World Health Organization guidelines study: Technical report

For: London Borough of Camden

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1 EXECUTIVE SUMMARY

In this study King's College London used the most recent air quality modelling data available at the time and developed a new high-resolution air quality map for Camden, showing modelled annual mean concentrations of NO_X, NO_2, PM_{10} and $PM_{2.5}$ for the year 2030. The purpose of this modelling exercise was to support Camden's Clean Air Action Plan 2019-2022 (CAAP) and Camden Transport Strategy (CTS) by investigating whether existing and proposed air quality policies would be capable of bringing air quality in Camden into compliance with Camden's World Health Organization targets for NO_2 and particulate matter.

The 2030 modelled data was based on the London Atmospheric Emissions Inventory (LAEI) 2013 dataset, which was the most recent at the time, and included the latest set of existing and imminent policies to be introduced in London including those of the London Environment Strategy. Key air quality and transport policy interventions proposed by Camden Council were then introduced to the 2030 model to explore the extent to which Camden could meet its World Health Organization air quality targets.

The model includes an interactive online analytical map tool displaying high-resolution overall concentrations of NOx, NO_2, PM_{10} and $PM_{2.5}$ plotted on a five-by-five metre grid, and the contribution of different emissions sources as separate layers. The individual emissions sources which were mapped were:

- Road transport
- Commercial and domestic gas heating
- Commercial catering
- Domestic wood burning
- Out-of-London background contribution (comprised of a 'rural background' contribution from UK-based sources outside of London and a 'regional background' contribution from outside of the UK)

This tool can be used to visualise and interrogate the data at any given location, and enables Camden to analyse the relative significance of different activities in different parts of the borough. This facilitates a more geographically targeted approach in the delivery of air quality policy measures in Camden's Clean Air Action Plan 2019-2022.

The tool has been used to establish the anticipated impact of existing air quality policies in London, to identify the key pollution sources in Camden in 2030, and to investigate the 'gap' between modelled concentrations of NO_2, PM_{10} and $PM_{2.5}$ in 2030 and the limit values and WHO targets for these pollutant species. This 2030 'business-as-usual' model scenario indicates that the 40 µg/m³ limit values for NO_2 will be achieved by 2030 throughout Camden, while the WHO targets for PM_{10} (20 µg/m³) and $PM_{2.5}$ (10 µg/m³) will be more difficult to reach, with all areas experiencing concentrations above these objectives under the current limitations of London-wide powers and existing interventions to improve air quality.

Camden then defined a set of overarching policy interventions and instructed King's to rerun the model for "2030 Camden Scenario" in 2030 using the following set of assumptions:

- 5% reduction in road transport traffic levels for all vehicle types (except Transport for London buses) on all roads within Camden
- Removal of all domestic wood burning within Camden
- Electrification of the Chiltern Main Line passenger railway route within London

Predicted 2030 concentrations of NOx, NO_2, PM_{10} and $PM_{2.5}$ are reduced at all locations under the 2030 Camden Scenario. However, the model still suggests that the WHO guideline objectives for PM_{10} (20 µg/m³) and $PM_{2.5}$ (10 µg/m³) would still not be achieved by 2030, with PM_{10} concentrations 25% above the target and $PM_{2.5}$ 39% above the target according to the average annual mean concentrations at 166 distinct locations in the model. It should be noted that only those policy interventions from the CAAP and CTS which were quantifiable as model inputs were able to be introduced to the 2030 Camden Scenario.

The study also finds that the significant majority of modelled PM_{10} and $PM_{2.5}$ present in Camden in 2030 originates from the out-of-London background contribution, under both the business-as-usual scenario and the 2030 Camden Scenario, with 65-75% of PM_{10} and 70-75% of $PM_{2.5}$ coming from this source under the latter scenario.

Since completing this modelling study for Camden, King's has undertaken a new research project which uses current PM data from monitoring sites within London and surrounding areas to produce amended forecast assumptions for the updated LAEI 2016 dataset[1]. This research finds that measured PM concentrations are lower than had previously been predicted, and suggests that reaching the WHO guideline objectives for PM_{10} and $PM_{2.5}$ in London by 2030 is now within a range of possible outcomes.

The Camden-specific modelling results which are presented in this study can therefore be considered to represent a 'worst-case' scenario. The overall conclusions of this study and King's new research both indicate that the WHO objectives are within reach but that additional support is required from Government.

Despite the uncertainty surrounding the achievement of the WHO guidelines, this work confirms the importance and the need for Camden to implement the best set of policies to reduce air pollution locally, whilst putting pressure on relevant legislative bodies to reduce the contribution of external emission sources to pollution in the borough.

The overarching outcome of this study places increased emphasis on the importance of setting a good example of best practice in air quality management, whilst adopting strong lobbying positions to influence national Government to implement more stringent air quality legislation, including setting ambitious targets for air quality, to tackle pollution sources at a regional, sectoral or national scale.

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[1] LAEI 2016 data can be viewed on the London Datastore: https://data.london.gov.uk/dataset/london-atmospheric-emissions-inventory--laei--2016

2 ABBREVIATIONS AND GLOSSARY

BAU: Business-as-usual

CAAP: Camden's Clean Air Action Plan 2019-2022

GLA: Greater London Authority

HGV: Heavy goods vehicle – vehicles with a gross weight more than 3.5 tonnes

LAEI: London Atmospheric Emissions Inventory

LES: London Environment Strategy

LCV: Light commercial vehicle – vehicles with a gross weight up to 3.5 tonnes

µg/m^3:   Micrograms (one-thousandth of a gram) per cubic metre of air

NAEI: National Atmospheric Emissions Inventory

NO$_x$:   Nitrogen oxides – collective term for NO and NO$_2$

NRMM: Non-road mobile machinery – construction machinery used in demolition and construction, such as excavators and generators

Part A and B processes:
Industrial processes which have the potential to cause air pollution – in urban areas these typically include premises such as petrol stations, cement plants, vehicle resprayers, etc.

PM: Particulate matter – airborne particles of which those with a diameter of less than 10 micrometres (µm – one-thousandth of a millimetre) are referred to as PM$_{10}$ and those with a diameter of less than 2.5 µm are referred to as PM$_{2.5}$

TfL: Transport for London

ULEZ: Ultra Low Emissions Zone

WHO: World Health Organization

3 INTRODUCTION

3.1 World Health Organization air quality guidelines

Camden has been in breach of the national air quality objective for NO_2, but has met the objective for PM_{10} at all PM_{10} monitoring locations since 1998. Figures 1 and 2 show annual mean PM_{10} and $PM_{2.5}$ concentrations at Camden monitoring sites since 2010, as well as the national objectives and the World Health Organization guideline objectives.
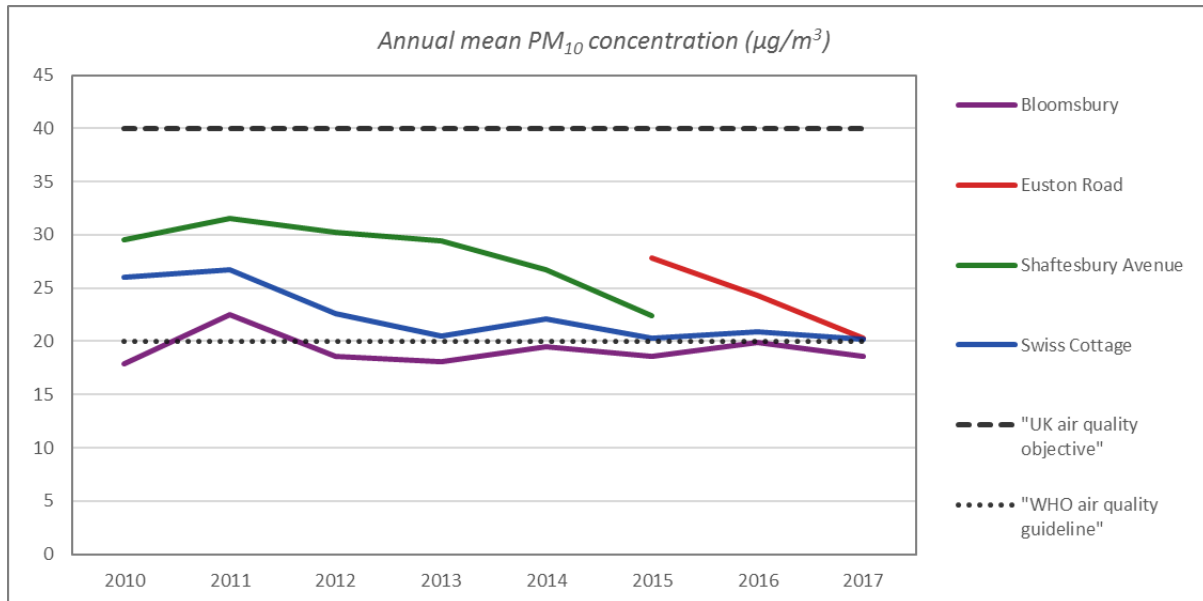

Figure 1: Annual mean PM_{10} concentration 2010-2017, in micrograms per cubic metre of air (µg/m³)
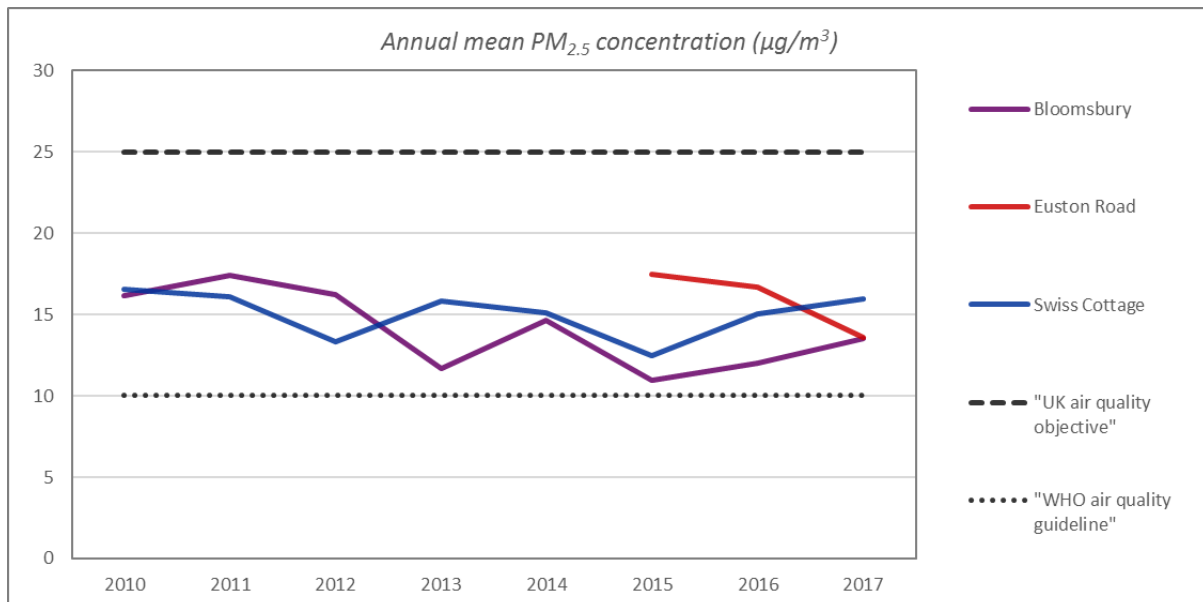

Figure 2: Annual mean $PM_{2.5}$ concentration 2010-2017, µg/m³

The WHO has campaigned worldwide for strict targets for air quality, which are based upon scientific evidence of the health impacts of air pollution. The WHO air quality guidelines are intended to support and drive actions in a local or regional context.

Although all PM monitoring sites comply with the UK national air quality objectives, two of three sites recorded annual mean PM_{10} concentrations above the WHO guideline objective (20 µg/m^3) in 2017, and all three were at least 35% above the objective for $PM_{2.5}$ (10 µg/m^3).

Exposure to PM is associated with a range of health impacts and the $PM_{2.5}$ component (fine particulate matter) is classed as carcinogenic. Epidemiological evidence shows that there is likely to be no threshold for PM below which adverse health impacts, including mortality, do not occur. These impacts are statistically associated with elevated outdoor 'ambient' concentrations of air pollutants, and are still seen at concentrations below the limit values.

The WHO air quality guidelines take account of the fact that a portion of PM comes from natural sources, and that any reduction in PM concentrations will achieve a reduction in the prevalence of adverse health impacts. Therefore whilst the WHO air quality guidelines for PM do not target zero exposure, they are much more stringent than UK national air quality objectives.

In 2018 Camden became the first local authority in London to formally adopt the WHO guideline objectives for air quality. Camden is aiming to meet the WHO guideline values of 40 µg/m^3 for NO_2, 20 µg/m^3 for PM_{10} and 10 µg/m^3 for $PM_{2.5}$ (fine particulate matter) by 2030. The WHO guideline objectives are much more stringent for particulate matter than the EU air quality objectives which form the UK national targets.

Tackling pollutant emissions sources is therefore essential to improve air quality to meet both the UK limit values and the WHO guidelines, and ultimately to achieve the lowest possible levels of pollution.

3.2 Camden 2030 air quality model

Camden Council commissioned King's College London (King's) to help determine whether measures introduced in Camden's Clean Air Action Plan 2019-2022 and Camden's Transport Strategy 2019-2041 would likely be sufficient to achieve Camden's World Health Organization (WHO) air quality objectives for PM_{10} and $PM_{2.5}$ by 2030.

King's modelled annual mean concentrations of NO_X, NO_2, PM_{10} and $PM_{2.5}$ in 2030 under a 'business-as-usual' (BAU) Scenario and produced several source apportionment outputs to show the estimated contribution of different emissions sources to total pollutant concentrations. These sources included road transportation, commercial and domestic gas heating, emissions from commercial catering premises, domestic wood burning and an out-of-London 'background' contribution.

The overall pollutant concentrations and the contributions from these individual sources were mapped on an online tool which enabled Camden to visualise the

modelled distribution of pollutants throughout the borough in 2030 at five-metre spatial resolution.

This allowed Camden to explore the relative significance of different pollution sources throughout the borough to assist in identifying which types of policy measures could have the most impact in different areas.

Other emissions sources which could not be mapped spatially – and which are typically associated with an estimated uniform contribution to localised air pollution in London as per the LAEI 2013 dataset – were included in the total pollutant concentrations displayed on the online map tool. These sources include demolition and construction activities and non-road mobile machinery (NRMM), aviation and marine activities.

As a final stage of the modelling exercise, King's introduced some of the overarching policy interventions which incorporated various individual measures of the CAAP to the modelled BAU Scenario to produce a 'Camden 2030 Scenario' which represented the combined impact of existing and imminent GLA and TfL policies under the LES and Camden action to improve air quality.

The BAU Scenario and the Camden 2030 Scenario were then compared in the online tool to examine the additional impact of Camden's CAAP air quality measures and to anticipate whether further interventions would be required in order to meet the WHO targets by 2030.

4 METHODOLOGY

4.1 LAEI 2013 reference air quality data

The NOx, NO$_2$, PM$_{10}$ and PM$_{2.5}$ emissions and air quality modelling reference year which formed the base of the Camden 2030 model was the London Atmospheric Emissions Inventory (LAEI) 2013 dataset. This was later refined by King's with the inclusion of updated EU standard vehicle emissions factors (COPERT version 5[2]), which improved the accuracy of modelling road transport emissions.

In the LAEI 2013 data, domestic wood burning (biomass) was modelled as a single, uniform background concentration across London, with no spatial variation, based upon detailed measurements of the contribution of biomass to overall PM emissions.

To allow Camden to assess the spatial distribution of biomass emissions it was necessary to replace this uniform concentration with an equivalent emissions total in London, including correctly representing the spatial distribution of the emissions across the city. This was achieved by spatially distributing 2,042 tonnes of PM emissions (the equivalent London-wide emissions total) onto the LAEI 1x1km grid using the National Atmospheric Emissions Inventory (NAEI) 2015 residential wood burning emissions inventory[3] to reflect the spatial changes in emissions.
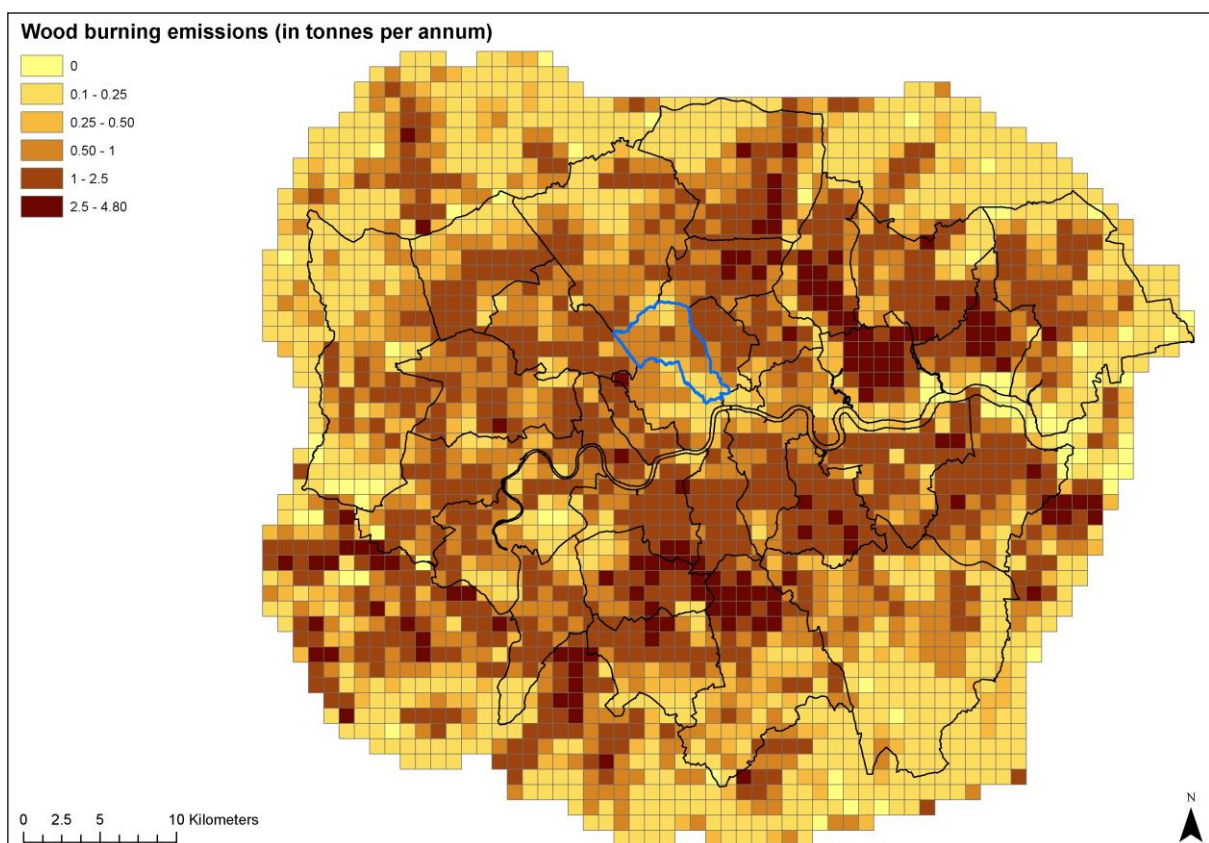

Figure 3: Distribution of domestic wood burning emissions in London (Camden borough border outlined in blue) based upon LAEI 2013 data, with emissions in tonnes per annum

[2] https://www.emisia.com/utilities/copert/

[3] https://uk-air.defra.gov.uk/assets/documents/reports/cat07/1710261436_Methodology_for_NAEI_2017.pdf

This new biomass emissions distribution has allowed Camden to model the impact of policies to limit domestic wood burning in the borough, and to investigate the extent to which the contribution of biomass to overall annual mean PM concentration varies throughout Camden.

Finally, components of the updated LAEI 2013 air quality model used by the Greater London Authority (GLA) and Transport for London (TfL) to develop the London Ultra Low Emissions Zone (ULEZ) and the London Environment Strategy (LES) was incorporated to further enhance the representativeness of the future projections in the Camden 2030 model.

This forms a future 2030 Camden 'Business-as-Usual' (BAU) Scenario based upon improved modelling, the original 2013 meteorology, and incorporating the impacts of London policies forming the LES. A more detailed description of the basis of this model can be found in the LAEI 2013 Methodology[4]. It should be noted that the policies incorporated in the BAU Scenario represent the extent of the legislative powers of the GLA and the Mayor of London at the time of modelling (2018).

4.2 2030 BAU Scenario source apportionment data and maps

The base output of the 2030 BAU Scenario is a set of interactive maps of annual mean concentrations of NO_X, NO_2, PM_{10} and $PM_{2.5}$, plotted at 5x5m spatial resolution. This would have enabled analysis of the overall estimated distribution of pollution in 2030, but could not have provided any insight into the relative contributions of difference emission sources.

In order to allow Camden to develop action plan measures more specifically targeted towards different emission sources in different parts of the borough, King's disaggregated the pollutant concentrations attributable to some of the main emission sources and added these as separate map layers on the interactive online map tool.

This modelled 'source apportionment' for air quality in 2030 was produced for the following emission sources:

- **Road transport** – the combined contribution of all road vehicles of all categories moving on roads in Camden
- **Commercial and domestic gas heating** – the contribution of boiler and other heating system exhaust gases from commercial and domestic premises with natural gas heating systems
- **Commercial catering** – the contribution of emissions from commercial catering facilities (not including mobile premises such as food stalls)
- **Domestic wood burning** – the contribution of wood-burning (biomass) emissions from domestic premises
- **Out-of-London 'background' contribution** – emissions imported into Camden, comprised of a 'rural background' contribution from UK-based sources outside of London and a 'regional background' contribution from sources outside of the UK

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[4] https://data.london.gov.uk/dataset/london-atmospheric-emissions-inventory-2013

As with the overall pollutant concentrations under the 2030 BAU Scenario, the source apportionment map layers are displayed at high spatial resolution (5x5m).

In addition to the visual representation of air quality in 2030, the online map tool is supplemented with a data table showing modelled pollutant concentrations at specific postcodes or latitude-longitude locations in Camden. This enabled a more detailed quantitative comparison of modelled air quality in relation to Camden's WHO targets.

Figure 4 shows a screenshot of the online map tool, which in this case is displaying modelled total annual NO_2 concentration under the 2030 BAU Scenario.
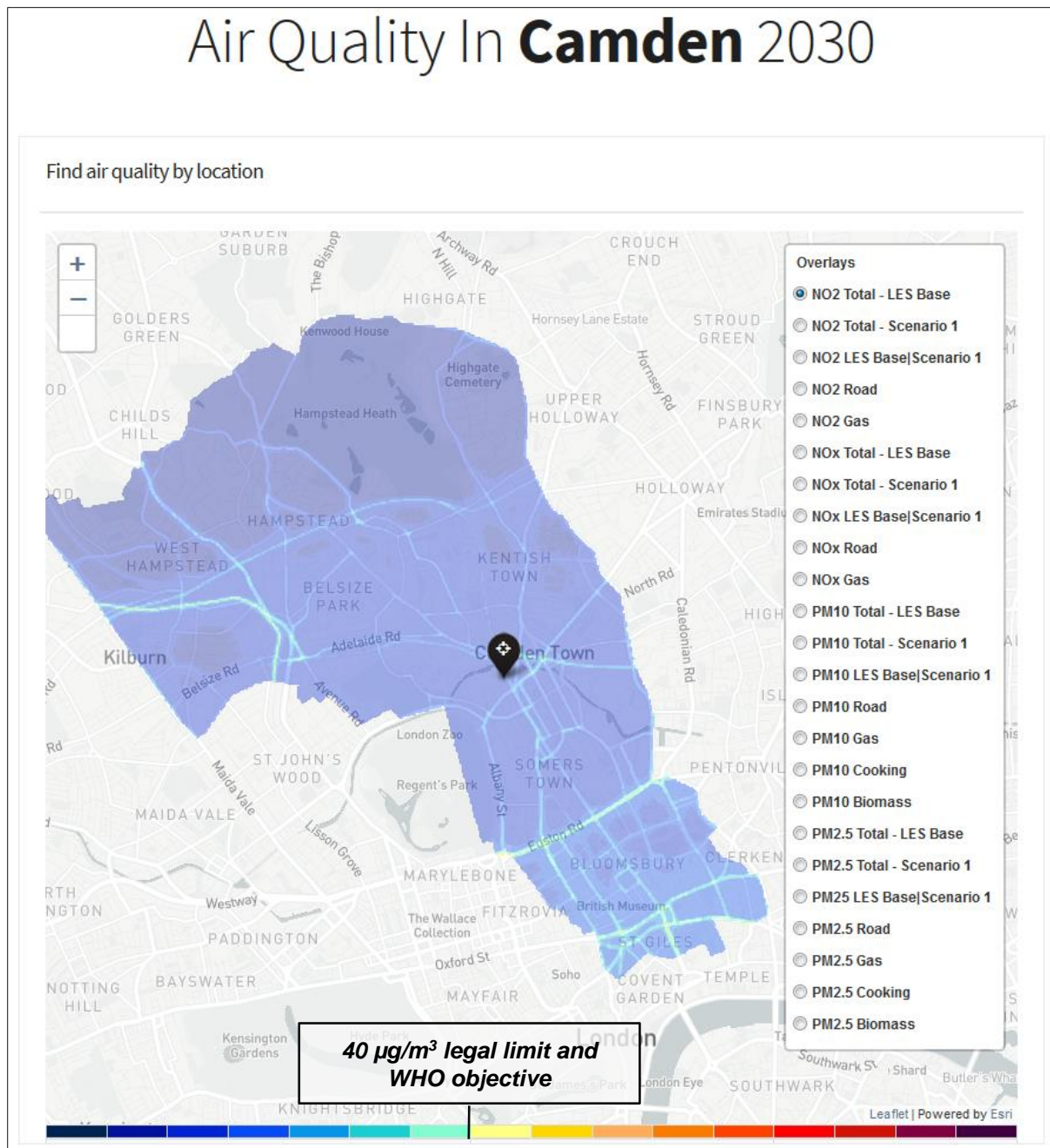

Figure 4: Total modelled annual mean NO$_2$ concentration in Camden in 2030, according to the 2030 BAU Scenario model. Areas coloured yellow through to purple are in breach of the WHO guidelines objective for NO$_2$, 40 µg/m^3

Figure 5 shows the accompanying data table which presents the modelled pollutant concentrations in 2030 at the location marked in Figure 4. All concentrations are in µg/m^3. The columns 'LES Base' and 'Scenario 1' represent total pollutant concentrations under the different modelling scenarios, and the 'Background', 'Road', 'Gas', 'Cooking' and 'Biomass' columns note the estimated concentration of pollutant attributable to that particular emission source. The remainder (left by the total minus the sum of the individual modelled sources) represents the unmodelled emission sources within Camden and the contribution of emission sources from other London boroughs.

It should be noted that whilst the concentration values shown in the data table in Figure 5 are given to two decimal places, this does not represent the precision of the modelling; rather, the values are the centre of the range of projected pollutant concentration.

Lat Lng Search

Click on the map, drag the marker, or enter a lat lng that location

Latitude

Longitude

Find

Postcode Search

Click on the map, drag the marker, or enter a postcode to see the pollutant concentrations at that location

Enter postcode

Find

Current Location (NW1 7HG- Camden)

Latitude: 51.54000
Longitude: -0.14423

Pollutant	LES Base	Scenario 1	Diff	Background	Road	Gas	Cooking	Biomass
NO2 (µg/m³)	20.26	20.02	0.23	-	1.56	1.19	-	-
NOX (µg/m³)	24.46	24.06	0.40	8.5	3.01	2.20	-	-
PM10 (µg/m³)	23.38	23.16	0.23	17.41	1.20	0.03	0.39	0.18
PM2.5 (µg/m³)	13.52	13.32	0.20	10.18	0.31	0.03	0.39	0.18

Figure 5: Data table accompanying online map tool

Figure 6 shows total NO$_2$ concentration, NO$_2$ concentration under the 2030 BAU Scenario, the NO$_2$ concentration attributable to road transport, and the NO$_2$ concentration attributable to commercial and domestic gas heating systems. For the map showing total NO$_2$ concentration, areas coloured yellow through to purple are those where the 40 µg/m^3 UK legal limit and WHO guidelines objective are estimated to be breached.

Figure 6 shows that NO_2 concentration is anticipated to meet the UK legal limit and WHO guideline objective by 2030 under the 2030 BAU Scenario, including in those areas which at present experience annual mean NO_2 far in exceedance of the target.

It is clear that the contribution of road transport to 2030 NO_2 concentrations is highly localised around key arterial roads in Camden, whilst the impact of commercial and domestic gas heating systems is more widely distributed, albeit with a distinct geographical stratification with higher concentrations of NO_2 from this source in the south of the borough.

Figures 7 and 8 show that all areas of Camden are below the UK legal limit for PM_{10} and $PM_{2.5}$, however all areas are predicted to experience concentrations above the WHO objectives for these pollutants.

As with NO_2 concentration, there is a clear association between the concentration of PM from road transport and proximity to busy roads. However, from the total PM_{10} and total $PM_{2.5}$ maps it is evident that the individual sources have a less significant influence on overall concentration than for NO_2, which indicates that a significant proportion of modelled 2030 PM is attributable to dispersed or external 'background' sources from outside of Camden, outside of London (rural background) and from outside of the UK (regional background).

For the rural background imported emissions, the model factors in a contribution of 8.5 µg/m^3 to NOx, 0.8 µg/m^3 to PM_{10} and 0.5 µg/m^3 to $PM_{2.5}$ concentrations in Camden. The regional background imported emissions account for 16.6 µg/m^3 of PM_{10} and 9.7 µg/m^3 of $PM_{2.5}$ in Camden, with no contribution to NOx as this pollutant is typically not transported as far as particulate matter.

The PM contribution from commercial and domestic gas heating has the same pattern as for NO_2 from this source, with the south of Camden experiencing increased concentrations of PM from gas heating and the north comparatively little, with the exception of residential areas around Gospel Oak and Highgate. The contribution of commercial catering premises is even more distinctly stratified with a clear decline in catering-derived PM with increasing distance from Central London. The impact of domestic wood burning is clearly most pronounced around Hampstead, Gospel Oak and Highgate.

In summary, the 2030 BAU Scenario maps suggest that Camden will achieve the UK air quality objectives for NO_2, PM_{10} and $PM_{2.5}$ by 2030. However, both PM_{10} and $PM_{2.5}$ modelling data suggests that Camden may fail to achieve compliance with the WHO guidelines objectives of 20 µg/m^3 and 10 µg/m^3 for PM_{10} and $PM_{2.5}$, respectively, by 2030.

2030 BAU Scenario total NO₂

>97	
76-97	
73-76	
58-73	
55-58	
43-55	
40-43	*40 µg/m³ legal limit and WHO objective*
37-40	
34-37	
31-34	
28-31	
25-28	
22-25	
19-22	
16-19	
<16	

2030 BAU Scenario road transport NO₂

28.6900 - 31
2.9695 - 28.6900
1.8754 - 2.9695
1.4229 - 1.8754
1.1396 - 1.4229
0.9701 - 1.1396
0.8439 - 0.9701
0.7091 - 0.8439
0.5303 - 0.7091
0.3030 - 0.5303
0 - 0.3030

2030 BAU Scenario commercial and domestic gas heating NO₂

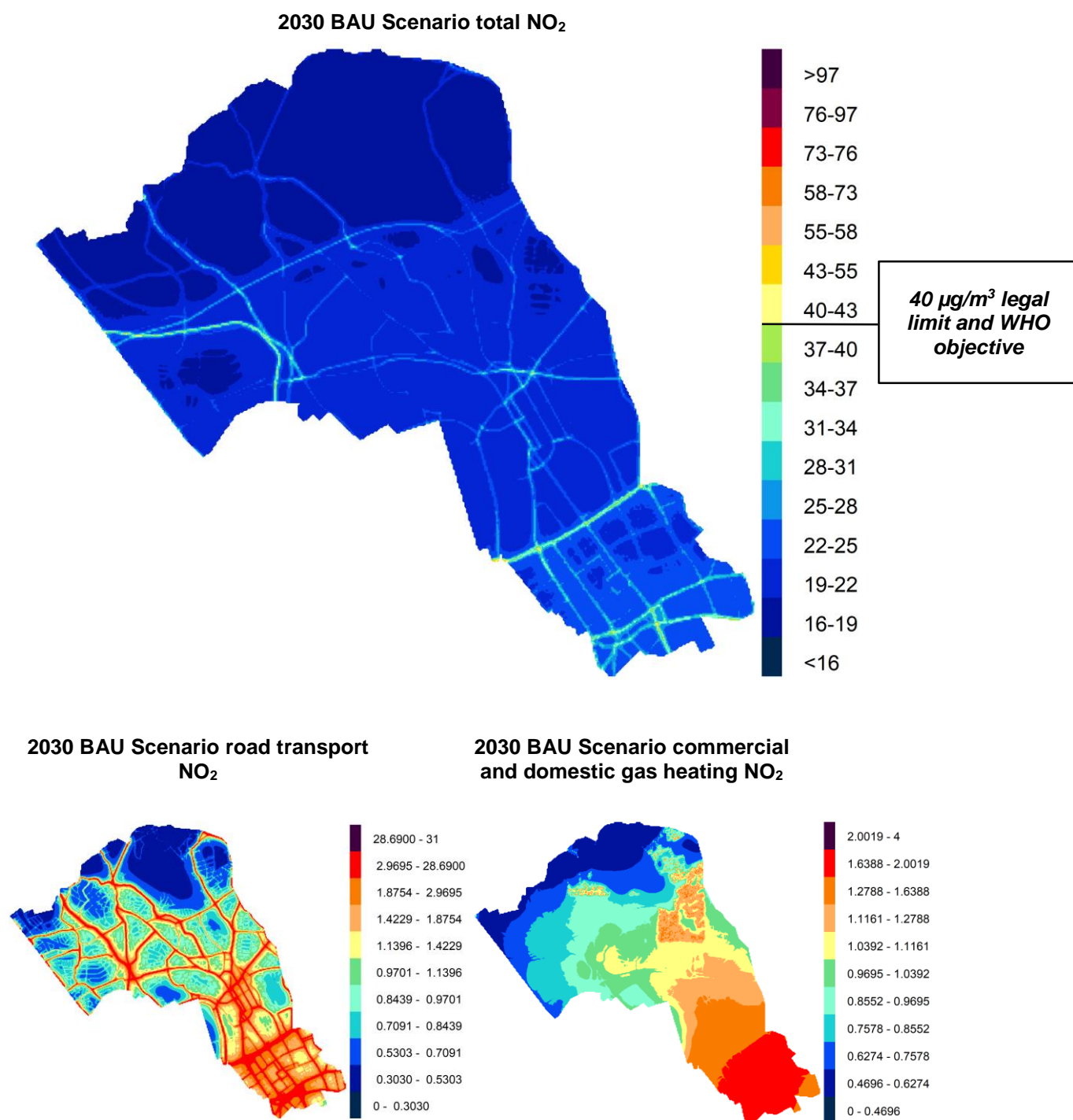| |
|---|
| 2.0019 - 4 |
| 1.6388 - 2.0019 |
| 1.2788 - 1.6388 |
| 1.1161 - 1.2788 |
| 1.0392 - 1.1161 |
| 0.9695 - 1.0392 |
| 0.8552 - 0.9695 |
| 0.7578 - 0.8552 |
| 0.6274 - 0.7578 |
| 0.4696 - 0.6274 |
| 0 - 0.4696 |

Figure 6: Total NO₂, road transport-derived NO₂ and commercial and domestic gas heating-derived NO₂ under the 2030 BAU Scenario. All units are µg/m³ - note different scales

Figure 7 shows the 2030 BAU Scenario maps for total PM_{10} concentration and the PM_{10} attributable to road transport, commercial and domestic gas heating, commercial catering and domestic wood burning. All units are µg/m³.

2030 BAU Scenario total PM₁₀

>97	
76-97	
73-76	
58-73	
55-58	
43-55	
40-43	
37-40	
34-37	
31-34	
28-31	
25-28	
22-25	
19-22	
16-19	
<16	

20 µg/m³ legal limit and WHO objective

2030 BAU Scenario road transport PM₁₀

19.9443 - 22
2.0948 - 19.9443
1.3422 - 2.0948
1.0517 - 1.3422
0.8673 - 1.0517
0.7448 - 0.8673
0.6520 - 0.7448
0.5541 - 0.6520
0.4190 - 0.5541
0.2488 - 0.4190
0 - 0.2488

2030 BAU Scenario commercial and domestic gas heating PM₁₀

0.0625 - 2
0.0426 - 0.0625
0.0350 - 0.0426
0.0302 - 0.0350
0.0286 - 0.0302
0.0269 - 0.0286
0.0240 - 0.0269
0.0211 - 0.0240
0.0169 - 0.0211
0.0119 - 0.0169
0 - 0.0119

2030 BAU Scenario commercial catering PM₁₀

1.2989 - 3
0.7535 - 1.2989
0.4156 - 0.7535
0.3367 - 0.4156
0.2884 - 0.3367
0.2597 - 0.2884
0.2265 - 0.2597
0.1816 - 0.2265
0.1403 - 0.1816
0.0976 - 0.1403
0 - 0.0976

2030 BAU Scenario domestic wood burning PM₁₀

0.2409 - 2
0.2109 - 0.2409
0.1897 - 0.2109
0.1718 - 0.1897
0.1631 - 0.1718
0.1547 - 0.1631
0.1354 - 0.1547
0.1086 - 0.1354
0.0889 - 0.1086
0.0565 - 0.0889
0 - 0.0565

Figure 7: Total PM_{10} concentration and PM_{10} from road transport, commercial and domestic gas heating, commercial catering and domestic wood burning. All units are µg/m³ - note different scales

Figure 8 shows the 2030 BAU Scenario maps for total $PM_{2.5}$ concentration and the $PM_{2.5}$ attributable to road transport, commercial and domestic gas heating, commercial catering and domestic wood burning. All units are μg/m³.
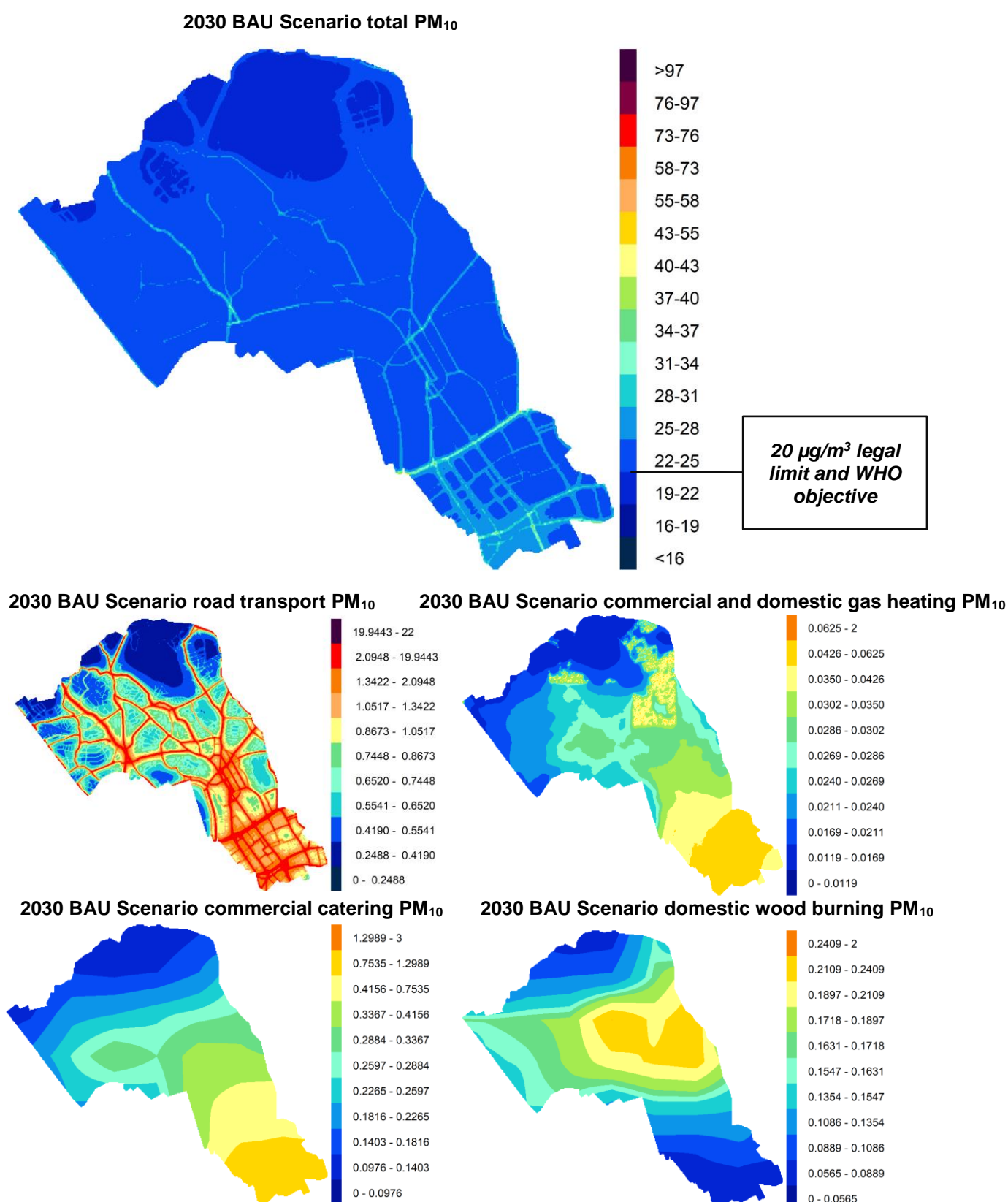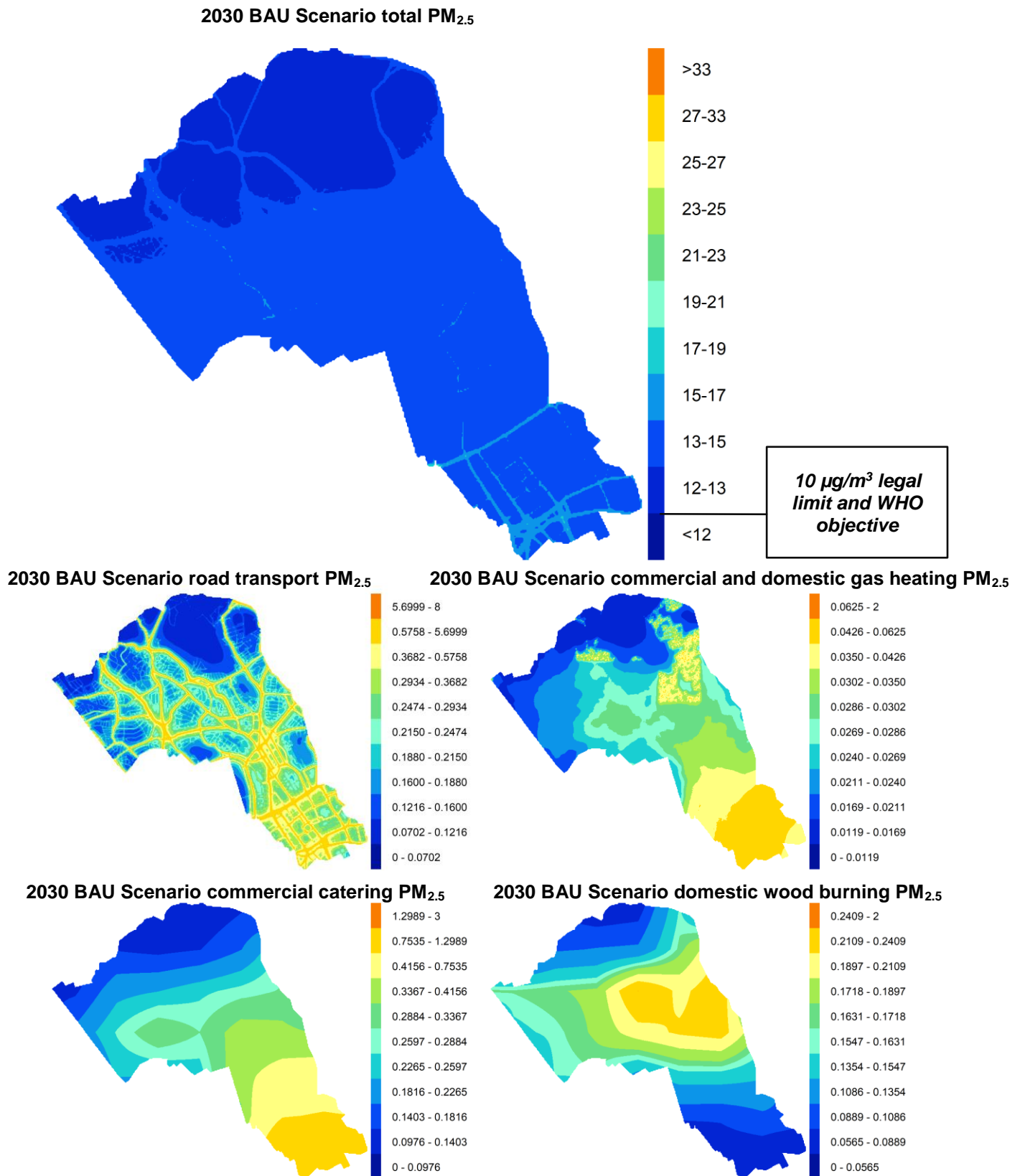
2030 BAU Scenario total PM$_{2.5}$

Scale	μg/m³
	>33
	27-33
	25-27
	23-25
	21-23
	19-21
	17-19
	15-17
	13-15
	12-13
	<12

10 μg/m³ legal limit and WHO objective

2030 BAU Scenario road transport PM$_{2.5}$

5.6999 - 8
0.5758 - 5.6999
0.3682 - 0.5758
0.2934 - 0.3682
0.2474 - 0.2934
0.2150 - 0.2474
0.1880 - 0.2150
0.1600 - 0.1880
0.1216 - 0.1600
0.0702 - 0.1216
0 - 0.0702

2030 BAU Scenario commercial and domestic gas heating PM$_{2.5}$

0.0625 - 2
0.0426 - 0.0625
0.0350 - 0.0426
0.0302 - 0.0350
0.0286 - 0.0302
0.0269 - 0.0286
0.0240 - 0.0269
0.0211 - 0.0240
0.0169 - 0.0211
0.0119 - 0.0169
0 - 0.0119

2030 BAU Scenario commercial catering PM$_{2.5}$

1.2989 - 3
0.7535 - 1.2989
0.4156 - 0.7535
0.3367 - 0.4156
0.2884 - 0.3367
0.2597 - 0.2884
0.2265 - 0.2597
0.1816 - 0.2265
0.1403 - 0.1816
0.0976 - 0.1403
0 - 0.0976

2030 BAU Scenario domestic wood burning PM$_{2.5}$

0.2409 - 2
0.2109 - 0.2409
0.1897 - 0.2109
0.1718 - 0.1897
0.1631 - 0.1718
0.1547 - 0.1631
0.1354 - 0.1547
0.1086 - 0.1354
0.0889 - 0.1086
0.0565 - 0.0889
0 - 0.0565

Figure 8: Total PM$_{2.5}$ concentration and PM$_{2.5}$ from road transport, commercial and domestic gas heating, commercial catering and domestic wood burning. All units are μg/m³ - note different scales

4.3 Road transport emissions and concentrations maps

In addition to the modelled 2030 pollutant concentration maps, King's produced another map tool to explore the emissions attributable to specific key roads in Camden, with estimations for the contribution of specific vehicle categories and a breakdown of whether the emissions are from the vehicle exhaust gases or from break and tyre wear.

This map layer gives proportion data for motorcycles, taxis, petrol cars, diesel cars, electric cars, petrol LDVs, diesel LDVs, electric LDVs, TfL buses, coaches, rigid HGVs and articulated HGVs. Combined with the estimations for the contribution of different components of vehicles and vehicle activity (vehicle exhaust, brake and tyre wear and resuspension), this allows Camden to anticipate the origins of road transport emissions of PM_{10} and $PM_{2.5}$ in 2030 under the 2030 BAU Scenario.

Figure 9 shows total $PM_{2.5}$ concentration under the 2030 BAU Scenario overlaid with additional road transport emissions data for a section of Mill Lane in north-west Camden.

Road Transport Air Quality And Emissions In **Camden** 2030

All concentration maps are in µg/m³

In the emissions layers, "Total" gives the road transport emissions in tonnes per annum (t/a) for the length of the TOID link, while the remaining numeric entries give percentage contributions to that total.
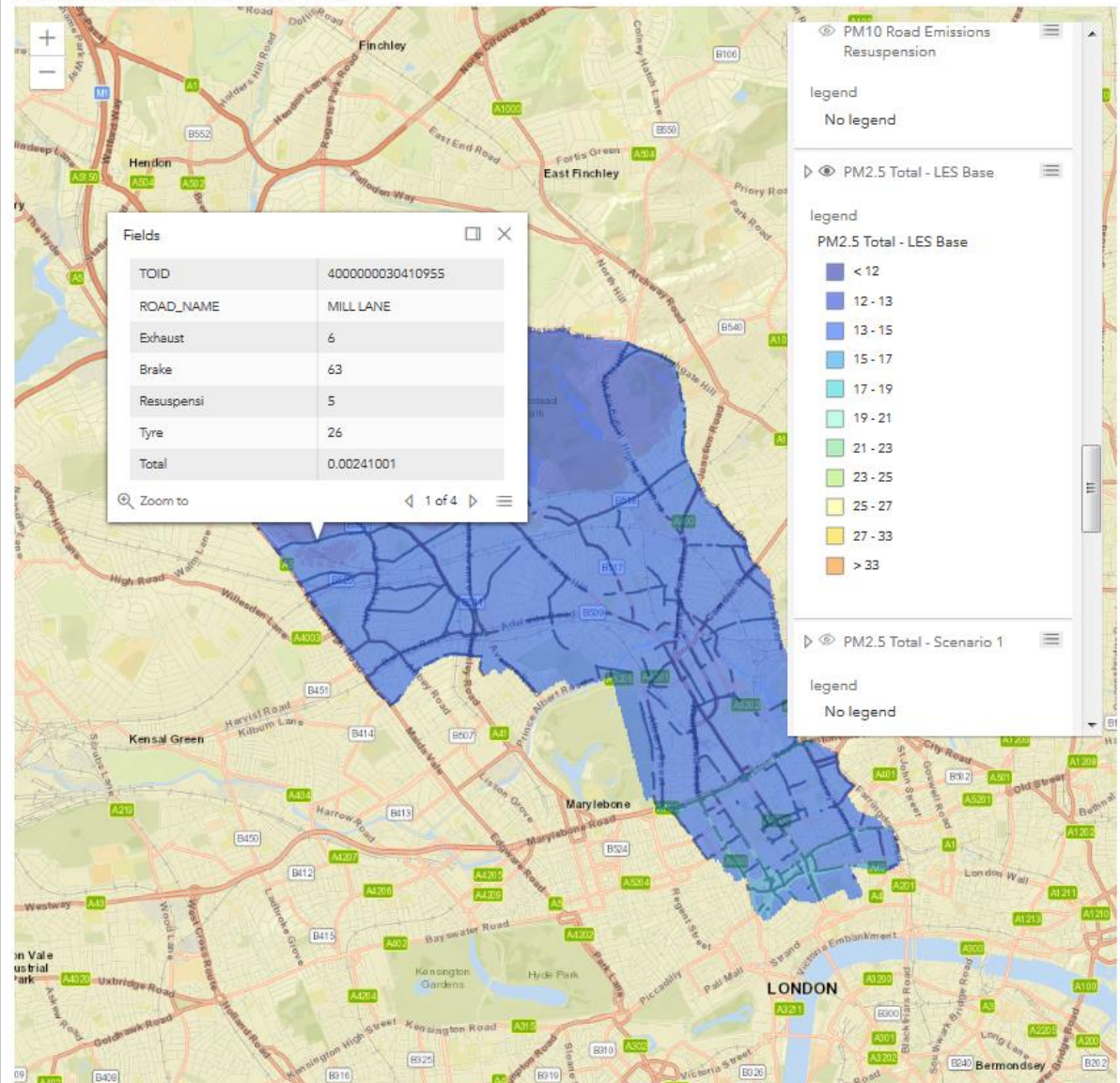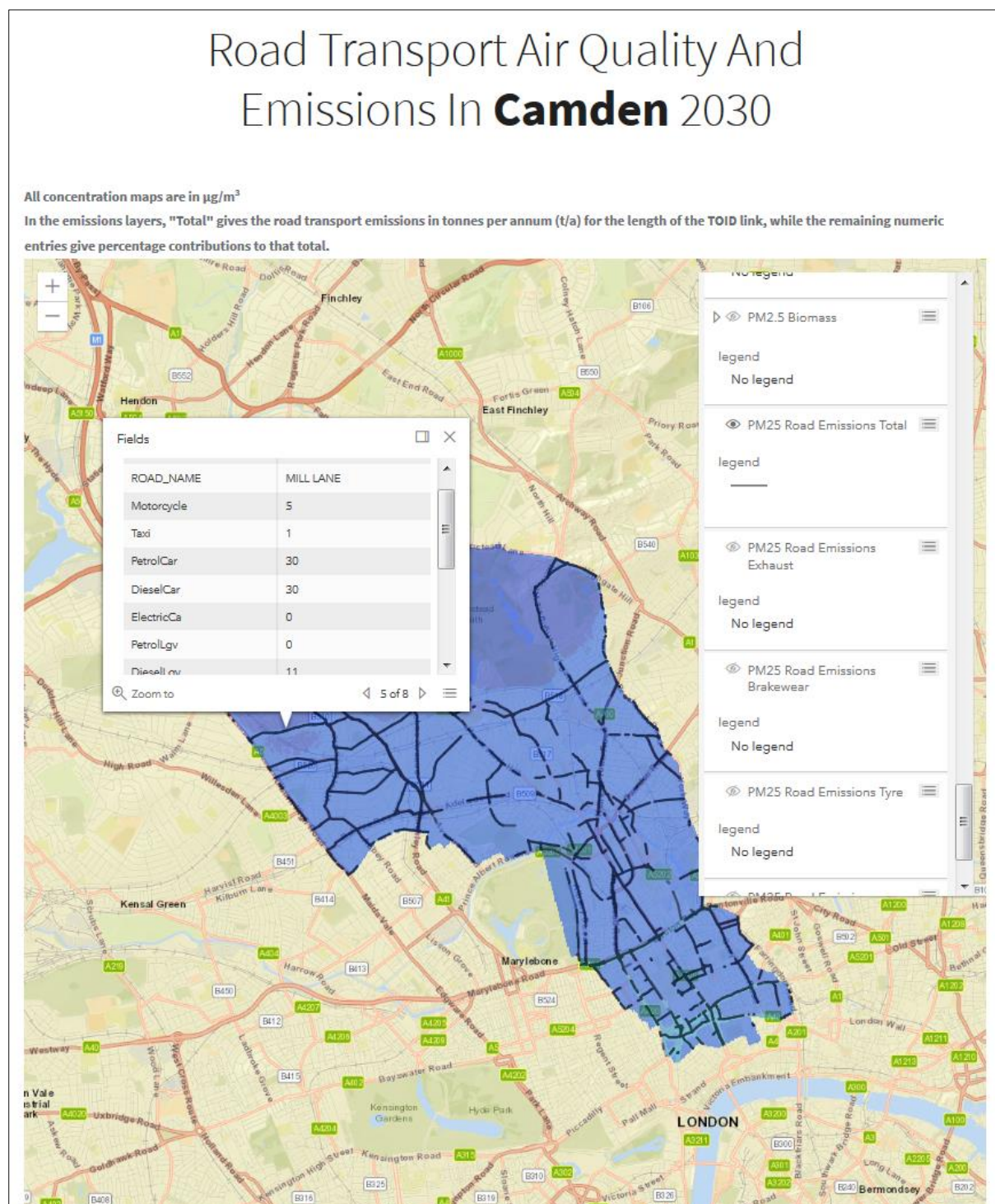

Figure 9: Total modelled PM$_{2.5}$ concentration under the 2030 BAU Scenario and modelled road transport emissions breakdown by emissions origin for a section of Mill Lane. Concentration is in µg/m³, and total emissions of PM$_{2.5}$ for the road link are in tonnes/year

Figure 10 again shows the total PM$_{2.5}$ under the 2030 BAU Scenario, this time overlaid with supplementary data showing the estimated proportion of emissions from different vehicle types from a specific stretch of Mill Lane.

Figure 10: Total modelled PM$_{2.5}$ concentration under the 2030 BAU Scenario and modelled road transport emissions breakdown (%) by vehicle type for a section of Mill Lane. Concentration is in µg/m³

4.4 2030 Camden Scenario model inputs

The interactive online tool provided Camden with the capability to test the impact of specific policy interventions on modelled air quality in 2030. Following the Camden Clean Air Partnership 'Design Day', Camden instructed King's to rerun the model based upon the original 2030 BAU Scenario but with the addition of the following specific interventions, which forms a '2030 Camden Scenario':

- **5% reduction in total annual vehicle travel** – a 5% reduction in total annual kilometres travelled was applied to all major and residential road traffic flows (except for those of TfL buses) and to the number of engine 'cold starts' in the borough. The average speeds on the major road links were updated accordingly, using the speed elasticity factors shown in Table 1. Therefore, for a traffic reduction of 5% during the inter-peak period outside of the Congestion Charging Zone (CCZ), for example, the corresponding speed change was a 4.5% increase. This modelling input represents the combined impact of various measures in the Camden Transport Strategy to incentivise and facilitate modal shift away from the use of private vehicles and towards use of 'active travel' and public transport

Speed changes in response to reduced vehicular traffic		
Time of day	**Location**	**Speed change (%)**
AM peak (07:00-10:00)	CCZ	-1.0
	Inner London	-1.0
Inter (10:00-16:00 + 19:00-22:00)	CCZ	-1.0
	Inner London	-0.9
PM peak (16:00-19:00)	CCZ	-1.0
	Inner London	-1.0
Overnight	All locations	No change

Table 1: Percent speed change per 1 % increase in traffic flow, by period and location

- **Removing all domestic wood burning (biomass) in Camden** – the 1x1km gridded domestic wood burning emissions were given a value of zero tonnes per annum within the Camden border outlined in blue as in Figure 3

- **Electrification of the Chiltern Main Line passenger railway route within London** – the 2030 BAU Scenario showed this route as being the only rail route in Camden to still generate a distinct contribution to localised NO_2, therefore representing an opportunity to lobby the Department for Transport, Network Rail and the franchise operator to electrify the route within London. The 2030 Camden Scenario assumes full electrification and the 1x1km gridded Chiltern railway emissions were given a value of zero tonnes per annum (see routes and grids highlighted in green in Figure 11)
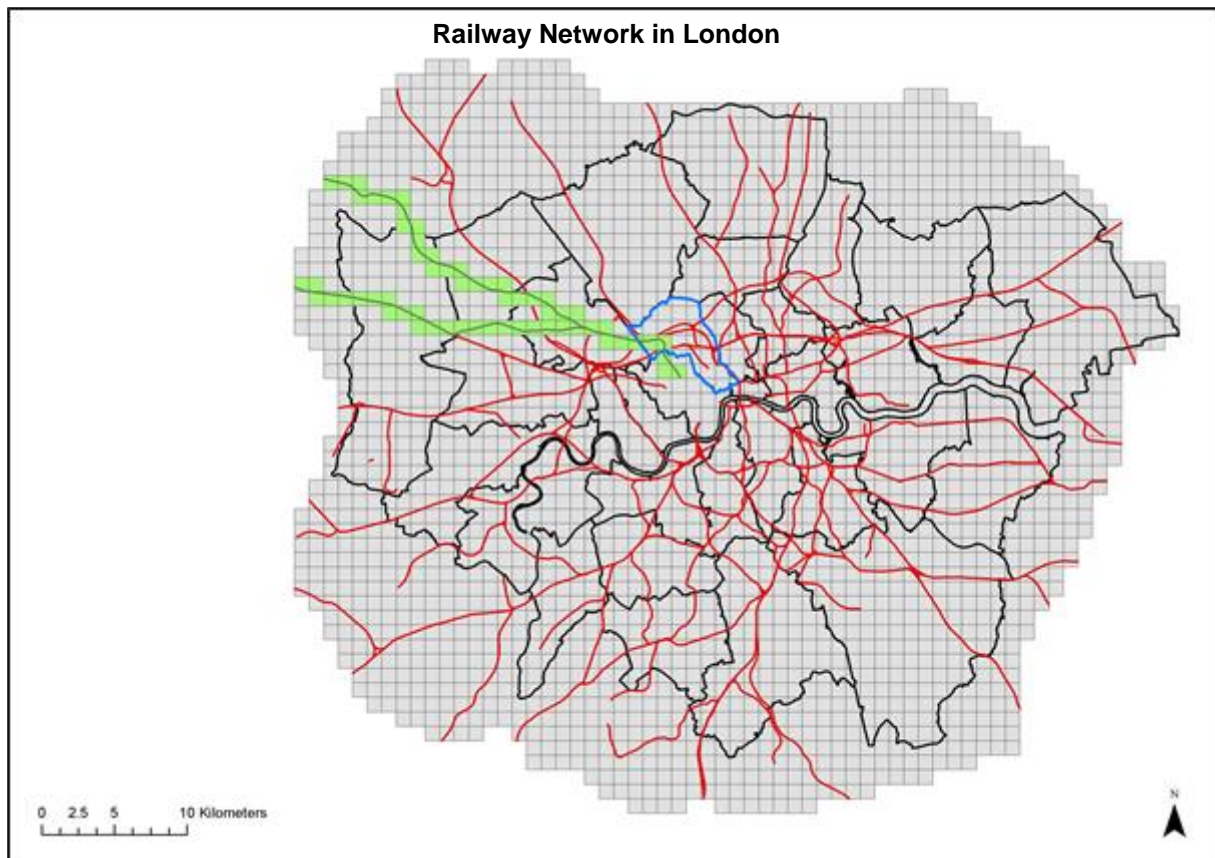
Figure 11: Railway network highlighted in red with Chiltern Main Line railway highlighted in green (Camden border outlined in blue)

4.5 2030 Camden Scenario data and maps

As with the 2030 BAU Scenario, the 2030 Camden Scenario total pollutant concentrations were apportioned into individual emission sources, and the total concentrations and individual emission source layers were plotted at 5x5m resolution on the online map tool.

The online map tool also displays the difference in pollutant concentration achieved by the inclusion of the Camden policy interventions under the 2030 Camden Scenario. The concentration data for a specific chosen location on the map is displayed in the accompanying data table, along with the numeric difference in concentration according to the two scenarios.

Figures 12, 13 and 14 show the reduction in annual mean concentrations achieved through the introduction of Camden interventions under the 2030 Camden Scenario for NO_2, PM_{10} and $PM_{2.5}$, respectively.
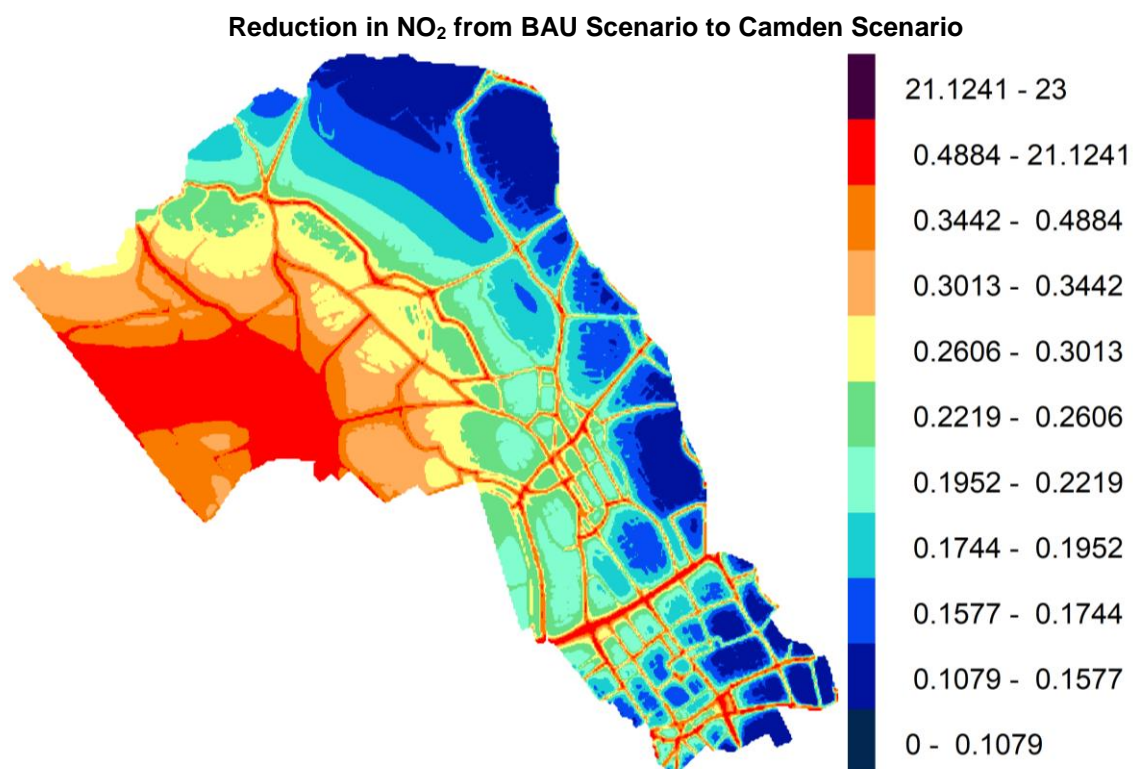
Reduction in NO₂ from BAU Scenario to Camden Scenario

Figure 12: Reduction in modelled annual mean NO$_2$ concentration (in μg/m^3) in 2030 from the 2030 BAU Scenario to the 2030 Camden Scenario, with the lowest change indicated with blue colouring and the most significant change indicated by red colouring
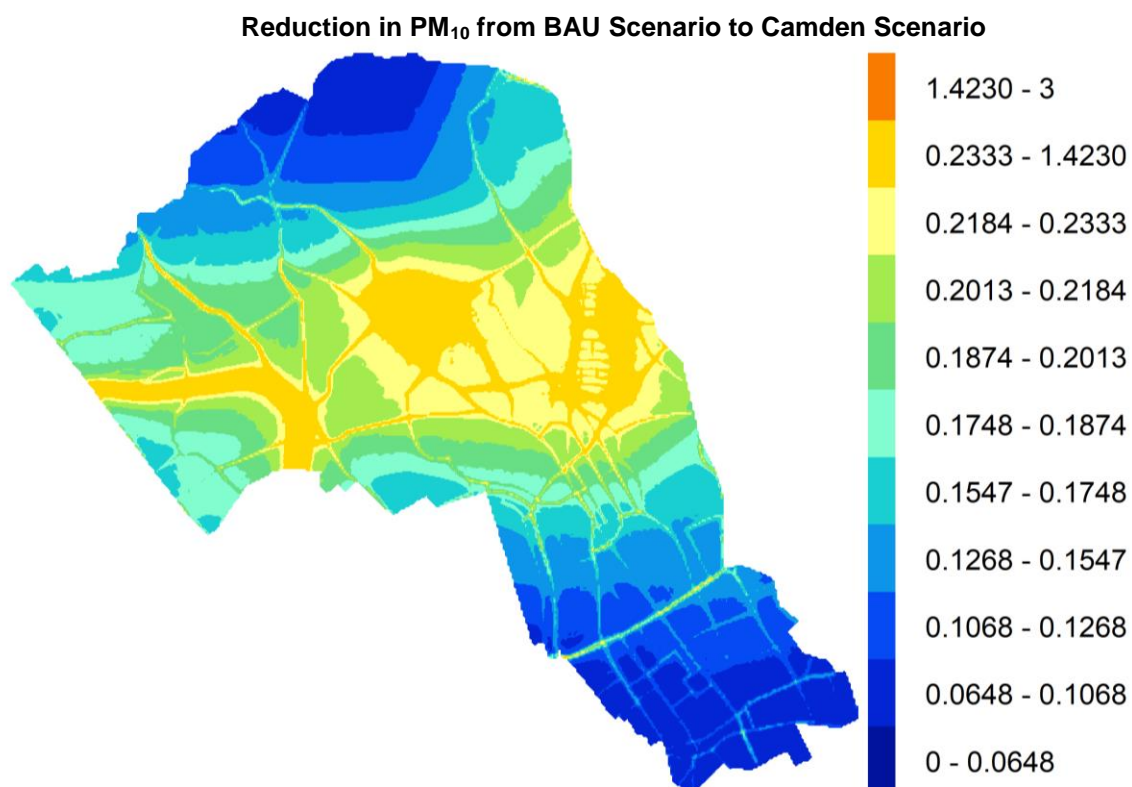
Reduction in PM₁₀ from BAU Scenario to Camden Scenario

Figure 13: Reduction in modelled annual mean PM$_{10}$ concentration (in μg/m^3) in 2030 from the 2030 BAU Scenario to the 2030 Camden Scenario, with the lowest change indicated with blue colouring and the most significant change indicated by red colouring
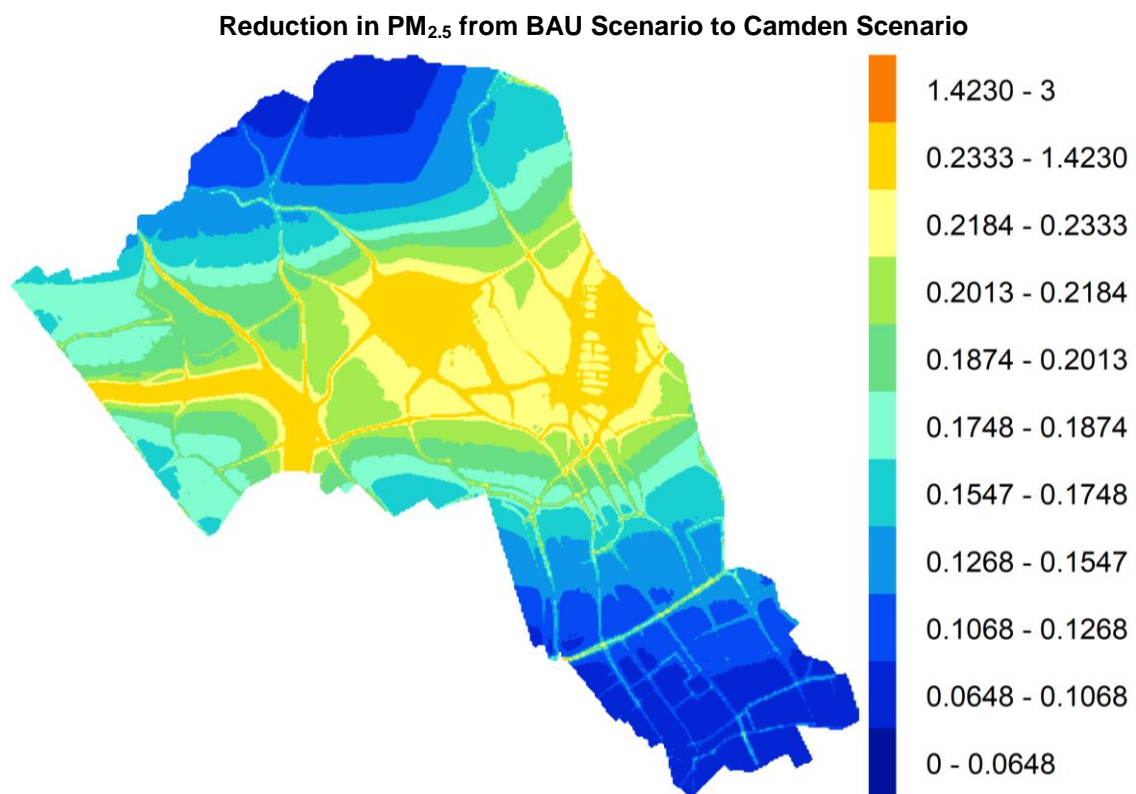
Reduction in PM$_{2.5}$ from BAU Scenario to Camden Scenario

Figure 14: Reduction in modelled annual mean PM$_{2.5}$ concentration (in µg/m^3) in 2030 from the 2030 BAU Scenario to the 2030 Camden Scenario, with the lowest change indicated with blue colouring and the most significant change indicated by red colouring

5 COMPARISON OF 2030 BAU SCENARIO AND 2030 CAMDEN SCENARIO

The online map tool was used to compare modelled concentrations of NO_2, PM_{10} and $PM_{2.5}$ in 2030 under the BAU Scenario and the Camden Scenario which incorporated several Camden policy interventions.

Figure 12 shows that major roads and the area immediately surrounding the Chiltern Main Line are most impacted by the introduction of Camden air quality interventions.

Figures 13 and 14 show that PM_{10} and $PM_{2.5}$ are equally impacted by the 2030 Camden Scenario, which suggests that Camden policy interventions included in the model impact the $PM_{2.5}$ size fraction of particulate matter without targeting the slightly larger PM with a diameter of greater than 2.5 micrometres.

These maps indicate that the reduction in vehicular movements and electrification of the Chiltern Main Line has an impact on reducing modelled 2030 PM_{10} and $PM_{2.5}$ concentrations in the centre and north of the borough, whilst the removal of domestic wood burning has a relatively significant impact in those areas which had the highest contribution from this source.

To provide a quantitative analysis of the impact of Camden policy interventions and to give an understanding of the relative contribution of Camden and out-of-London background emission sources, Camden extracted data from 166 unique points on the interactive map tool. These points were chosen to represent relevant exposure to air pollution across a range of land uses and building types and areas of differing public realm use within the borough.

This analysis indicated that under the 2030 Camden Scenario, the UK legal limit and WHO objective for NO_2 would be met throughout Camden. Similarly, the existing legal limits for PM were expected to be met throughout the borough. However the more stringent WHO objectives for PM_{10} and $PM_{2.5}$, which are much more reflective of the health impacts of exposure to particulate matter, are modelled to be exceeded throughout the borough by around 25% for PM_{10} and 39% for $PM_{2.5}$.

The annual mean concentration of NO_2 was expected to be reduced by an average of 1.6% across all 166 sample locations after the introduction of Camden policy interventions (compared to the 2030 BAU Scenario), whilst PM_{10} and $PM_{2.5}$ concentrations were expected to be reduced by 1% and 1.3%, respectively. The most significant changes in annual mean concentrations are more considerable than these average values due to the localised impact of the modelled policy interventions.

Seasonal variability in pollutant concentrations and the relative contribution of different emission sources is also not captured by the estimates of annual mean concentration. For example, the impact of domestic wood burning is much more serious for urban air quality during winter than during warmer months when heating demand is lower.

The modelling data also shows that the significant majority of PM_{10} and $PM_{2.5}$ in Camden in 2030 under both the 2030 BAU Scenario and the 2030 Camden Scenario is derived from the out-of-London rural background and regional background sources.

In the 2030 Camden Scenario an average of 30% of NOx, 70% of PM_{10} and 73% of $PM_{2.5}$ is predicted to be derived from sources outside of London, across all 166 sample locations.

The majority of this imported source is modelled to be due to the contribution of regional background emissions from outside of the UK (equivalent to 16.6 µg/m^3 of PM_{10} and 9.7 µg/m^3 of $PM_{2.5}$ in Camden), whilst a smaller portion comes from the rural background which includes other UK-based sources outside of London (0.8 µg/m^3 of PM_{10} and 0.5 µg/m^3 of $PM_{2.5}$).

6 CONCLUSION

The objective of air quality policy in Camden is to achieve the WHO guideline objectives for NO_2 and particulate matter by 2030, and to reduce the negative effects of those pollutants on health still found at very low concentrations. New modelling undertaken by King's helped Camden to better understand the anticipated future distribution of pollutants and the relative impact of different emission sources in the borough, and to assist in the development of specific policy interventions which will help Camden to achieve compliance with the WHO guideline objectives.

Comparison of a business-as-usual scenario and a scenario inclusive of Camden policy interventions showed that Camden's interventions would be effective in reducing the contribution from localised pollution sources. The air quality source apportionment showed that a significant proportion of Camden's air pollution is also coming from outside of Camden, which includes:

- London background concentrations from all local emission sources (such as road transport, commercial and domestic gas heating, domestic wood burning, commercial catering, railways, aviation, Part A and B industrial processes and construction – see LAEI 2013 Methodology[5] for a complete list) in each local authority within London
- The rural background concentration from outside of London accounts for 8.5 $\mu g/m^3$ of total NOx, 0.8 $\mu g/m^3$ of total PM_{10} and 0.5 $\mu g/m^3$ of total $PM_{2.5}$ concentrations in Camden
- The regional background concentration from outside of the UK accounts for 16.6 $\mu g/m^3$ of total PM_{10} and 9.7 $\mu g/m^3$ of total $PM_{2.5}$ concentrations in Camden

The modelling demonstrates that Camden cannot act alone in addressing air pollution within its boundaries, and should seek to work collaboratively with other authorities at the local, national and international scale to mitigate the impact of pollution sources outside of its direct influence.

In this study King's used the LAEI 2013 data which was the best emissions and air quality modelling data available at the time. Although not yet available, since this study has been completed, TfL and GLA have updated the London Atmospheric Emissions Inventory (LAEI) for the base year 2016, namely the LAEI v2016[6].

Associated with the LAEI update is a preliminary report on the year-on-year changes in $PM_{2.5}$ concentration from outside of London, which shows that this pollutant is highly sensitive to the prevailing meteorology and long-range transportation of pollution from distant emission sources during each year, and that as a consequence, modelled 2030 predictions are likely to be very dependent upon the base year chosen for the modelling. The preliminary report advises policy makers to remain vigilant to the current measured $PM_{2.5}$ concentrations and in the coming years to establish whether there is a clear pollutant trend. It also recommends projecting $PM_{2.5}$ in 2030 using alternative base years to establish a range of possible future scenarios.

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[5] https://data.london.gov.uk/dataset/london-atmospheric-emissions-inventory-2013
[6] https://data.london.gov.uk/dataset/london-atmospheric-emissions-inventory--laei--2016

The new evidence indicates that this study has used a highly conservative PM_{10} and $PM_{2.5}$ prediction for modelled 2030 air quality, and that reaching the WHO guidelines for PM by 2030 is now within a range of possible outcomes.

The overarching outcome of this study indicates that in recognition of the World Health Organization's advocacy that there is no safe limit for exposure to particulate matter, it is necessary for Camden to implement all possible measures to reduce emissions with the borough, whilst lobbying national Government and other stakeholders to implement ambitious policy to drive down the impact of pollution sources which are outside of the influence of Camden or any single local authority.