is worth noting that the estimates of future concentrations have been applied as supplied and that no sensitivity analysis has been undertaken as part of this study.

Various datasets have been used in this analysis, with different base years. Census data has been taken from the 2011 census and therefore does not completely reflect population patterns in 2013. Moreover, no attempt was made to analyse previous census data to provide a trend which could be extrapolated into the future. Likewise, data on the IMD rating for each LSOA (2015 base year) is assumed to remain unchanged, as is the number and location of schools, hospitals and care homes (2017 base year). The only dataset which varies for future years other than air pollution concentrations is the total population of London, for which population projections were provided by TfL. This means that the total population is assumed to grow but that distribution of IMD ratings, proportion of different ethnic groups resident in each area and the number and location of schools, etc. remains unchanged. This is unlikely to be the case in reality but it is not possible to provide any assessment of the impact this assumption could have on the study’s outputs.

Using LSOAs and even OAs as the basic geographical unit means that statistics become normalised across areas in a way that might not reflect reality. In particular, air pollution concentrations, even at OA level, may not capture the full range of concentrations to which residents are exposed. Thus, where areas are described as, for example, being below the EU Limit Value for annual average $NO_2$ concentrations, that does not necessarily mean that there are no points within the area that exceed that value. OAs capture such peaks far better than LSOAs but are still subject to variations in concentrations across their areas. Using annual average statistics reduces this effect but does not eliminate it. Thus, the concentration maps and analysis presented here are not intended as a compliance assessment.

# 3 Exposure Analysis

## 3.1 Introduction

Using the datasets described in Section 2 (above), analysis was undertaken to assess the relationship between exposure to air pollution in London and three key social indicators:

- Index of Multiple Deprivation (IMD) scores at LSOA level;
- The reported ethnic makeup at LSOA level, split into frequency deciles for that ethnic group
- Vulnerable receptor locations: schools, hospitals and care homes

This section describes the outcome of that analysis and builds on analysis previously undertaken by Aether in 2017[6] and 2013[7]. The key difference in this analysis is the assessment of exposure in future years, between the Baseline Scenario (including the ULEZ-CL) and the LES Scenario, i.e. with the additional policies and measures set out in the LES. However, no comment is offered on the impact of any particular policy or measure with regard to changing exposures. Analysis has been undertaken for exposure to $NO_2$, $PM_{10}$ and $PM_{2.5}$. It is important to note that benefits from the ULEZ-CL, introduced in April 2019, are captured in the baseline scenario and that the LES scenario does not take into account the additional powers and action by the UK government and the EU called for by the Mayor.

## 3.2 General Exposure

**General Exposure: key messages**

- Exposure to both $NO_2$, $PM_{10}$ and $PM_{2.5}$ greatly reduces between 2013 and 2030, with the LES significantly accelerating that improvement
- For $NO_2$, the majority of LSOAs are below *20µg/m³ by 2030 in the LES scenario but above that level for the baseline scenario*, with some areas still above 25µg/m³
- For $PM_{2.5}$, there is a marked improvement in the LES scenario compared with the baseline between 2025 and 2030, with almost all areas exposed to between 12 and 14 µg/m³. However, no areas are below 10 µg/m³.

This section describes the general concentration and exposure pattern for $NO_2$, $PM_{10}$ and $PM_{2.5}$. The maps in Figure 2, Figure 3 and Figure 4 show the average concentrations in each LSOA across London, colour coding them according to magnitude. Note that the scale varies for each pollutant. They show a familiar pattern of higher concentrations towards the centre of London, with both key arterial roads and Heathrow Airport clearly visible. For all pollutants, there is a decrease in concentrations across the time period, with the LES accelerating that trend.

The impact of the LES is further demonstrated in Figure 5, Figure 6 and Figure 7, below, which show the difference in concentrations across London between the LES and baseline (including the ULEZ-CL) scenarios. They show that the differences are significant

[6] https://www.london.gov.uk/WHAT-WE-DO/environment/environment-publications/updated-analysis-air-pollution-exposure-london-final
[7] https://www.london.gov.uk/WHAT-WE-DO/environment/environment-publications/analysing-air-pollution-exposure-london

and increase over time. Of particular note is the acceleration of that difference for Particulate Matter, in particular $PM_{2.5}$ after 2025.

The way in which the concentration changes are reflected in population exposure is illustrated by the figures below. These show the total number of people exposed to different concentrations over time, with and without LES policies and measures. This analysis is based on the population recorded in each LSOA in the 2011 census, which is then projected forward using future population estimates. The distribution of the population across London is assumed to remain constant and the height of the bars reflects the projected growth in London’s resident population.

*Figure 2: Average concentrations at LSOA Level for $NO_2$, 2013-2030, for the baseline (including the ULEZ-CL) and LES scenarios*

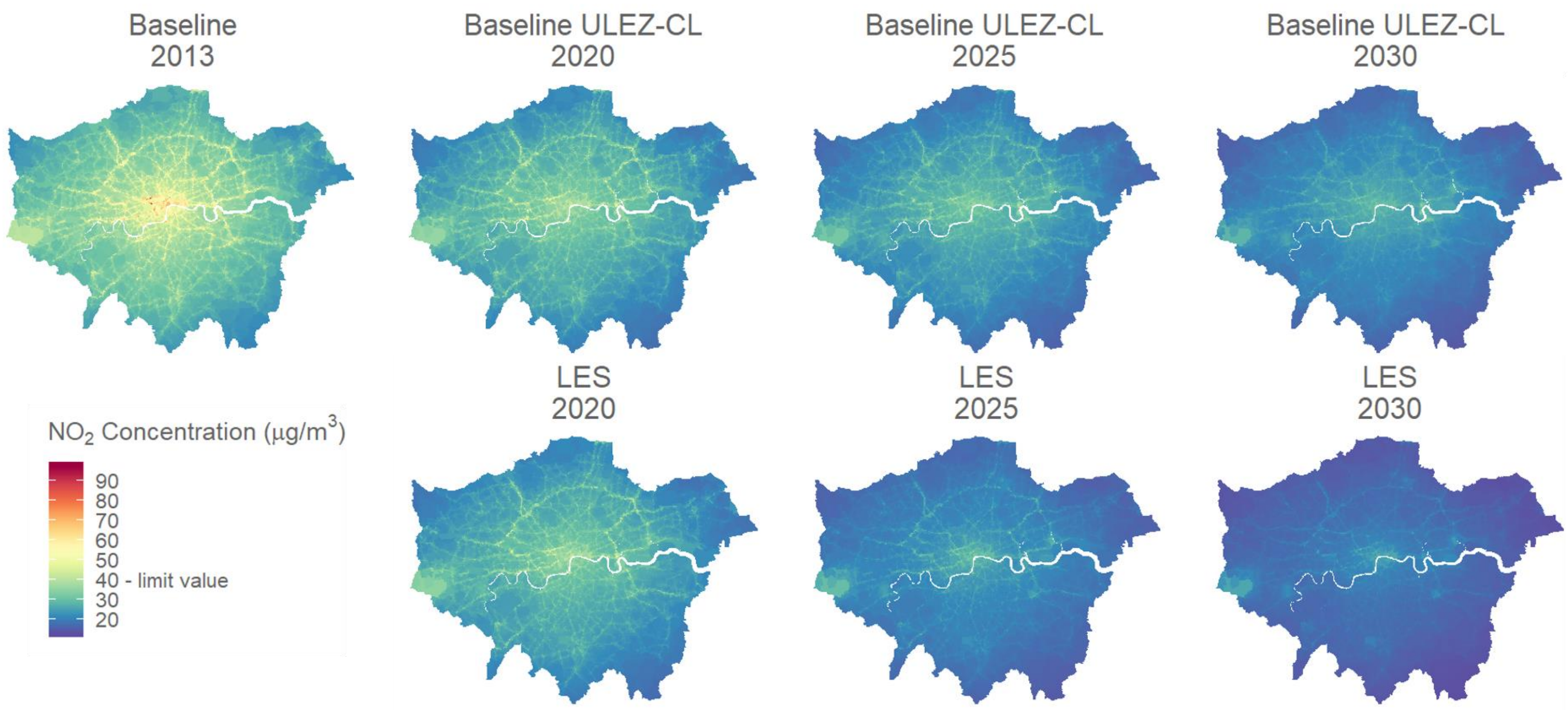


*Figure 3: Average concentrations at LSOA Level for $PM_{10}$, 2013-2030, for the baseline (including the ULEZ-CL) and LES scenarios*

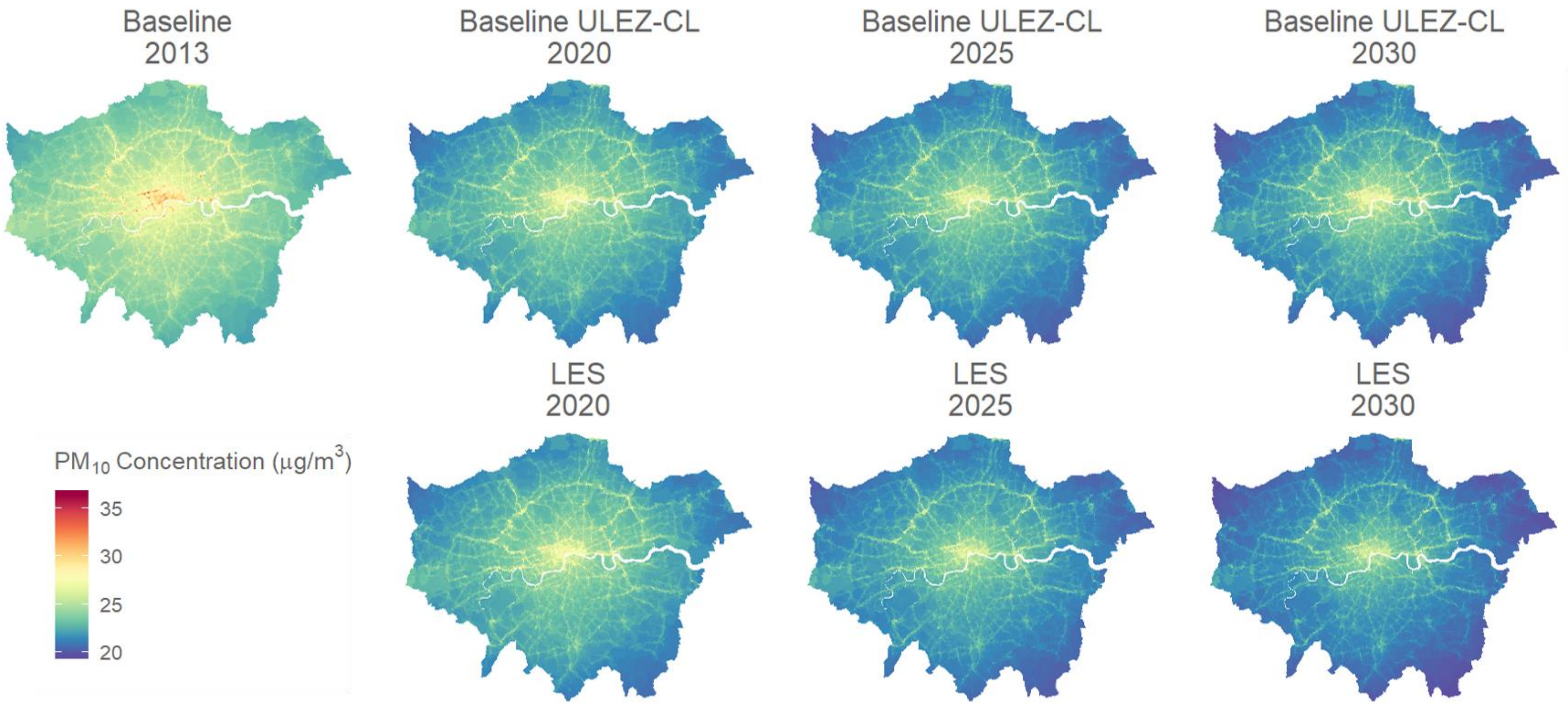


*Figure 4: Average concentrations at LSOA Level for $PM_{2.5}$, 2013-2030, for the baseline (including the ULEZ-CL) and LES scenarios*

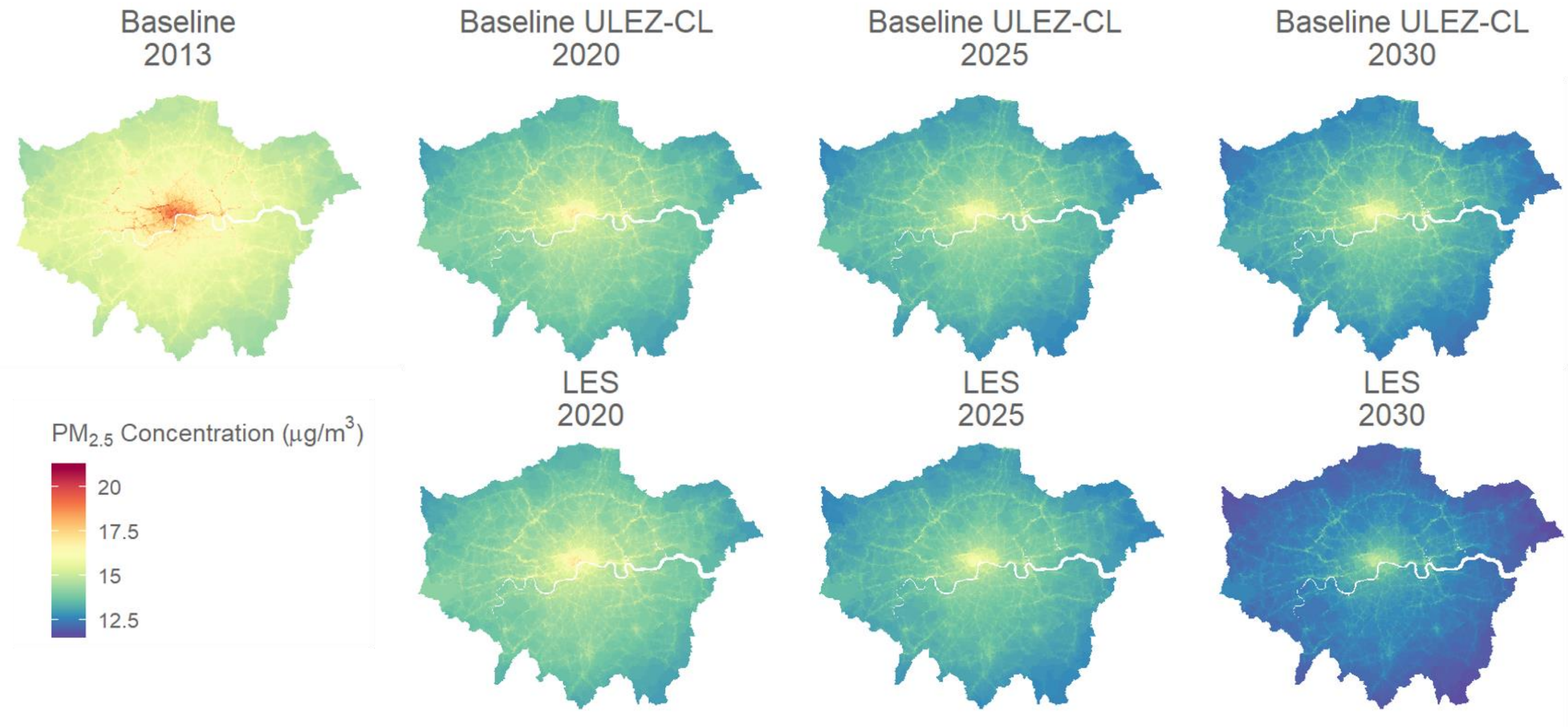


*Figure 5: Difference in concentrations between the baseline (including the ULEZ-CL) and LES scenarios for $NO_2$, 2020-2030*

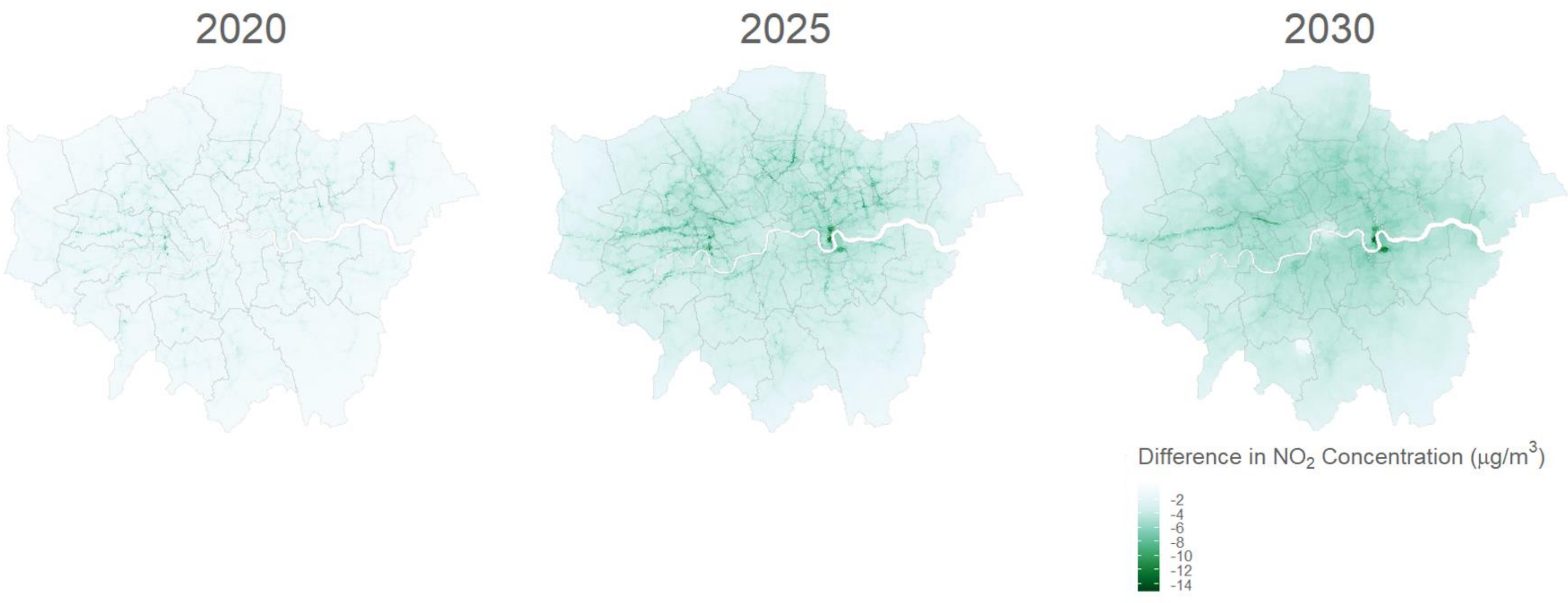


*Figure 6: Difference in concentrations between the baseline (including the ULEZ-CL) and LES scenarios for $PM_{10}$, 2020-2030*

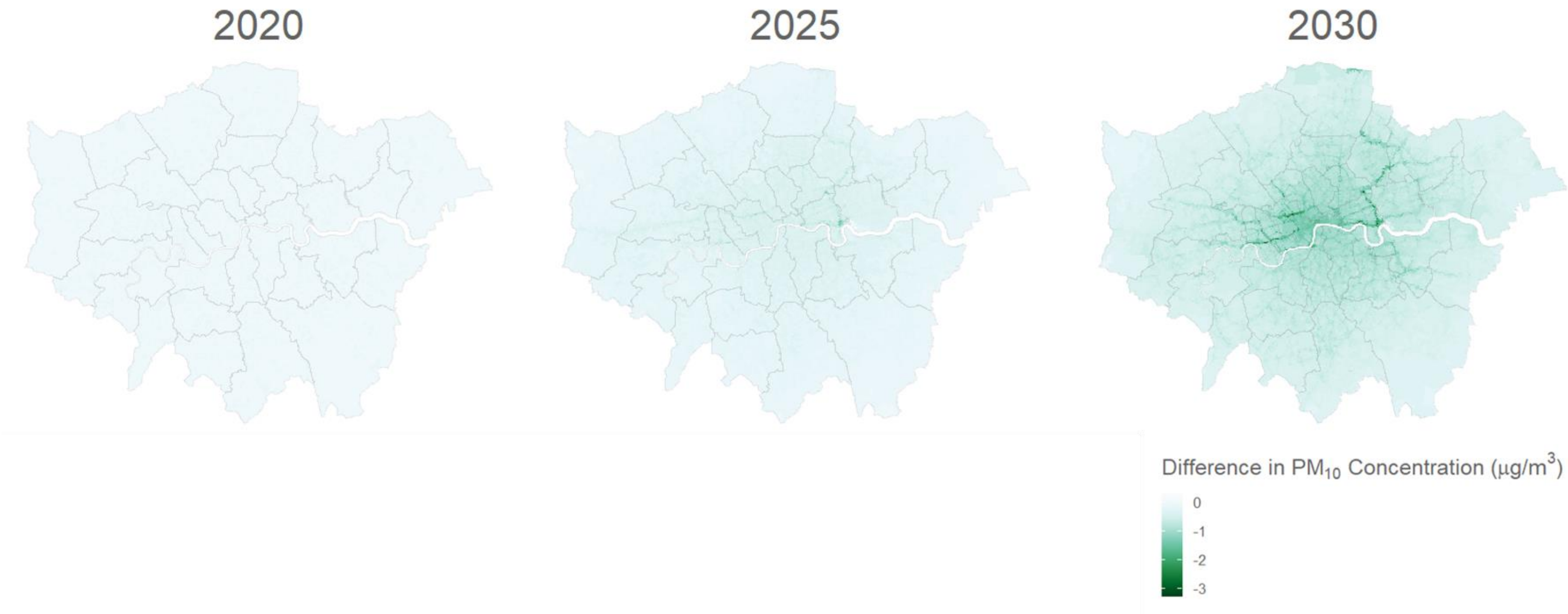
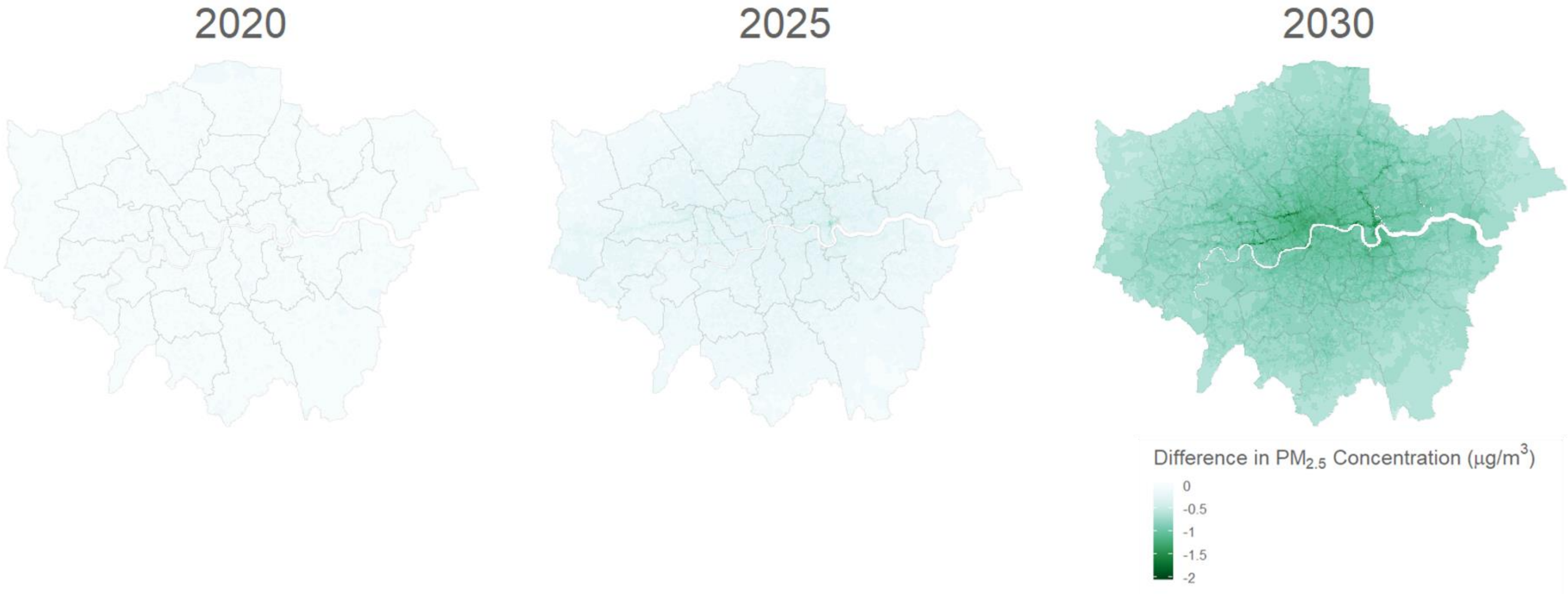
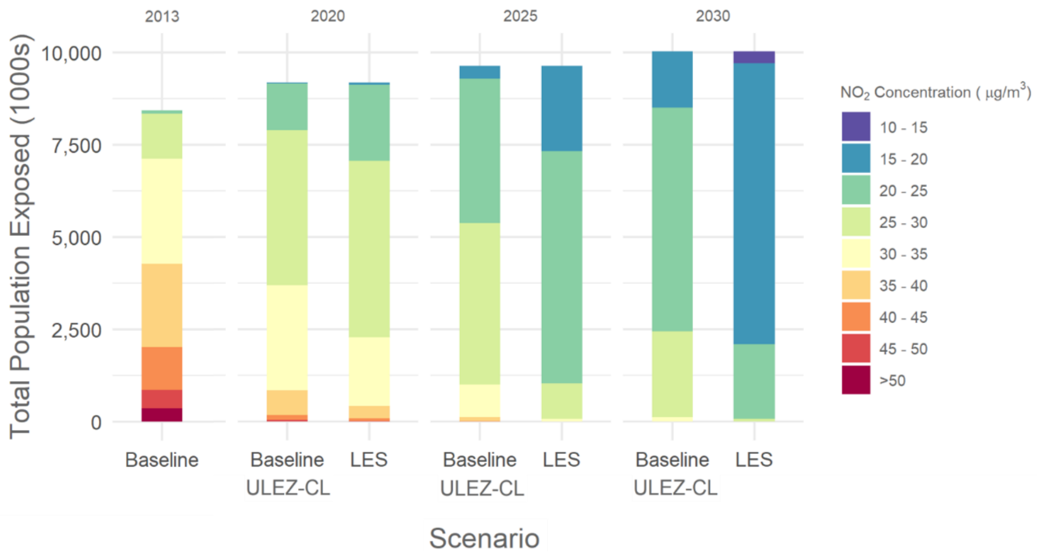


*Figure 7: Difference in concentrations between the baseline (including ULEZ-CL) and LES scenarios for $PM_{2.5}$, 2020-2030*



For $NO_2$, the baseline trend, including the effect of the central London ULEZ, shows exceedances of the 40 µg/m$^3$ annual average EU Limit Value greatly reduced between 2013 and 2020 and eliminated by 2025, as shown in Figure 8. However, there is still a significant population at risk of exceedances, i.e. projected exposure is between 35 and 40 µg/m$^3$, in 2020 and some of this risk remains in 2025. By 2030, the whole population is projected to be exposed to concentrations below 30 µg/m$^3$, although the great majority of the population is exposed to concentrations above 20 µg/m$^3$. With LES policies and measures, improvement is accelerated, with the populations either in exceedance or at risk from exceedance, of the annual average Limit Value to be reduced further. The "at risk" group is virtually eliminated in 2025 and by 2030, the majority of the population is exposed to concentrations below 20 µg/m$^3$.

*Figure 8: Population exposure for $NO_2$ for the baseline (including the ULEZ-CL) and LES scenarios, 2013-2030*




The exposure pattern for $PM_{10}$ and $PM_{2.5}$ varies between the two pollutants, with the LES having a greater impact on $PM_{2.5}$. In contrast to $NO_2$, particulate matter generally has a lower concentration gradient, i.e. the concentration tends not to vary as much over the same distance. As Figure 9 and Figure 10 show, the LES scenario has less of an impact on PM concentrations by 2020 and a relatively small impact by 2025. However, the period 2025-2030 shows a significant reduction in exposure to $PM_{10}$ and even more so for $PM_{2.5}$. By 2030, almost half of the population is exposed to annual average $PM_{10}$ concentrations below 22 µg/m$^3$ under the LES scenario, whereas this is reduced to just over a quarter for the baseline scenario. It should be borne in mind that even small changes in population exposure to PM can have significant, long term health benefits.

For $PM_{2.5}$, the effect is even greater. By 2030, almost all the population is exposed to annual average concentrations below 14 µg/m$^3$, with around 3 quarters exposed to concentration below 13 µg/m$^3$ under the LES scenario. Under the baseline scenario, only a small proportion of the population is exposed below 13 µg/m$^3$, with almost a quarter exposed to concentrations above 14 µg/m$^3$. However, there are almost no areas where the annual average concentrations fall below the WHO Air Quality Guidelines[8] for particulate matter of 20 µg/m$^3$ for $PM_{10}$ and 10 µg/m$^3$ for $PM_{2.5}$.

[8] http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications/pre2009/air-quality-guidelines.-global-update-2005.-particulate-matter,-ozone,-nitrogen-dioxide-and-sulfur-dioxide

*Figure 9: Population exposure for $PM_{10}$ for the baseline (including the ULEZ-CL) and LES scenarios, 2013-2030*

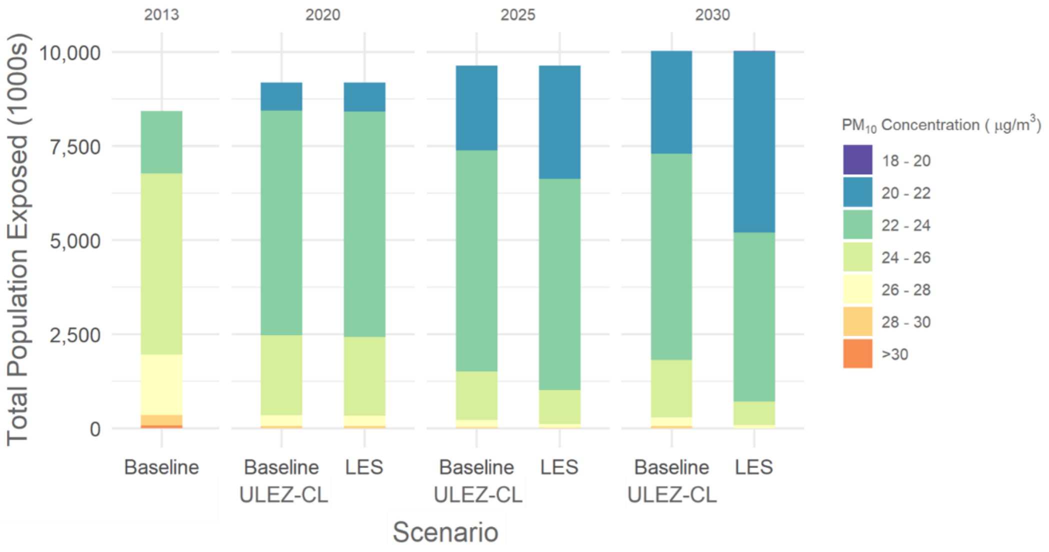
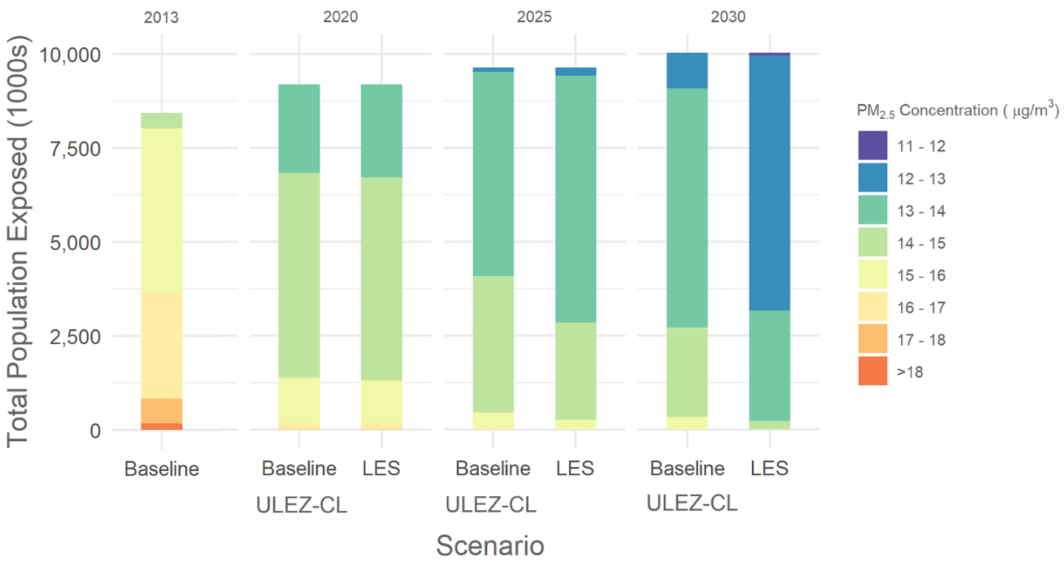



*Figure 10: Population exposure for $PM_{2.5}$ for the baseline (including the ULEZ-CL) and LES scenarios, 2013-2030*



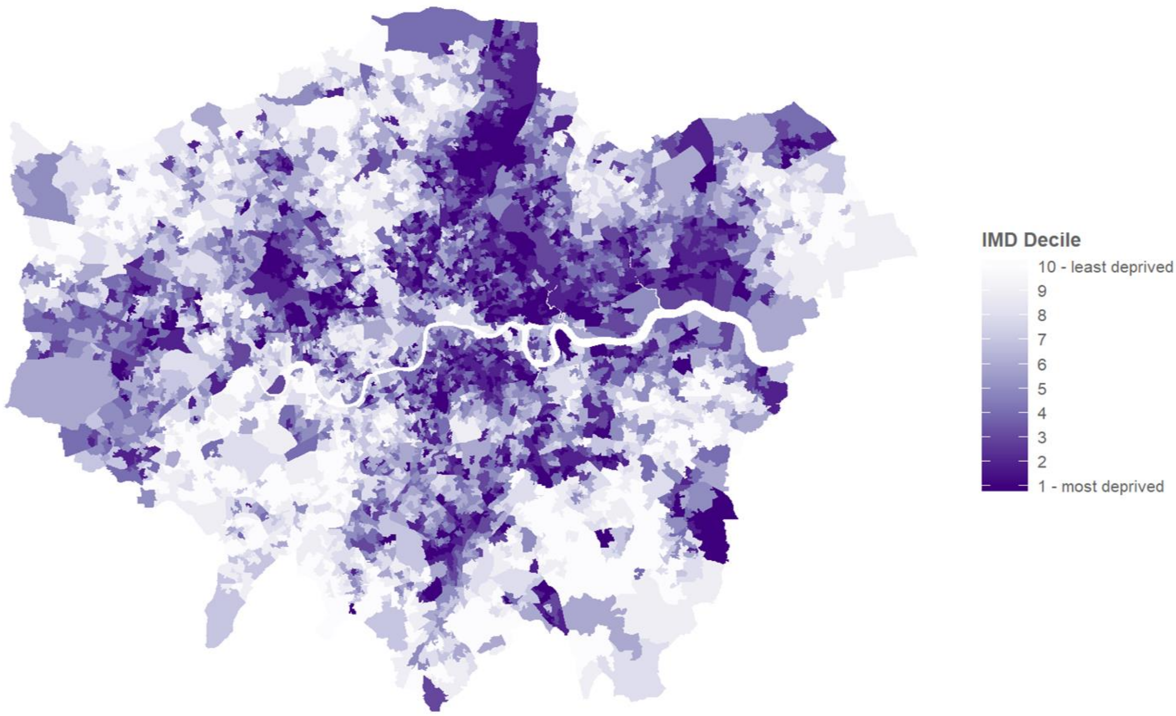
## 3.3 Air Pollution Exposure and Deprivation

**Exposure and deprivation: key messages**

- There is a clear difference between air pollution concentrations in the most and least deprived areas in 2013, with more deprived areas being exposed to higher pollution concentrations.
- The inequality is greatly reduced by 2030. For $NO_2$ the difference in average concentrations in the most to the least deprived areas goes from 7.6 µg/m$^3$ (24% higher) in 2013 to 3.7 (18%) in 2030 in the baseline scenario and 2.2 (13%) in the LES scenario.
- For NO2 the difference in average concentrations in the most to the least deprived areas goes from 7.7 µg/m$^3$ in 2013 to 3.7 in 2030 under baseline and 2.2 under the LES scenario, a reduction of 71%
- The reduction in inequality is less marked for particulate matter but is lower than for $NO_2$ in any case. The difference for $PM_{2.5}$ goes from 0.9 µg/m$^3$ in 2013 (6%) to 0.5 (4%) in 2030 under the LES scenario, a reduction of 44%

Each LSOA in London has been allocated to a deprivation decile, defined as 10 percent groups of LSOAs ranked by their Index of Multiple Deprivation (IMD) scores. Figure 11, below, shows the distribution of IMD scores, divided into 10 deciles, for London in 2015 (the latest date for which data are available). The darker colours indicate lower IMD scores and so higher levels of deprivation.

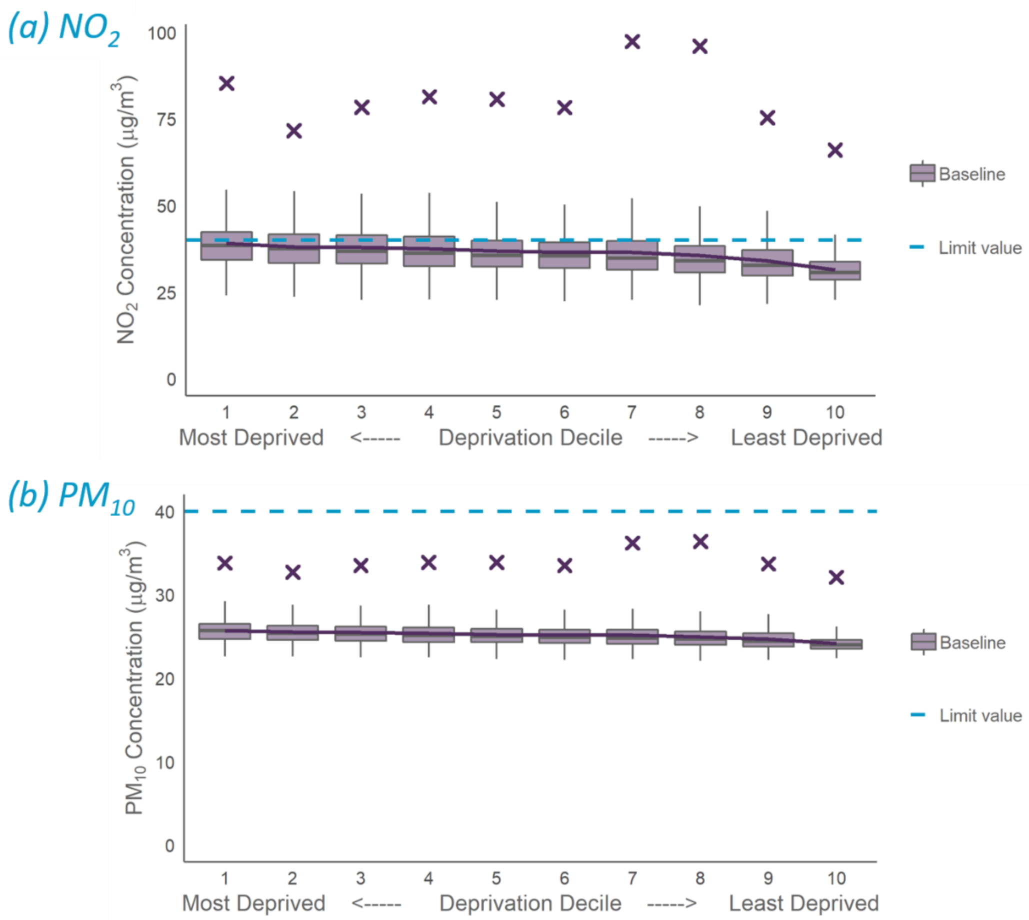
*Figure 11: LSOAs in London shaded according to IMD Deciles, 2015*




Each decile contains around 483 LSOAs and for each decile the average air pollution concentration and other statistics have been calculated from the air pollution concentrations in those LSOAs based on the data provided by TfL (see section 2). Air pollution data for each deprivation decile has then been summarised to show the trend in pollution across the social gradient of deprivation. This has been done for 2013 and for 2020, 2025 and 2030 with and without the implementation of LES policies and measures, for $NO_2$, $PM_{10}$ and $PM_{2.5}$.

Figure 12 (a-c), below, shows the analysis for 2013, using “box and whisker” style plots. The box gives the 25th and 75th percentile for each decile, while the central line provides the median concentration. The “whiskers” mark the 2.5th and 97.5th percentiles and the crosses the maximum concentrations. The trend in mean average concentrations for each decile is also shown. As in previous analysis, this shows a clear correlation between higher levels of deprivation and higher exposures to air pollution, particularly for $NO_2$. This association is present but less marked for both $PM_{10}$ and $PM_{2.5}$.

*Figure 12: LSOA pollution concentrations by deprivation decile groups in London 2013 (a) $NO_2$, (b) $PM_{10}$, (c) $PM_{2.5}$. Note the differing y axis scales used for each figure*



*(c) $PM_{2.5}$*

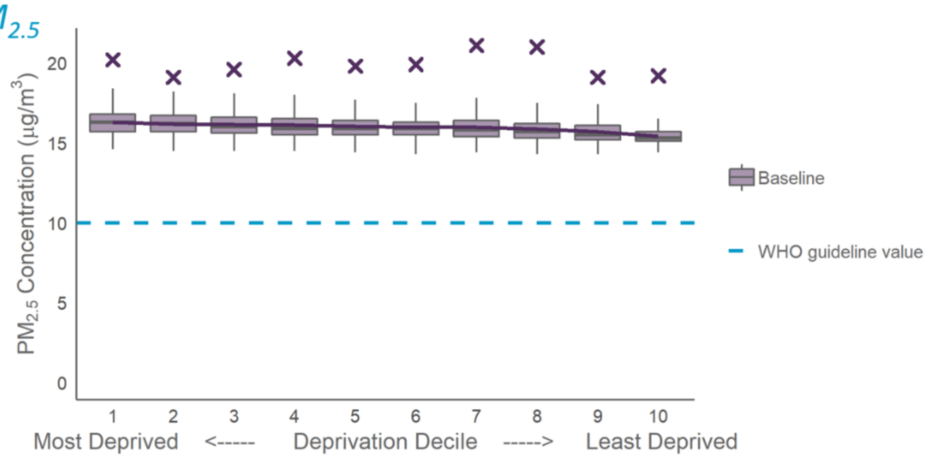
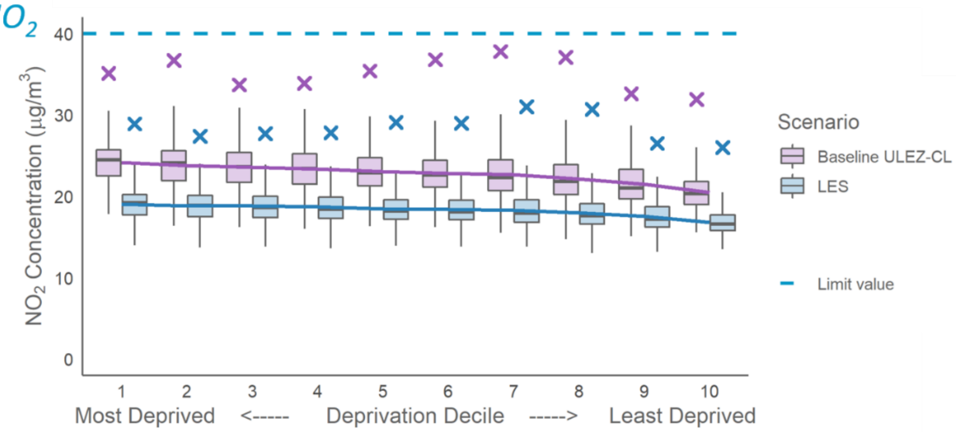


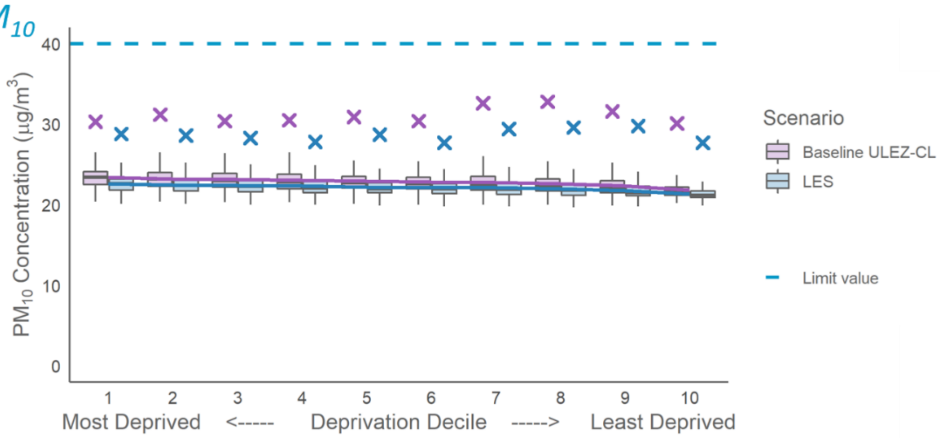

**Figure 13 (a-c)** provides the same information but this time for 2030, with different boxes showing the impact of LES policies and measures, and the projected situation without the LES. **Figure 14 (a-c)** summarises this information, showing only the trend in average concentration, with trend lines for 2013 data, and for 2030 baseline and LES scenarios.

*Figure 13: LSOA pollution concentrations by deprivation decile groups in London 2030 (a) $NO_2$, (b) $PM_{10}$, (c) $PM_{2.5}$, with and without LES policies and measures*

*(a) $NO_2$*




*(b) $PM_{10}$*



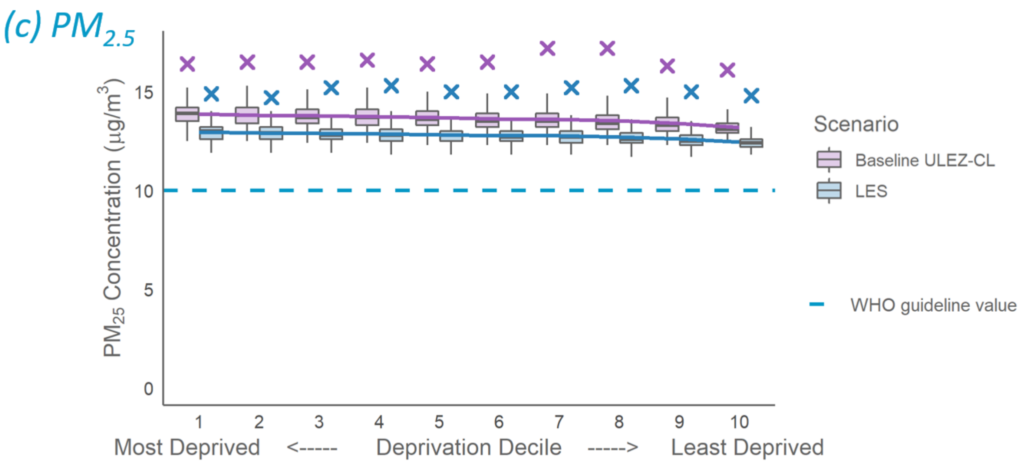
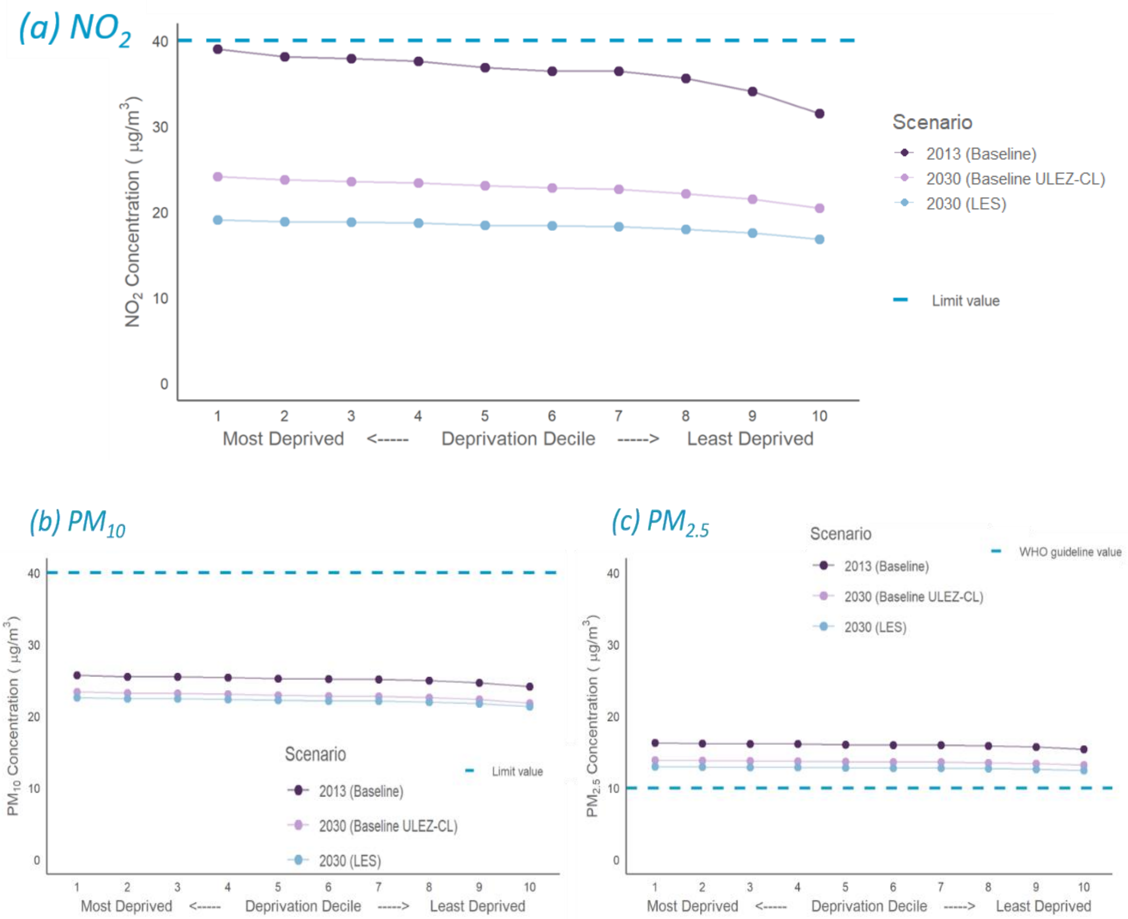



*Figure 14: Summary concentration trends by deprivation decile in 2013 and 2030, with and without LES policies and measures (a) $NO_2$, (b) $PM_{10}$, (c) $PM_{2.5}$*



There are two key features of these charts:

1. Exposure to air pollution is significantly reduced for all deprivation deciles between 2013 and 2030, consistent with the analysis shown in Section 3.2

2. The difference in average exposure between the most and the least deprived areas is greatly reduced for $NO_2$ by 2030 (for PM, the essentially flat trend remains)

The second point means that exposure inequality related to deprivation in London is projected to be reduced significantly through the application of the policies and measures in the LES. Table 2, below, shows the difference between the average concentrations in the greatest and least deprived deciles (the “increment” in µg/m$^3$), and the ratio of these concentrations: a ratio of 1 would indicate that the concentrations are the same and the increment is zero. The table shows that, for $NO_2$, the difference in average concentration between the most and least deprived areas in 2013 is 7.6 µg/m$^3$, with a ratio of 0.81, which means that the average exposure in the most deprived deciles is 24% higher than the least deprived. Without LES policies and measures (but including the ULEZ-CL), this becomes 3.7 µg/m$^3$ and 0.85 in 2030. With the application of LES policies and measures, these are further reduced to 2.2 µg/m$^3$ and 0.88, in 2030. This again illustrates how the distribution of air pollution by deprivation level is more equal by 2030 with the baseline scenario but that this is accelerated further by the LES.

The table also provides these figures for $PM_{10}$ and $PM_{2.5}$. The differences here are less marked, reflecting the shallower concentration gradient for particulate matter (i.e. it tends not to vary so much over short distances). The increments for $PM_{10}$ and $PM_{2.5}$ reduce slightly over the period, although the ratios remain constant. However, the ratios for both $PM_{10}$ and $PM_{2.5}$ are closer to 1 (no inequality) than those for $NO_2$, meaning that there is less inequality in exposure to particulate matter than for $NO_2$.

*Table 2: Average concentration increment and ratio of average concentrations of $NO_2$, $PM_{10}$ and $PM_{2.5}$ in 2013 and 2030 between the most and least deprived areas in London*

| Scenario | $NO_2$ | | $PM_{10}$ | | $PM_{2.5}$ | |
|---|---|---|---|---|---|---|
| | increment (µg/m3) | ratio (most:least deprived) | increment (µg/m3) | ratio (most:least deprived) | increment (µg/m3) | ratio (most:least deprived) |
| **2013** | 7.6 | 0.81 | 1.6 | 0.94 | 0.9 | 0.95 |
| **2030, baseline (with ULEZ-CL)** | 3.7 | 0.85 | 1.6 | 0.93 | 0.7 | 0.95 |
| **2030, with LES** | 2.2 | 0.88 | 1.3 | 0.94 | 0.5 | 0.96 |

## 3.4 Exposure and Ethnicity

**Exposure and ethnicity: key messages**

- Areas which have the highest numbers of mixed/multiple ethnic group residents are more likely to have the highest levels of $NO_2$ in 2013, whereas those with the highest numbers of white residents are more likely to have lower concentrations.
- This distribution does not change significantly by 2030 in either the baseline or LES scenarios, although the difference in highest concentrations across the ethnic groups is greatly reduced.
- The difference in the highest annual average concentrations of $NO_2$ in decile 10 for each ethnic group reduces from 22.5 µg/m$^3$ in 2013 to 6.6 in 2030 under the baseline scenario and 3.3 under the LES scenario, a reduction of 85%

Each LSOA in London has been allocated to an ethnicity decile for each of the five ethnic groups (see Table 1), defined as 10 percent groups of LSOAs ranked by percentage population of the relevant ethnic group. Decile 1 represents the LSOAs with the lowest percentage population of the relevant ethnic group, and decile 10 the LSOAs with the highest percentage population. The deciles have been based on percentage populations rather than actual population to prevent a skewing effect on LSOAs with larger populations.

Note that, because the deciles are defined and ordered according to the distribution of each ethnic group individually, it does not necessarily mean that the areas in the highest decile for an ethnic group are dominated by that group. For example, in those LSOAs which are in the highest decile for Mixed/Multi-ethnic population, no more than 25% of the total population of those LSOAs identifies as being from that group. Mixed/Multi Ethnic is a relatively small population and doesn't form the majority in any LSOAs. This is an important point when interpreting the analysis results.

Each LSOA has been allocated an ethnicity decile per ethnic group within which the air pollution concentration has been calculated by averaging air pollution in each modelled 20m grid square. The population distributions for each ethnic group are shown in Figure 15.

In the previous analysis undertaken by Aether, the areas above 40 µg/m$^3$ where overlaid on these maps and analysed to give a distribution of air pollution by ethnicity. However, this approach is less effective for the current analysis given that the areas above 40µg/m$^3$ are very small (in proportion to the whole of London) in 2020 and virtually disappear by 2025. As an alternative approach, the LSOAs have been ranked in Figure 16 and Figure 17 by ascending annual average concentration for $NO_2$, and colour coded to show whether they are a 10$^{th}$ decile LSOA for any non-white ethnic group (red), for the white group (green) or not in the 10$^{th}$ decile for any group (grey). Only the 10$^{th}$ decile is used as some LSOAs can be 8$^{th}$ or 9$^{th}$ decile for more than one ethnic group.

*Figure 15: Population distributions (population deciles) for five ethnic groupings in London, 2011*

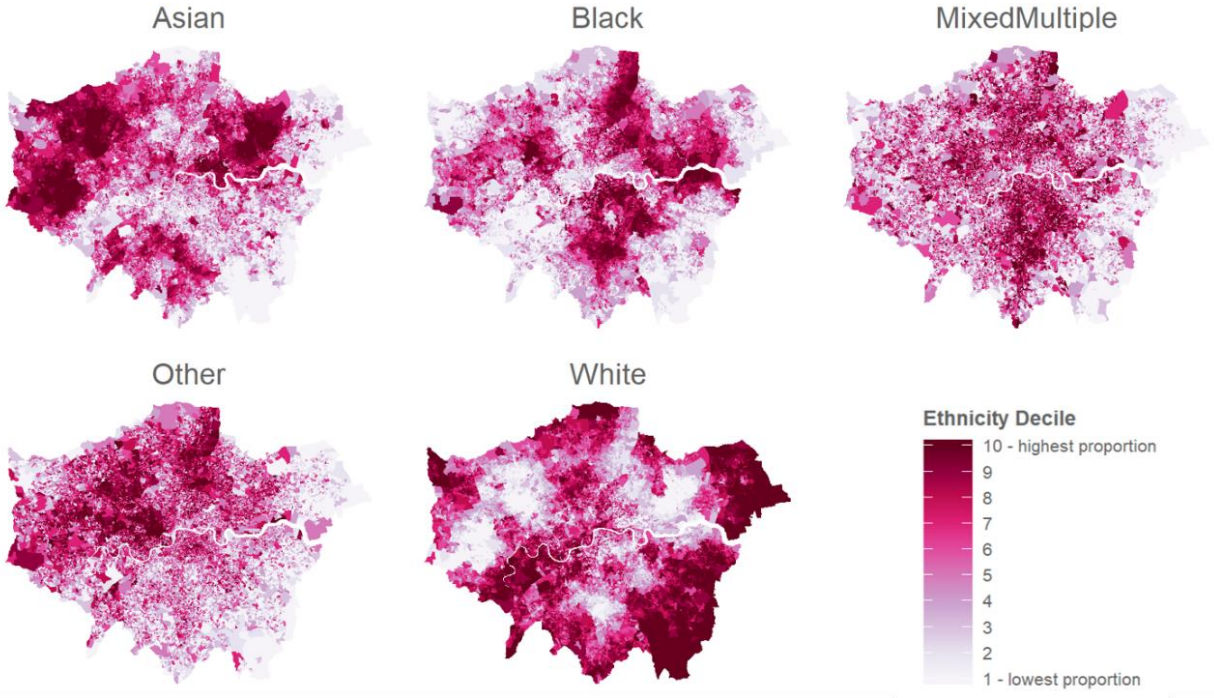



*Figure 16: All LSOAs ranked by annual average $NO_2$ concentration and colour coded where they are the 10th decile for ethnicity, 2013*

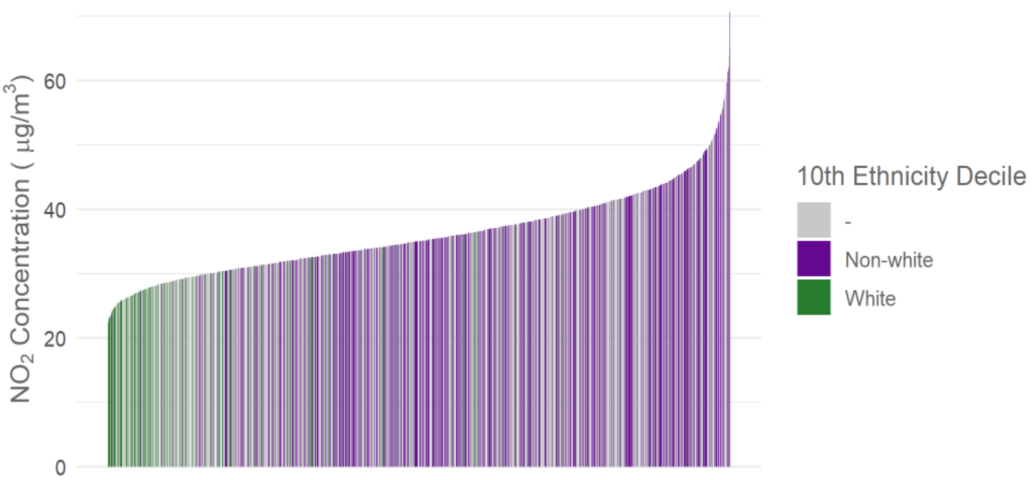
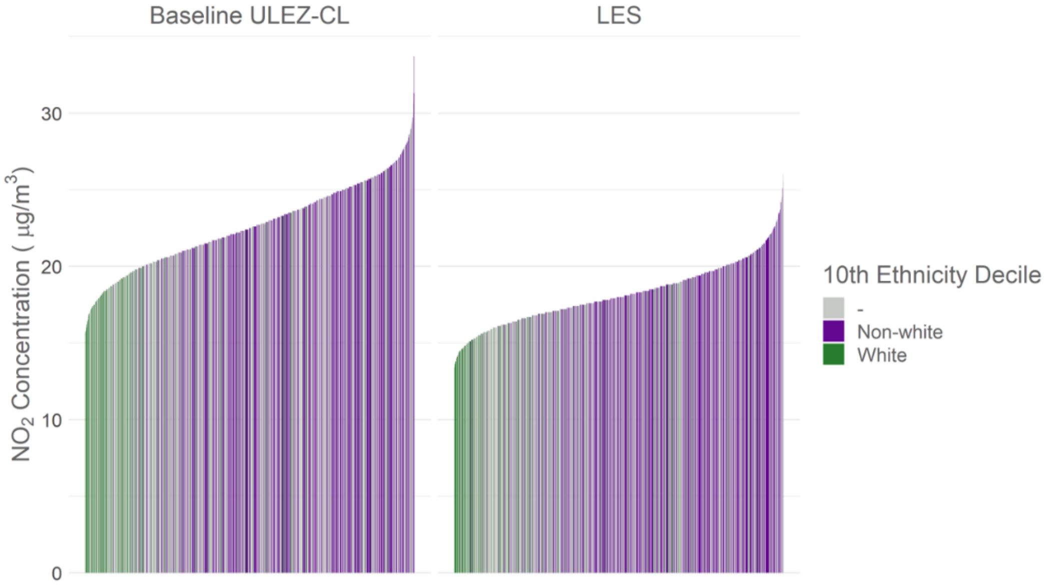


*Figure 17: All LSOAs ranked by annual average $NO_2$ concentration and colour coded where they are the 10th decile for ethnicity, 2030 Baseline (including the ULEZ-CL) and LES scenarios*




The data used for the graphs above have been further analysed to calculate the proportion of the ethnicity decile 10 LSOAs that are also LSOAs with the 25% highest concentrations. These results are shown in Table 3, below.

*Table 3: Proportion of "decile 10" LSOAs by ethnicity in the top 25% highest LSOA Concentrations for annual average $NO_2$*

| Ethnic group | 2013 | | 2030 Baseline (with the ULEZ-CL) | | 2030 LES | |
|---|---|---|---|---|---|---|
| | % LSOAs in top 25% highest concentrations | Highest $NO_2$ conc. | % LSOAs in top 25% highest concentrations | Highest $NO_2$ conc. | % LSOAs in top 25% highest concentrations | Highest $NO_2$ conc. |
| Asian | 13% | 56.9 | 15% | 33.7 | 17% | 24.2 |
| Black | 20% | 59.3 | 22% | 29.3 | 20% | 24.4 |
| Mixed/ Multiple | 30% | 59.9 | 30% | 29.2 | 28% | 23.6 |
| Other | 34% | 70.7 | 31% | 31.3 | 31% | 25.9 |
| White | 4% | 48.2 | 3% | 27.1 | 4% | 22.6 |

This reveals a number of features:

- LSOAs containing the highest numbers of Mixed/Multiple and Other ethnic groups (decile 10) have the highest proportion of LSOAs in the top 25%, followed by Black, Asian and White. This is related to the tendency for high decile areas to be closer to the centre of London
- The proportions do not change significantly by 2030, either for the baseline or LES scenarios. This is related to the fact that the population distribution by ethnicity is fixed at the 2011 census and does not change for future years
- However, the range of concentrations at the highest exposure for each group reduces greatly over the period, and more so for the LES than the baseline. To

clarify, this means the highest concentration found in a decile 10 area for each ethnic group. In 2013, the highest is for mixed/multiple ethnic (70.7 µg/m$^3$) and the lowest is for White (48.2 µg/m$^3$) making the range 22.5 µg/m$^3$. This reduces to 6.6 µg/m$^3$ in 2030 in the baseline scenario and 3.3 µg/m$^3$ in 2030 in the LES scenario, a reduction of 85%.

## 3.5 Exposure and vulnerable receptors

**Exposure and vulnerable groups: key messages**

- Out of a total of 2,367 schools analysed, 487 were shown to be in areas above the 40µg/m$^3$ Limit Value for annual average $NO_2$ concentrations in 2013. This reduced to 15 in 2020 under the baseline scenario and 5 under the LES. Both scenarios reduce to zero in 2025
- For future years (when the vast majority of schools have been brought into compliance with the legal limits for $NO_2$), no clear association was found between the level of eligibility for free school meals (used as a metric for deprivation) and air pollution exposure at schools
- For schools, hospitals and care homes, levels of exposure to $NO_2$ reduce over the study period, with the LES scenario significantly accelerating that improvement. Facilities closer to central London receive the greatest relative improvement in air quality

Data were provided by Transport for London on air pollution concentrations within 150m[9] of schools (nurseries, primary and secondary schools), hospitals and care-homes in London, using the 2013 air pollution maps and projections for 2020, 2025 and 2030, with and without LES policies and measures. This analysis includes all such sites in London for which TfL and GLA have data.

### 3.5.1 Schools

The table below shows the total numbers of different types of schools that are exposed to above the $NO_2$ EU limit value (Table 4). This is included for consistency with previous analysis and, not surprisingly given the analysis presented above, the numbers reduce to zero by 2025 under both scenarios. This analysis was repeated but this time against the WHO Guideline Value for $PM_{2.5}$ (10 µg/m$^3$ annual average), with the results shown in Table 5. This shows that all schools are exposed to concentrations above the Guideline Value in 2013 and under both scenarios in 2030.

In terms of the distribution of exposure to $NO_2$, $PM_{10}$ and $PM_{2.5}$, the pattern is similar to that for the population as a whole, i.e. increasing towards the centre of the city and decreasing over time, with the decrease more evidence with the application of LES Policies and measures. This distribution and its change over time is shown in Figure 19, Figure 20 and Figure 21 on the pages that follow below.

[9] 150m was used to provide consistency with previous analysis for schools

*Table 4: Schools within London which are exposed to $NO_2$ concentrations above the EU limit (40 µg/m$^3$ annual average) by school type*

| Type of School | Number | No. schools with mean annual $NO_2$ concentrations > 40µg/m$^3$ | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2013 | 2020 baseline with ULEZ-CL | 2020 LES | 2025 baseline with ULEZ-CL | 2025 LES | 2030 baseline with ULEZ-CL | 2030 LES |
| Primary | 1,815 | 371 | 12 | 4 | 0 | 0 | 0 | 0 |
| Secondary | 453 | 82 | 3 | 1 | 0 | 0 | 0 | 0 |
| 16 plus | 53 | 27 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other | 46 | 7 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total** | **2,367** | **487** | **15** | **5** | **0** | **0** | **0** | **0** |

*Table 5: Schools within London which are exposed to $PM_{2.5}$ concentrations above the WHO guideline value (10 µg/m$^3$ annual average) by school type*

| Type of School | Number | No. schools with mean annual $PM_{2.5}$ concentrations > 10µg/m$^3$ | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2013 | 2020 baseline with ULEZ-CL | 2020 LES | 2025 baseline with ULEZ-CL | 2025 LES | 2030 baseline | 2030 LES |
| Primary | 1,815 | 1,815 | 1,815 | 1,815 | 1,815 | 1,815 | 1,815 | 1,815 |
| Secondary | 453 | 453 | 453 | 453 | 453 | 453 | 453 | 453 |
| 16 plus | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 53 |
| Other | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 |
| **Total** | **2,367** | **2,367** | **2,367** | **2,367** | **2,367** | **2,367** | **2,367** | **2,367** |

Analysis was also undertaken to assess the relationship between deprivation and air pollution exposure at schools, using eligibility for free school meals as a measure of deprivation. In the 2017 report, *Updated London Air Pollution Exposure*[10], an association was reported between deprivation at schools and air pollution concentrations. This association was based on an analysis of the schools exposed above and below the annual average $NO_2$ Limit Value and the proportion of these that were classed as deprived, based on the level of free school meal eligibility. This report found that of the primary schools in areas exceeding the legal limit for $NO_2$, 82% were deprived schools. In contrast, of the primary schools that were not exposed to above EU limit values of $NO_2$, 39% were deprived. This shows a valid association between high air pollution and a measure of deprivation for 2013.

In future years the vast majority of, and in some cases all, schools are projected to be compliant with the $NO_2$ limit value. This means that the "above and below" analysis discussed above is no longer possible and so a broader analysis was undertaken for this

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10 ttps://www.london.gov.uk/sites/default/files/aether_updated_london_air_pollution_exposure_final_20-2-17.pdf

report. This analysis attempted to find an association between the actual level of free school meal eligibility (rather than using a threshold to indicate deprivation) and the full range of air pollution exposure.

Figure 18 below shows the distribution of free school meal eligibility across London and, while there is some apparent trend towards greater deprivation (by this measure) in central London, the pattern is far more evenly distributed than that for air pollution. This is born out when the statistical correlation between air pollution concentrations and the proportion of pupils eligible for free school meals is assessed. This shows no apparent correlation, which could due to the removal of the higher peak values for $NO_2$ in 2020 under both scenarios and could also be due to the emphasis of the previous work on peak levels rather than the full range of concentrations. For future years, LES shows lower concentrations than the baseline scenario but this benefit is distributed evenly across the range of free school meal eligibility levels. However, it is the case that while the conclusions from the 2017 report remain valid, once the number of schools in areas of exceedance has been reduced to zero (or to very low levels), that association is no longer identifiable using these datasets.

*Figure 18: Map showing the distribution pattern for free school meal eligibility at schools across London*

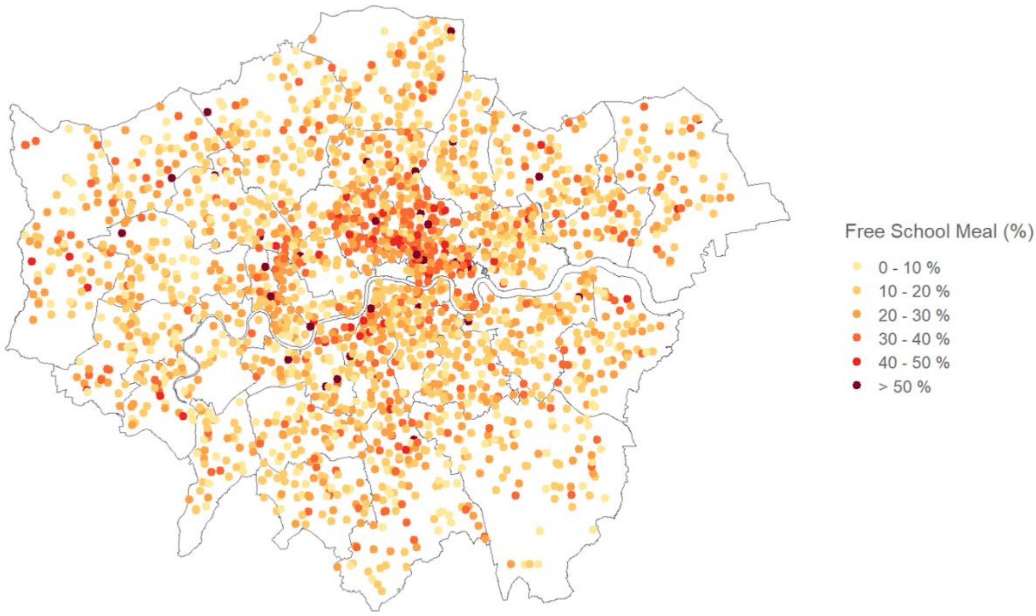


*Figure 19: Map showing annual average $NO_2$ concentrations within 150m of schools in London, in 2013 and in 2020, 2025 and 2030, for baseline (including the ULEZ-CL) and with LES*

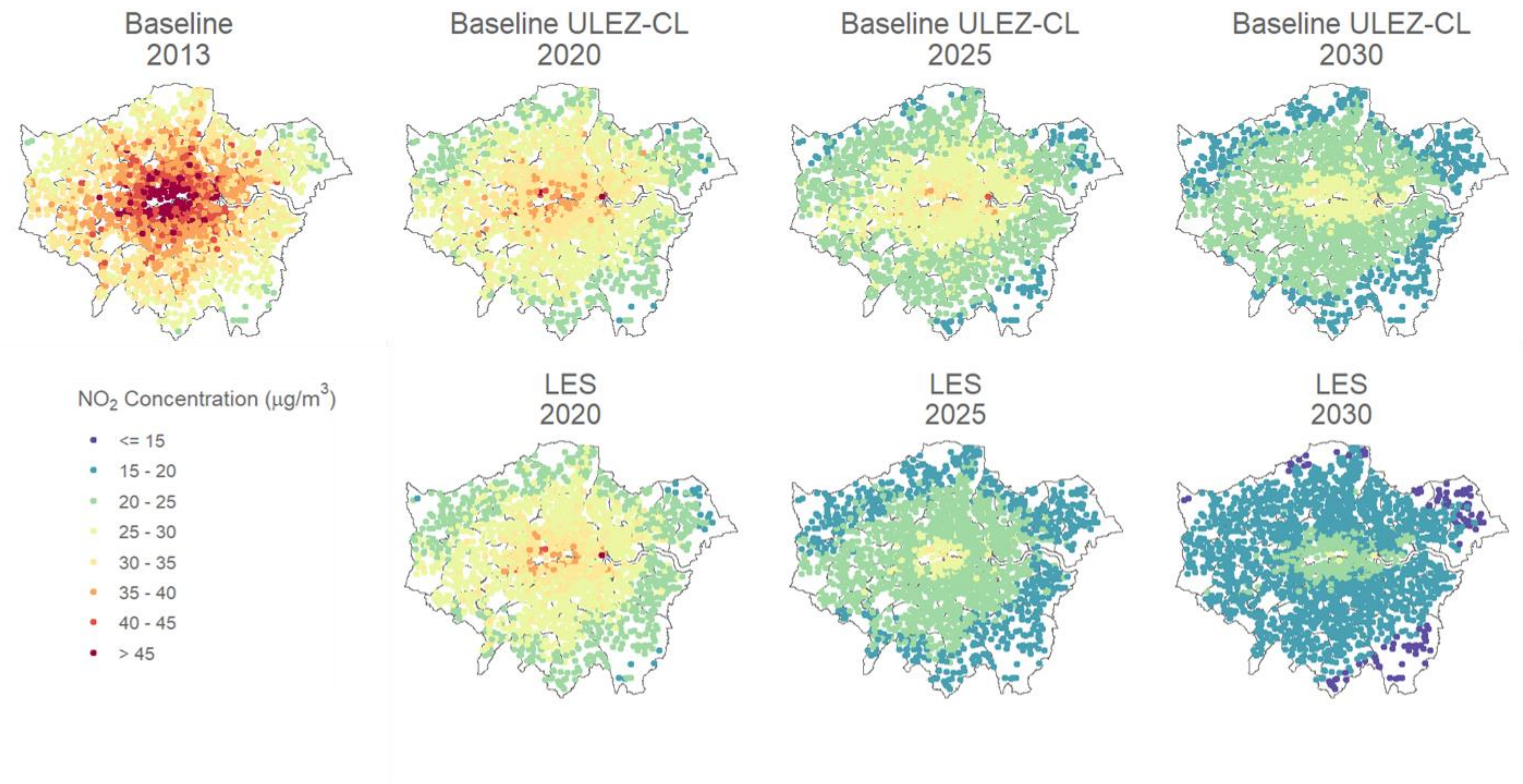


*Figure 20: Map showing annual average $PM_{10}$ concentrations within 150m of schools in London, in 2013 and in 2020, 2025 and 2030, for baseline (including the ULEZ-CL) and with LES*

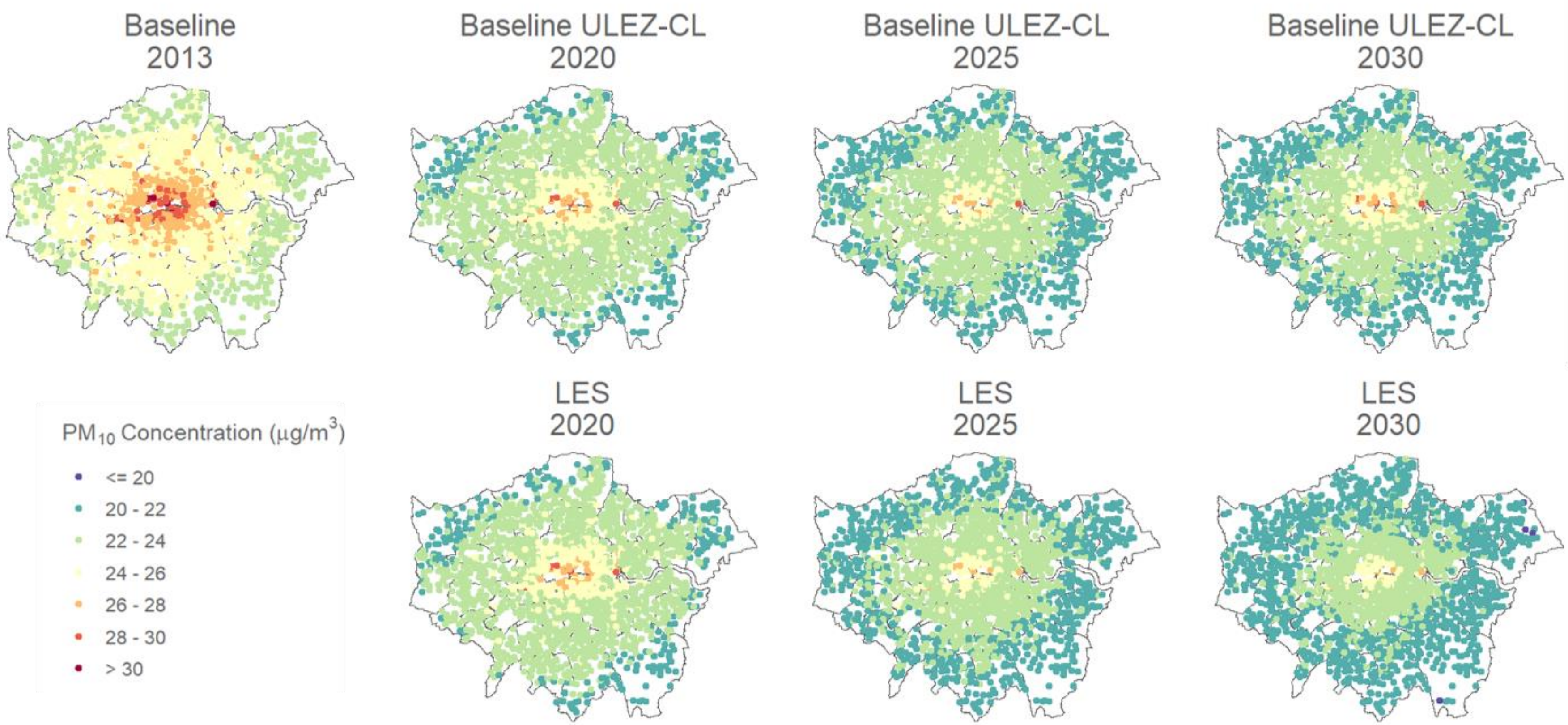
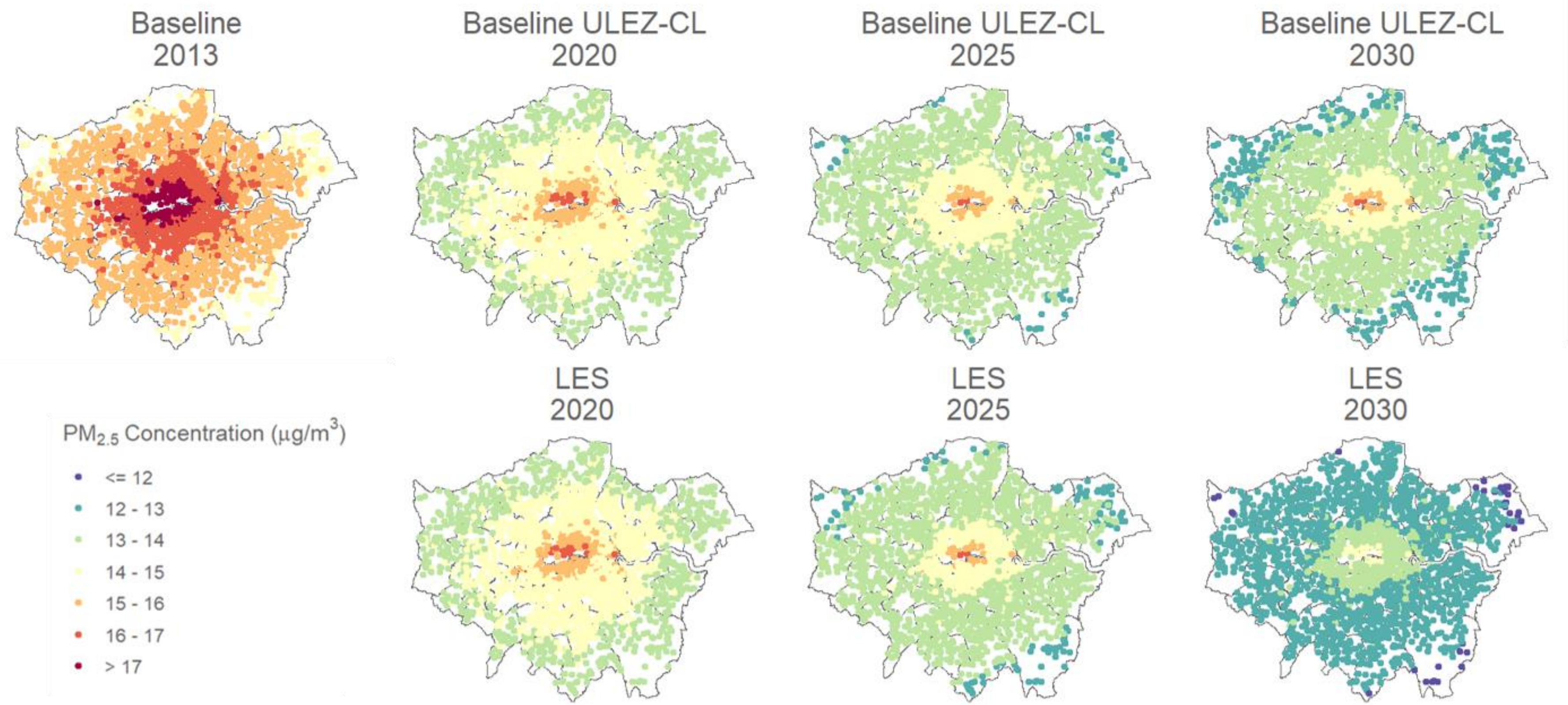


*Figure 21: Map showing annual average $PM_{2.5}$ concentrations within 150m of schools in London, in 2013 and in 2020, 2025 and 2030, for baseline (including the ULEZ-CL) and with LES*



### 3.5.2 Hospitals

Similar analysis was undertaken for hospitals in London as that done for schools. Figure 22, below, shows the pattern of annual average concentrations of $NO_2$ for Hospitals in 2013 and in 2020, 2025 and 2030 for the baseline and LES scenarios. The 2013 map clearly shows that hospitals in central London tend to be exposed to higher concentrations of $NO_2$ which, given their need to be readily accessible and thus positions near main roads, is perhaps not surprising. As with earlier analysis, concentrations greatly reduce in future years, more so for the LES than for the baseline. Figure 23 shows the difference in concentrations between baseline and LES scenarios for 2020, 2025 and 2030. This shows that the largest reductions in concentration as a result of the LES are experienced by the Hospitals in Central London, i.e. those subject to the highest concentrations in 2013. Analysis was also undertaken for particulate matter, showing a similar, although less distinct, pattern. The results are not included in this report but are available on request from the authors.

### 3.5.3 Care Homes

Similar analysis was undertaken for care homes in London as that done for schools. Figure 24, below, shows the pattern of annual average concentrations of $NO_2$ for care homes in 2013 and in 2020, 2025 and 2030 for baseline and with LES policies and measures. The 2013 map clearly shows that care homes in central London tend to be exposed to higher concentrations of $NO_2$. As with earlier analysis, concentrations greatly reduce in future years, more so for the LES than for the baseline. Figure 25 shows the difference in concentrations between baseline and LES for 2020, 2025 and 2030. This shows that the largest reductions in concentration as a result of the LES are experienced by the care homes in Central London, i.e. those subject to the highest concentrations in 2013. Note also that there appears to be an area to the west of Central London where there are no care homes. A simple search shows that there are care homes in this area and so there is an apparent gap in the supplied data for care homes west of central London. It is not known at this stage the reason for this gap. Analysis was also undertaken for particulate matter, showing a similar, although less distinct, pattern. The results are not included in this report but are available on request from the authors.

*Figure 22: Map showing annual average $NO_2$ concentrations within 150m of hospitals in London, in 2013 and in 2020, 2025 and 2030, for baseline (including the ULEZ-CL) and LES scenarios*

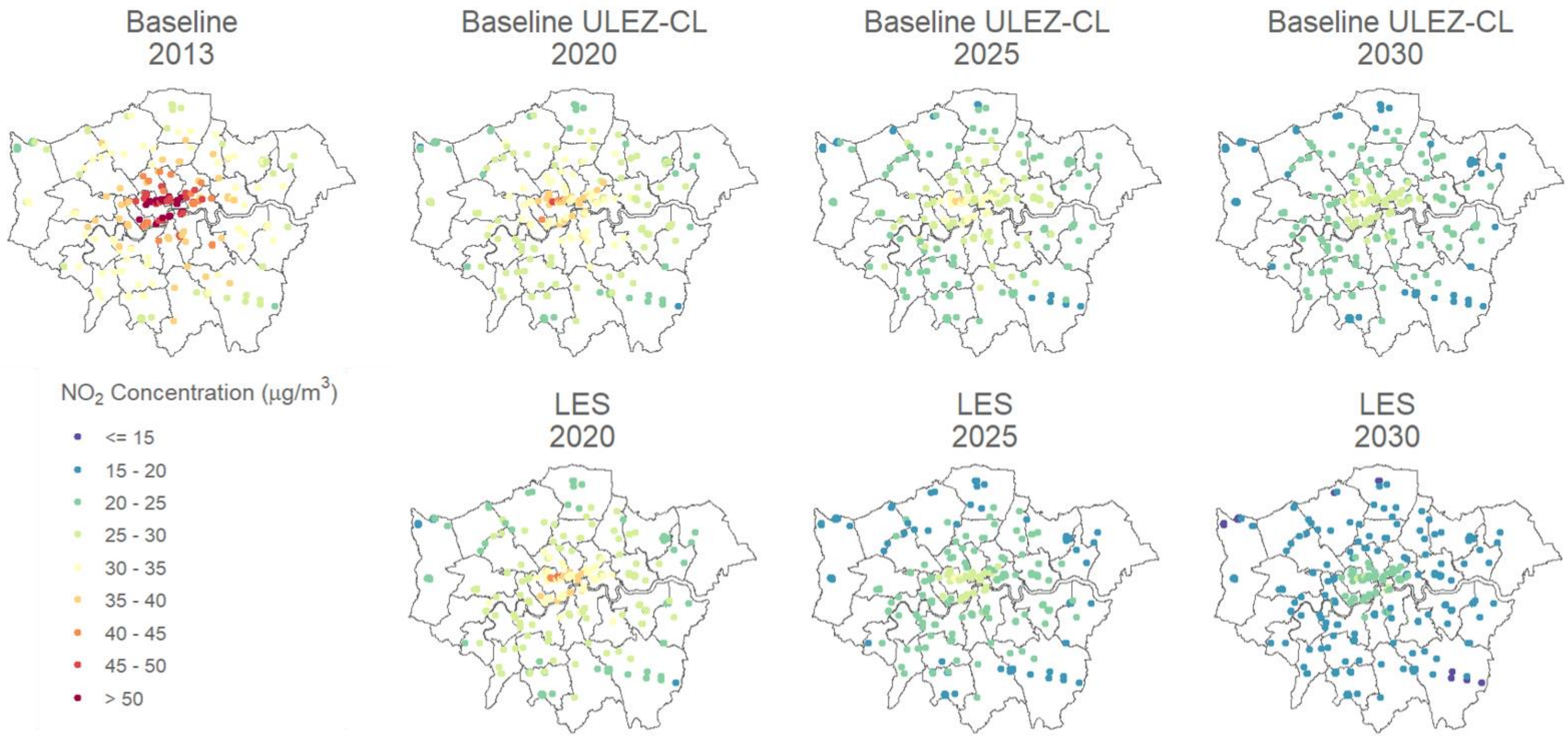


*Figure 23: The difference in annual average $NO_2$ concentrations at hospitals in London, between baseline (including the ULEZ-CL) and LES, 2020, 2025 and 2030*

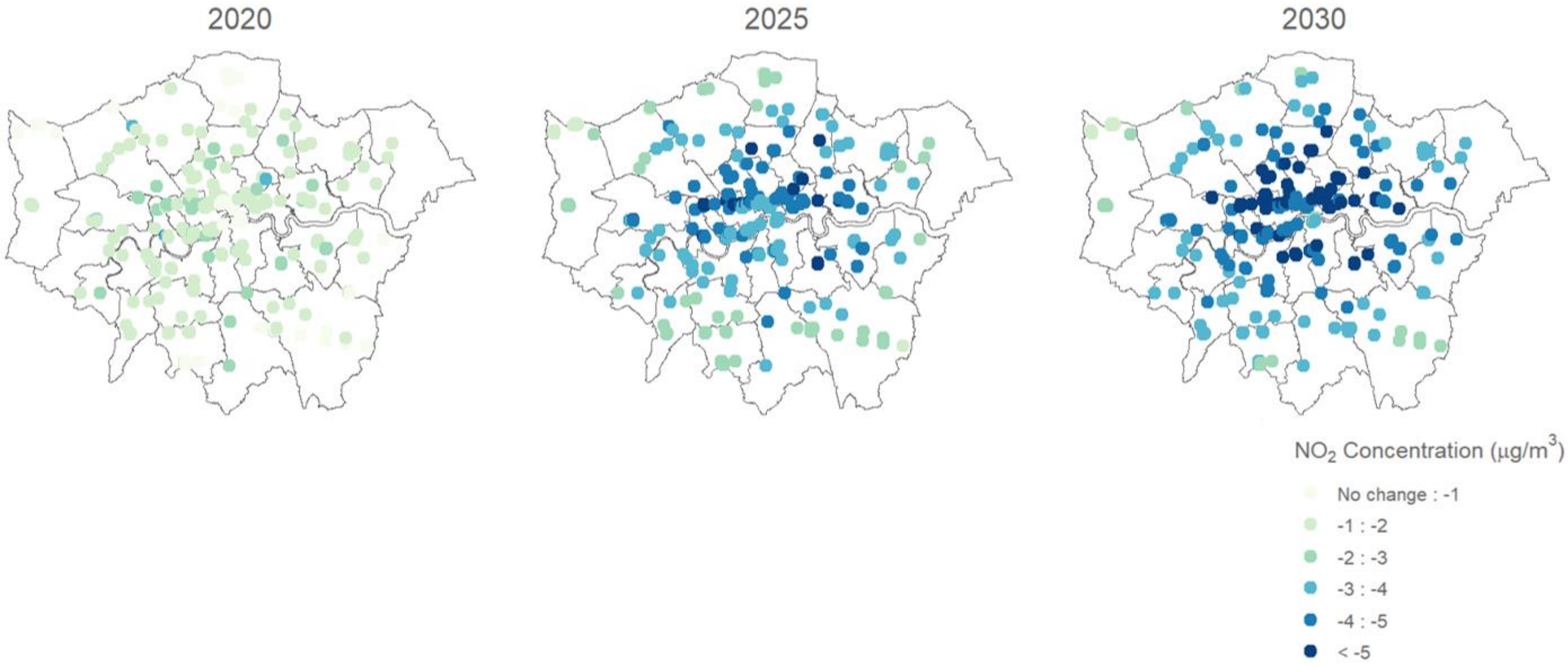


*Figure 24: Map showing annual average $NO_2$ concentrations within 150m of care homes in London, in 2013 and in 2020, 2025 and 2030, for baseline (including the ULEZ-CL) and with LES*

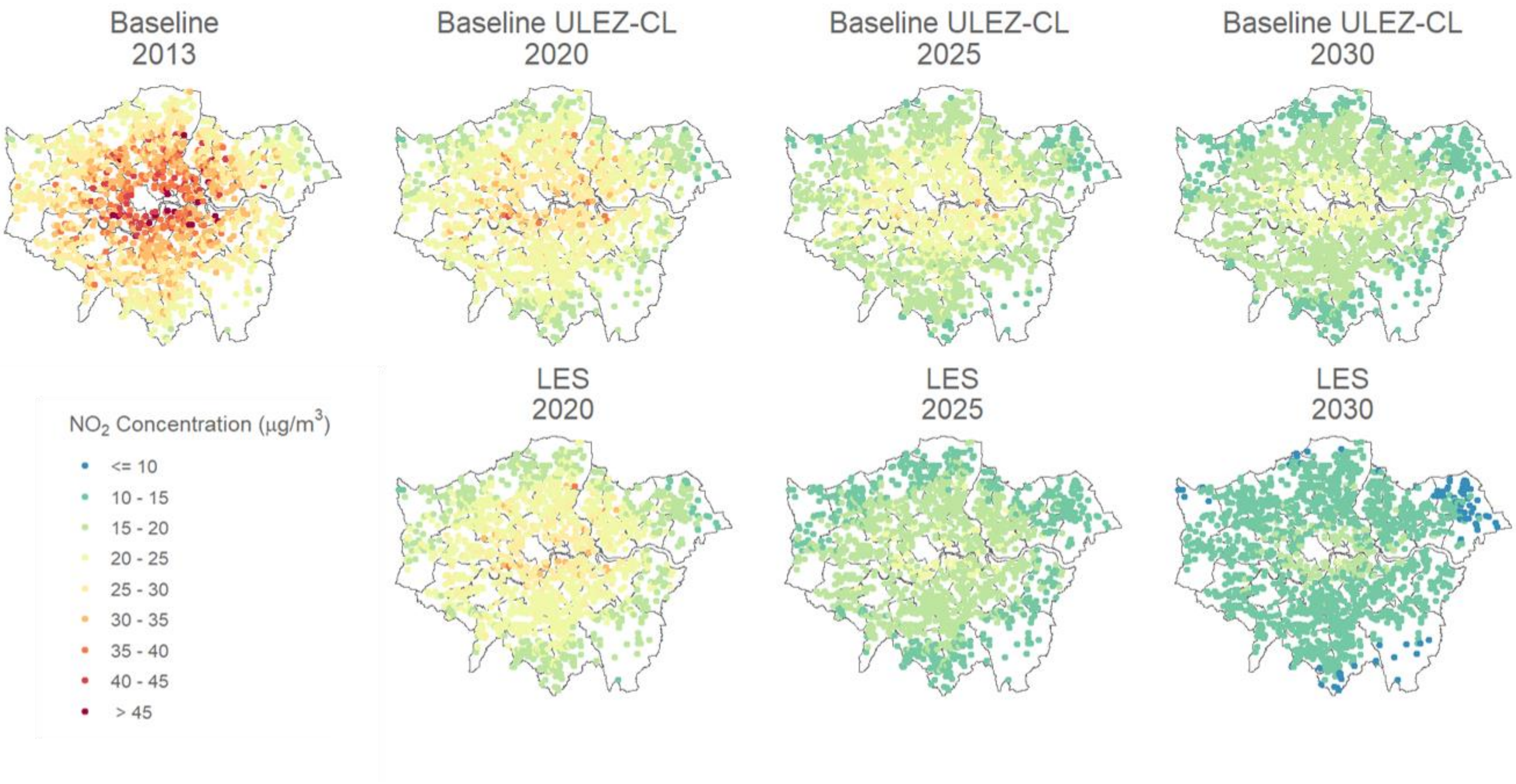
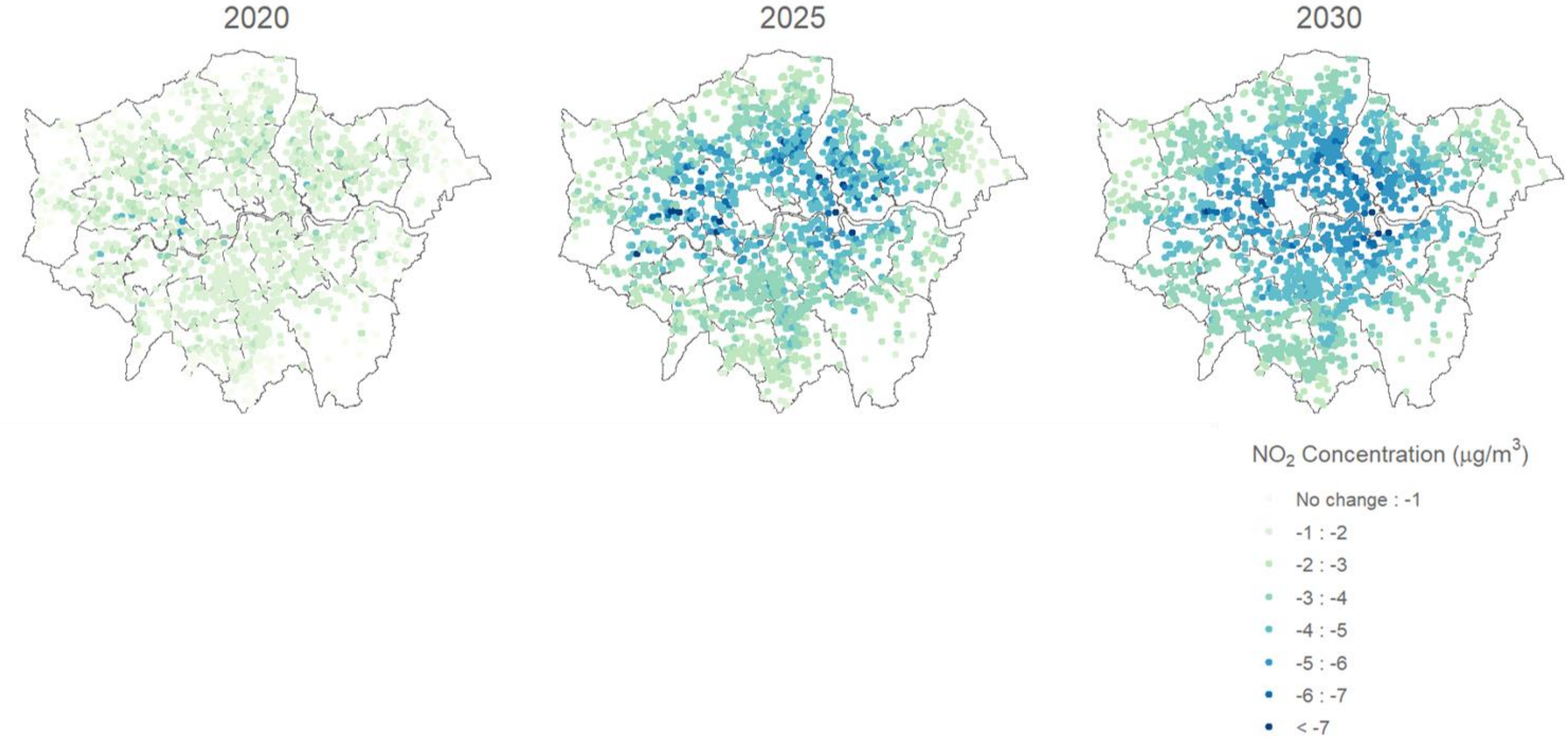


*Figure 25: The difference in annual average $NO_2$ concentrations at care homes in London, between baseline (including the ULEZ-CL) and LES, 2020, 2025 and 2030*



# 4 Key findings

The central aim of this study was not to assess whether there is a link between poor air quality and social inequality – which has been demonstrated in the previous studies – but to assess how improvements to air quality in the future as a result of the implementation of the LES change the magnitude and nature of that link. However, as the previous work showed, the interaction between air quality and deprivation and other social indicators is complex and describing the extent of the correlation can be difficult. Straightforward numerical indicators are either not available or tend to over simplify the nature of the issue.

Nevertheless, some clear messages can be drawn from the analysis. The first is that the implementation of the LES, as modelled for TfL, will make a significant difference to air quality across the period from 2013 to 2030. This can be most clearly seen in Figure 8 - Figure 10 which show significant shifts in population exposure between the baseline (which includes the central London ULEZ) and LES scenarios in 2030. The assessment of air quality against IMD, the distribution of ethnicity and the location of vulnerable groups further showed that:

- For $NO_2$, the difference in average concentration between the most and least deprived areas in 2013 is 7.6 µg/m$^3$, with a ratio of 0.81, which means that the average concentration in the most deprived deciles is 24% higher than the least deprived.
- The inequality in exposure across the deprivation scale is greatly reduced by 2030. For $NO_2$ the difference in average concentrations in the most to the least deprived areas goes from 7.6 µg/m$^3$ in 2013 to 3.7 in 2030 in baseline (including the ULEZ-CL) and 2.2 in the LES scenario, a reduction of 71%
- The reduction in inequality is less marked for particulate matter but is lower than for $NO_2$ in any case. The difference for $PM_{2.5}$ goes from 0.9 µg/m$^3$ in 2013 to 0.5 in 2030 under the LES scenario, a reduction of 44%
- Areas which have the highest numbers of mixed/multiple ethnic group residents are more likely to have the highest levels of $NO_2$ in 2013, whereas those with the highest numbers of white residents are more likely to have lower concentrations.
- This ethnicity exposure distribution does not change significantly by 2030 under either the baseline (including the ULEZ-CL) or LES scenarios, although the difference in highest concentrations across each ethnic group is greatly reduced
- The difference in the highest annual average concentrations of $NO_2$ across areas where non-white ethnic groups are most frequently resident (i.e. decile 10) and where they are less frequently residence reduces from 22.5 µg/m$^3$ in 2013 to 6.6 in 2030 in the baseline scenario and 3.3 in the LES scenario, a reduction of 85%.
- Out of a total of 2,367 schools analysed, 487 were shown to be in areas above the 40 µg/m$^3$ Limit Value for annual average $NO_2$ concentrations in 2013. This reduced to 15 in 2020 in the baseline scenario and 5 in the LES. Both scenarios reduce to zero in 2025. No schools were below the WHO Guideline Value for $PM_{2.5}$ in either 2013 or 2030
- For future years (when the vast majority of schools have been brought into compliance with the legal limits for $NO_2$), no o clear association was found between the level of eligibility for free school meals (used as a metric for deprivation) and air pollution exposure at schools

- For schools, hospitals and care homes, levels of exposure to $NO_2$ reduce over the study period, with the LES scenario significantly accelerating that improvement. Facilities closer to central London receive the greatest relative improvement in air quality

It is difficult to envisage the link between air pollution and deprivation in London being completely broken, given the relatively higher proportion of low deprivation areas in the outskirts of the city where there are fewer pollution sources (e.g. lower traffic levels). Reversing this pattern would require a major demographic shift or a fundamental change in the nature of pollution emissions. This latter point is not beyond feasibility. For example, as the proportion of electric vehicles increases, it may be that internal combustion powered vehicles are restricted to the outskirts of cities at some point in the future. However, this is highly unlikely to be the case in the next 10-20 years.

One key message is apparent from this analysis: that the LES will make a significant improvement to future air quality and that the areas currently facing the worst challenges are projected to undergo the greatest improvement. These areas are often those with the highest levels of deprivation and with the largest proportion of residents from non-white ethnic groups. In this way, the LES will make a valuable contribution towards reducing inequality in London.

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