# OXFORD SOURCE APPORTIONMENT STUDY

Report for: Oxford City Council

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Oxford City Council

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# Abbreviations

| Abbreviation | Explanation |
|---|---|
| AADT | Annual Average Daily Traffic |
| AERMOD | American Meteorological Society/Environmental Protection Agency Regulatory MODel |
| AQAP | Air Quality Action Plan |
| AQMA | Air Quality Management Area |
| AQO | Air Quality Objective |
| AQS | Air Quality Strategy |
| ASR | Annual Status Report |
| AURN | Automatic Urban and Rural Network |
| BEIS | (UK Department for) Business, Energy & Industrial Strategy |
| CAZ | Clean Air Zone |
| COPERT | COmputer Programme to calculate Emissions from Road Transport |
| DT | Diffusion Tube |
| EEA | European Environment Agency |
| EFT | Emissions Factor Toolkit |
| EMEP | European Monitoring and Evaluation Programme |
| GIS | Geographic Information System |
| HCV | Hackney Carriage Vehicle (taxi) |
| HGV | Heavy Goods Vehicle |
| IAQM | Institute of Air Quality Management |
| LAQM | Local Air Quality Management |
| LES | Low Emission Strategy |
| LEZ | Low Emission Zone |
| LGV | Light Goods Vehicle |
| OCC | Oxford City Council |
| NAEI | National Atmospheric Emissions Inventory |
| $NO_2$ | Nitrogen dioxide |
| NOx | Nitrogen oxides (NO + $NO_2$) |
| NOAA | National Oceanic Atmospheric Administration |
| NTEM | National Trip End Model |
| NTS | National Travel Survey |
| PHI | Priority Habitat Inventory, a GIS dataset from Natural England |
| PHV | Private Hire Vehicle (taxi) |
| $PM_{2.5}$ | Particulate matter 2.5 micrometres or less in diameter |
| $PM_{10}$ | Particulate matter 10 micrometres or less in diameter |
| RMSE | Root Mean Square Error |
| SSF | Smokeless Solid Fuel |
| TEMPro | Trip End Model Presentation Program |
| ZEBRA | Zero Emission Bus Regional Areas scheme |
| ZEZ | Zero Emission Zone |

# 1. INTRODUCTION

The city of Oxford, as with many urban areas throughout the United Kingdom, is subject to poor air quality, particularly in areas with high levels of road traffic. In Oxford, nitrogen dioxide ($NO_2$) is still the pollutant of most concern, and the entire city has been a designated Air Quality Management Area (AQMA) for $NO_2$ since 2010.

The city's current Air Quality Action Plan (AQAP) sets out a list of actions that Oxford City Council (OCC) and its partners have committed to deliver during the period 2021-2025 in pursuit of an improvement of $NO_2$ levels in the city. OCC will soon be required to deliver a new Air Quality Action Plan (AQAP) in line with the Environment Act requirement that AQAPs are regularly reviewed and must be revised if a local authority considers there is a need for further or different measures to be taken in order to achieve air quality standards; or if significant changes to sources occur within the local area. In England, local authorities are expected to review AQAPs at least every five years. The AQAP measures are intended to be targeted towards the predominant sources of emissions within the area under OCC's jurisdiction. A source apportionment exercise is therefore required to identify the current percentage source contributions of emission sources in the city.

Air quality has improved in Oxford in recent years, with an 18% average reduction of annual mean $NO_2$ across the city between 2021 and 2023., In 2023, there were no exceedances of the legal limits within Oxford city's jurisdiction in all places considered of relevant exposure (i.e. all locations where members of the public are likely to be regularly present for a period of time appropriate to the averaging period of the annual mean limit value).

Although this is a very important milestone that has been achieved, OCC are committed to continue to reduce $NO_2$ to the lowest possible levels for the protection of human health. This commitment results from the 2021 World Health Organisation (WHO) guidelines[1,2] which incorporate clear evidence of damage to human health at much lower concentrations than previously understood. Therefore, the city's current AQAP seeks to go further than the prevailing UK legal annual mean limit value for $NO_2$ of 40 $\mu g/m^3$, by establishing a much more stringent local annual mean $NO_2$ target of 30 $\mu g/m^3$ to be achieved by 2025 in recognition that there is no safe level of air pollution.[3]

Some of the most relevant air quality measures delivered under the city's current AQAP (2021-2025) include:

- The UK's first Zero Emission Zone (ZEZ) was launched in Oxford in February 2022, building on the work of the Low Emission Zone (LEZ) which was introduced for buses in 2014. Public consultation on expansion of the ZEZ is due in 2025[4].
- 159 fully electric buses were introduced to the city from early 2024 to January 2025, from the Zero Bus Regional Areas (ZEBRA) scheme, which means that 69% of total bus mileage operating in the city are now operating in electric mode.
- Delivery of Energy SuperHub Oxford[5].
- Delivery of an Oxford City-wide Smoke Control Area[6].

This source apportionment study will focus on concentrations of $NO_2$, the main pollutant of concern, however particulate matter ($PM_{10}$ and $PM_{2.5}$) will also be included in the emissions modelling, air quality concentration modelling and a complementary PM source apportionment provided.

[1] World Health Organisation (2021) "WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide" Available online: https://www.who.int/publications/i/item/9789240034228

[2] World Health Organisation "What are the WHO air quality guidelines" Available online: https://www.who.int/news-room/feature-stories/detail/what-are-the-who-air-quality-guidelines

[3] Oxford City Council 2024 Air Quality Annual Status Report (ASR) Available online: https://mycouncil.oxford.gov.uk/documents/s80203/Annual%20Air%20Quality%20Status%20Report.pdf Page iii

[4] Oxfordshire County Council "Proposed wider zero emission zone" Available online: https://www.oxfordshire.gov.uk/residents/roads-and-transport/connecting-oxfordshire/city-centre-zez

[5] Energy Superhub Oxford, Available online: https://energysuperhuboxford.org/

[6] Oxford City Council "Smoke Control Areas" Available online: https://www.oxford.gov.uk/air-quality-management/domestic-smoke-control-areas

These dispersion model outputs will be used in conjunction with Defra air pollution background concentration maps to:

- Carry out source apportionment to understand the contribution of all sources of emissions to exceedances of the air quality objectives within Oxford's AQMA.
- Identify the reduction in pollutant emissions required to attain the OCC $NO_2$ annual mean target within the AQMA, to determine the scale of effort likely to be required.

# 2. METHOD STATEMENT

## 2.1 AIR DISPERSION MODELLING METHODOLOGY

The RapidAIR Urban Air Quality Modelling Platform[7] was used to model air pollutant concentrations for this study. This is Ricardo's proprietary modelling system developed for urban air pollution assessment. It was set up for the ongoing 'Oxford ZEZ air quality and carbon modelling and assessment' which Oxfordshire County Council are currently leading, based on the model that was used previously in the 2017 Oxford Zero Emission Zone Feasibility and Implementation Study.

RapidAIR has been developed to provide graphic and numerical outputs which are comparable with other models used widely in the United Kingdom. The model approach is based on three elements:

- Road traffic emissions model conducted using fleet specific COPERT v.5.6 (via the Defra EFT) algorithms to prepare grams/kilometre/second (g $km^{-1}$ $s^{-1}$) emission rates of air pollutants originating from traffic sources.
- Convolution of an emissions grid with dispersion kernels derived from the USEPA AERMOD[8] model, at resolutions ranging from 1 m to 20 m. AERMOD provides the algorithms which govern the dispersion of the emissions and is an accepted international model for road traffic studies.
- The kernel-based RapidAIR model running in GIS software to prepare dispersion fields of concentration for further analysis with a set of decision support tools coded by Ricardo in Python/arcpy.

RapidAIR includes an automated meteorological processor based on AERMET which obtains and processes meteorological data of a format suitable for use in AERMOD. Surface meteorological data is obtained from the NOAA online repository[9] and upper air data is downloaded from the NOAA Radiosonde database.[10]

The model produces high resolution concentration fields at the city scale (down to a 1 m scale) so is ideal for spatially detailed compliance modelling. The combination of an internationally recognised model code and careful parameterisation matching international best practice makes RapidAIR ideal for this study.

A baseline air quality model was developed covering the city of Oxford as a combination of the years 2022. The model was based on the latest available data; however, it was determined that $NO_2$ monitoring data for automatic and non-automatic monitoring sites from 2023 may be impacted by unusual traffic conditions (as a result of the Botley Road closure in the vicinity of Oxford Station). As such, 2022 was the most recent full year of monitoring data available that is not impacted by this closure. Therefore 2022 monitoring data is used, alongside 2023 traffic data. In this report, we will refer to the baseline year as 2022.

Emission and concentration outputs were generated for the city of Oxford using the following methodology and datasets for the given years (in bold):

- Traffic flows (AADT) were taken from the **2023** baseline local traffic model provided by Atkins. The 2023 baseline local traffic model assumes normal traffic conditions (i.e. Botley Road is open).
- Fleet composition was calculated based on ANPR data recorded at 13 sites in Oxford city centre on the 25th, 26th, 27th and 28th April **2023**. Data were provided for the two directions of traffic flow at each site (defined as either east and west or north and south). The data were processed to inform the average number of unique daily vehicles visiting the city centre for each of the ZEZ charging bands and to provide a fuel type and Euro standard split for each vehicle type (cars, light goods vehicles

[7] Ricardo RAPID AIR. Available online: https://www.rapidair.co.uk/

[8] US EPA "Air Quality Dispersion Modeling - Preferred and Recommended Models". Available online: https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models

[9] National Oceanic and atmospheric Administration (NOAA) Institutional Repository Available online: https://repository.library.noaa.gov/

[10] National Oceanic and atmospheric Administration (NOAA) Radiosonde database. Available online: https://www.esrl.noaa.gov/roabs/

(LGVs), heavy good vehicles (HGVs), buses, private hire taxis, Oxford Hackney taxis, and 'other' Hackney taxis).

- Road traffic emissions were generated by applying COPERT v5.6 emissions factors (most up to date at time of assessment).
- Administrative boundary wide concentration contour maps were generated using Ricardo's RapidAIR modelling system and application of **2022** meteorological data.
- The 2018 Defra air pollution background concentration maps (most up to date at time of assessment) were used to calculate the background concentration contribution for **2022**.
- The model was validated using **2022** air quality monitoring data.

## 2.2 MODEL VALIDATION

The model validation process was conducted in line with Defra's Local Air Quality Management Technical Guidance (TG22)[11].

Diffusion tube $NO_2$ measurements for 2022 within the City of Oxford AQMA (118 in total) were used for model verification after applying annualisation and national bias adjustment factors[12]. As previously discussed in Section 2.1, 2023 monitoring data was not used for model validation as Botley Road was closed in 2023, such that traffic was not operating under "business as usual" conditions, which will have impacted the $NO_2$ concentrations measured in 2023.

The modelled 2022 vs measured 2022 concentrations at each of the monitoring locations were compared. A linear adjustment factor of **2.3366** was calculated for the road emissions component of the $NO_X$ model (see Appendix 1).

Total $NO_X$ was calculated as the sum of the adjusted $NO_X$ road contribution from RapidAIR and the Defra 2018 background maps projected for 2022 (with main road sources removed from the background map). Total $NO_2$ concentrations were derived using the following equation (see Appendix 1 for further details):

$$(NO_2 \text{ in } \mu g/m^3) = -0.0011(NO_X \text{ in } \mu g/m^3)^2 + 0.5824(NO_X \text{ in } \mu g/m^3) + 3.0955$$

To evaluate model performance and uncertainty, the Root Mean Square Error (RMSE) for the observed vs predicted $NO_2$ annual mean concentrations was calculated. This guidance indicates that an RMSE of up to 4 $\mu g/m^3$ for $NO_2$ is ideal, and an RMSE of up to 10 $\mu g/m^3$ is acceptable. In this case the RMSE was calculated at **4.049 $\mu g/m^3$**, which is acceptable.

There are only two monitoring locations for $PM_{10}$ and $PM_{2.5}$ within the City of Oxford AQMA. Therefore, it was not suitable to compare measured vs modelled concentrations for $PM_{10}$ or $PM_{2.5}$ to generate bespoke adjustment factors for these pollutants. We have adopted an approach in line with Section 7.570 of the Technical Guidance LAQM.TG(22) which suggests that, in the absence of measured data for model verification of a traffic pollutant (in this case, $PM_{10}$ and $PM_{2.5}$), it may be appropriate to apply the adjustment factor derived from another traffic pollutant to the pollutant that does not have any monitoring data available. RapidAIR was used to model $PM_{10}$ and $PM_{2.5}$ annual mean concentrations arising from road traffic sources across the study area, and these values were subsequently multiplied by the linear adjustment factor (see above) to obtain adjusted $PM_{10}$ and $PM_{2.5}$ road contribution values.

[11] DEFRA Local Air Quality Management Technical Guidance (TG22). Available online: https://laqm.defra.gov.uk/wp-content/uploads/2022/08/LAQM-TG22-August-22-v1.0.pdf

[12] The details on methodology and data for $NO_2$ diffusion tube measurements are available in the Oxford Air Quality Annual Status Report 2023: https://www.oxford.gov.uk/downloads/download/601/download-the-air-quality-annual-status-report-2023

## 2.3 ZEBRA MODEL

As discussed in Section 1, in January 2025, 159 electric buses were introduced to the city of Oxford from the ZEBRA scheme. At the time of this assessment, the scheme was yet to be implemented, so, to ensure that the results of this source apportionment study would be applicable in guiding the upcoming AQAP and future decisions around air quality management in Oxford, it was important that the source apportionment results represent the Oxford traffic fleet including the ZEBRA electric buses.

The baseline model was therefore adapted, to include 159 electric buses, representative of 69% of the total bus mileage operating in the city.

The proportion of buses that would be electric in the ZEBRA model fleet was set at 69%, as outlined in Table 2-1. It was assumed that the remaining buses in the fleet would be proportional to the 2022 baseline model proportions of Euro VI or newer, and older buses are below the Euro VI emissions standard. This represents a worst-case scenario for the remaining non-electric bus emissions.

Outside of this change to the proportion of buses by fuel type, the ZEBRA model used the same data inputs as the 2022 baseline model, including the AADT from the traffic model, and the fuel type and Euro standard proportions applied to the non-electric fleet. These proportions were applied uniformly across road links which had bus AADT in the baseline model.

Table 2-1 Assumed proportions of the Oxford bus fleet, under the baseline model and ZEBRA model.

| Category Description | 2022 Baseline model Percentages | 2022 ZEBRA Model Percentages |
|---|---|---|
| Zero tailpipe emissions buses | 0% | 69% |
| Euro VI or newer buses | 70% | 22% |
| Older buses | 30% | 9% |

The model road component for $NO_x$, $PM_{10}$ and $PM_{2.5}$ emissions were adjusted using the same linear adjustment factor of **2.3366** that was calculated for the baseline $NO_X$ model (see Section 2.2 and Appendix 1).

# 3. LOCATIONS FOR SOURCE APPORTIONMENT

Conducting a source apportionment assessment of road emission sources enables a better understanding of the nature of vehicles contributing to exceedances along roads in Oxford. A review was undertaken as part of the 2020 Source Apportionment Study (henceforth referred to as 'the 2020 Study') to determine the most appropriate locations for source apportionment to be conducted. This was based on the maximum $NO_2$ concentration predicted within the city of Oxford AQMA, using a national fleet, as well as the measured annual mean $NO_2$ at diffusion tube locations in 2019.

Hot spots are areas of high pollutant concentrations where relevant human exposure is present and are therefore the focus of the source apportionment study. Hot spots were identified in Oxford using the following methodology:

- Monitoring locations which showed a high concentration of $NO_2$ relative to the national Air Quality Objectives (AQOs).
- Extraction of high modelled $NO_2$ concentrations at locations of relevant exposure.
- Discussion and review of findings with OCC and confirmation of the three locations for source apportionment.

The same locations selected in the 2020 Study have been selected again for this source apportionment study, for the following reasons:

1. These continue to be hotspot areas, and therefore up to date knowledge of sources is needed to aid action planning for remaining areas of elevated concentrations.

2. To assess how impacts from different sources have changed over time at these locations.

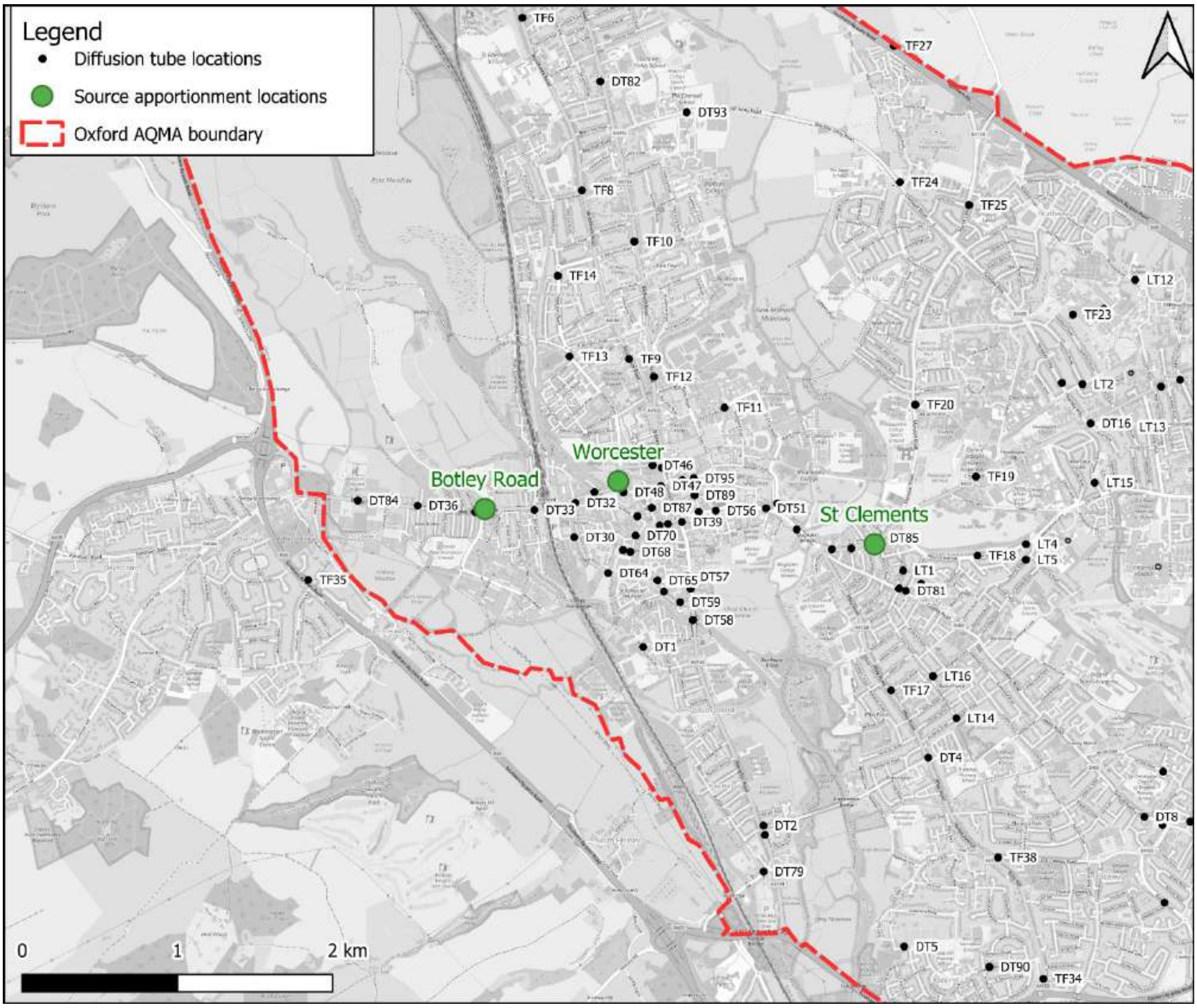
Table 3-1 shows the receptors selected for source apportionment within each designated hot spot location. Diffusion Tubes DT55, DT45 and DT35 are consistent with the locations selected for source apportionment in the 2020 Study. One additional receptor was selected for St Clements/ The Plain hotspot area (TF19), which is a monitoring location that is not representative of relevant exposure. TF19 was introduced in 2022 to evaluate the impact of future transport schemes in Oxford. TF19 is located directly on the road, which is enclosed within vegetation barriers either side of the road. This results in a canyon-effect, resulting high $NO_2$ concentrations measured to be 70 µg/m$^3$ in 2022 and 53 µg/m$^3$ in 2023. Section 3.1 further elaborates on the reasoning behind including TF19 in this study.

Table 3-1 Receptors selected for source apportionment for each hotspot area.

| Hotspot area | Selected receptors |
|---|---|
| St Clements/ The Plain | DT55, TF19 |
| Worcester Street | DT45 |
| Botley Road | DT35 |

The three locations chosen for source apportionment are shown in Figure 3-1. Detailed summaries of the chosen hotspot locations are presented in Sections 3.1 to 3.3, including figures of the modelled concentrations of $NO_2$ in 2022 and diffusion tube locations labelled with the corresponding measured annual mean $NO_2$ concentration in 2022.

Figure 3-1 Diffusion tubes within the centre of Oxford City AQMA and locations selected for source apportionment.




## 3.1 ST CLEMENTS/ THE PLAIN

Figure 3-2 shows that in the vicinity of St Clements/The Plain there are high modelled and monitored concentrations present in 2022. Diffusion tube DT55 measures the highest $NO_2$ concentrations in the vicinity of the roundabout, with 43 µg/m$^3$ in 2022. This diffusion tube is in a street canyon and adjacent to a busy roundabout.

Figure 3-2 Baseline model results and measured $NO_2$ in 2022 at St Clements/ The Plain.


The St Clements/ The Plain area also includes the diffusion tube at Headington Hill (TF19) in this source apportionment study (also shown in Figure 3-2). As referenced above, TF19 is a site of interest due to high measured $NO_2$ concentrations (70 µg/m$^3$ in 2022), which has been underpredicted by the 2022 baseline model. It is important to note that TF19 is not a location which is representative of human exposure. It was added to the monitoring network in 2022 with several other sites to assess potential AQ impacts from traffic displacement that results from future transport schemes. TF19 measured the highest $NO_2$ concentrations in the AQMA in 2022.

It is important to highlight that the modelling results do not indicate elevated concentrations or an exceedance of the $NO_2$ annual mean AQO at location TF19. The modelled 2022 concentrations are just above 20 µg/m$^3$. This location was removed from the baseline model validation as a result of being an extreme outlier. It was the only outlier removed. Whilst this site does not need to be investigated in terms of being a concern for human exposure to $NO_2$, it is useful to understand the sources which might be contributing to higher emissions at this location, and furthermore, to understand why the model might be underpredicting at this location.

Factors which might by contributing to the underpredicting of the model at TF19 include:

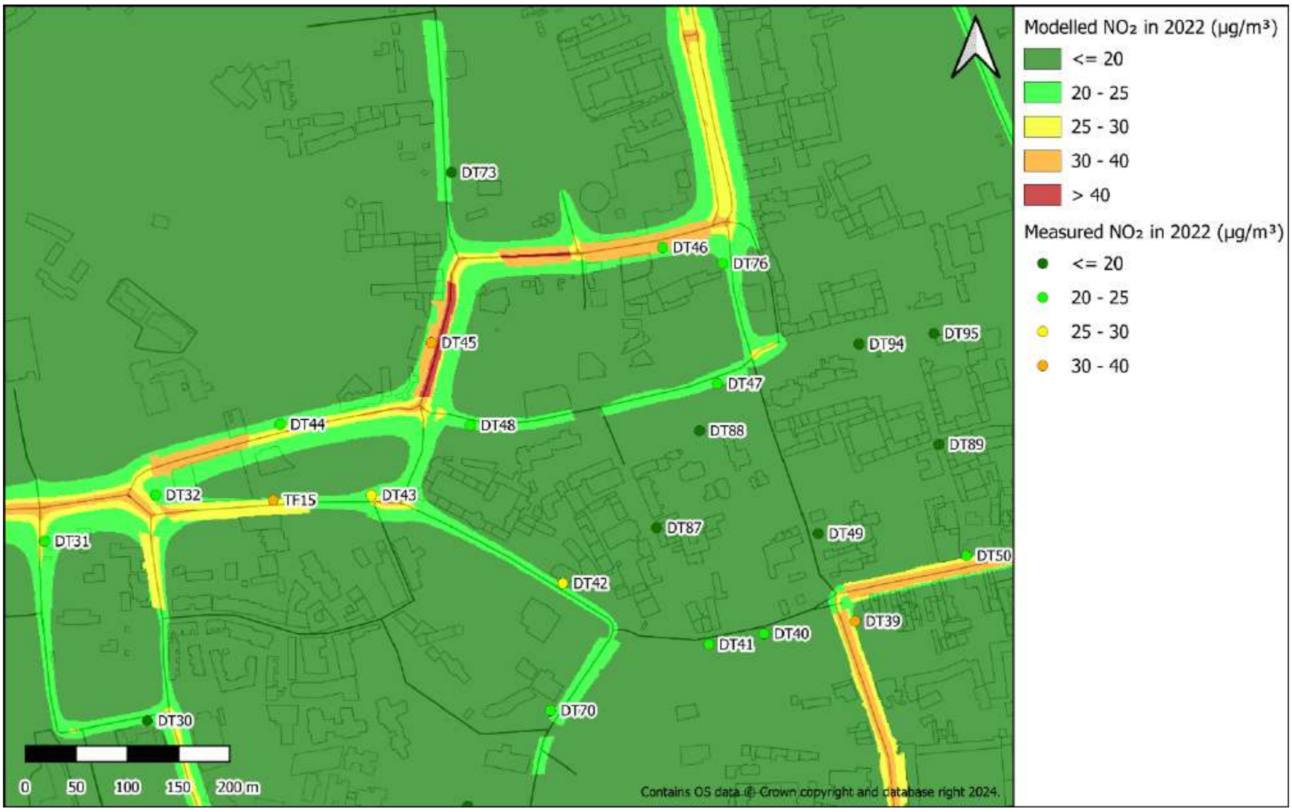
- Canyon effect - TF19 is located on a road with walls at the height of the diffusion tube to the immediate side of the road (on both sides), above which steep slightly vegetated banks lead to a vegetation barrier of trees at height, in parallel to the road on both sides. The air quality dispersion model incorporates the effects of canyons from buildings, but not from vegetation.
- Data capture was at 67% for 2022 and 75% for 2023 and was adjusted for 2022 using annualisation calculations in line with the LAQM TG22 guidance (as required for diffusion tubes with >75% and >25% data capture). This means that the average annual concentration for TF19 is less accurate than an average taken across a full 12 months.

## 3.2 GEORGE STREET / PARK END STREET / WORCESTER STREET

This system of roads showed exceedances of the $NO_2$ annual mean AQO on Worcester Street in the 2022 baseline modelling, and to a lesser extent on Beaumont Street. These exceedances are in the centre of the road, so are less relevant for human exposure. However, diffusion tubes DT45 on Worcester Street and TF15 on Park End Street exceeded the OCC $NO_2$ annual mean objective of 30 µg/m$^3$ in 2022 (31 µg/m$^3$ and 36 µg/m$^3$ respectively).

Diffusion tubes DT32, DT42, DT43, DT44 and DT48 appear to be in locations with good dispersion (i.e. not in street canyons). DT46 is in an area with some limited dispersion, but not a street canyon. TF15 is located at a bus stop in a street canyon and is likely to be the worst location for dispersion in this area, but is not representative of human exposure. DT45 is the location that was chosen for source apportionment in the 2020 study. DT45 is adjacent to the location of highest modelled concentrations in this area (modelled $NO_2$ at DT45 is 35 µg/m$^3$). DT45 is in a street canyon, and is representative of human exposure. It was considered to still be the most suitable diffusion tube receptor location for source apportionment of Worcester Street for this source apportionment study.

Figure 3-3 Baseline model results and measured $NO_2$ in 2022 at Worcester Steet.




## 3.3 BOTLEY ROAD

Botley Road is one of the major routes into the city with significant levels of traffic and high levels of human exposure at nearby houses. To the west, is the Botley Interchange roundabout on the A34, where modelled $NO_2$ concentrations are increased to above the AQO of 40 µg/m$^3$. There is no human exposure in this area of modelled exceedance beyond houses in the vicinity of DT84.

In April 2023, Botley Road was closed at the railway bridge (between Bridge Street and the Beckett Street/Park End Street roundabout), as part of a scheme to improve Oxford railway station and remains closed at the time of conducting this study. This closure will have impacts on the numbers and types of vehicles using the section of Botley Road which remains open. It will also have impacts to other roads in terms of displaced traffic.

DT35 was chosen as the diffusion tube most representative of this route in the 2020 Study and is still considered to be the most representative location for this route in this source apportionment study.

Figure 3-4 Baseline model results and measured $NO_2$ in 2022 at Botley Road.


## 3.4 ADDITIONAL AREAS NOT TAKEN FORWARD FOR SOURCE APPORTIONMENT

### 3.4.1 Areas of elevated concentrations which are not representative of human exposure

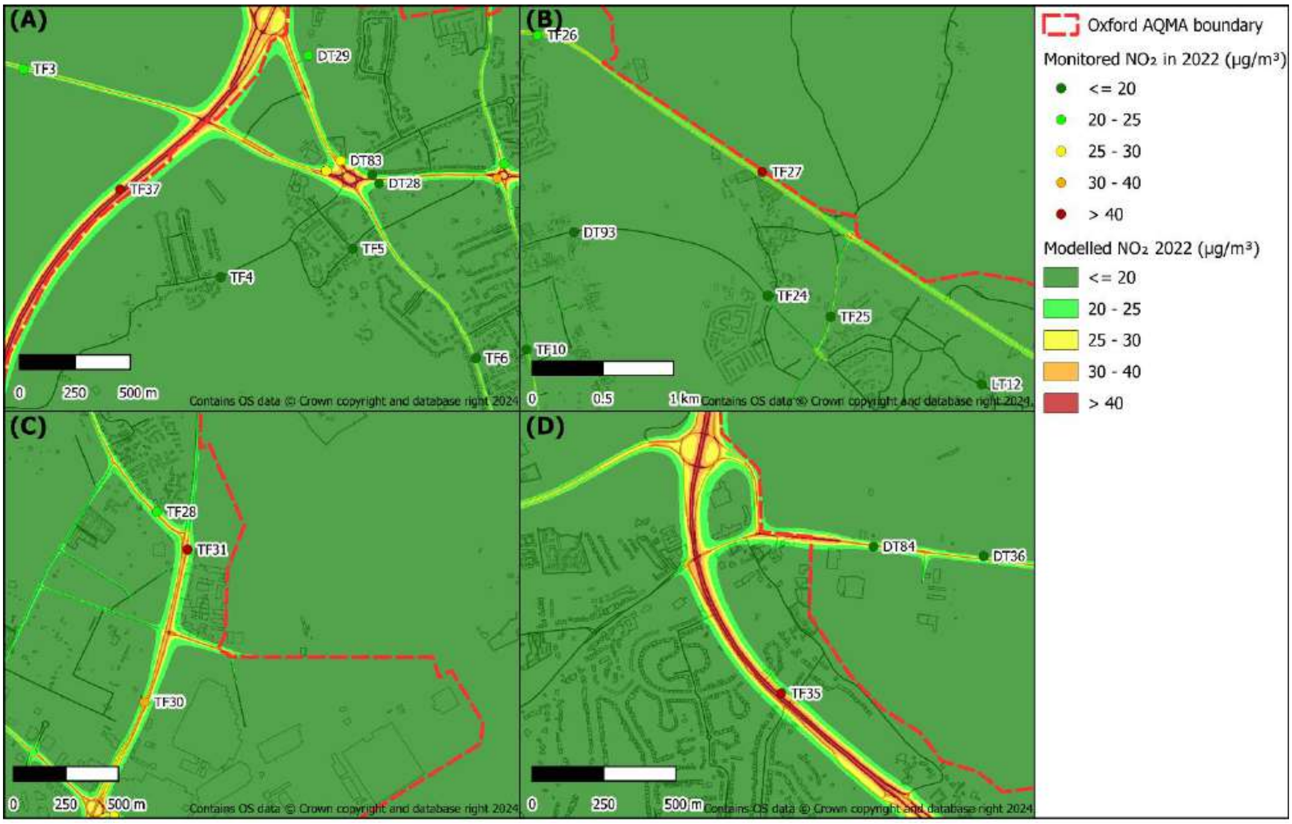
There are a number of sites in exceedance of the AQO which come under the following group of sites, as set out in Oxford's 2024 Annual Status Report: "These sites have not been put in place to directly assess the level of human exposure to air pollution, but instead to measure the potential impact of future transport schemes on traffic displacement. They are located in isolated areas, (mostly around Oxford's ring road), at a considerable distance from residential zones, and hence they are not relevant for the direct purposes of the LAQM regime."[13]

- TF37 – monitored exceedance in 2022 (42 $\mu g/m^3$). Located outside of the AQMA and OCC's administrative boundary, directly adjacent to the A34.
- TF27 – monitored exceedance in 2022 (42 $\mu g/m^3$). Located directly adjacent to the A40.
- TF31 – monitored exceedance in 2022 (43 $\mu g/m^3$). Located directly adjacent to the A4142 Eastern By-pass Road
- TF35 – monitored exceedance in 2022 (57 $\mu g/m^3$). Located outside of the AQMA and OCC's administrative boundary, directly adjacent to the A34.[14]

[13] Oxford City Council 2024 Air Quality Annual Status Report (ASR) Available online: https://mycouncil.oxford.gov.uk/documents/s80203/Annual%20Air%20Quality%20Status%20Report.pdf Page 36

[14] This location falls outside the City Council's jurisdiction, and forms part of an existing AQMA that is being managed by Vale of the White Horse District Council.

Figure 3-5 Baseline model results and measured $NO_2$ in 2022 at other areas of elevated concentrations (A) TF37, (B) TF27, (C) TF31 and (D) TF35




### 3.4.2 Other areas

**High Street.** On the High Street there are modelled exceedances of the AQO for $NO_2$, though these are in the centre of the roads. There are both modelled and monitored exceedances of OCC's local annual mean $NO_2$ target of 30 µg/m$^3$ (monitoring points DT56, DT51 and DT52).

Figure 3-6 Baseline model results and measured $NO_2$ in 2022 on the High Street


**Cuttleslowe Roundabout.** There are modelled exceedances of the AQO for $NO_2$ in this area, though these are in the centre of the roads and roundabouts, and do not extend to locations of human exposure. Monitoring location DT26 is in exceedance of OCC's local annual mean $NO_2$ target of 30 µg/m$^3$ in 2022.

Figure 3-7 Baseline model results and measured $NO_2$ in 2022 at Cutteslowe Roundabout

# 4. SOURCE APPORTIONMENT OF MODELLED ROAD TRANSPORT EMISSIONS

This section presents results of source apportionment of road transport at the three hotspot locations: St Clements/ The Plain, Worcester Street, and Botley Road, based on air dispersion modelling. Source apportionment of non-road transport (background) concentrations at these hotspot locations is provided in Appendix 3.

These modelled results represent the baseline year 2022, but with electric “ZEBRA” buses included in the fleet. As previously discussed, by January 2025, 159 fully electric buses had been introduced to the city from the Zero Bus Regional Areas (ZEBRA) Scheme, accounting for 69% of total bus mileage operating in the city. These model results therefore assumes that 69% of all buses in the modelling domain are electric buses. All other model inputs remain the same as in the 2022 baseline model.

The **key trends observed** at all three chosen air quality hot spot locations are:

- Cars have the greatest contributions to $NO_X$, $PM_{10}$ and $PM_{2.5}$ emissions.
  - Diesel cars contributed a higher proportion of $NO_X$ emissions than petrol cars.
  - $PM_{10}$ and $PM_{2.5}$ emissions have fairly equal contributions from petrol and diesel cars, with slightly higher contributions from petrol.
- LGVs and HGVs are the next greatest contributors, depending on location.
- Buses are the 4$^{th}$ contributor, depending on location
- Rigid HGVs contributed significantly more $NO_X$, $PM_{10}$ and $PM_{2.5}$ emissions than articulated HGVs.
- Private hire vehicle (PHV) taxis contributed more to emissions from taxis than Oxford or other Hackney Carriage vehicles (HCVs).
- Diesel taxis (both PHVs and HCVs) contributed to more emissions than petrol taxis.
- For $PM_{10}$ and $PM_{2.5}$ the background concentrations are considerably more than the road contribution. This is not the case for $NO_X$.

Table 4-1, Table 4-4 and Table 4-7 show the source apportionment in terms of percentage contribution of the major vehicle types to the total vehicular NOx, $PM_{10}$ and $PM_{2.5}$ emissions. The percentage emissions again are presented in pie charts (Figure 4-1, Figure 4-2, Figure 4-4 and Figure 4-6).

Table 4-2, Table 4-5 and Table 4-8 show the source apportionment in terms of the amount of NOx, $PM_{10}$ and $PM_{2.5}$ originating from each of these sources (in µg $m^{-3}$).

Table 4-3, Table 4-6 and Table 4-9 show the source apportionment of modelled $NO_2$ concentrations at each of the source apportionment locations.

Figure 4-3, Figure 4-5 and Figure 4-7 show the total modelled $NO_2$ concentrations at each of the source apportionment locations. They compare the modelled results for the baseline fleet for 2022 with the results for the model run of the ZEBRA scenario for 2022. This demonstrates the extent of the estimated reduction in $NO_2$ as a result of the introduction of the electric buses at the source apportionment locations. In all locations, there are improvements in modelled $NO_2$ concentrations as a result of introducing the ZEBRA buses.

Appendix 2 breaks down taxi emissions by fuel type, and at all three locations, diesel PHVs and Diesel Oxford Hackney Carriages dominate NOx taxi emissions with fairly equal contributions, and diesel PHVs dominate for $PM_{10}$ and $PM_{2.5}$.

## 4.1 ST CLEMENT'S / THE PLAIN

Diffusion tube TF19 (Headington Hill) is included in Table 4-1 (percentage breakdown of road transport emissions), but not in Table 4-2 and Table 4-3. This is because TF19 was an outlier in the 2022/23 Baseline Model (as discussed in section 3.1), and therefore the concentration contributions from modelled road and background contributions will not be accurate at this location.

Along **St Clement's Street / The Plain diffusion tube DT55**, in the ZEBRA Scenario for 2022, source apportionment shows that cars account for approximately 60% of $NO_x$ road emissions (51% of which are attributed to diesel cars), and approximately 74% of $PM_{10}$ and $PM_{2.5}$ road emissions (37 – 39% from petrol cars, 31 – 33% from diesel). These are slightly higher than the results for Worcester Street and Botley Road for the ZEBRA scenario, which is to be expected, as a reduced contribution from buses to emissions will result in an increased contribution from other vehicle types. LGVs are now the next-largest contributor (where previously in the baseline scenario it was buses) at 17% for $NO_X$ road emissions, and 11% for $PM_{10}$ and $PM_{2.5}$ road emissions. This is followed by rigid HGVs being the next greatest source for $NO_X$ road emissions (11%) and buses being the next greatest source for $PM_{10}$ and $PM_{2.5}$ road emissions (6%).

Buses now account for 10% of $NO_X$ road emissions and 6% of road emissions for $PM_{10}$ and $PM_{2.5}$. The taxi fleet in total accounts for 2.5% of $NO_X$ road emissions, and 4.5% of road emissions for both $PM_{10}$ and $PM_{2.5}$. PHVs are contributing the greatest proportion of emissions of the three taxi categories, with 1% of NOx road emissions and 3% for both $PM_{10}$ and $PM_{2.5}$ road emissions. This is consistent for all three locations. These can be further broken down by fuel types, which is provided in Appendix 2.

At **diffusion tube TF19**, $NO_X$ road emissions are more dominated by cars in the ZEBRA scenario than the baseline scenario. Cars are the greatest contributing vehicle type for $NO_X$ and PM road emissions, accounting for nearly half (39% from diesel and 7% from petrol) of $NO_X$ road emissions at TF19, and 62 – 63% of $PM_{10}$ and $PM_{2.5}$ road emissions (31 – 33% from petrol cars, 26 – 28% from diesel) in the ZEBRA scenario. LGVs are the next greatest contributing vehicle type to road emissions, accounting for 22% of $NO_x$ road emissions and 16% of $PM_{10}$ and $PM_{2.5}$ road emissions, followed by HGVs, contributing 17% of $NO_X$ road emissions and 8 – 9% of $PM_{10}$ and $PM_{2.5}$ road emissions.

Buses now account for 13% of $NO_X$ road emissions and 9% of road emissions for $PM_{10}$ and $PM_{2.5}$. The taxi fleet in total accounts for 1.9% of $NO_X$ road emissions, and 3.6% of road emissions for both $PM_{10}$ and $PM_{2.5}$

Table 4-1 Source apportionment for all road transport emissions at DT55 and TF19 on St Clement's / The Plain (%) for the 2022 ZEBRA model fleet.

| | Cars | | | | | Bus | HGV (Rigid) | HGV (Artic) | LGV | Taxi | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cars (petrol) | Cars (diesel) | Car (petrol hybrid) | Car (diesel hybrid) | Car (electric) | | | | | Taxi (Oxford HCV) | Taxi (Other HCV) | Taxi (PHV) | |
| *DT55 – St Clements/ The Plain Roundabout* | | | | | | | | | | | | | |
| **$NO_X$** | 9.0% | 50.5% | 0.1% | 0.1% | 0.0% | 9.7% | 11.3% | 0.1% | 16.8% | 1.1% | 0.2% | 1.2% | 100% |
| **$PM_{10}$** | 39.4% | 31.2% | 1.6% | 0.0% | 2.2% | 5.9% | 4.2% | 0.1% | 11.1% | 0.9% | 0.2% | 3.2% | 100% |
| **$PM_{2.5}$** | 36.9% | 32.9% | 1.5% | 0.0% | 2.3% | 6.1% | 4.5% | 0.1% | 11.3% | 1.0% | 0.2% | 3.0% | 100% |
| *TF19 – Headington Hill* | | | | | | | | | | | | | |
| **$NO_X$** | 6.9% | 38.8% | 0.1% | 0.1% | 0.0% | 12.8% | 17.4% | 0.1% | 22.0% | 0.8% | 0.1% | 0.9% | 100.0% |
| **$PM_{10}$** | 33.5% | 26.4% | 1.3% | 0.0% | 1.9% | 8.8% | 8.1% | 0.3% | 16.1% | 0.7% | 0.1% | 2.7% | 100.0% |
| **$PM_{2.5}$** | 31.2% | 27.7% | 1.3% | 0.0% | 2.0% | 9.1% | 8.6% | 0.3% | 16.3% | 0.9% | 0.2% | 2.6% | 100.0% |

Table 4-2 Source apportionment for all road transport modelled concentrations at DT55 on St Clement's / The Plain (µg/m$^3$) for the 2022 ZEBRA model fleet (measured $NO_X$ concentrations derived from the $NO_X$ to $NO_2$ calculator).

| | Background | Cars | | | | | Bus | HGV (Rigid) | HGV (Artic) | LGV | Taxi | | | Total modelled (µg/m$^3$) | Total measured $NO_X$ (µg/m$^3$)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cars (petrol) | Cars (diesel) | Car (petrol hybrid) | Car (diesel hybrid) | Car (electric) | | | | | Taxi (Oxford HCV) | Taxi (Other HCV) | Taxi (PHV) | | |
| *DT55 – St Clements/ The Plain Roundabout* | | | | | | | | | | | | | | | |
| **$NO_X$** | 15.5 | 4.8 | 26.9 | 0.1 | 0.0 | 0.0 | 5.2 | 6.0 | 0.0 | 8.9 | 0.6 | 0.1 | 0.6 | 68.6 | 80.8 |
| **$PM_{10}$** | 14.7 | 2.4 | 1.9 | 0.1 | 0.0 | 0.1 | 0.4 | 0.3 | 0.0 | 0.7 | 0.1 | 0.0 | 0.2 | 20.9 | |
| **$PM_{2.5}$** | 10.2 | 1.2 | 1.1 | 0.1 | 0.0 | 0.1 | 0.2 | 0.2 | 0.0 | 0.4 | 0.0 | 0.0 | 0.1 | 13.5 | |

Table 4-3 Source apportionment for all road transport measured concentrations at DT55 on St Clement's / The Plain (µg/m³) for the 2022 ZEBRA model fleet ($NO_2$ concentration measured at DT55 in 2022).

| | Background | Cars | | | | | Bus | HGV (Rigid) | HGV (Artic) | LGV | Taxi | | | Total Modlelled $NO_2$ (µg/m³) | Total Measured $NO_2$ (µg/m³) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cars (petrol) | Cars (diesel) | Car (petrol hybrid) | Car (diesel hybrid) | Car (electric) | | | | | Taxi (Oxford HCV) | Taxi (Other HCV) | Taxi (PHV) | | |
| **$NO_2$** | 16.6 | 2.4 | 13.3 | 0.0 | 0.0 | 0.0 | 2.6 | 3.0 | 0.0 | 4.4 | 0.3 | 0.0 | 0.3 | 37.9 | 43.1 |

*Background $NO_2$ was estimated by applying the same percentage of NOx that is background in the modelled results, to the total measured $NO_2$.

Figure 4-1 Pie chart representation of source apportionment for all road transport emissions on St Clement's / The Plain – DT55 (%) for the 2022 ZEBRA model.

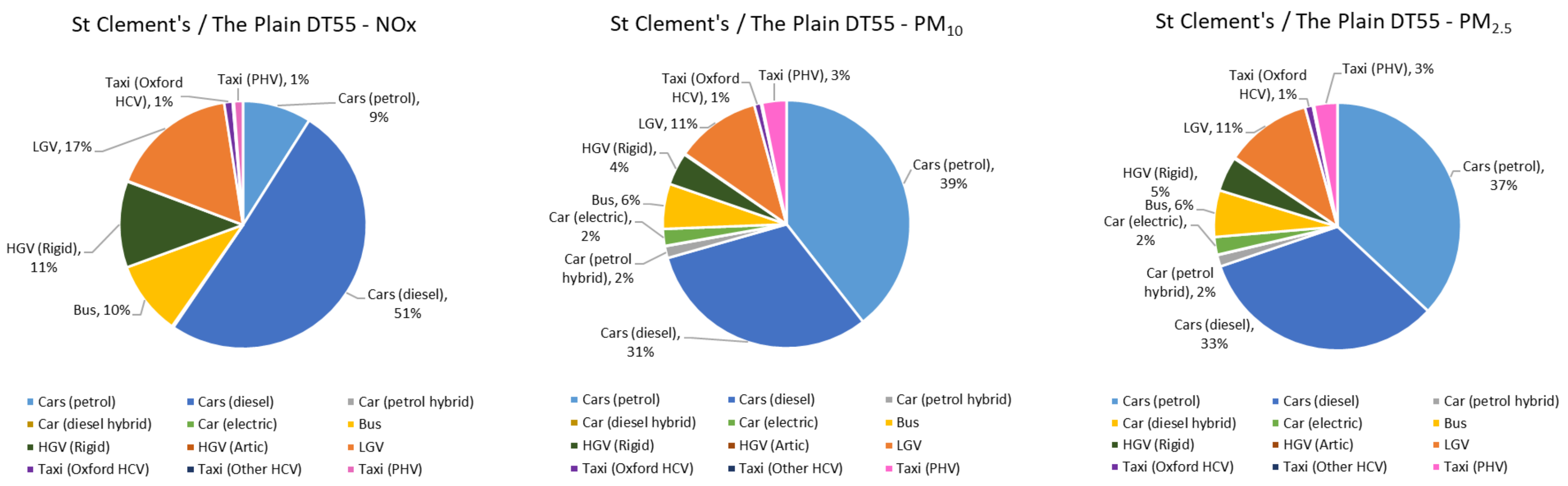


Figure 4-2 Pie chart representation of source apportionment for all road transport emissions on St Clement's / The Plain – TF19 (%) for the 2022 ZEBRA model.

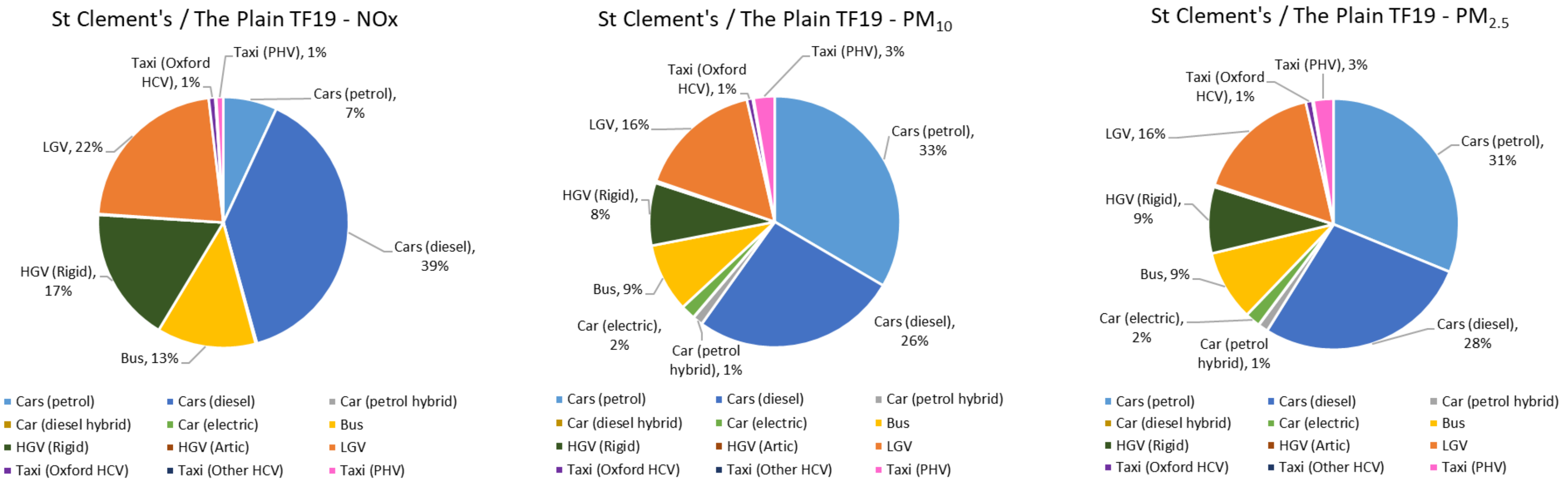


Figure 4-3 Modelled total $NO_2$ concentrations (2022) at St Clement's / The Plain using (A) a baseline fleet and (B) the ZEBRA fleet in which 69% of buses are zero emission.

## 4.2 WORCESTER STREET

On **Worcester Street**, at diffusion tube DT45, in the ZEBRA Scenario for 2022/2023, cars again dominate the road emissions, accounting for 50% of the $NO_X$, 68% of the $PM_{10}$, and 67% of $PM_{2.5}$ road emissions, which is similar to the baseline results. This due to the small contribution of buses to emissions at Worcester Street in the baseline scenario. In the ZEBRA scenario, diesel cars account for 42% of the total 50% of $NO_X$ road emissions from cars, and for $PM_{10}$ and $PM_{2.5}$, 33 - 36% of road emissions were from petrol cars and 28 – 30% were from diesel cars. The next greatest contributing vehicle type to road emissions on Worcester Street is LGVs comprising 29% of $NO_X$ road emissions, and 21% of $PM_{10}$ and $PM_{2.5}$ emissions, followed by HGVs, comprising 18% of $NO_X$ road emissions, and 7% and 8% of $PM_{10}$ and $PM_{2.5}$ road emissions respectively.

Buses account for 1% of $NO_X$ road emissions and 0.6% of $PM_{10}$ and $PM_{2.5}$ road emissions on Worcester Street, which is the lowest proportion of bus emissions across all three locations. Again, this is consistent with baseline results. The taxi fleet accounts for 2% of $NO_X$ road emissions and 4% of $PM_{10}$ and $PM_{2.5}$ road emissions. PHVs are contributing the greatest proportion of emissions of the three taxi categories, with 1% of $NO_x$ road emissions and 3% for both $PM_{10}$ and $PM_{2.5}$ road emissions, and this is the same for all three locations. These can be further broken down by fuel types, which is provided in Appendix 2.

Table 4-4 Source apportionment for all road transport emissions on Worcester Street (%) for the 2022 ZEBRA model fleet.

| Worcester Street | Cars | | | | | Bus | HGV (Rigid) | HGV (Artic) | LGV | Taxi | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cars (petrol) | Cars (diesel) | Car (petrol hybrid) | Car (diesel hybrid) | Car (electric) | | | | | Taxi (Oxford HCV) | Taxi (Other HCV) | Taxi (PHV) | |
| **$NO_x$** | 7.4% | 42.4% | 0.1% | 0.1% | 0.0% | 1.1% | 18.1% | 0.1% | 28.7% | 0.9% | 0.1% | 1.0% | 100% |
| **$PM_{10}$** | 35.8% | 28.3% | 1.4% | 0.0% | 2.0% | 0.6% | 7.2% | 0.2% | 20.5% | 0.8% | 0.1% | 2.9% | 100% |
| **$PM_{2.5}$** | 33.4% | 29.8% | 1.4% | 0.0% | 2.1% | 0.6% | 7.7% | 0.2% | 20.9% | 0.9% | 0.2% | 2.7% | 100% |

Table 4-5 Source apportionment for all road transport modelled concentrations on Worcester Street (µg/m$^3$) for the 2022 ZEBRA model fleet (measured $NO_x$ concentrations derived from the $NO_x$ to $NO_2$ calculator).

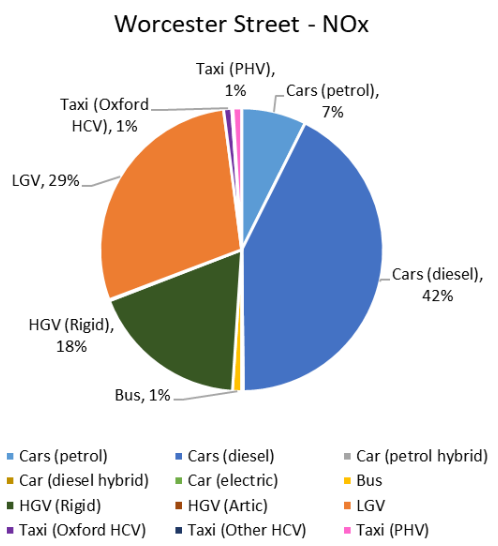
| Worcester Street | Background | Cars | | | | | Bus | HGV (Rigid) | HGV (Artic) | LGV | Taxi | | | Total modelled (µg/m$^3$) | Total measured $NO_x$ (µg/m$^3$)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cars (petrol) | Cars (diesel) | Car (petrol hybrid) | Car (diesel hybrid) | Car (electric) | | | | | Taxi (Oxford HCV) | Taxi (Other HCV) | Taxi (PHV) | | |
| **$NO_x$** | 19.0 | 3.3 | 18.7 | 0.0 | 0.0 | 0.0 | 0.5 | 8.0 | 0.1 | 12.6 | 0.4 | 0.1 | 0.4 | 62.9 | 52.5 |
| **$PM_{10}$** | 14.3 | 1.6 | 1.3 | 0.1 | 0.0 | 0.1 | 0.0 | 0.3 | 0.0 | 0.9 | 0.0 | 0.0 | 0.1 | 18.9 | |
| **$PM_{2.5}$** | 9.6 | 0.8 | 0.7 | 0.0 | 0.0 | 0.1 | 0.0 | 0.2 | 0.0 | 0.5 | 0.0 | 0.0 | 0.1 | 12.1 | |

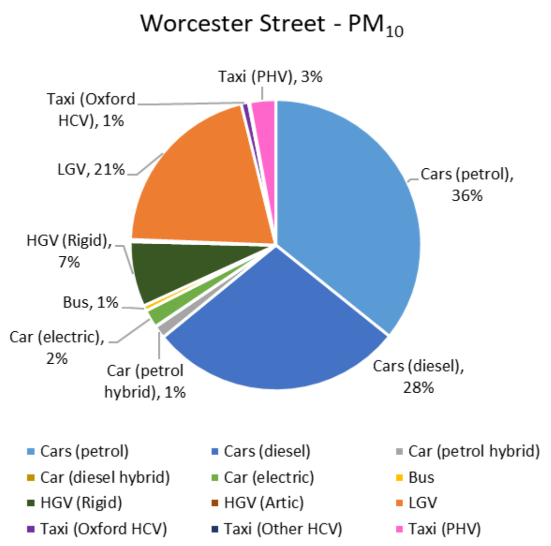
Table 4-6 Source apportionment for all road transport measured concentrations on Worcester Street (µg/m$^3$ for the 2022 ZEBRA model fleet ($NO_2$ concentration measured at DT45 in 2022).

| | Background | Cars | | | | | Bus | HGV (Rigid) | HGV (Artic) | LGV | Taxi | | | Total Modlelled $NO_2$ (µg/m$^3$) | Total Measured $NO_2$ (µg/m$^3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cars (petrol) | Cars (diesel) | Car (petrol hybrid) | Car (diesel hybrid) | Car (electric) | | | | | Taxi (Oxford HCV) | Taxi (Other HCV) | Taxi (PHV) | | |
| **$NO_2$** | 8.7 | 1.6 | 9.4 | 0.0 | 0.0 | 0.0 | 0.2 | 4.0 | 0.0 | 6.3 | 0.2 | 0.0 | 0.2 | 35.4 | 30.8 |

*Background $NO_2$ was estimated by applying the same percentage of NOx that is background in the modelled results, to the total measured $NO_2$.

Figure 4-4 Pie chart representation of source apportionment for all road transport emissions on Worcester Street (%) for the 2022 ZEBRA model.



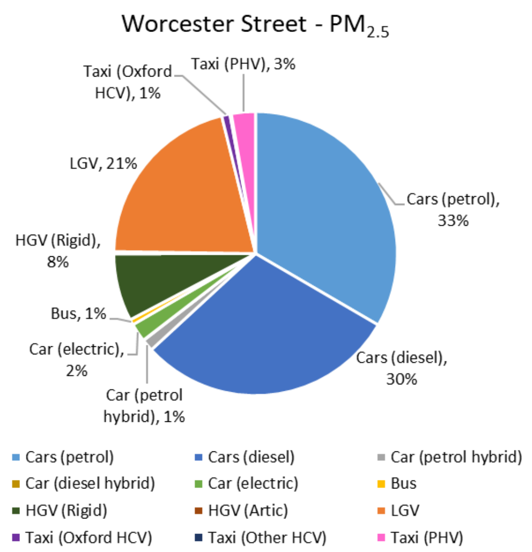
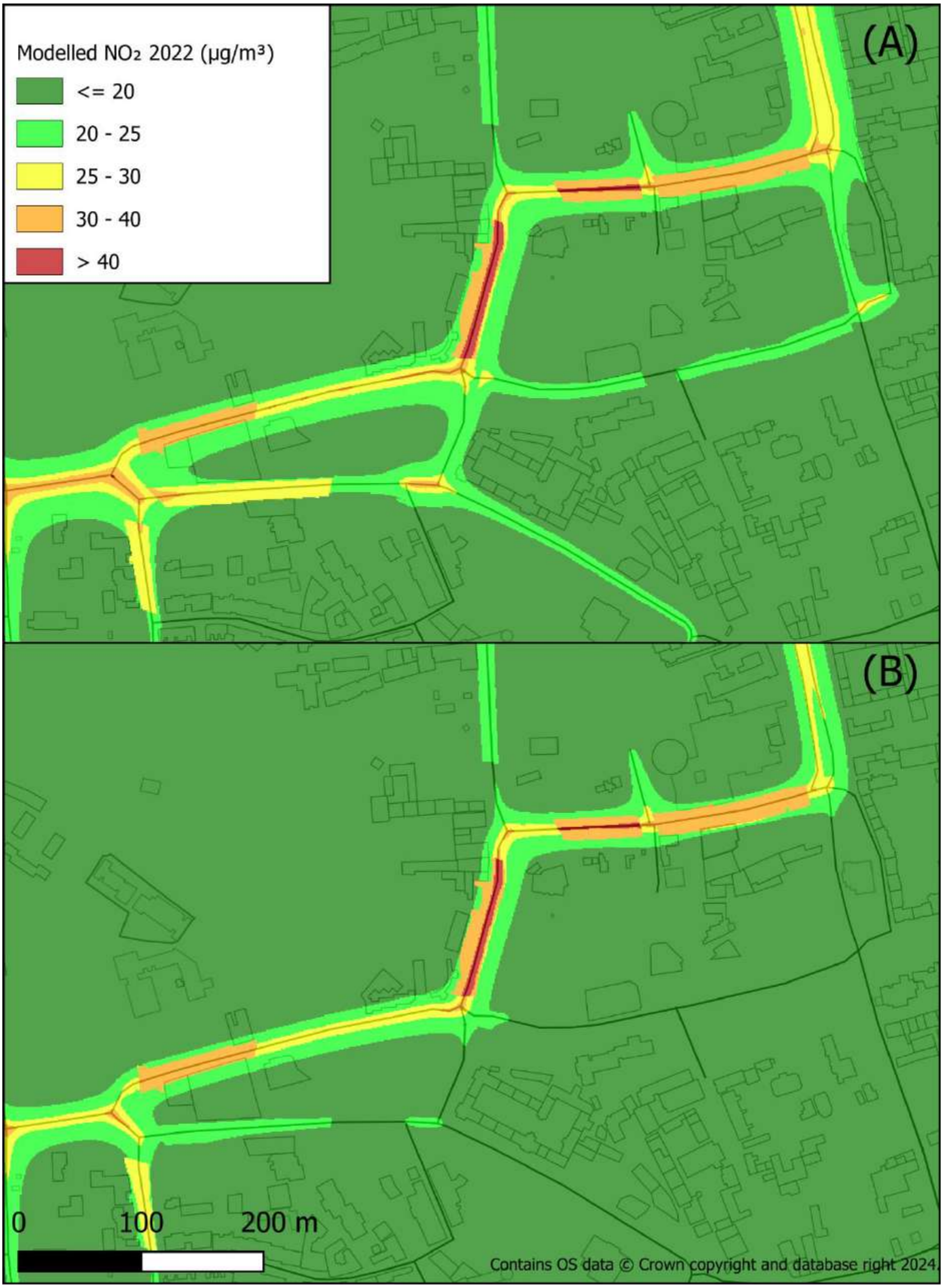



Figure 4-5 Modelled total $NO_2$ concentrations (2022) at Worcester Street using (A) a baseline fleet and (B) the ZEBRA fleet in which 69% of buses are zero emission.



## 4.3 BOTLEY ROAD

On **Botley Road**, at diffusion tube DT25, in the ZEBRA Scenario for 2022, cars account for 53% of road $NO_X$ emissions, 29% of $PM_{10}$ road emissions and 30% of $PM_{2.5}$ road emissions. These contributions are slightly higher in the ZEBRA scenario than the baseline, and the results are similar to St Clements/ The Plain DT55 and Worcester Street. For $NO_X$ road emissions at Worcester Street, diesel cars accounted for 44% of the total 53% of $NO_X$ road emissions from cars. For $PM_{10}$ and $PM_{2.5}$, 34 - 37% of road emissions were from petrol cars and 29 – 30% were from diesel cars. The next greatest contributing vehicle type to emissions on Worcester Street were LGVs comprising 27% of $NO_X$ road emissions, and 18% of $PM_{10}$ and $PM_{2.5}$ road emissions, followed by HGVs comprising 13% of $NO_X$ road emissions, and 7% of $PM_{10}$ and $PM_{2.5}$ road emissions.

Buses now account for 4% of $NO_X$ road emissions and 3% of $PM_{10}$ and $PM_{2.5}$ road emissions. The taxi fleet in total accounts for 2% of $NO_X$ road emissions, and 4% of road emissions for both $PM_{10}$ and $PM_{2.5}$. PHVs are contributing the greatest proportion of emissions of the three taxi categories, with 1% of $NO_X$ road emissions and 3% for both $PM_{10}$ and $PM_{2.5}$ road emissions, and this is the same for all three locations. These can be further broken down by fuel types, which is provided in Appendix 2.

Table 4-7 Source apportionment for all road transport emissions on Botley Road (%) for the 2022 ZEBRA model fleet.

| | Cars | | | | | Bus | HGV (Rigid) | HGV (Artic) | LGV | Taxi | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cars (petrol) | Cars (diesel) | Car (petrol hybrid) | Car (diesel hybrid) | Car (electric) | | | | | Taxi (Oxford HCV) | Taxi (Other HCV) | Taxi (PHV) | |
| **NOx** | 8.4% | 44.3% | 0.1% | 0.1% | 0.0% | 4.4% | 13.3% | 0.1% | 27.2% | 1.0% | 0.2% | 1.0% | 100% |
| **$PM_{10}$** | 36.5% | 28.5% | 1.4% | 0.0% | 2.0% | 3.1% | 6.8% | 0.2% | 17.5% | 0.8% | 0.1% | 3.0% | 100% |
| **$PM_{2.5}$** | 34.4% | 29.9% | 1.4% | 0.0% | 2.2% | 3.2% | 7.2% | 0.2% | 17.7% | 0.9% | 0.2% | 2.8% | 100% |

Table 4-8 Source apportionment for all road transport modelled concentrations on Botley Road (µg/m³) for the 2022 ZEBRA model fleet ($NO_2$ concentrations derived from the $NO_x$ to $NO_2$ calculator).

| | Background | Cars | | | | | Bus | HGV (Rigid) | HGV (Artic) | LGV | Taxi | | | Total modelled (µg/m³) | Total measured $NO_x$ (µg/m³)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cars (petrol) | Cars (diesel) | Car (petrol hybrid) | Car (diesel hybrid) | Car (electric) | | | | | Taxi (Oxford HCV) | Taxi (Other HCV) | Taxi (PHV) | | |
| **NOx** | 17.3 | 1.8 | 9.6 | 0.0 | 0.0 | 0.0 | 0.9 | 2.9 | 0.0 | 5.9 | 0.2 | 0.0 | 0.2 | 39.0 | 38.0 |
| **$PM_{10}$** | 14.3 | 1.0 | 0.8 | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.0 | 0.5 | 0.0 | 0.0 | 0.1 | 17.0 | |
| **$PM_{2.5}$** | 9.6 | 0.5 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 11.1 | |

Table 4-9 Source apportionment for all road transport measured concentrations on Botley Road (µg/m³) for the 2022 ZEBRA model fleet ($NO_2$ concentration measured at DT35 in 2022).

| | Background | Cars | | | | | Bus | HGV (Rigid) | HGV (Artic) | LGV | Taxi | | | Total Modlelled $NO_2$ (µg/m³) | Total Measured $NO_2$ (µg/m³) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cars (petrol) | Cars (diesel) | Car (petrol hybrid) | Car (diesel hybrid) | Car (electric) | | | | | Taxi (Oxford HCV) | Taxi (Other HCV) | Taxi (PHV) | | |
| **$NO_2$** | 12.2 | 1.0 | 5.1 | 0.0 | 0.0 | 0.0 | 0.5 | 1.5 | 0.0 | 3.1 | 0.1 | 0.0 | 0.1 | 24.1 | 23.7 |

*Background $NO_2$ was estimated by applying the same percentage of NOx that is background in the modelled results, to the total measured $NO_2$.

Figure 4-6 Pie chart representation of source apportionment for all road transport emissions on Botley Road (%) for the 2022 ZEBRA model.

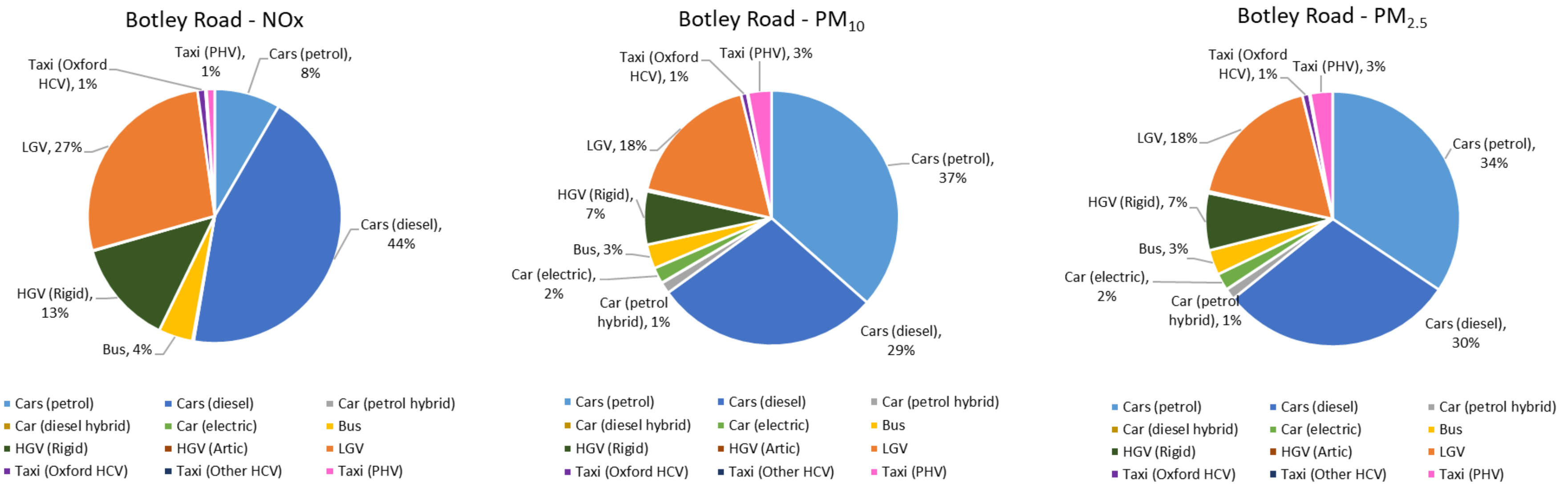
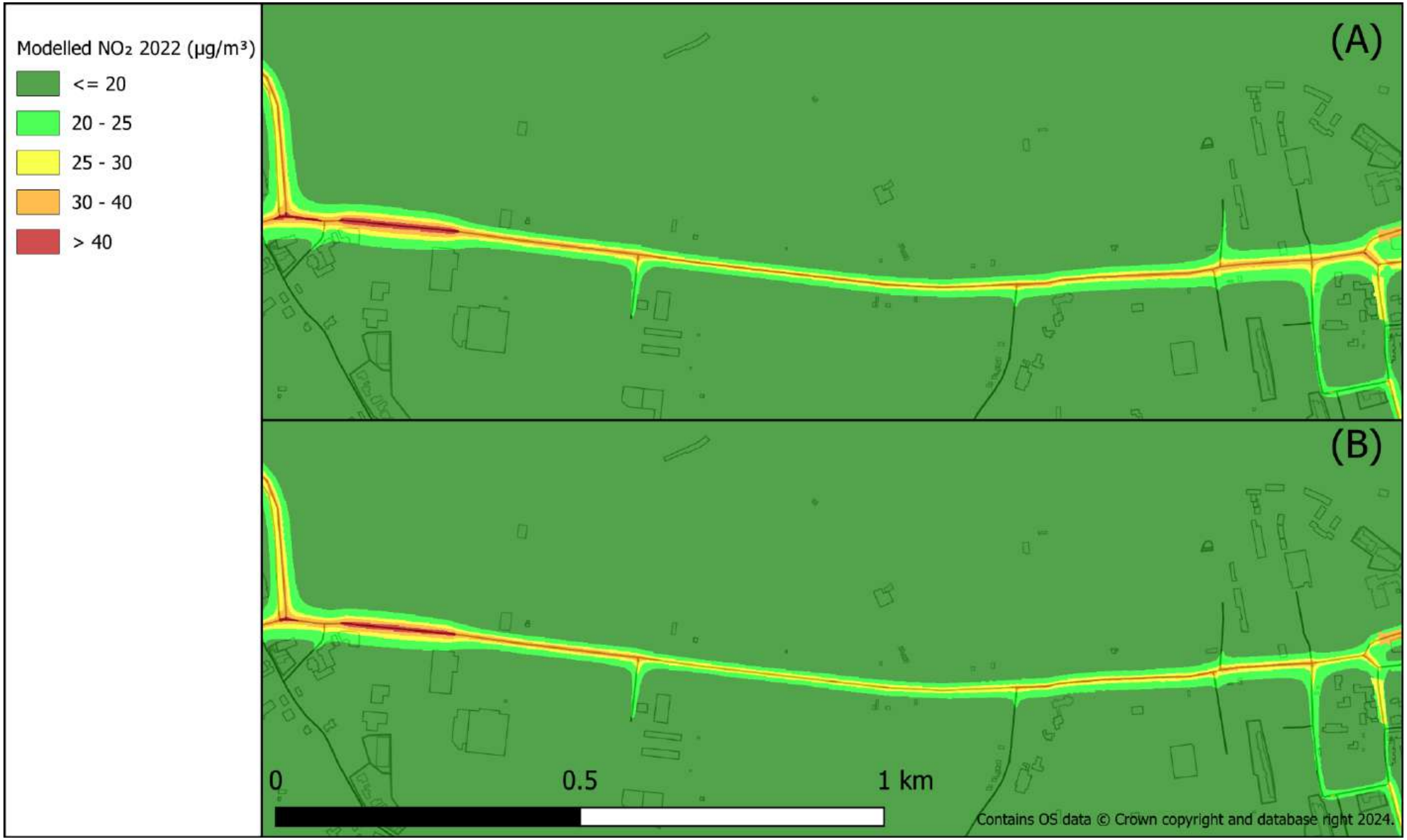


Figure 4-7 Modelled total $NO_2$ concentrations (2022) at Botley Road using (A) a baseline fleet and (B) the ZEBRA fleet in which 69% of buses are zero emissions.



## 4.4 COMPARISON TO 2022 BASELINE

In this section the ZEBRA model results are compared to the baseline results for 2022. Table 4-10 shows the pollutant concentrations attributable to buses in the baseline, and following the introduction of the ZEBRA buses. The reduction in concentration is also given. Of the three hotspot locations, the greatest impact of the ZEBRA bus scheme will be seen at diffusion tube DT55 at St Clements / The Plain, with a reduction of 5.82 µg/m$^3$ in $NO_2$ concentrations. Botley Road is the location with the next greatest improvement in $NO_2$ concentrations as a result of the ZEBRA bus scheme. The reductions seen in $NO_2$ at Worcester Street is marginal, due to lower levels of bus activity at this location.

Improvements in $PM_{10}$ and $PM_{2.5}$ concentrations are also small across all three locations. This is expected, $NO_2$ emissions from buses are largely tailpipe or exhaust emissions. There are no tailpipe or exhaust emissions from electric buses. However, electric buses will still have non-exhaust emissions of PM from brake and tyre wear, and road abrasion.

Table 4-10 Comparison of results between the baseline model and the ZEBRA model: Pollutant **concentrations attributed to bus** emissions (in µg m$^{-3}$).

| | Total Modelled $NO_2$ (ug.m$^3$) | | | Total Modelled $PM_{10}$ (ug.m$^3$) | | | Total Modelled $PM_{2.5}$ (ug.m$^3$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Baseline | ZEBRA | Reduction | Baseline | ZEBRA | Reduction | Baseline | ZEBRA | Reduction |
| **St Clement's / The Plain DT55** | 8.38 | 2.56 | **5.82** | 1.17 | 0.36 | **0.81** | 0.65 | 0.20 | **0.45** |
| **Worcester Street DT45** | 0.76 | 0.23 | **0.53** | 0.09 | 0.03 | **0.06** | 0.05 | 0.02 | **0.04** |
| **Botley Road DT35** | 1.74 | 0.50 | **1.24** | 0.27 | 0.08 | **0.19** | 0.15 | 0.05 | **0.10** |

Table 4-11 shows the difference in total modelled $NO_2$, $PM_{10}$ and $PM_{2.5}$ concentrations between the baseline scenario, and following the introduction of the ZEBRA buses. Overall, the impact of the electric buses from the ZEBRA scheme reduces modelled $NO_2$ by 14% at St Clements/ The Plain, by 8% at Botley Road, and by 2% at Worcester Street. At St Clements/ The Plain, total modelled $PM_{10}$ concentrations are reduced by 4% and $PM_{2.5}$ by 3%. There is a 1% reduction in total modelled $PM_{10}$ and $PM_{2.5}$ concentrations at both Worcester Street and Botley Road.

Table 4-11 Comparison of results between the baseline model and the ZEBRA model: **Total pollutant concentrations** (in µg m$^{-3}$).

| | Total Modelled $NO_2$ (ug.m$^3$) | | | Total Modelled $PM_{10}$ (ug.m$^3$) | | | Total Modelled $PM_{2.5}$ (ug.m$^3$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Baseline | ZEBRA | % Reduction | Baseline | ZEBRA | % Reduction | Baseline | ZEBRA | % Reduction |
| **St Clement's / The Plain DT55** | 44.0 | 37.9 | **14%** | 21.7 | 20.9 | **4%** | 14.0 | 13.5 | 3% |
| **Worcester Street DT45** | 36.3 | 35.4 | **2%** | 19.0 | 18.9 | **1%** | 12.2 | 12.1 | 1% |
| **Botley Road DT35** | 26.3 | 24.1 | **8%** | 17.2 | 17.0 | **1%** | 11.2 | 11.1 | 1% |

Table 4-12 applies the percentage reductions calculated from a comparison of the baseline modelled results against the "ZEBRA" modelled results to the latest available monitoring data for the monitoring locations at St Clements/ The Plain (DT55), Worcester Street (DT45) and Botley Road (DT35). This gives us an estimate of improvements that might be achieved at each location, as a results of introducing the ZEBRA buses, based on the latest available monitoring data.

Both 2022 and 2023 monitoring data have been included in this table, as the latest available monitoring data for 2023 may not reflect normal traffic conditions due to the closure of Botley Road in this monitoring year, as previously discussed.

The estimations in Table 4-12 show that at DT55 in St Clements/ The Plain, a 14% decrease in $NO_2$ concentrations as a result of ZEBRA buses being introduced brings the 2022 monitored 43 µg/m$^3$ at DT55 under the AQO to 37 µg/m$^3$. However, the ZEBRA buses may not be sufficient to achieve the OCC target of 30 µg m$^3$ – additional emissions reduction measures may be needed.

Table 4-12 Estimated reductions in $NO_2$ concentrations as a result of introduction of ZEBRA buses.

| | Monitored $NO_2$ concentrations (µg/m$^3$) | | Estimated pollutant reduction with ZEBRA buses (%) | Estimated $NO_2$ concentrations with ZEBRA buses (µg/m$^3$) | |
|---|---|---|---|---|---|
| | 2022 | 2023 | | 2022 | 2023 |
| **St Clement's / The Plain DT55** | 43 | 38 | 14% | 37 | 33 |
| **Worcester Street DT45** | 31 | 25 | 2% | 30 | 24 |
| **Botley Road DT35** | 24 | 19 | 8% | 22 | 17 |

## 4.5 COMPARISON WITH THE 2020 STUDY

This section compares the current results for the 2022 ZEBRA model against the previous “2020 Source Apportionment Study”’ results for 2018.

At St Clements/ The Plain, there was a decrease in total measured $NO_2$ from 46.0 µg/m$^3$ in 2018 to 43.1 µg/m$^3$ in 2022. Figure 4-8 shows that in 2018, the main sources of NOx at St Clements / The Plain are buses, which were contributing more than half the emissions for all three pollutants from vehicles. In the 2022 ZEBRA model source apportionment, contributions from buses to all pollutants are significantly decreased. This improvement is likely as a result of the introduction of the electric buses, but this may also be due to other improvements to the bus fleet (such as upgrades to Euro VI emissions standard) or changes to bus activity at this location. Contributions from cars are increased in 2022 compared to the 2018 source apportionment.

At Worcester Street, there was a decrease in total measured $NO_2$ from 37.0 µg/m$^3$ in 2018 to 30.8 µg/m$^3$ in 2022. This is the greatest improvement of the three hotspot locations. The decrease in $NO_2$ at this location may be the result of roadworks undertaken in 2020 to improve the Worcester Street Junction[15,16], making it safer for cyclists and improving overall traffic flows. It’s worth noting that AADT traffic flows are relatively unchanged in this period[17], suggesting that the improvement can by largely explained by the changes at the junction which have improved the traffic flow.

Figure 4-9 shows that at Worcester Street, cars are the biggest contributor to emissions for all pollutants in both 2018 and 2022, but there is an increase in contributions from cars in 2022, particularly from $PM_{10}$ and $PM_{2.5}$, as well as a decrease in $PM_{10}$ and $PM_{2.5}$ contributions from LGVs, and a decrease in contributions from buses for all pollutants.

At Botley Road, there was a decrease in total measured $NO_2$ from 32.0 µg/m$^3$ in 2018 to 30.8 µg/m$^3$ in 2022. This is the smallest improvement of the three hotspot locations, but also the location with the lowest measured $NO_2$ of the three. Figure 4-10 shows that at Botley Road cars are the biggest contributor to emissions for all pollutants in both 2018 and 2022, though for NOx, contributions from buses are a close second biggest contributor. Contributions from buses to all pollutants decreased between 2018 and 2022. Contributions from most other vehicles, particularly cars, have increased. An exception to this is a decrease in $PM_{10}$ and $PM_{2.5}$ contributions from LGVs.

For the 2020 Study, taxi data was more limited – it was only available for Worcester Street and classifies all taxis into: Taxi (diesel), taxi (petrol) and Hackney cabs (all). These differ from the taxi classes used in the 2022 source apportionment, which was able to use more detailed taxi data from the traffic model and ANPR surveys, and classified taxis into Private Hire Vehicles (PHVS), Oxford Hackney Carriage Vehicles (Oxford HCVs) and other Hackney Carriage Vehicles (Other HCVs), with extra detail on fuel types for these broken down in Appendix 2. Additionally, 2018 source apportionment included motorcycles, which are not included in the 2022 source apportionment as this data was not included in the underlying 2023 traffic model. Therefore, it is not possible to directly compare source apportionment results for taxis and motorcycles between 2018 and 2022.

Other trends have remained the same in both studies:

- Diesel cars contributed a higher proportion of NOx emissions than petrol cars.
- Rigid HGVs contributed significantly more NOx, $PM_{10}$ and $PM_{2.5}$ emissions than artic HGVs.
- Diesel taxis contributed a higher proportion of NOx emissions than petrol taxis (see Appendix 2).
- For $PM_{10}$ and $PM_{2.5}$ the background concentrations are considerably more than the road contribution. This is not the case for NOx.

[15] Oxford Mail (2020) “Worcester Street roadworks, Oxford: council pledge to tackle delays” Available online: https://www.oxfordmail.co.uk/news/18225666.worcester-street-roadworks-oxford-council-pledge-tackle-delays/

[16] Oxford Mail (2020) “Worcester Street roadworks finished during coronavirus lockdown” Available online: https://www.oxfordmail.co.uk/news/18357414.worcester-street-roadworks-finished-coronavirus-lockdown/

[17] Oxfordshire County Council ArcGIS map of AADT counts. Closest count point ID A4144. v Available online: https://oxfordshire.maps.arcgis.com/apps/webappviewer/index.html?id=afe8bef2e7514f91bb1bf6ec034fb69b

Figure 4-8 Comparison of the 2018 baseline and the ZEBRA 2022 model source apportionment results for St Clements / The Plain (%).

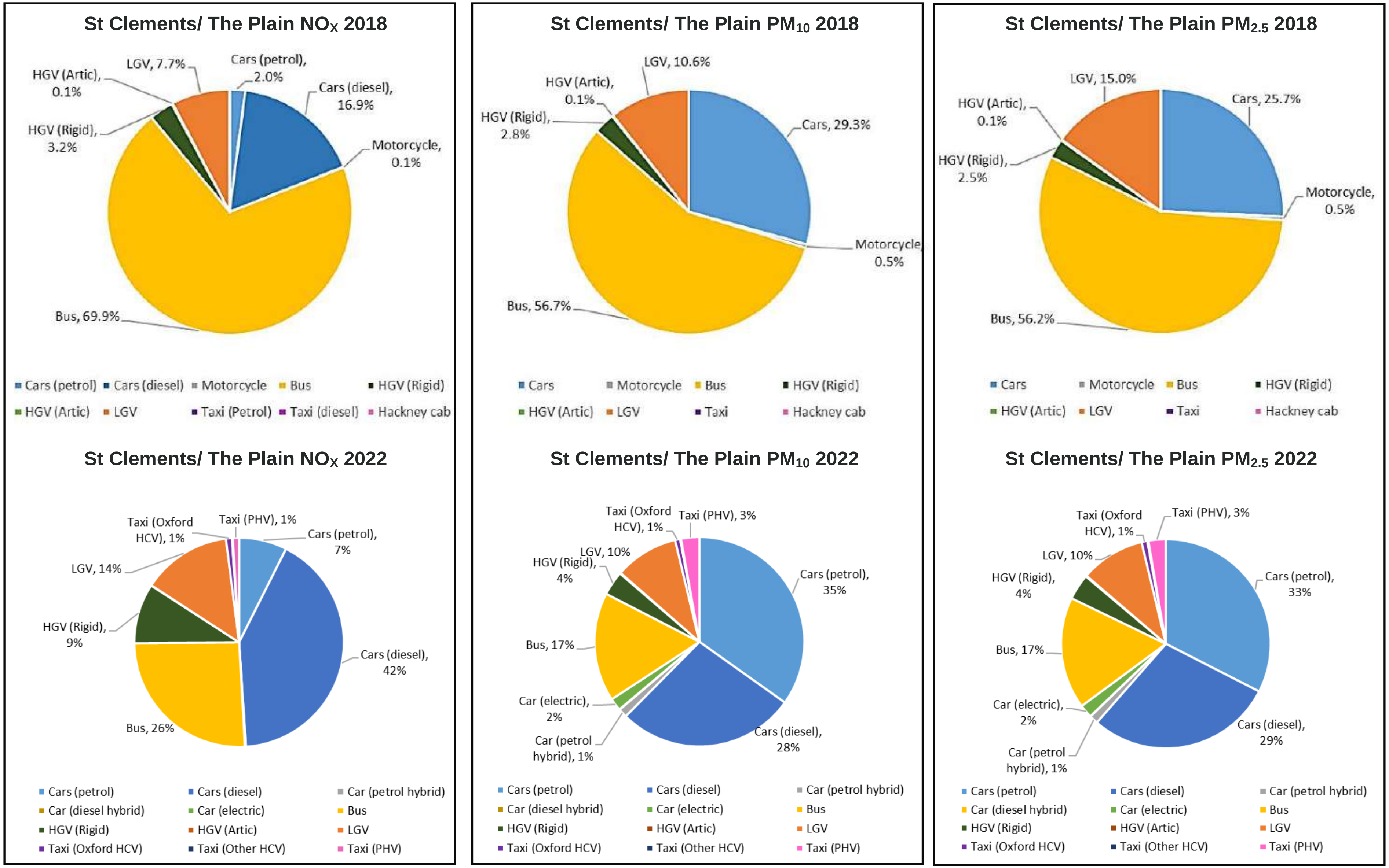


Figure 4-9 Comparison of the 2018 baseline and the ZEBRA 2022 model source apportionment results for Worcester Street (%).

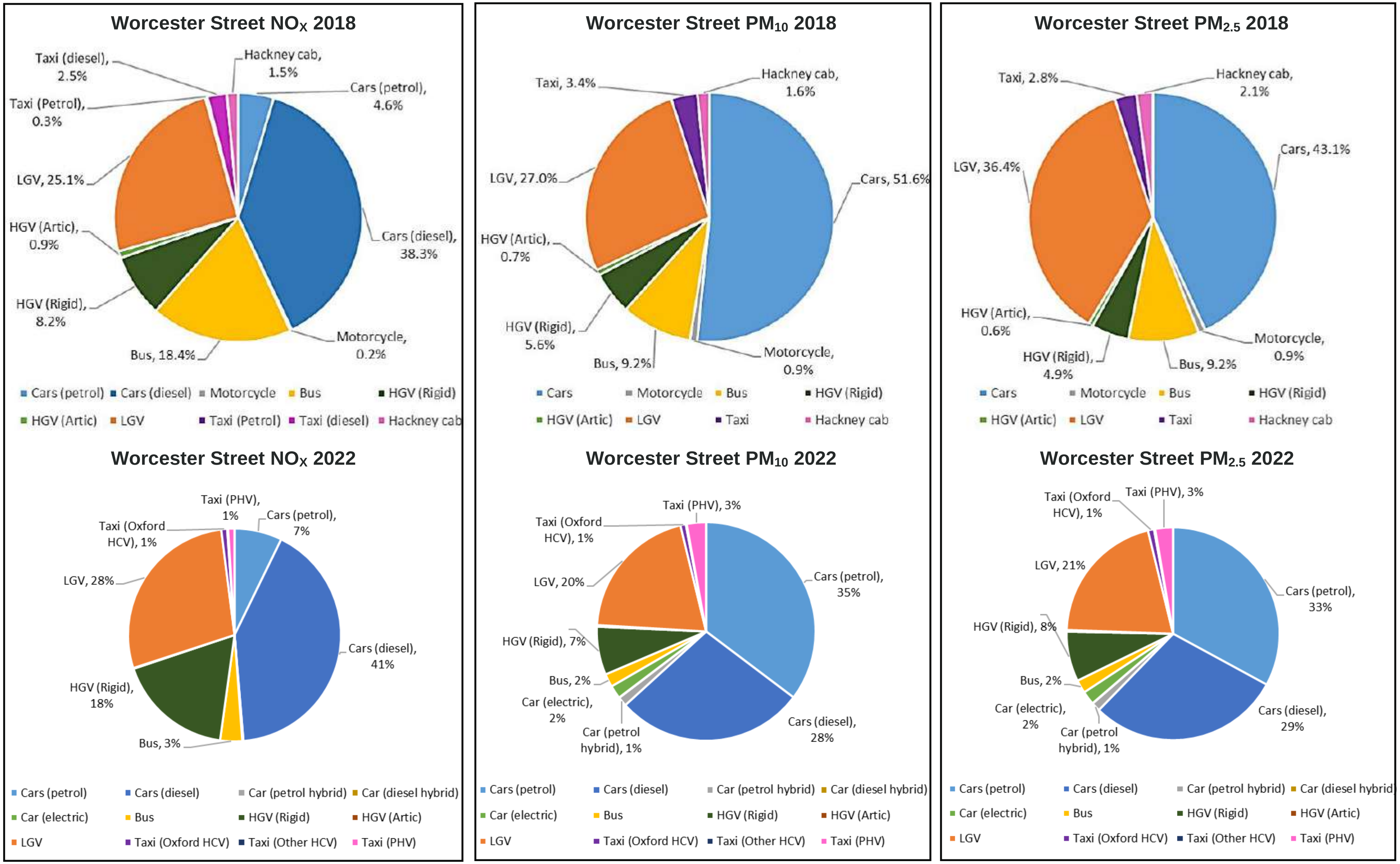
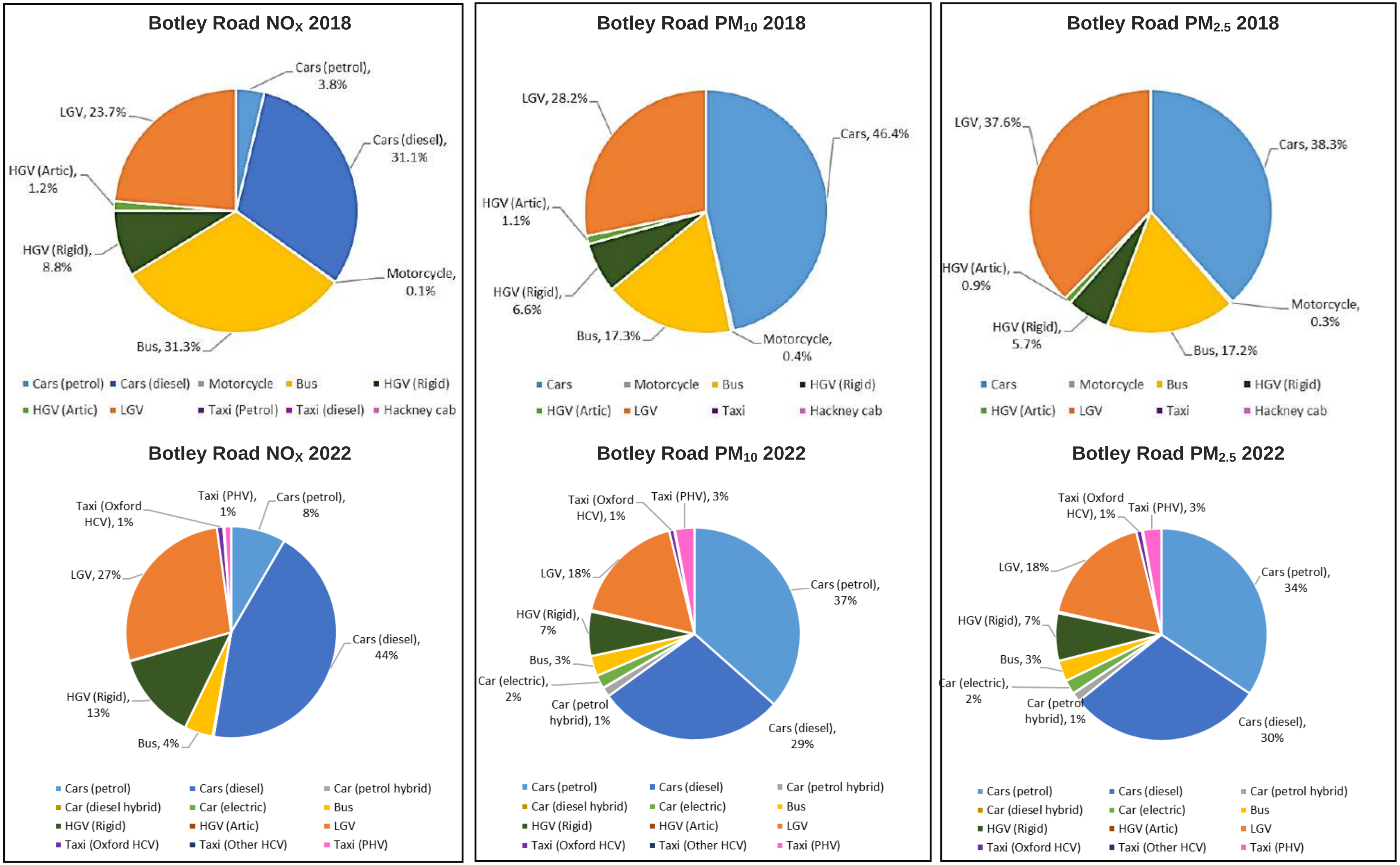


Figure 4-10 Comparison of the 2018 baseline and the ZEBRA 2022 model source apportionment results for Botley Road (%).



# 5. SOURCE APPORTIONMENT OF NAEI EMISSIONS

The UK National Atmospheric Emissions Inventory (NAEI) estimates annual pollutant emissions for the UK on an annual basis[18]. The latest available data is for the year 2022, which aligns with the baseline model year for this report. The NAEI calculates and reports on the quantity of pollutants that are emitted to air. This impacts on the concentrations of pollution in the air, although there is not a direct relationship between the two as concentrations can be affected by weather patterns, chemical transformations, and pollutants emitted elsewhere.[19]

To gain an understanding of the key polluting sectors across the wider Oxford area, including contributions from non-road sources, the NAEI emissions data has been used to apportion contributions to $NO_X$ as $NO_2$, $PM_{10}$ and $PM_{2.5}$ across both the whole Oxford administrative area, and within Oxford inner city centre.

The National Atmospheric Emissions Inventory (NAEI) emissions maps[20,21,22] are downloaded at 1 km x 1 km resolution for both the Oxford City Council administrative boundary and Oxford inner city cordon. boundary. The total emissions for each NAEI sector were summed across the whole of the local authority and inner city. These emissions were converted to a percentage of all emissions across both areas. The sectors are described in Table 5-1.

Table 5-1 NAEI emission source sectors for $NO_X/NO_2$, $PM_{10}$ and $PM_{2.5}$.

| Emission source sectors | Pollutants |
|---|---|
| Combustion in energy and transformation industry (or “Energy production”) | $NO_X$ as $NO_2$, $PM_{10}$, $PM_{2.5}$ |
| Non-Industrial combustion (or “Domestic combustion”) total | $NO_X$ as $NO_2$, $PM_{10}$, $PM_{2.5}$ |
| - Commercial | $PM_{2.5}$ |
| - Domestic Smokeless Solid Fuel (SSF) | $PM_{2.5}$ |
| - Domestic Wood | $PM_{2.5}$ |
| - Domestic Other | $PM_{2.5}$ |
| Combustion in manufacturing industry (or “Industry combustion”) | $NO_X$ as $NO_2$, $PM_{10}$, $PM_{2.5}$ |
| Production processes[23] | $NO_X$ as $NO_2$, $PM_{10}$, $PM_{2.5}$ |
| Extraction and distribution of fossil fuels and geothermal energy (or “Offshore”) | $NO_X$ as $NO_2$, $PM_{10}$, $PM_{2.5}$ |
| Solvents | $NO_X$ as $NO_2$, $PM_{10}$, $PM_{2.5}$ |
| Road transports total | $NO_X$ as $NO_2$, $PM_{10}$, $PM_{2.5}$ |
| - Major roads (tailpipe) | $NO_X$ as $NO_2$, $PM_{10}$, $PM_{2.5}$ |
| - Minor roads (tailpipe) | $NO_X$ as $NO_2$, $PM_{10}$, $PM_{2.5}$ |
| - Road abrasion | $PM_{10}$, $PM_{2.5}$ |
| - Tyre and brake-wear | $PM_{10}$, $PM_{2.5}$ |
| - Cold starts | $NO_X$ as $NO_2$, $PM_{2.5}$ |
| Non-Road Transport total | $NO_X$ as $NO_2$, $PM_{10}$, $PM_{2.5}$ |

18 NAEI “The UK National Atmospheric Emissions Inventory (NAEI)” Available online: https://naei.energysecurity.gov.uk/

19 NAEI “Air Pollutants” Available online: https://naei.energysecurity.gov.uk/air-pollutants

20 Emission map data for Nitrogen oxides (NOx expressed as $NO_2$) in 2022, NAEI, Available online: https://naei.energysecurity.gov.uk/emissionsapp/

21 Emission map data for $PM_{10}$ (Particulate Matter < 10µm) in 2022, NAEI, 2022, Available online: https://naei.energysecurity.gov.uk/emissionsapp/

22 Emission map data for $PM_{2.5}$ (Particulate Matter < 2.5µm) in 2022, NAEI, 2022, Available online: https://naei.energysecurity.gov.uk/emissionsapp/

23 “Production processes” includes emissions from sectors such as metal production, chemical processing, fuel production, and other manufacturing, as well as emissions from construction.

| | |
|---|---|
| - Non-road mobile machinery[24] | $NO_X$ as $NO_2$, $PM_{10}$, $PM_{2.5}$ |
| - Aircraft | $NO_X$ as $NO_2$, $PM_{2.5}$ |
| - Rail | $NO_X$ as $NO_2$, $PM_{10}$, $PM_{2.5}$ |
| - Shipping | $NO_X$ as $NO_2$, $PM_{10}$, $PM_{2.5}$ |
| - Other transport (including inland waterways and military aircraft) | $NO_X$ as $NO_2$, $PM_{10}$, $PM_{2.5}$ |
| Waste collection, treatment and disposal activities | $NO_X$ as $NO_2$, $PM_{10}$, $PM_{2.5}$ |
| Agriculture and farming | $NO_X$ as $NO_2$, $PM_{10}$, $PM_{2.5}$ |
| Other Sources and Sinks (or "Nature") | $NO_X$ as $NO_2$, $PM_{10}$, $PM_{2.5}$ |
| Point sources[25] | $NO_X$ as $NO_2$, $PM_{10}$, $PM_{2.5}$ |

Major road tailpipe emissions, grouped together with road abrasion and tyre and brake-wear (and referred to in Sections 5.1 and 5.2 as "major road" emissions), has been broken down to vehicle type emissions using our emissions modelling from Section 4.

- The Defra background map[26] concentrations at a 1 km x 1 km scale were used to generate a proportion of emissions for the major roads (motorway, primary and trunk roads) from minor roads.
- The contributions of emissions by vehicle type across all modelled major road links (from the results presenting in Section 4).
- These percentages were multiplied by the proportion of NAEI emissions from major roads to give an estimate of the percentage of total emissions across the City of Oxford for each vehicle type.

As the "major road" component incorporates tailpipe and non-tailpipe (road abrasion and brake and tyre wear) emissions, non-tailpipe $PM_{10}$ and $PM_{2.5}$ emissions are not distinct in the results presented in Sections 5.1 and 5.2. However, these specific contributions can be seen in comprehensive NAEI emissions pie charts presented in Appendix 5.

The NAEI emissions source apportionment has been carried out for both the whole Oxford Administrative area (results in Section 5.1), and Oxford Inner City (Section 5.2). These boundaries are shown in Figure 5-1, alongside locations of point sources with $NO_X$, $PM_{10}$ and $PM_{2.5}$ emissions in 2022.

Point sources were included where they were located within the Administrative Area and the Oxford City Centre boundary where identified, a list of sites, operator and emissions are presented in Table 5-2.

[24] "Non-Road Mobile Machinery (NRMM) is a broad category. It includes mobile machines and transportable industrial equipment or vehicles, fitted with internal combustion engines but not made to transport goods or passengers on roads." From Mayor of London website Available online: https://www.london.gov.uk/programmes-and-strategies/environment-and-climate-change/pollution-and-air-quality/nrmm

[25] A point source is an emission source at a known location, which has grid references and therefore, it can be mapped directly. Detailed emissions data are supplied the NAEI for these industrial and commercial sources.

[26] Defra UK AIR "Background Mapping data for local authorities – 2018" Available online: https://uk-air.defra.gov.uk/data/laqm-background-maps?year=2018

Figure 5-1 Map of the Oxford Administrative Area boundary and Oxford Inner City cordon and point sources

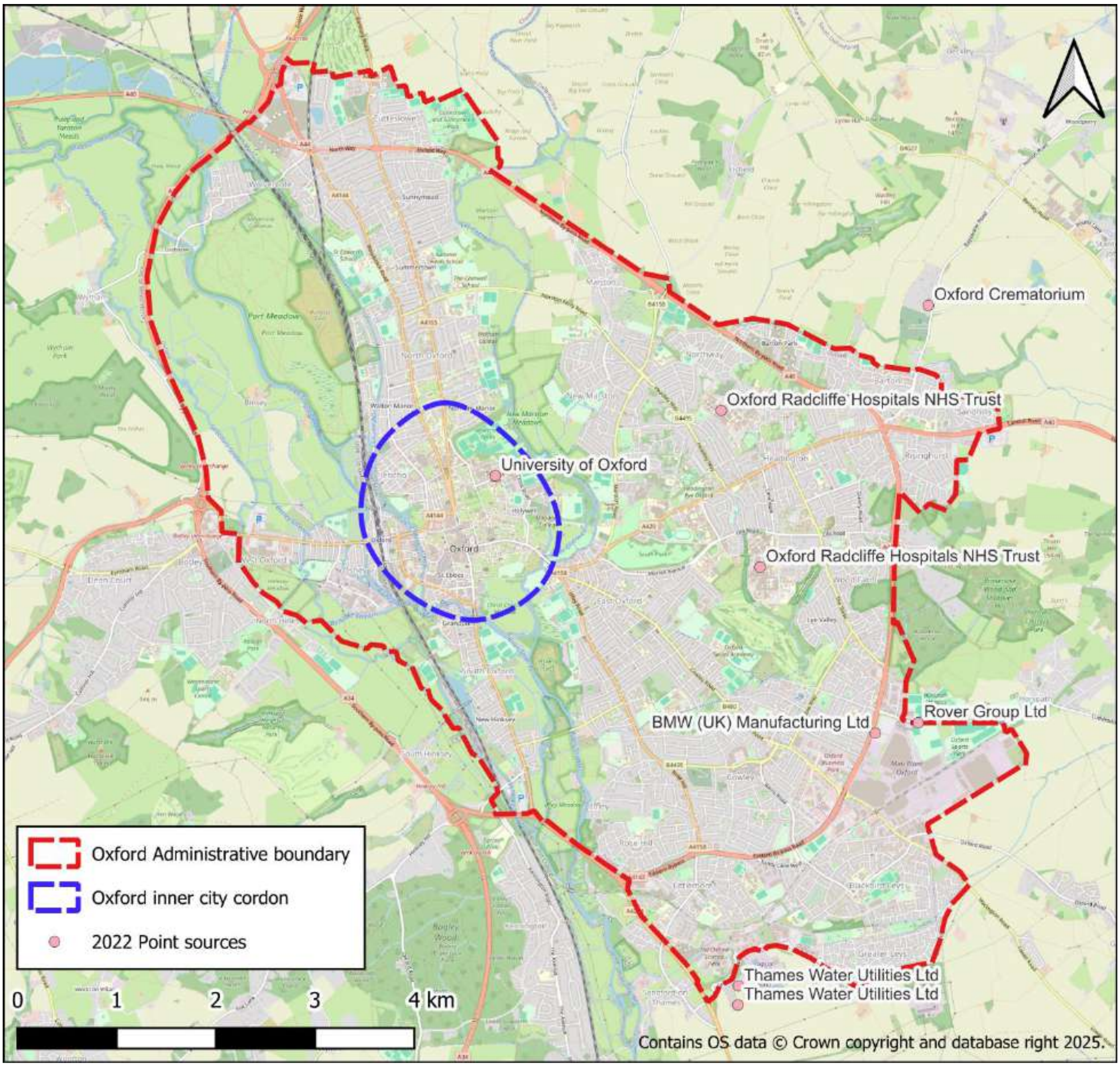



Table 5-2 List of point sources in Oxford Administrative Area. Sites are denoted with * if they also are located within the Oxford Inner City boundary.

| Plant ID | Site | Operator | Sector | NOx Emissions (tonnes) | $PM_{10}$ Emissions (tonnes) | $PM_{2.5}$ Emissions (tonnes) |
|---|---|---|---|---|---|---|
| 3478 | Cowley | Rover Group Ltd | Vehicles | N/A | 5.83 | 4.84 |
| 8175 | Cowley | BMW (UK) Manufacturing Ltd | Vehicles | 66.59 | 0.4 | 0.4 |
| 8356 | Oxford* | University of Oxford | Public administration | 9 | 0.09 | 0.09 |
| 8872 | Churchill Hospital | Oxford Radcliffe Hospitals NHS Trust | Public administration | 38.08 | 1.53 | 1.43 |
| 8873 | John Radcliffe Hospital | Oxford Radcliffe Hospitals NHS Trust | Public administration | 24.35 | 0.26 | 0.25 |

## 5.1 OXFORD ADMINISTRATIVE AREA

In the following pie charts, the NAEI sectors in Table 5-1 are represented in the larger pie charts on the left. The smaller pie charts on the right show source apportionment of the major roads (motorway, primary and trunk road emissions), as well as non-exhaust emissions from road abrasion and brake and tyre wear. These emissions can be broken down further by vehicle type, as taken from ZEBRA model emission results averaged across the Administrative Area.

There are no $NO_X$, $PM_{10}$ or $PM_{2.5}$ emissions from offshore and shipping sources in Oxford Administrative Area, so these are not included in the pie charts below.

Across the whole Administrative Area of Oxford, $NO_X$ emissions are dominated by combined road transport sources (major roads, minor roads and cold starts), domestic combustion and point sources. $PM_{10}$ emissions are dominated by production processes, and $PM_{2.5}$ emissions are dominated by domestic combustion and combined road transport sources.

Road transport sources (major roads, minor roads and cold starts) comprise a combined 32% of $NO_X$ emissions in comparison to around 15% of $PM_{10}$ and 17% of $PM_{2.5}$ emissions in Oxford Administrative Area. Domestic combustion comprises approximately 26% of $NO_X$ emissions, 18% of $PM_{10}$ emissions and 35% of $PM_{2.5}$ emissions. Figure 5-5 breaks down domestic combustion further for $PM_{2.5}$, which shows that in Oxford Administrative Area, the domestic combustion contributions break down to approximately 25% from Wood, 5% each for commercial heating and domestic "other", and 0.5% from smokeless solid fuel.

Other prominent sources across Oxford Administrative Area are production processes, which contribute to nearly half of $PM_{10}$ emissions, but only 10% of $PM_{2.5}$ emissions, and contribute no $NO_X$ emissions; and Point Sources, which contribute to approximately 20% of $NO_X$ emissions, but only 5% of $PM_{10}$ and 9% of $PM_{2.5}$ emissions.

Figure 5-2 Source apportionment of NAEI sources of $NO_X$, and road transport, in Oxford Administrative Area

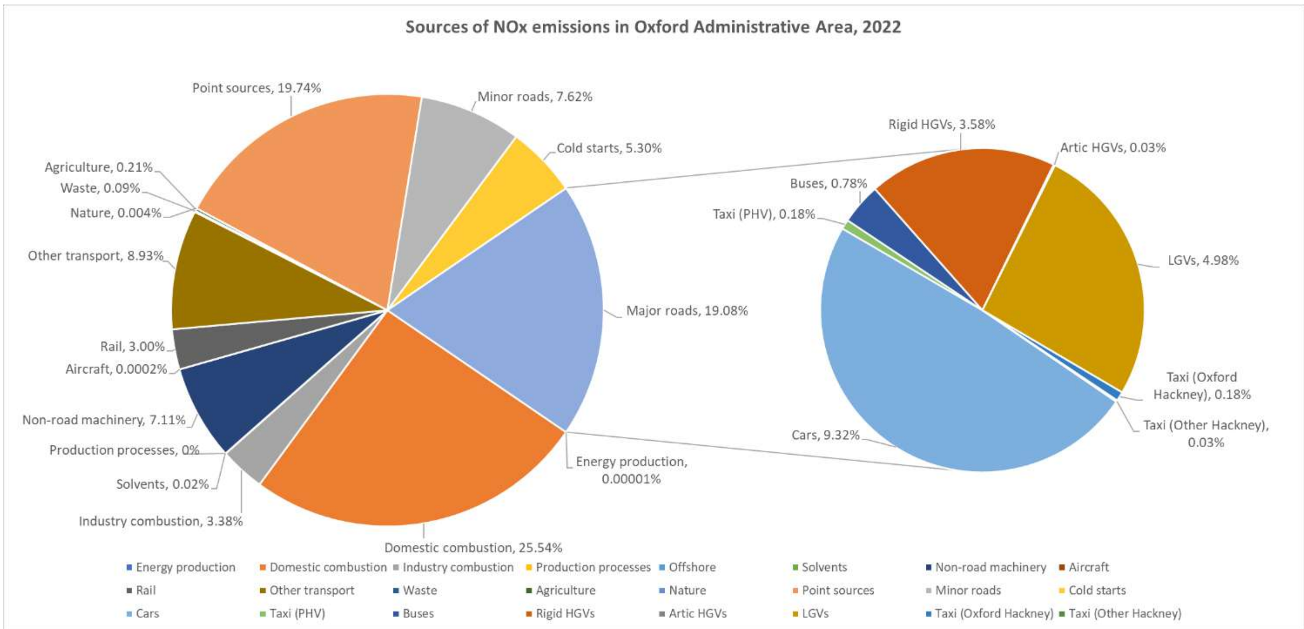


Figure 5-3 Source apportionment of NAEI sources of $PM_{10}$ and road transport, in Oxford Administrative Area

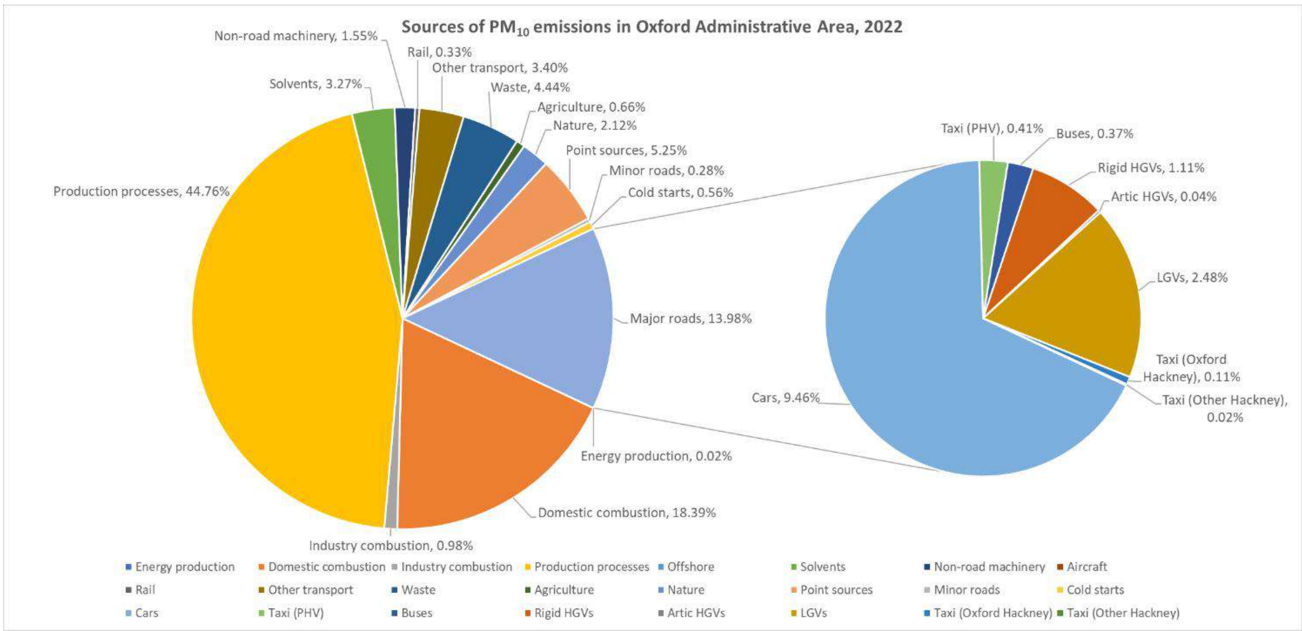



Figure 5-4 Source apportionment of NAEI sources of $PM_{2.5}$ and road transport, in Oxford Administrative Area

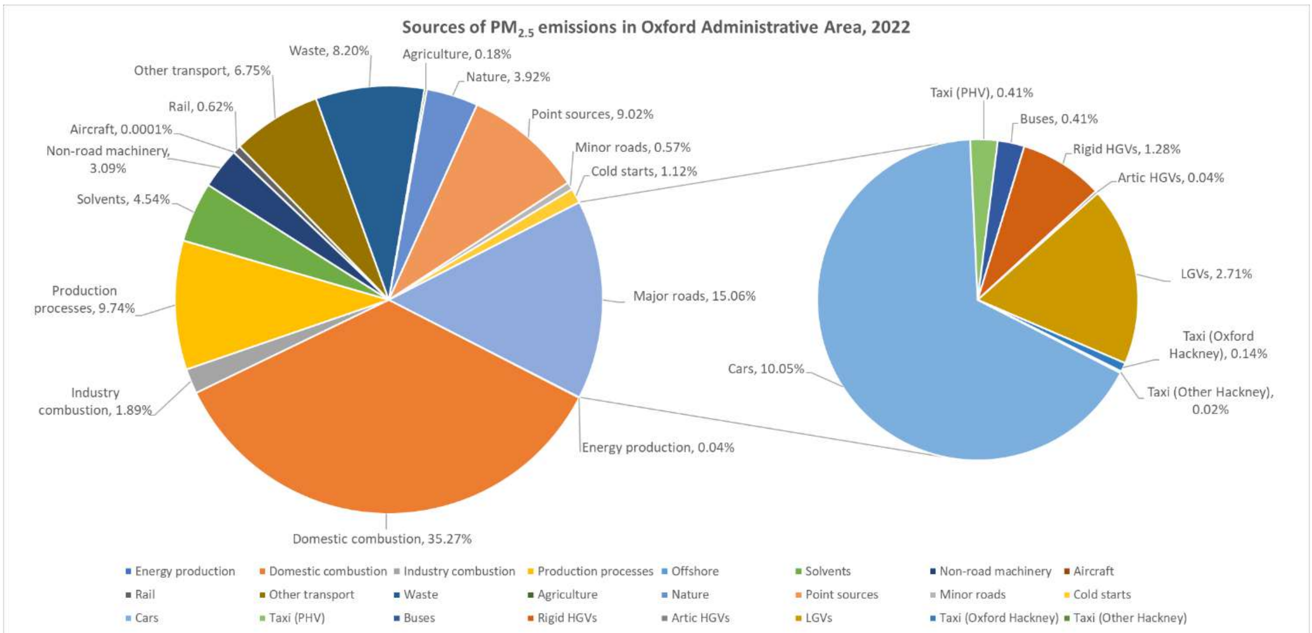
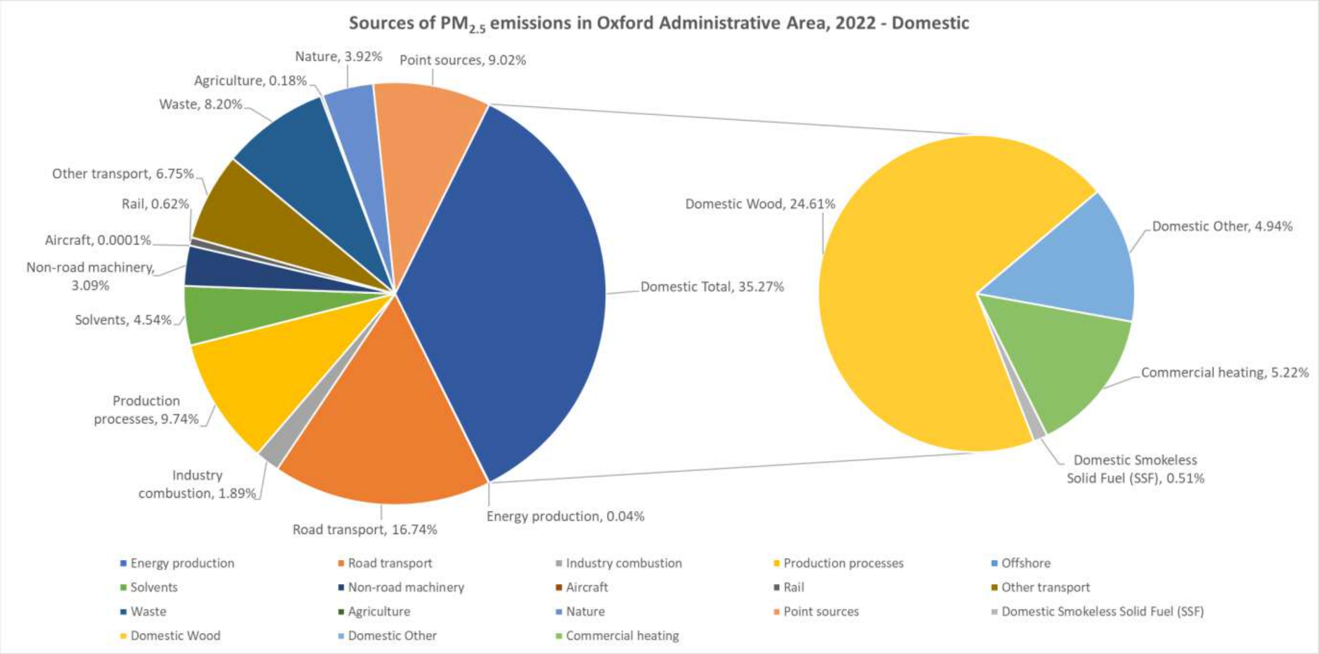


Figure 5-5 Source apportionment of NAEI sources of $PM_{2.5}$ including domestic combustion breakdown, in Oxford Administrative Area




## 5.2 OXFORD INNER CITY

In the following pie charts, source apportionment is presented for Oxford Inner City, as shown in Figure 5-1. Again, the NAEI sectors in Table 5-1 are represented in the larger pie charts on the left, and the smaller pie charts on the right show source apportionment of the major roads (motorway, primary and trunk road emissions). As well as exhaust/tailpipe emissions, the major road component also include emissions from road abrasion and brake and tyre wear. Major road emissions can be broken down further by vehicle type, as taken from ZEBRA model emission results averaged across the Inner City area.

There are no $NO_X$, $PM_{10}$ or $PM_{2.5}$ emissions from aircraft, offshore and shipping in Oxford Inner City, so these are not included in the pie charts below.

In the Inner City, $NO_X$ emissions are dominated by domestic combustion, $PM_{10}$ emissions are dominated by production processes, and $PM_{2.5}$ emissions are dominated by domestic combustion, production processes, other transport (including inland waterways and military aircraft), and combined road transport sources.

Road transport (major roads, minor roads and cold starts) sources comprise a combined 18% of $NO_X$ emissions across the Inner City area (compared to 32% across the whole Oxford Administrative Area). For $PM_{10}$, combined road transport sources comprise a combined 9% of emissions across the Inner City area (compared to 15% across the whole Oxford Administrative Area). For $PM_{2.5}$, combined road transport sources comprise a combined 12% of emissions across the Inner City area (compared to 17% across the whole Oxford Administrative Area).

Domestic combustion comprises much higher proportion of NOx emissions in the Inner City (49%) than the Administrative Area (26%). Conversely for $PM_{10}$ and $PM_{2.5}$, domestic combustion comprises lower (by about 3%) proportions of emissions in the Inner City compared to the Administrative Area. Figure 5-9 breaks down domestic combustion further for $PM_{2.5}$, which shows that in the Inner City the domestic combustion contributions are dominated by commercial heating (rather than by wood across the whole Administrative Area), breaking down to approximately 20% from commercial, 10% from wood, 2% for domestic “other”, and 0.15% from smokeless solid fuel.

Similarly to the Administrative Area, production process dominate $PM_{10}$ emissions comprising 56% (increased proportion from the Administrative Area of 45%), though only 15% of $PM_{2.5}$ (but increased from the Administrative Area of 10%) and again, no emissions to NOx as $NO_2$.

As mentioned, other transport (including inland waterways and military aircraft) is among the key sources contributing to $PM_{2.5}$ emissions in the Inner City. Other transport comprises 12% of $NO_X$, 6% of $PM_{10}$ and 14% of $PM_{2.5}$ in the Inner City, which is increased from the other transport contributions averages across the whole Administrative Area (9% of $NO_X$, 3% of $PM_{10}$ and 7% of $PM_{2.5}$ respectively).

The contribution of point sources to NOx emissions is reduced in the Inner City to 8% (from 20% across the Administrative Area). This is to be expected given the location of point sources - Figure 5-1 shows only one point source within the Inner City cordon.

Figure 5-6 Source apportionment of NAEI sources of $NO_X$, and road transport, in Oxford Inner City.

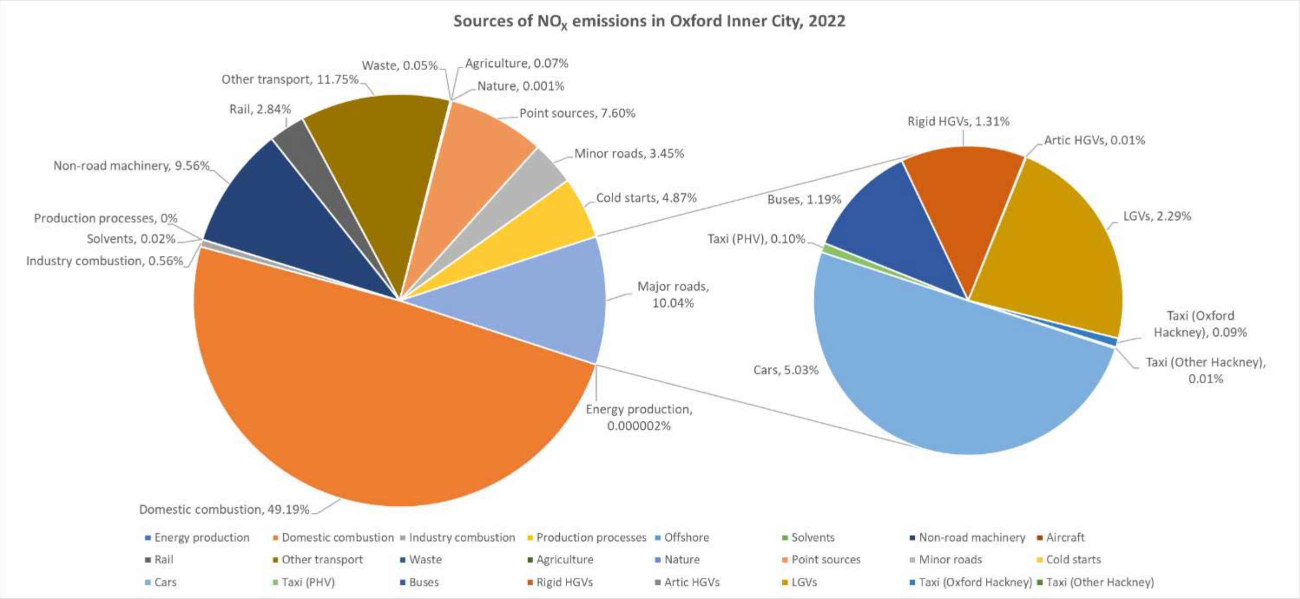



Figure 5-7 Source apportionment of NAEI sources of $PM_{10}$ and road transport, in Oxford Inner City.

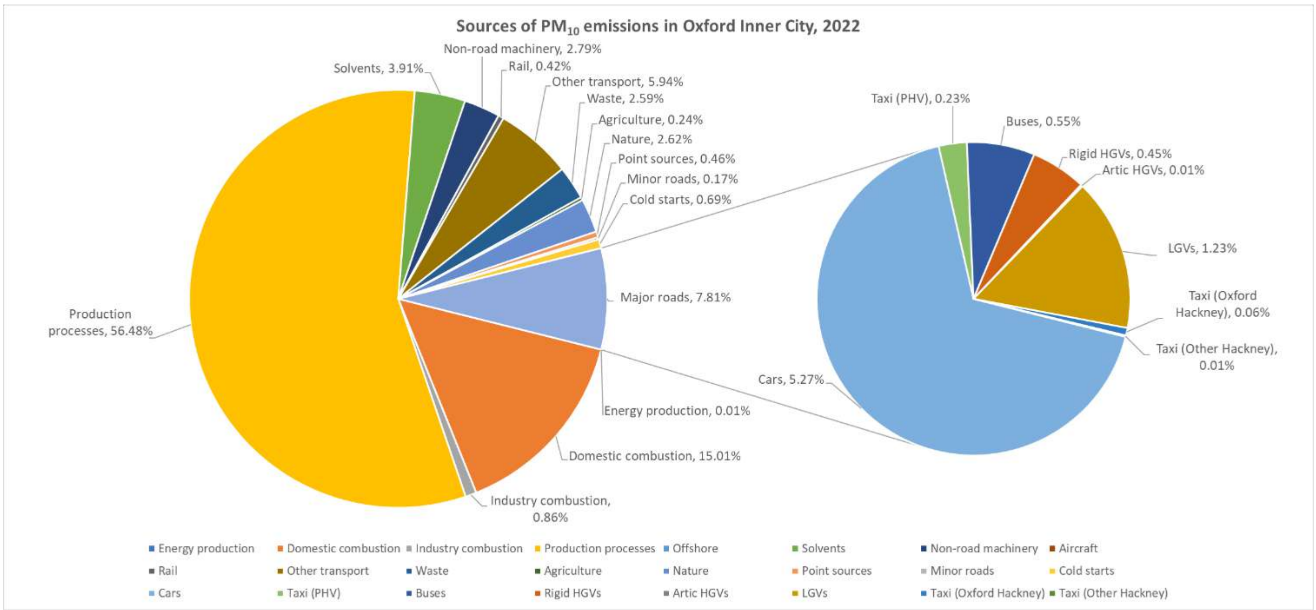


Figure 5-8 Source apportionment of NAEI sources of $PM_{2.5}$ and road transport, in Oxford Inner City.

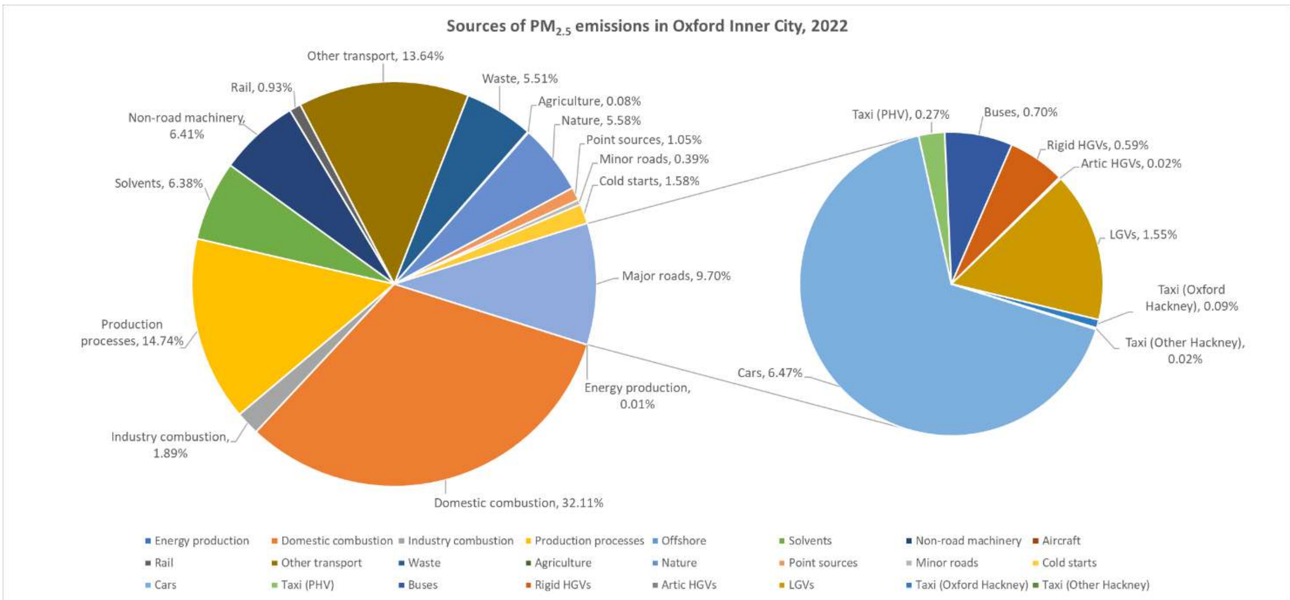
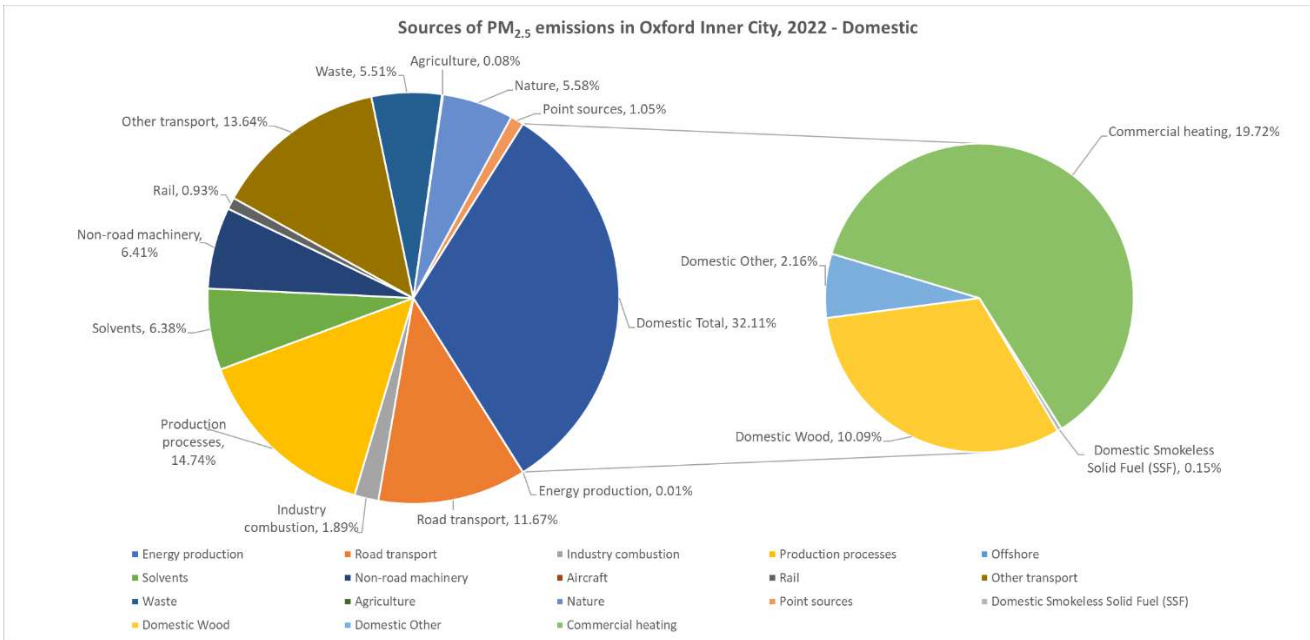



Figure 5-9 Source apportionment of NAEI sources of $PM_{2.5}$ including domestic combustion breakdown, in Oxford Inner City



# 6. REQUIRED REDUCTION IN EMISSIONS

## 6.1 REQUIRED REDUCTIONS USING 2022 MONITORING DATA

The 2022 annual mean monitoring data is the latest available year which is not impacted by the Botley Road closure. Table 6-1 presents a list of monitoring sites which are in exceedance of the national AQO for annual mean $NO_2$ (40 µg/m$^3$) in 2022, and the required reduction in road emissions that would be needed to achieve compliance. Table 6-2 represents a list of monitoring sites which are in exceedance of the OCC local annual mean $NO_2$ target (30 µg/m$^3$ to be achieved by 2025,) in 2022, and the required reductions in emissions to achieve the target.

Both the AQO for annual mean $NO_2$, and OCC's target for annual mean $NO_2$, are only applicable to locations of relevant human exposure. Therefore, diffusion tubes which are not at locations of relevant human exposure are not included in this analysis. Table 6-2 shows that there was only one measured exceedance of the annual mean $NO_2$ AQO in 2022, at DT55 St Clements. An 11% reduction in road $NO_X$ emissions would be required to achieve compliance with the annual mean $NO_2$ AQO at DT55 in St Clements/ The Plain. Table 6-2 shows that the largest required reduction in road $NO_X$ emissions to achieve OCC's annual mean $NO_2$ target is 44% at DT55 in St Clements/ The Plain.

Table 6-1 $NO_2$ concentrations measured within The City of Oxford AQMA and the required $NO_X$ emissions from road traffic required to achieve the local annual mean $NO_2$ target of 40 µg/m$^3$.

| Code | Location | $NO_2$ measured in 2022 (µg/m$^3$) | $NO_X$ background (µg/m$^3$) | Roadside $NO_X$ from $NO_2$ calculator (µg/m$^3$) | Road $NO_X$ to achieve compliance with the AQO, (µg/m$^3$) | Road $NO_X$ reduction required, (µg/m$^3$) | Road $NO_X$ reduction required, % |
|---|---|---|---|---|---|---|---|
| DT55 | St Clements | 43 | 15.5 | 66.39 | 59.35 | 7.0 | 11% |

Table 6-2 $NO_2$ concentrations measured in 2022 within The City of Oxford AQMA and the required $NO_X$ emissions from road traffic required to achieve the local annual mean $NO_2$ target of 30 µg/m$^3$.

| Code | Location | $NO_2$ measured in 2022 (µg/m$^3$) | $NO_X$ background (µg/m$^3$) | Roadside $NO_X$ from $NO_2$ calculator (µg/m$^3$) | Road $NO_X$ to achieve compliance with OCC target, (µg/m$^3$) | Road $NO_X$ reduction required, (µg/m$^3$) | Road $NO_X$ reduction required, % |
|---|---|---|---|---|---|---|---|
| CM1 | AURN Oxford Centre | 33 | 19.4 | 39.4 | 33 | 6.4 | 16% |
| DT26 | Cuttleslowe 3 Summers Place | 32 | 12.5 | 44.7 | 40.4 | 4.3 | 10% |
| DT39 | St Aldate's | 33 | 17.1 | 41.8 | 35.4 | 6.4 | 15% |
| DT45 | Worcester St. | 31 | 19.0 | 35.6 | 33.5 | 2.1 | 6% |
| DT51 | 50 High St. | 31 | 16.1 | 38.7 | 36.6 | 2.1 | 5% |
| DT52 | Longwall St. | 32 | 15.9 | 41.1 | 36.8 | 4.3 | 10% |
| DT55 | St Clements | 43 | 15.5 | 66.4 | 37.2 | 29.2 | 44% |
| DT56 | High St | 35 | 16.9 | 46.5 | 35.7 | 10.8 | 23% |
| DT77 | St Clements 2 | 35 | 15.4 | 48.1 | 37.3 | 10.8 | 22% |
| DT80 | Holloway Road | 34 | 17.0 | 44.2 | 35.6 | 8.6 | 19% |

## 6.2 REQUIRED REDUCTIONS USING 2023 MONITORING DATA

Although the Botley Road closures will have impacted some of the monitoring results in 2023, it is likely that it will not have impacted all locations in the AQMA.

A table of required reductions in emissions to achieve compliance with the national AQO for $NO_2$ is not needed in this assessment against 2023 data, because in 2023 there were no exceedances to the AQO in all the areas of the city considered of relevant exposure.

Table 6-3 presents a list of monitoring sites which were in exceedance of the OCC local annual mean $NO_2$ target of 30 µg/m$^3$ in 2023, and the required reduction in emissions to achieve compliance with the target. This assessment has been carried out using the latest available 2023 monitoring data is presented in, applying $NO_X$ background contributions from the 2022 baseline. The largest required reduction of road $NO_X$ emissions is 32% at DT55 in St Clements/ The Plain.

Table 6-3 $NO_2$ concentrations measured in 2023 within The City of Oxford AQMA and the required $NO_X$ emissions from road traffic required to achieve the local annual mean $NO_2$ target of 30 µg/m$^3$.

| Code | Location | $NO_2$ measured in 2023 (µg/m$^3$) | $NO_x$ background in 2022 (µg/m$^3$) | Roadside $NO_x$ from $NO_2$ calculator (µg/m$^3$) | Road $NO_x$ to achieve compliance, (µg/m$^3$) | Road $NO_x$ reduction required, (µg/m$^3$) | Road $NO_x$ reduction required, % |
|---|---|---|---|---|---|---|---|
| CM1 | AURN Oxford Centre | 31 | 19.4 | 35.1 | 33.0 | 2.1 | 6% |
| DT39 | St Aldate's | 32 | 17.1 | 39.7 | 35.4 | 4.3 | 11% |
| DT55 | St Clements | 38 | 15.5 | 54.8 | 37.2 | 17.5 | 32% |
| DT56 | High Street | 31 | 16.9 | 37.8 | 35.7 | 2.1 | 6% |
| DT77 | St Clements 2 | 34 | 15.4 | 45.9 | 37.3 | 8.6 | 19% |
| DT80 | Holloway Road | 31 | 17.0 | 37.7 | 35.6 | 2.1 | 6% |

Monitoring data for 2024 is expected to show further reductions in $NO_2$ concentrations across Oxford, reflecting the positive impacts of the ZEBRA scheme, and achieving further reductions of $NO_X$ levels in all of the monitoring locations in Table 6-3.

# 7. CONCLUSIONS

In 2022, there was only one location of relevant human exposure which was in exceedance of the annual mean $NO_2$ AQO in Oxford – diffusion tube location DT55. An 11% reduction in road $NO_X$ emissions would be required to achieve compliance with the AQO at this location. In their AQAP, OCC have established a local annual mean $NO_2$ target of 30 µg/m$^3$ to be achieved by 2025. The largest required reduction in emissions to achieve compliance with OCC's local annual mean $NO_2$ target at any one site of relevant human exposure is 44%.

In 2023 the Oxford LAQM monitoring network showed compliance with all air quality objectives (AQOs) for $NO_2$, $PM_{10}$ and $PM_{2.5}$, for the first time[27] since declaration of the first Oxford AQMAs. However, these results may be impacted by the Botley Road closure and so may not be representative of normal conditions. Based on the 2023 monitoring results, the largest required reduction in emissions to achieve compliance with the OCC local annual mean $NO_2$ target at any one site of relevant human exposure is 32% (DT55). This figure is expected to reduce when 2024 monitoring data is published, reflecting the impact of the roll-out of ZEBRA buses in 2024 on concentrations.

Detailed source apportionment has been carried out at three hotspot locations (road transport source apportionment presented in Section 4, and background source apportionment for these locations available in Appendix 3).These locations were determined by a detailed review as part of the 2020 source apportionment study. The same locations have been selected again for this study, because:

1. These locations continue to be hotspot areas, and therefore up to date knowledge of sources is needed to aid action planning for remaining areas of elevated concentrations.

2. It is useful to assess how impacts from different sources have changed over time at these locations.

These locations, and the diffusion tube most representative of the location are as follows:

- St Clement's / The Plain (relevant diffusion tubes DT55 and TF19)
- Worcester Street (relevant diffusion tube DT45)
- Botley Road (relevant diffusion tube DT35)

The results of the source apportionment study were presented in terms of percentage contribution to modelled road emissions, as well as modelled concentrations of $NO_X$, $NO_2$ $PM_{10}$ and $PM_{2.5}$, and measured $NO_2$ concentrations at relevant diffusion tubes in 2022. The source apportionment results presented have incorporated the ZEBRA buses which were introduced to the Oxford fleet in January 2025, and assumes that 69% of buses in the fleet are fully electric buses.

The **key trends observed** across all three locations are:

- Cars have the greatest contributions to $NO_X$, $PM_{10}$ and $PM_{2.5}$ emissions at all locations.
- Diesel cars contribute a higher proportion of $NO_X$ emissions than petrol cars at all locations.
- $PM_{10}$ and $PM_{2.5}$ emissions have fairly equal contributions from petrol and diesel cars, with slightly higher contributions from petrol.
- LGVs are the next greatest contributors, followed by HGVs, at all locations.
- Rigid HGVs contributed significantly more $NO_X$, $PM_{10}$ and $PM_{2.5}$ emissions than articulated HGVs.
- Private hire vehicle (PHV) taxis contributed more to emissions from taxis than Oxford or other Hackney Carriage vehicles.
- Diesel taxis (both PHVs and HCVs) contributed to more emissions than petrol taxis.
- For $PM_{10}$ and $PM_{2.5}$ the background concentrations are considerably more than the road contribution. This is not the case for $NO_X$.

[27] In 2020, compliance was achieved at all of the monitoring sites, but this was due to the effect of COVID related restrictions reducing traffic in the city.

Along **St Clement's Street / The Plain,** at diffusion tube DT55, emissions are dominated by cars, accounting for approximately 60% of $NO_x$ road emissions (51% of which are attributed to diesel cars), and approximately 74% of $PM_{10}$ and $PM_{2.5}$ road emissions (37 – 39% from petrol cars, 31 – 33% from diesel). These are slightly higher than the results for Worcester Street and Botley Road for the ZEBRA scenario, which is to be expected, as a reduced contribution from buses to emissions will result in an increased contribution from other vehicle types. LGVs are now the next-largest contributor (where previously in the baseline scenario it was buses) at 17% for $NO_X$ road emissions, and 11% for $PM_{10}$ and $PM_{2.5}$ road emissions. This is followed by rigid HGVs being the next greatest source for $NO_X$ road emissions (11%) and buses being the next greatest source for $PM_{10}$ and $PM_{2.5}$ road emissions (6%). Buses now account for 10% of $NO_X$ road emissions and 6% of road emissions for $PM_{10}$ and $PM_{2.5}$. St Clements / The Plain shows the greatest impact of the ZEBRA bus scheme at any of the assessed locations, with a reduction of 5.82 $\mu g/m^3$ in $NO_2$ concentrations as a result of a 14% reduction in $NO_X$ road emissions. Total modelled $PM_{10}$ concentrations are reduced by 4% and $PM_{2.5}$ by 3% compared to the baseline.

On **Worcester Street**, at diffusion tube DT45, road emissions are also dominated by cars, accounting for 50% of the $NO_X$, 68% of the $PM_{10}$, and 67% of $PM_{2.5}$ road emissions. Diesel cars account for 42% of the total 50% of $NO_X$ road emissions from cars, and for $PM_{10}$ and $PM_{2.5}$, 33 - 36% of road emissions were from petrol cars and 28 – 30% were from diesel cars. The next greatest contributing vehicle type to road emissions on Worcester Street is LGVs comprising 29% of $NO_X$ road emissions, and 21% of $PM_{10}$ and $PM_{2.5}$ emissions, followed by HGVs, comprising 18% of $NO_X$ road emissions, and 7% and 8% of $PM_{10}$ and $PM_{2.5}$ road emissions respectively. Worcester Street shows the least improvement of all three locations as a result of the ZEBRA buses being introduced, which is to be expected given the low contribution of buses to emissions in the baseline scenario. The ZEBRA scheme reduces total $NO_2$ concentrations by 2%, and $PM_{10}$ and $PM_{2.5}$ concentrations by 1% compared to the baseline..

On **Botley Road** at diffusion tube DT35, cars account for 53% of road $NO_X$ emissions, 29% of $PM_{10}$ road emissions and 30% of $PM_{2.5}$ road emissions. These contributions are slightly higher in the ZEBRA scenario than the baseline, and the results are similar to St Clements/ The Plain DT55 and Worcester Street. For $NO_X$ road emissions at Worcester Street, diesel cars accounted for 44% of the total 53% of $NO_X$ road emissions from cars. For $PM_{10}$ and $PM_{2.5}$, 34 - 37% of road emissions were from petrol cars and 29 – 30% were from diesel cars. The next greatest contributing vehicle type to emissions on Worcester Street were LGVs comprising 27% of $NO_X$ road emissions, and 18% of $PM_{10}$ and $PM_{2.5}$ road emissions, followed by HGVs comprising 13% of $NO_X$ road emissions, and 7% of $PM_{10}$ and $PM_{2.5}$ road emissions. At Botley Road, the ZEBRA scheme reduces total $NO_2$ concentrations by 8%, and $PM_{10}$ and $PM_{2.5}$ concentrations by 1% compared to the baseline.

Source apportionment was also carried out for all emissions types, using the 2022 NAEI emissions data[28]. This was carried out both for the whole Oxford Administrative Area, and for the Inner City. Source apportionment of emissions at this scale gives important insight into the most significant sources of pollutant across Oxford and Oxford Inner City.

Across the whole **Administrative Area of Oxford**, $NO_X$ emissions are dominated by combined road transport sources (32% total of major roads, minor roads and cold starts), domestic combustion (26%) and point sources (20%). $PM_{10}$ emissions are dominated by production processes (45%), and $PM_{2.5}$ emissions are dominated by domestic combustion (35%) and combined road transport sources (17%).

In the **Inner City**, $NO_X$ emissions are dominated by domestic combustion (49%), $PM_{10}$ emissions are dominated by production processes (56%), and $PM_{2.5}$ emissions are dominated by domestic combustion (32%), production processes (15%), other transport (including inland waterways and military aircraft) (14%), and combined road transport sources (12%).

[28] NAEI UK Emissions Interactive Map. Available online: https://naei.energysecurity.gov.uk/emissionsapp/

# APPENDIX 1. AIR DISPERSION MODEL VERIFICATION AND ADJUSTMENT

Verification of the model involves comparison of the modelled results with any local monitoring data at relevant locations. This helps to identify how the model is performing and the appropriate model adjustments that should be applied. The verification process involves checking and refining the model input data to try and reduce uncertainties and produce model outputs that are in better agreement with the monitoring results. This can be followed by adjustment of the modelled results if required. The LAQM.TG(22) guidance recommends making the adjustment to the road contribution of the pollutant only and not the background concentration these are combined with.

The approach outlined in LAQM.TG (22) section 7.55 – 7.578 (also in Box 7.17 and 7.18) has been used in this case. To verify the model, the modelled annual mean road $NO_X$ concentrations (summated to background $NO_X$ concentrations) were compared with concentrations measured at the various monitoring sites for the year 2022.

The model output of road $NO_X$ (the total $NO_X$ originating from road traffic) was compared with measured road $NO_X$, where the measured road $NO_X$ contribution is calculated as the difference between the total measured $NO_X$ and the background $NO_X$ value sampled at each site. Total measured $NO_X$ for each monitoring site was calculated from the measured $NO_2$ concentration using Version 8.1 of the Defra $NO_X/NO_2$ calculator available from the LAQM website[29]. Background $NO_X$ values for 2022 were obtained from the 2018 reference year background maps available on the LAQM website.

The gradient of the best-fit line for the modelled road $NO_X$ contribution compared with measured road $NO_X$ contribution was then determined using linear regression and used as a global/domain wide road $NO_X$ adjustment factor. This factor was then applied to the modelled road $NO_X$ concentration at each individual modelled receptor point to provide adjusted modelled road $NO_X$ concentrations. A linear regression plot comparing modelled and monitored road $NO_X$ concentrations before and after adjustment was produced. A primary $NO_X$ adjustment factor of **2.3994** based on model verification using all of the included 2022 $NO_2$ measurements was applied to all modelled road $NO_X$ data prior to calculating an $NO_2$ annual mean.

Following this, four sites were removed from the validation. One site was removed due to being a significant outlier: TF19 (previously discussed in section 3.1 of this report), and three sites were removed due to modelled road $NO_X$ contribution being below zero: LT2, LT11 and TF1.

Following their removal, an updated Road NOx adjustment factor of **2.3366** was applied to the modelled road $NO_X$ concentration at each individual modelled receptor point to provide adjusted modelled road $NO_X$ concentrations, and a new linear regression plot comparing modelled and monitored road $NO_X$ concentrations before and after adjustment was produced.

The total annual mean $NO_2$ concentrations were then determined at points within the model domain using the $NOx/NO_2$ calculator to combine background and adjusted road contribution concentrations. For this step of the process, regional concentrations of ozone, oxides of nitrogen ($NO_X$) and nitrogen dioxide ($NO_2$) were set to those of the local authority where the calibration point was located. The following relationship was determined for conversion of total $NO_X$ concentrations to total $NO_2$ concentrations:

$$\mathbf{(NO_2 \text{ in } \mu g/m^3) = -\ 0.0011\ (NOx \text{ in } \mu g/m^3)^{2} + 0.5825\ (NOx \text{ in } \mu g/m^3) + 3.0955}$$

To evaluate the model performance and uncertainty, the Root Mean Square Error (RMSE) for the observed vs predicted $NO_2$ annual mean concentrations was calculated, as detailed in Technical Guidance LAQM.TG (22). The calculated RMSE is presented in Table A1-1. In this case the RMSE was calculated at **4.0491** $\mu g/m^3$.

[29] DEFRA NOx to NO2 Calculator Available online: https://laqm.defra.gov.uk/air-quality/air-quality-assessment/nox-to-no2-calculator/

Table A-1-1 Modelled and measured $NO_2$ concentrations for 2022 (baseline model) and calculated RMSE value

| Site ID | Location | Measured $NO_2$ 2022 (µg/m$^3$) | Total Modelled $NO_2$ (µg/m$^3$) | Difference (µg/m$^3$) |
|---|---|---|---|---|
| DT2 | Weirs Lne./Abingdon Rd. LP1 | 21.2 | 24.4 | 3.2 |
| DT3 | LP 52 Abingdon Rd. | 27.2 | 25.1 | -2.2 |
| DT4 | Boundary Brook Rd/ Iffley Rd | 27.1 | 24.3 | -2.8 |
| DT7 | Oxford Rd/ Between Towns Rd | 29.8 | 23.3 | -6.5 |
| DT8 | Oxford Rd(Cowley) LP13 | 28.8 | 25.6 | -3.2 |
| DT14 | Windmill Rd. W | 28.5 | 20.1 | -8.4 |
| DT15 | London Rd./BHF | 17.8 | 31.2 | 13.4 |
| DT16 | Headley Way/London Rd. LP2 | 20.6 | 23.3 | 2.7 |
| DT18 | The Roundway | 22.7 | 19.9 | -2.8 |
| DT20 | Barton Lane LP2 | 20.0 | 19.8 | -0.2 |
| DT25 | Cuttleslowe Rbout 3 Elsfield Rd. | 25.0 | 27.3 | 2.3 |
| DT26 | Cuttleslowe 3 Summers Place | 32.1 | 33.8 | 1.7 |
| DT27 | Wolvercote 78 Sunderland Ave. | 20.2 | 22.5 | 2.2 |
| DT28 | Wolvercote 51 Sunderland Ave | 20.0 | 22.8 | 2.9 |
| DT29 | Pear Tree P&R N Gateway | 20.7 | 16.8 | -3.9 |
| DT30 | Osney Lne/Hollybush Row | 19.9 | 22.4 | 2.4 |
| DT31 | Beckett St. | 22.9 | 25.2 | 2.3 |
| DT32 | Royal Oxford Hotel | 24.8 | 23.3 | -1.5 |
| DT33 | Botley RD/ Mill St | 18.0 | 22.3 | 4.3 |
| DT35 | Botley Rd /Hillview Rd | 23.7 | 26.6 | 2.9 |
| DT36 | Botley Rd N (Prestwich Place) | 16.0 | 20.3 | 4.4 |
| DT39 | St Aldate's | 32.9 | 29.6 | -3.3 |
| DT40 | Queen St. | 21.7 | 17.9 | -3.7 |
| DT41 | Bonn Square | 21.5 | 17.8 | -3.7 |
| DT42 | New Rd. | 29.0 | 19.4 | -9.6 |
| DT43 | Park End St. | 26.6 | 22.7 | -3.8 |
| DT44 | Hythe Bridge St. | 22.6 | 22.7 | 0.1 |
| DT45 | Worcester St. | 30.8 | 36.8 | 6.0 |
| DT46 | Beaumont St. | 21.5 | 32.4 | 10.9 |
| DT47 | George St. / Magdalen St. | 22.7 | 20.7 | -2.0 |
| DT48 | George St. | 24.3 | 22.7 | -1.6 |
| DT49 | Cornmarket St. | 18.3 | 15.3 | -3.0 |
| DT50 | High St. / Turl St. | 23.3 | 18.7 | -4.7 |
| DT51 | 50 High St. | 31.4 | 36.6 | 5.2 |
| DT52 | Longwall St. | 31.8 | 34.3 | 2.5 |
| DT53 | Magdalen Bridge | 17.3 | 25.9 | 8.6 |
| DT54 | York Place | 18.9 | 20.8 | 1.9 |
| DT55 | St Clements | 43.1 | 44.7 | 1.6 |
| DT56 | High St. | 34.9 | 33.7 | -1.2 |
| DT57 | Speedwell St. / St. Aldate's | 29.2 | 35.4 | 6.2 |

| Site ID | Location | Measured $NO_2$ 2022 (µg/m³) | Total Modelled $NO_2$ (µg/m³) | Difference (µg/m³) |
|---|---|---|---|---|
| DT58 | Folly Bridge | 23.1 | 24.1 | 1.0 |
| DT59 | Thames St. | 19.5 | 21.0 | 1.4 |
| DT60 | New Butterwyke P./ Thames St. | 22.7 | 20.3 | -2.4 |
| DT61 | Friars Wharf | 14.0 | 21.0 | 7.0 |
| DT64 | Thames St. / Oxpens Rd. | 15.8 | 23.1 | 7.3 |
| DT65 | Speedwell St. / Littlegate | 22.3 | 20.5 | -1.8 |
| DT68 | Norfolk St. | 21.7 | 16.2 | -5.5 |
| DT69 | Paradise Square | 18.2 | 14.9 | -3.3 |
| DT70 | Castle St. | 21.5 | 16.8 | -4.8 |
| DT71 | BP City Motors | 26.7 | 30.3 | 3.6 |
| DT72 | Cowley Rd./ James Street | 26.6 | 28.4 | 1.9 |
| DT73 | Walton Street LP18 | 18.1 | 18.6 | 0.4 |
| DT76 | St Gilles | 21.7 | 20.4 | -1.3 |
| DT77 | St Clements 2 | 34.8 | 40.4 | 5.6 |
| DT79 | Old Abingdon Rd. | 18.2 | 17.7 | -0.5 |
| DT80 | Hollow way Road | 33.8 | 22.9 | -10.9 |
| DT81 | Cowley Rd/ Union Street | 18.6 | 24.7 | 6.1 |
| DT82 | Summertown Parade | 17.2 | 16.2 | -1.1 |
| DT83 | A44 Woodstock Rd. | 30.1 | 34.2 | 4.1 |
| DT84 | 226 Botley Rd. | 18.2 | 25.6 | 7.3 |
| DT85 | St Clements 3 | 30.4 | 36.9 | 6.5 |
| DT86 | 72 Blackbird Leys | 16.4 | 14.1 | -2.3 |
| DT87 | New Inn Hall St | 15.3 | 15.2 | -0.1 |
| DT88 | St Michaels St | 14.2 | 15.9 | 1.7 |
| DT89 | Turl St/Market St | 14.5 | 14.9 | 0.4 |
| DT90 | Rose Hill (Ashhurst Way) | 18.5 | 14.9 | -3.6 |
| DT91 | Garsington Rd (Premier Place) | 27.7 | 28.3 | 0.6 |
| DT92 | BB Leys (Cuddesdon Way) | 15.6 | 14.9 | -0.7 |
| DT93 | Marston Ferry Rd | 12.7 | 17.6 | 4.8 |
| DT94 | Broad St LP6 | 14.4 | 15.5 | 1.0 |
| DT95 | Broad S -Lbay | 14.2 | 15.0 | 0.8 |
| LT1 | 26 Prince St | 13.0 | 13.9 | 0.8 |
| LT3 | 47 Quarry Rd | 12.9 | 14.0 | 1.1 |
| LT4 | 138-146 Morrell Av | 13.2 | 16.1 | 2.9 |
| LT5 | 189 Divinity Rd | 12.4 | 12.4 | 0.0 |
| LT7 | 126 The slade | 21.9 | 20.5 | -1.4 |
| LT9 | 4 Quarry school | 12.8 | 15.1 | 2.3 |
| LT10 | 23 Gladstone Rd | 11.8 | 13.7 | 1.9 |
| LT12 | Ruskin Hall | 16.4 | 15.9 | -0.5 |
| LT13 | 21 Latimer Rd | 12.4 | 13.8 | 1.3 |
| LT14 | 94 Howard St | 12.6 | 12.3 | -0.3 |
| LT15 | 96 Valentia Rd | 12.1 | 12.9 | 0.8 |
| LT16 | 103-139 Hurst St | 13.2 | 12.5 | -0.8 |

| Site ID | Location | Measured $NO_2$ 2022 (µg/m³) | Total Modelled $NO_2$ (µg/m³) | Difference (µg/m³) |
|---|---|---|---|---|
| TF2 | Oxey Mead Lake 2 | 12.9 | 18.0 | 5.2 |
| TF3 | Oxey Mead Lake 3 | 25.4 | 25.1 | -0.3 |
| TF4 | Wolvercote Village | 12.4 | 13.6 | 1.2 |
| TF5 | Wolvercote Primary School | 14.2 | 14.6 | 0.4 |
| TF6 | 306 Woodstock Road | 15.1 | 20.1 | 5.0 |
| TF7 | 339 Banbury Road | 23.4 | 18.9 | -4.5 |
| TF8 | 191 Woodstock Road | 19.7 | 20.5 | 0.8 |
| TF9 | 48 Woodstock Road | 20.5 | 20.2 | -0.3 |
| TF10 | 99 Banbury Road | 19.4 | 16.9 | -2.5 |
| TF11 | 9 S. Park Road | 17.1 | 20.0 | 2.9 |
| TF12 | 15 Banbury Road | 16.8 | 20.8 | 4.0 |
| TF13 | Walton Street 76 | 19.9 | 18.3 | -1.6 |
| TF14 | 69 Kingston Road | 14.7 | 16.6 | 1.9 |
| TF15 | Park End Street | 35.6 | 27.7 | -7.9 |
| TF16 | St Aldates 61 | 27.9 | 27.0 | -0.9 |
| TF17 | 23 Iffley Rd/Stanley Rd | 25.7 | 25.0 | -0.7 |
| TF18 | 143 Morrell Avenue | 16.0 | 16.1 | 0.1 |
| TF20 | Marston Rd/St Michaels Primary | 16.2 | 15.7 | -0.5 |
| TF21 | 189 Headley Way | 21.7 | 15.3 | -6.5 |
| TF22 | 255 London Rd/Gladstone Rd | 25.0 | 20.5 | -4.5 |
| TF23 | JR Hospital | 22.4 | 14.0 | -8.4 |
| TF24 | Marston Ferry Rd/Cherwell Drive | 15.6 | 16.5 | 0.9 |
| TF25 | 39 Marsh Lane | 17.4 | 22.0 | 4.5 |
| TF26 | Northway/Cutteslowe Park | 23.0 | 24.4 | 1.4 |
| TF27 | Northern Bypass/Phillips Tyres | 41.8 | 26.1 | -15.7 |
| TF28 | Horspath Driftway/Agwar Stone Rd | 21.7 | 26.4 | 4.7 |
| TF29 | 109 Old Road | 14.7 | 15.7 | 1.0 |
| TF30 | 99 Oliver Road | 34.5 | 30.0 | -4.4 |
| TF31 | Brasenose Farm/Eastern Bypass | 42.8 | 35.5 | -7.3 |
| TF32 | 22 Garsington Road | 20.2 | 24.9 | 4.7 |
| TF33 | 119 Barns Road | 17.5 | 18.2 | 0.7 |
| TF34 | Oxford Road/Newmans Road | 34.9 | 24.4 | -10.4 |
| TF35 | 67 Southern Bypass Road | 56.5 | 34.7 | -21.8 |
| TF36 | Wolvercote Meadows 1 | 35.7 | 37.2 | 1.5 |
| TF37 | Wolvercote Meadows 2 | 42.1 | 42.8 | 0.7 |
| | | | **RMSE (all sites in this table)** | **4.0491** |

# APPENDIX 2. TAXI EMISSIONS BY FUEL TYPE

These tables provide a breakdown of taxi emissions as a percent of the total contribution from taxis to emissions. As a result of the total contributions from taxis being so small, the proportions by taxi type and fuel type remain largely unchanged between the baseline model and the ZEBRA scenario model, and also are relatively unchanged between the three source apportionment locations.

Table A-2-1 Breakdown of 2022 baseline and ZEBRA modelled taxi emissions at diffusion tube DT55 in St Clement's / The Plain, by taxi type and fuel type.

| DT55 | Private Hire Vehicles (PHVs) | | | | | | | Oxford Hackney Carriages (HCVs) | | | | | Other Hackney Carriages (HCVs) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total PHVs (of Total Taxi Fleet) | Petrol Car | Diesel Car | Petrol Hybrid Car | Petrol Plugin Hybrid Car | Diesel Hybrid Car | Electric Car | Total Oxford HCVs (of Total Taxi Fleet) | Petrol Taxis | Petrol Hybrid Taxis | Diesel Taxis | Electric Taxi | Total Other HCVs (of Total Taxi Fleet) | Petrol Taxis | Petrol Hybrid Taxis | Diesel Taxis | Electric Taxi |
| *Baseline* | | | | | | | | | | | | | | | | | |
| **$NO_X$** | 48% | 1% | 46% | 1% | 0% | 0% | 0% | 45% | 0% | 0% | 45% | 0% | 7% | 0% | 0% | 7% | 0% |
| **$PM_{10}$** | 76% | 2% | 66% | 5% | 2% | 0% | 1% | 21% | 0% | 5% | 16% | 0% | 4% | 0% | 1% | 3% | 0% |
| **$PM_{2.5}$** | 72% | 2% | 62% | 5% | 2% | 0% | 1% | 24% | 0% | 5% | 19% | 0% | 4% | 0% | 1% | 4% | 0% |
| *ZEBRA model* | | | | | | | | | | | | | | | | | |
| **$NO_X$** | 48% | 1% | 46% | 1% | 0% | 0% | 0% | 45% | 0% | 0% | 45% | 0% | 7% | 0% | 0% | 7% | 0% |
| **$PM_{10}$** | 76% | 2% | 66% | 5% | 2% | 0% | 1% | 21% | 0% | 5% | 16% | 0% | 4% | 0% | 1% | 3% | 0% |
| **$PM_{2.5}$** | 72% | 2% | 62% | 5% | 2% | 0% | 1% | 24% | 0% | 5% | 19% | 0% | 4% | 0% | 1% | 4% | 0% |

Table A-2-2 Breakdown of 2022 baseline and ZEBRA modelled taxi emissions at diffusion tube DT45 on Worcester Street, by taxi type and fuel type.

| DT45 | Private Hire Vehicles (PHVs) | | | | | | | Oxford Hackney Carriages (HCVs) | | | | | Other Hackney Carriages (HCVs) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total PHVs (of Total Taxi Fleet) | Petrol Car | Diesel Car | Petrol Hybrid Car | Petrol Plugin Hybrid Car | Diesel Hybrid Car | Electric Car | Total Oxford HCVs (of Total Taxi Fleet) | Petrol Taxis | Petrol Hybrid Taxis | Diesel Taxis | Electric Taxi | Total Other HCVs (of Total Taxi Fleet) | Petrol Taxis | Petrol Hybrid Taxis | Diesel Taxis | Electric Taxi |
| *Baseline* | | | | | | | | | | | | | | | | | |
| **NOx** | 48% | 1% | 46% | 1% | 0% | 0% | 0% | 45% | 0% | 0% | 45% | 0% | 7% | 0% | 0% | 7% | 0% |
| **$PM_{10}$** | 75% | 2% | 65% | 5% | 2% | 0% | 1% | 21% | 0% | 5% | 16% | 0% | 4% | 0% | 1% | 3% | 0% |
| **$PM_{2.5}$** | 71% | 2% | 62% | 5% | 2% | 0% | 1% | 24% | 0% | 5% | 20% | 0% | 4% | 0% | 1% | 4% | 0% |
| *ZEBRA model* | | | | | | | | | | | | | | | | | |
| **NOx** | 48% | 1% | 46% | 1% | 0% | 0% | 0% | 45% | 0% | 0% | 45% | 0% | 7% | 0% | 0% | 7% | 0% |
| **$PM_{10}$** | 75% | 2% | 65% | 5% | 2% | 0% | 1% | 21% | 0% | 5% | 16% | 0% | 4% | 0% | 1% | 3% | 0% |
| **$PM_{2.5}$** | 71% | 2% | 62% | 5% | 2% | 0% | 1% | 24% | 0% | 5% | 20% | 0% | 4% | 0% | 1% | 4% | 0% |

Table A-2-3 Breakdown of 2022 baseline and ZEBRA modelled taxi emissions at diffusion tube DT35 on Botley Road (DT35), by taxi type and fuel type.

| DT35 | Private Hire Vehicles (PHVs) | | | | | | | Oxford Hackney Carriages (HCVs) | | | | | Other Hackney Carriages (HCVs) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total PHVs (of Total Taxi Fleet) | Petrol Car | Diesel Car | Petrol Hybrid Car | Petrol Plugin Hybrid Car | Diesel Hybrid Car | Electric Car | Total Oxford HCVs (of Total Taxi Fleet) | Petrol Taxis | Petrol Hybrid Taxis | Diesel Taxis | Electric Taxi | Total Other HCVs (of Total Taxi Fleet) | Petrol Taxis | Petrol Hybrid Taxis | Diesel Taxis | Electric Taxi |
| *Baseline* | | | | | | | | | | | | | | | | | |
| **$NO_x$** | 48% | 1% | 46% | 1% | 0% | 0% | 0% | 45% | 0% | 0% | 45% | 0% | 7% | 0% | 0% | 7% | 0% |
| **$PM_{10}$** | 76% | 2% | 66% | 5% | 2% | 0% | 1% | 21% | 0% | 5% | 16% | 0% | 4% | 0% | 1% | 3% | 0% |
| **$PM_{2.5}$** | 72% | 2% | 62% | 5% | 2% | 0% | 1% | 24% | 0% | 5% | 19% | 0% | 4% | 0% | 1% | 4% | 0% |
| *ZEBRA model* | | | | | | | | | | | | | | | | | |
| **$NO_x$** | 47% | 1% | 45% | 1% | 0% | 0% | 0% | 46% | 0% | 0% | 46% | 0% | 7% | 0% | 0% | 7% | 0% |
| **$PM_{10}$** | 76% | 2% | 66% | 5% | 2% | 0% | 1% | 20% | 0% | 5% | 15% | 0% | 3% | 0% | 1% | 3% | 0% |
| **$PM_{2.5}$** | 73% | 2% | 63% | 5% | 2% | 0% | 1% | 23% | 0% | 5% | 18% | 0% | 4% | 0% | 1% | 3% | 0% |

# APPENDIX 3. BACKGROUND MAPS SOURCE APPORTIONMENT

The point sampled background concentrations at each of the study locations have been apportioned into the contributions from each source.

The Defra background maps[30] were downloaded at 1 km x 1 km resolution for baseline year 2022 for $NO_x$ as $NO_2$, $PM_{10}$ and $PM_{2.5}$, using the latest available reference year maps at the time of the assessment (which was reference year 2018 at the time of the assessment). RapidAIR interpolates these concentrations to a 1 m x 1 m grid to match the resolution of the modelled road contribution output. The background concentrations at the exact location of each diffusion tube have then been extracted, to provide the most accurate estimate of the background concentration at that site.

The 'Sources In' column therefore accounts for all pollution sources within the 1 km x 1 km grid square (as well as a number of other sources, see the note beneath each table) and the remaining background pollution comes from outside the 1 km x 1 km grid square the diffusion tube is located in.

Some sources are not included in the background concentrations; at the time of download their relative contributions were removed because they are already included in our road source modelling.

- For $NO_X$, these are: motorway, trunk, primary and minor roads.
- For $PM_{10}$ and $PM_{2.5}$ these are: motorway, trunk, and primary roads, tyre and brake wear, and road abrasion.

The remaining background sources / sectors not included in our road modelling have been apportioned in terms of percentage of the background concentration as well as the associated pollutant concentration in µg/m$^3$.

The definitions of each source / sector are provided in Table 5-1.

[30] DEFRA Background Mapping data for local authorities reference year 2018 https://uk-air.defra.gov.uk/data/laqm-background-maps?year=2018

Table A-3-1 Source apportionment of background $NO_X$ concentrations (%) at hotspots in 2022

| NOx (%) | Minor Road & Cold Start | | Industry | | Domestic | | Aircraft | | Rail | | Other | | Point Sources | Rural | Total In* | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | In | Out | In | Out | | | | |
| **DT55** | 3% | 5% | 0% | 4% | 7% | 12% | 0% | 0% | 2% | 8% | 9% | 9% | 3% | 38% | 20% | 100% |
| **TF19** | 7% | 5% | 0% | 4% | 12% | 12% | 0% | 0% | 0% | 7% | 1% | 9% | 3% | 40% | 20% | 100% |
| **DT45** | 2% | 4% | 0% | 4% | 7% | 8% | 0% | 0% | 13% | 5% | 11% | 8% | 2% | 36% | 33% | 100% |
| **DT35** | 2% | 5% | 0% | 6% | 3% | 10% | 0% | 0% | 0% | 7% | 1% | 11% | 3% | 53% | 6% | 100% |

*Total In includes all In sources as well as Point Sources and Rural

Table A-3-2 Source apportionment of background $NO_X$ concentrations ($\mu g/m^3$) at hotspots in 2022

| NOx ($\mu g/m^3$) | Minor Road & Cold Start | | Industry | | Domestic | | Aircraft | | Rail | | Other | | Point Sources | Rural | Total In* | Total BG NOx |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | In | Out | In | Out | | | | |
| **DT55** | 0.5 | 0.8 | 0.0 | 0.6 | 1.1 | 2.0 | 0.0 | 0.0 | 0.3 | 1.4 | 1.4 | 1.5 | 0.4 | 6.2 | 3.3 | 16.2 |
| **TF19** | 1.1 | 0.8 | 0.0 | 0.6 | 1.9 | 1.8 | 0.0 | 0.0 | 0.0 | 1.1 | 0.2 | 1.4 | 0.5 | 6.2 | 3.2 | 15.7 |
| **DT45** | 0.3 | 0.7 | 0.0 | 0.6 | 1.2 | 1.5 | 0.0 | 0.0 | 2.3 | 0.9 | 1.9 | 1.5 | 0.4 | 6.2 | 5.7 | 17.3 |
| **DT35** | 0.3 | 0.6 | 0.0 | 0.7 | 0.3 | 1.2 | 0.0 | 0.0 | 0.0 | 0.8 | 0.1 | 1.3 | 0.3 | 6.2 | 0.7 | 11.7 |

*Total In includes all In sources as well as Point Sources and Rural

Table A-3-3 Source apportionment of background $PM_{10}$ concentrations (%) at hotspots in 2022

| $PM_{10}$ (%) | Minor Road & Cold Start | | Industry | | Domestic | | Rail | | Other | | Secondary PM | Residual & Salt | Point Sources | Total In* | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | In | Out | | | | | |
| **DT55** | 0% | 0% | 1% | 3% | 3% | 5% | 0% | 0% | 1% | 1% | 46% | 39% | 0% | 5% | 100% |
| **TF19** | 0% | 0% | 2% | 3% | 7% | 6% | 0% | 0% | 0% | 1% | 44% | 36% | 0% | 9% | 100% |
| **DT45** | 0% | 0% | 0% | 3% | 1% | 5% | 1% | 0% | 1% | 1% | 47% | 41% | 0% | 3% | 100% |
| **DT35** | 0% | 0% | 0% | 3% | 1% | 4% | 0% | 0% | 0% | 1% | 44% | 47% | 0% | 1% | 100% |

*Total In includes all In sources as well as Secondary PM, Residual & Salt, and Point Sources

Table A-3-4 Source apportionment of background $PM_{10}$ concentrations (µg/m³) at hotspots in 2022

| $PM_{10}$ (µg/m³) | Minor Road & Cold Start | | Industry | | Domestic | | Rail | | Other | | Secondary PM | Residual & Salt | Point Sources | Total In* | Total BG $PM_{10}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | In | Out | | | | | |
| **DT55** | 0.0 | 0.0 | 0.2 | 0.5 | 0.4 | 0.8 | 0.0 | 0.0 | 0.1 | 0.1 | 6.6 | 5.6 | 0.1 | 0.7 | 14.3 |
| **TF19** | 0.0 | 0.0 | 0.3 | 0.5 | 1.0 | 0.9 | 0.0 | 0.0 | 0.0 | 0.1 | 6.6 | 5.3 | 0.1 | 1.3 | 14.8 |
| **DT45** | 0.0 | 0.0 | 0.1 | 0.4 | 0.1 | 0.7 | 0.1 | 0.0 | 0.1 | 0.1 | 6.6 | 5.7 | 0.0 | 0.4 | 13.9 |
| **DT35** | 0.0 | 0.0 | 0.0 | 0.4 | 0.2 | 0.6 | 0.0 | 0.0 | 0.0 | 0.1 | 6.6 | 6.9 | 0.0 | 0.2 | 14.9 |

*Total In includes all In sources as well as Secondary PM, Residual & Salt, and Point Sources

Table A-3-5 Source apportionment of background $PM_{2.5}$ concentrations (%) at hotspots in 2022

| $PM_{2.5}$ (%) | Minor Road & Cold Start | | Industry | | Domestic | | Rail | | Other | | Secondary PM | Residual & Salt | Point Sources | Total In* | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | In | Out | | | | | |
| **DT55** | 0% | 0% | 0% | 2% | 4% | 8% | 0% | 0% | 1% | 1% | 59% | 24% | 1% | 5% | 100% |
| **TF19** | 0% | 0% | 1% | 2% | 10% | 9% | 0% | 0% | 0% | 1% | 55% | 21% | 1% | 11% | 100% |
| **DT45** | 0% | 0% | 0% | 2% | 1% | 7% | 1% | 0% | 1% | 1% | 61% | 25% | 0% | 4% | 100% |
| **DT35** | 0% | 0% | 0% | 2% | 2% | 6% | 0% | 0% | 0% | 1% | 58% | 30% | 0% | 2% | 100% |

*Total In includes all In sources as well as Secondary PM, Residual & Salt, and Point Sources

Table A-3-6 Source apportionment of background $PM_{2.5}$ concentrations (µg/m³) at hotspots in 2022

| $PM_{2.5}$ (µg/m³) | Minor Road & Cold Start | | Industry | | Domestic | | Rail | | Other | | Secondary PM | Residual & Salt | Point Sources | Total In* | Total BG $PM_{2.5}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | In | Out | | | | | |
| **DT55** | 0.0 | 0.0 | 0.0 | 0.2 | 0.4 | 0.8 | 0.0 | 0.0 | 0.1 | 0.1 | 5.7 | 2.3 | 0.0 | 0.5 | 9.7 |
| **TF19** | 0.0 | 0.0 | 0.1 | 0.2 | 1.0 | 0.9 | 0.0 | 0.0 | 0.0 | 0.1 | 5.7 | 2.2 | 0.1 | 1.1 | 10.2 |
| **DT45** | 0.0 | 0.0 | 0.0 | 0.2 | 0.1 | 0.6 | 0.1 | 0.0 | 0.1 | 0.1 | 5.7 | 2.3 | 0.0 | 0.3 | 9.3 |
| **DT35** | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.6 | 0.0 | 0.0 | 0.0 | 0.1 | 5.7 | 2.9 | 0.0 | 0.2 | 9.8 |

*Total In includes all In sources as well as Secondary PM, Residual & Salt, and Point Sources

# APPENDIX 4. SOURCE APPORTIONMENT OF BASELINE ROAD TRANSPORT EMISSIONS

Table A-4-1, Table A-4-4 and Table A-4-7 show the source apportionment in terms of percentage contribution of the major vehicle types to the total modelled vehicular $NO_X$, $NO_2$, $PM_{10}$ and $PM_{2.5}$ emissions at the three hotspot locations. The percentage emissions are also presented in pie charts (Figure A-4-1, Figure A-4-2, Figure A-4-3 and Figure A-4-4).

Table A-4-2, Table A-4-5 and Table A-4-8 show the source apportionment in terms of the amount of *modelled* $NO_X$, $NO_2$, $PM_{10}$ and $PM_{2.5}$ originating from each of these sources (in µg/m$^3$).

Table A-4-4, Table A-4-6 and Table A-4-9 show the source apportionment in terms of the amount of *measured* $NO_2$ attributed to each of these sources (in µg/m$^3$).

## ST CLEMENTS/ THE PLAIN

Table A-4-1 Source apportionment for all road transport emissions on St Clement's / The Plain (%) for the baseline fleet, 2022

| | Cars | | | | | Bus | HGV (Rigid) | HGV (Artic) | LGV | Taxi | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cars (petrol) | Cars (diesel) | Car (petrol hybrid) | Car (diesel hybrid) | Car (electric) | | | | | Taxi (Oxford HCV) | Taxi (Other HCV) | Taxi (PHV) | |
| *DT55 – St Clements/ The Plain Roundabout* | | | | | | | | | | | | | |
| **NOx** | 7.4% | 41.5% | 0.1% | 0.1% | 0.0% | 25.7% | 9.3% | 0.1% | 13.8% | 0.9% | 0.1% | 1.0% | 100% |
| **$PM_{10}$** | 34.8% | 27.6% | 1.4% | 0.0% | 1.9% | 16.8% | 3.7% | 0.1% | 9.8% | 0.8% | 0.1% | 2.8% | 100% |
| **$PM_{2.5}$** | 32.5% | 28.9% | 1.3% | 0.0% | 2.0% | 17.3% | 4.0% | 0.1% | 10.0% | 0.9% | 0.2% | 2.7% | 100% |
| *TF19 – Headington Hill* | | | | | | | | | | | | | |
| **NOx** | 5.4% | 30.2% | 0.1% | 0.0% | 0.0% | 32.1% | 13.5% | 0.1% | 17.2% | 0.7% | 0.1% | 0.7% | 100% |
| **$PM_{10}$** | 28.0% | 22.1% | 1.1% | 0.0% | 1.6% | 23.8% | 6.7% | 0.2% | 13.5% | 0.6% | 0.1% | 2.3% | 100% |
| **$PM_{2.5}$** | 25.9% | 23.0% | 1.1% | 0.0% | 1.6% | 24.4% | 7.1% | 0.2% | 13.6% | 0.7% | 0.1% | 2.1% | 100% |

Table A-4-2 Source apportionment for all road transport on modelled concentrations at St Clement's / The Plain (μg/m³) for the baseline fleet, 2022 ($NO_2$ concentrations derived from the NOx to $NO_2$ calculator)

| | Background | Cars | | | | | Bus | HGV (Rigid) | HGV (Artic) | LGV | Taxi | | | Total (μg/m³) | Total $NO_2$ (μg/m³) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cars (petrol) | Cars (diesel) | Car (petrol hybrid) | Car (diesel hybrid) | Car (electric) | | | | | Taxi (Oxford HCV) | Taxi (Other HCV) | Taxi (PHV) | | |
| *DT55 – St Clements/ The Plain Roundabout* | | | | | | | | | | | | | | | |
| **NOx** | 15.5 | 5.0 | 28.0 | 0.1 | 0.0 | 0.0 | 17.4 | 6.3 | 0.0 | 9.3 | 0.6 | 0.1 | 82.9 | 82.9 | 44.0 |
| **$PM_{10}$** | 14.7 | 2.4 | 1.9 | 0.1 | 0.0 | 0.1 | 1.2 | 0.3 | 0.0 | 0.7 | 0.1 | 0.0 | 0.2 | 21.7 | |
| **$PM_{2.5}$** | 10.2 | 1.2 | 1.1 | 0.1 | 0.0 | 0.1 | 0.7 | 0.2 | 0.0 | 0.4 | 0.0 | 0.0 | 0.1 | 14.0 | |

Table A-4-3 Source apportionment for all road transport on measured concentrations at St Clement's / The Plain (μg/m³) for the baseline fleet, 2022 ($NO_2$ concentration measured at DT55 in 2022)

| | Background* | Cars | | | | | Bus | HGV (Rigid) | HGV (Artic) | LGV | Taxi | | | Total Measured $NO_2$ (μg/m³) | Total $NO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cars (petrol) | Cars (diesel) | Car (petrol hybrid) | Car (diesel hybrid) | Car (electric) | | | | | Taxi (Oxford HCV) | Taxi (Other HCV) | Taxi (PHV) | | |
| **$NO_2$** | 10.5 | 2.4 | 13.5 | 0.0 | 0.0 | 0.0 | 8.4 | 3.0 | 0.0 | 4.5 | 0.3 | 0.0 | 0.3 | 43.1 | 44.0 |

*Background $NO_2$ was estimated by applying the same percentage of NOx that is background in the modelled results, to the total measured $NO_2$.

Figure A-4-1 Pie chart representation of source apportionment for all road transport emissions on St Clement's / The Plain – DT55 (%) for the baseline fleet, 2022

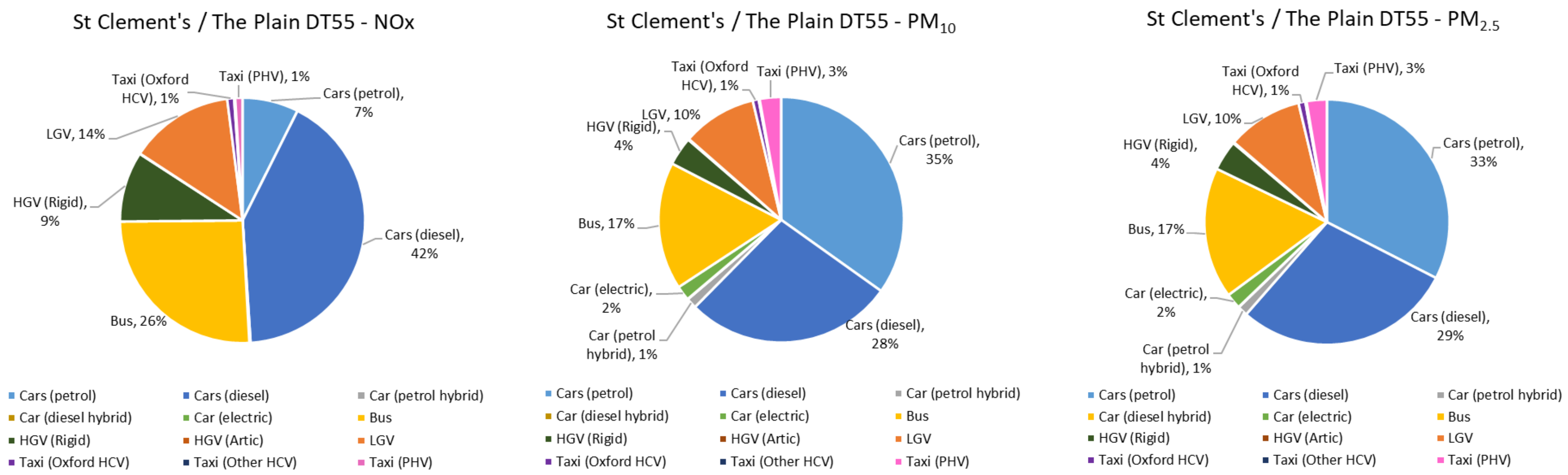
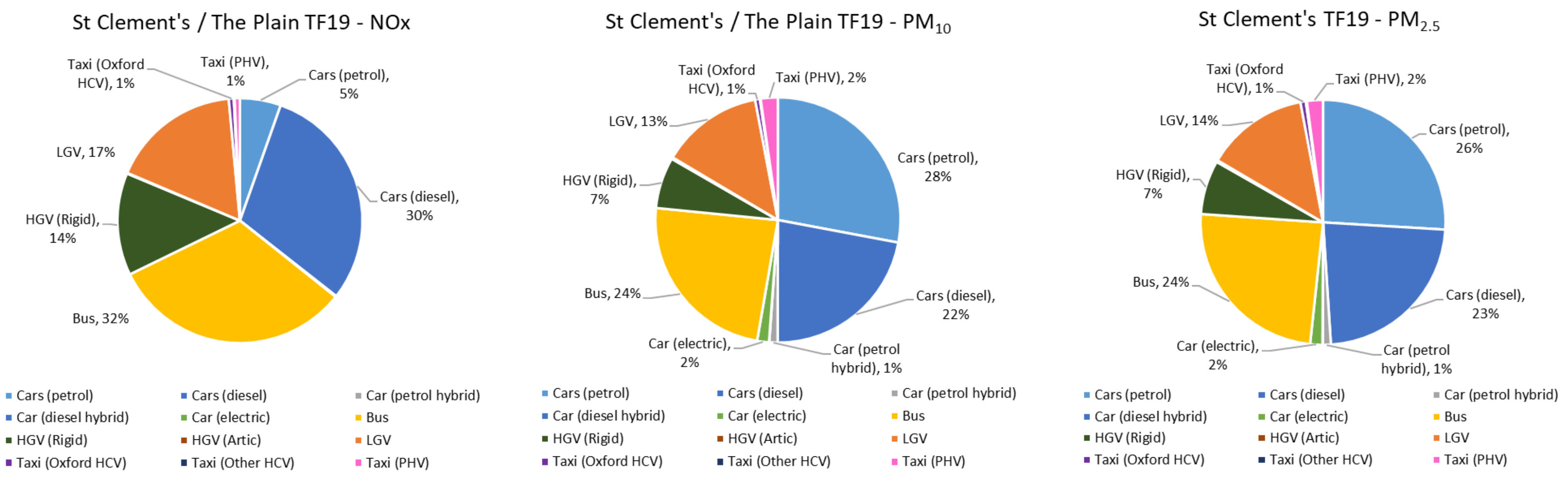


Figure A-4-2 Pie chart representation of source apportionment for all road transport emissions at St Clement's / The Plain – TF19 (%) for the baseline fleet, 2022



# WORCESTER STREET

Table A-4-4 Source apportionment for all road transport emissions on Worcester Street (%) for the baseline fleet, 2022

| | Cars | | | | | Bus | HGV (Rigid) | HGV (Artic) | LGV | Taxi | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cars (petrol) | Cars (diesel) | Car (petrol hybrid) | Car (diesel hybrid) | Car (electric) | | | | | Taxi (Oxford HCV) | Taxi (Other HCV) | Taxi (PHV) | |
| **NOx** | 7.2% | 41.4% | 0.1% | 0.1% | 0.0% | 3.3% | 17.7% | 0.1% | 28.0% | 0.9% | 0.1% | 1.0% | 100% |
| **$PM_{10}$** | 35.3% | 28.0% | 1.4% | 0.0% | 2.0% | 1.9% | 7.1% | 0.2% | 20.3% | 0.8% | 0.1% | 2.9% | 100% |
| **$PM_{2.5}$** | 32.9% | 29.4% | 1.3% | 0.0% | 2.1% | 2.0% | 7.6% | 0.2% | 20.6% | 0.9% | 0.2% | 2.7% | 100% |

Table A-4-5 Source apportionment for all road transport modelled concentrations on Worcester Street (µg/m³) for the baseline fleet, 2022 ($NO_2$ concentrations derived from the NOx to $NO_2$ calculator)

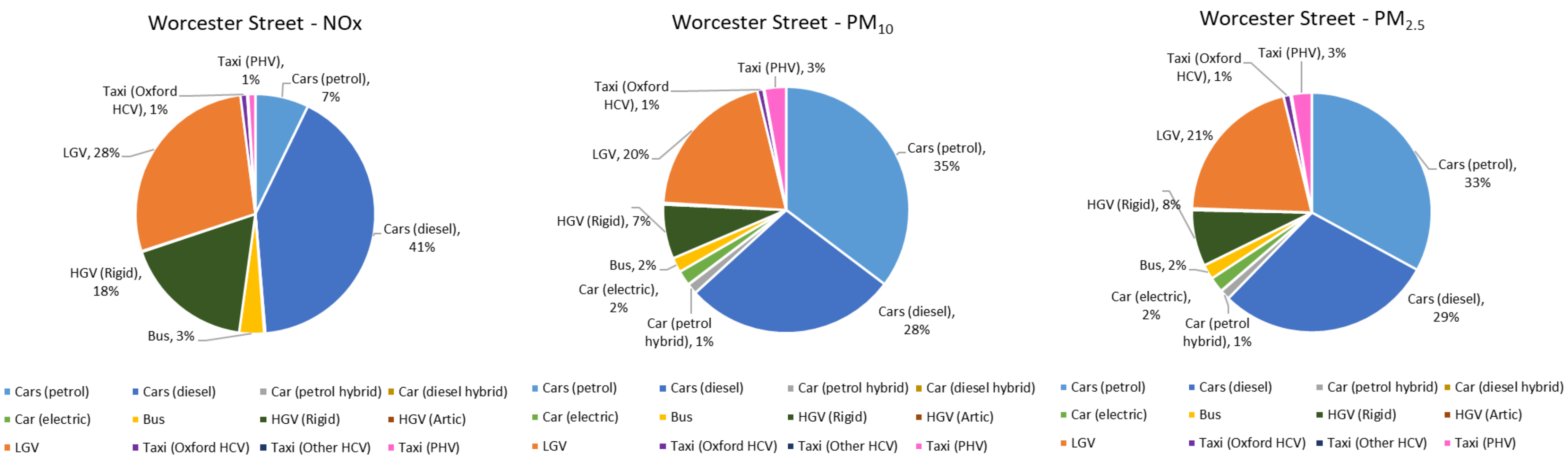
| | Background | Cars | | | | | Bus | HGV (Rigid) | HGV (Artic) | LGV | Taxi | | | Total (µg/m³) | Total $NO_2$ (µg/m³) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cars (petrol) | Cars (diesel) | Car (petrol hybrid) | Car (diesel hybrid) | Car (electric) | | | | | Taxi (Oxford HCV) | Taxi (Other HCV) | Taxi (PHV) | | |
| **NOx** | 19.0 | 3.3 | 18.9 | 0.0 | 0.0 | 0.0 | 1.5 | 8.0 | 0.1 | 12.8 | 0.4 | 0.1 | 0.4 | 64.5 | 36.3 |
| **$PM_{10}$** | 14.3 | 1.6 | 1.3 | 0.1 | 0.0 | 0.1 | 0.1 | 0.3 | 0.0 | 0.9 | 0.0 | 0.0 | 0.1 | 19.0 | |
| **$PM_{2.5}$** | 9.6 | 0.8 | 0.7 | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.0 | 0.5 | 0.0 | 0.0 | 0.1 | 12.2 | |

Table A-4-6 Source apportionment for all road transport measured concentrations on Worcester Street (µg/m³) for the baseline fleet, 2022 ($NO_2$ concentration measured at DT45 in 2022)

| | Background | Cars | | | | | Bus | HGV (Rigid) | HGV (Artic) | LGV | Taxi | | | Total Measured $NO_2$ (µg/m³) | Total $NO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cars (petrol) | Cars (diesel) | Car (petrol hybrid) | Car (diesel hybrid) | Car (electric) | | | | | Taxi (Oxford HCV) | Taxi (Other HCV) | Taxi (PHV) | | |
| **$NO_2$** | 20.5 | 0.7 | 4.3 | 0.0 | 0.0 | 0.0 | 0.3 | 1.8 | 0.0 | 2.9 | 0.1 | 0.0 | 0.1 | 30.8 | 36.3 |

*Background $NO_2$ was estimated by applying the same percentage of NOx that is background in the modelled results, to the total measured $NO_2$.

Figure A-4-3 Pie chart representation of source apportionment for all road transport emissions on Worcester Street (%) for the baseline fleet, 2022




## BOTLEY ROAD

Table A-4-7 Source apportionment for all road transport emissions on Botley Road (%) for the baseline fleet, 2022

| | Cars | | | | | Bus | HGV (Rigid) | HGV (Artic) | LGV | Taxi | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cars (petrol) | Cars (diesel) | Car (petrol hybrid) | Car (diesel hybrid) | Car (electric) | | | | | Taxi (Oxford HCV) | Taxi (Other HCV) | Taxi (PHV) | |
| **NOx** | 7.7% | 40.3% | 0.1% | 0.1% | 0.0% | 12.8% | 12.2% | 0.1% | 24.8% | 0.9% | 0.1% | 0.9% | 100% |
| **$PM_{10}$** | 34.2% | 26.7% | 1.3% | 0.0% | 1.9% | 9.3% | 6.3% | 0.2% | 16.4% | 0.7% | 0.1% | 2.8% | 100% |
| **$PM_{2.5}$** | 32.1% | 27.9% | 1.3% | 0.0% | 2.0% | 9.6% | 6.8% | 0.2% | 16.5% | 0.8% | 0.1% | 2.6% | 100% |

Table A-4-8 Source apportionment for all road transport on modelled concentrations on Botley Road (µg m-3) for the baseline fleet, 2022 ($NO_2$ concentrations derived from the NOx to $NO_2$ calculator)

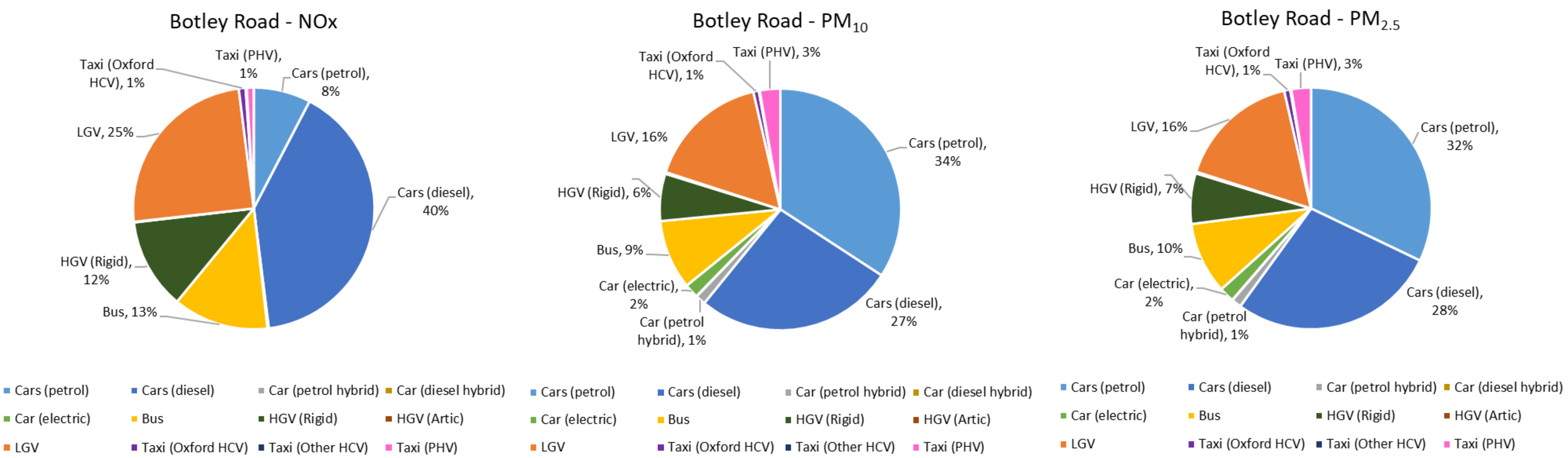
| | Background | Cars | | | | | Bus | HGV (Rigid) | HGV (Artic) | LGV | Taxi | | | Total (µg/m$^3$) | Total $NO_2$ (µg/m$^3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cars (petrol) | Cars (diesel) | Car (petrol hybrid) | Car (diesel hybrid) | Car (electric) | | | | | Taxi (Oxford HCV) | Taxi (Other HCV) | Taxi (PHV) | | |
| **NOx** | 17.3 | 2.0 | 10.4 | 0.0 | 0.0 | 0.0 | 3.3 | 3.2 | 0.0 | 6.4 | 0.2 | 0.0 | 0.2 | 43.2 | 26.3 |
| **$PM_{10}$** | 14.3 | 1.0 | 0.8 | 0.0 | 0.0 | 0.1 | 0.3 | 0.2 | 0.0 | 0.5 | 0.0 | 0.0 | 0.1 | 17.2 | |
| **$PM_{2.5}$** | 9.6 | 0.5 | 0.4 | 0.0 | 0.0 | 0.0 | 0.2 | 0.1 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 11.2 | |

Table A-4-9 Source apportionment for all road transport on measured concentrations on Botley Road (µg m-3) for the baseline fleet, 2022 ($NO_2$ concentration measured at DT35 in 2022)

| | Background | Cars | | | | | Bus | HGV (Rigid) | HGV (Artic) | LGV | Taxi | | | Total Measured $NO_2$ (µg/m$^3$) | Total $NO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cars (petrol) | Cars (diesel) | Car (petrol hybrid) | Car (diesel hybrid) | Car (electric) | | | | | Taxi (Oxford HCV) | Taxi (Other HCV) | Taxi (PHV) | | |
| **$NO_2$** | 17.7 | 0.5 | 2.4 | 0.0 | 0.0 | 0.0 | 0.8 | 0.7 | 0.0 | 1.5 | 0.1 | 0.0 | 0.1 | 23.7 | 26.3 |

*Background $NO_2$ was estimated by applying the same percentage of NOx that is background in the modelled results, to the total measured $NO_2$.

Figure A-4-4 Pie chart representation of source apportionment for all road transport emissions on Botley Road (%) for the baseline fleet, 2022



# APPENDIX 5 NAEI EMISISONS SOURCE APPORTIONMENT IN FULL ($PM_{10}$ AND $PM_{2.5}$)

This Appendix presents NAEI emissions source apportionment for $PM_{10}$ and $PM_{2.5}$, without breaking down the major roads (major road tailpipe, road abrasion and brake and tyre wear) component by vehicle types. These charts therefore allow consideration of the distinct major road tailpipe, road abrasion and brake and tyre wear contributions to $PM_{10}$ and $PM_{2.5}$ emissions.

Figure A-5-1 and Figure A-5-2 show results for the whole Oxford Administrative Area, and Figure A-5-3 and Figure A-5-4 show results for Oxford Inner City.

Please note that road abrasion and brake and tyre wear emissions are not available for $NO_X$ as $NO_2$.

Figure A-5-1 NAEI emissions source apportionment for $PM_{10}$ across Oxford Administrative Area, including distinct major road tailpipe (0.77%), road abrasion (3.19%) and brake and tyre wear (10.02%) contributions.

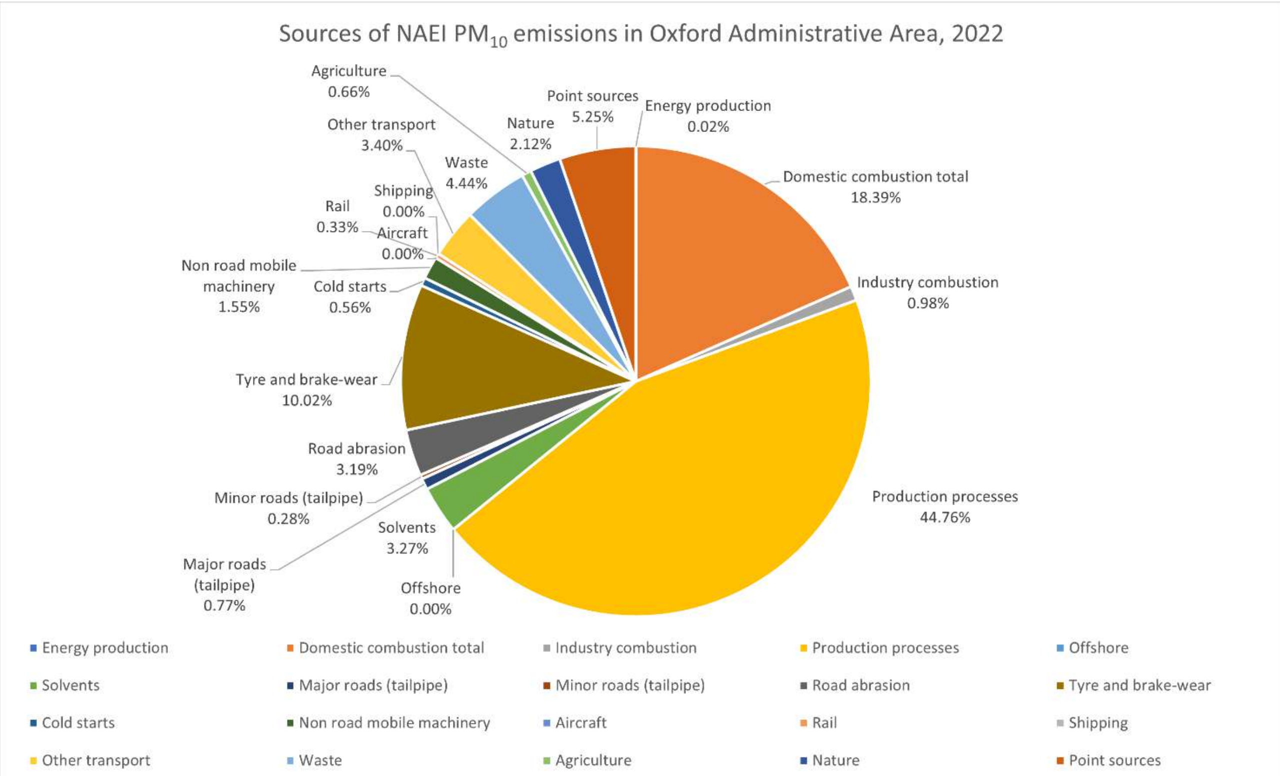


Figure A-5-2 NAEI emissions source apportionment for $PM_{2.5}$ across Oxford Administrative Area, including distinct major road tailpipe (1.52%), road abrasion (3.43%) and brake and tyre wear (10.11%) contributions.

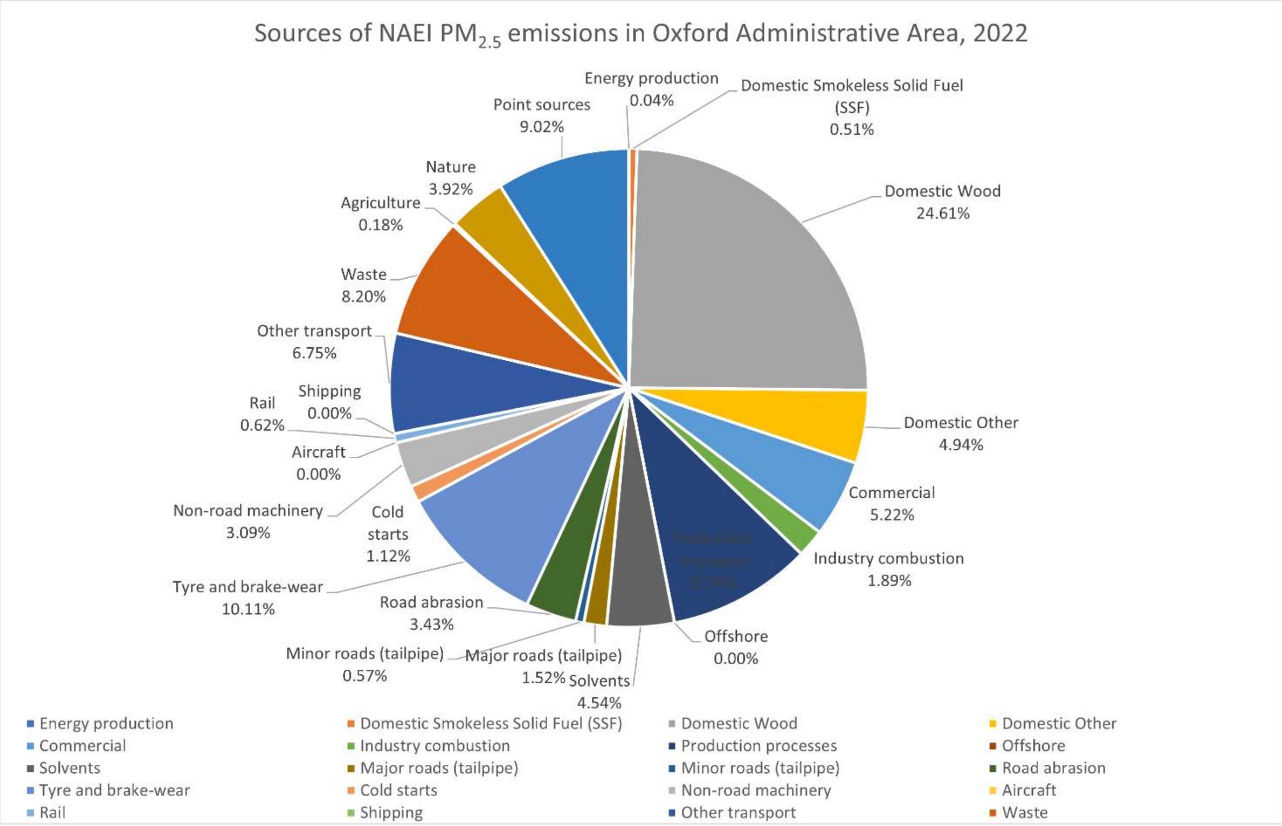



Figure A-5-3 NAEI emissions source apportionment for $PM_{10}$ across Oxford Inner City, including distinct major road tailpipe (0.55%), road abrasion (1.61%) and brake and tyre wear (5.90%) contributions.

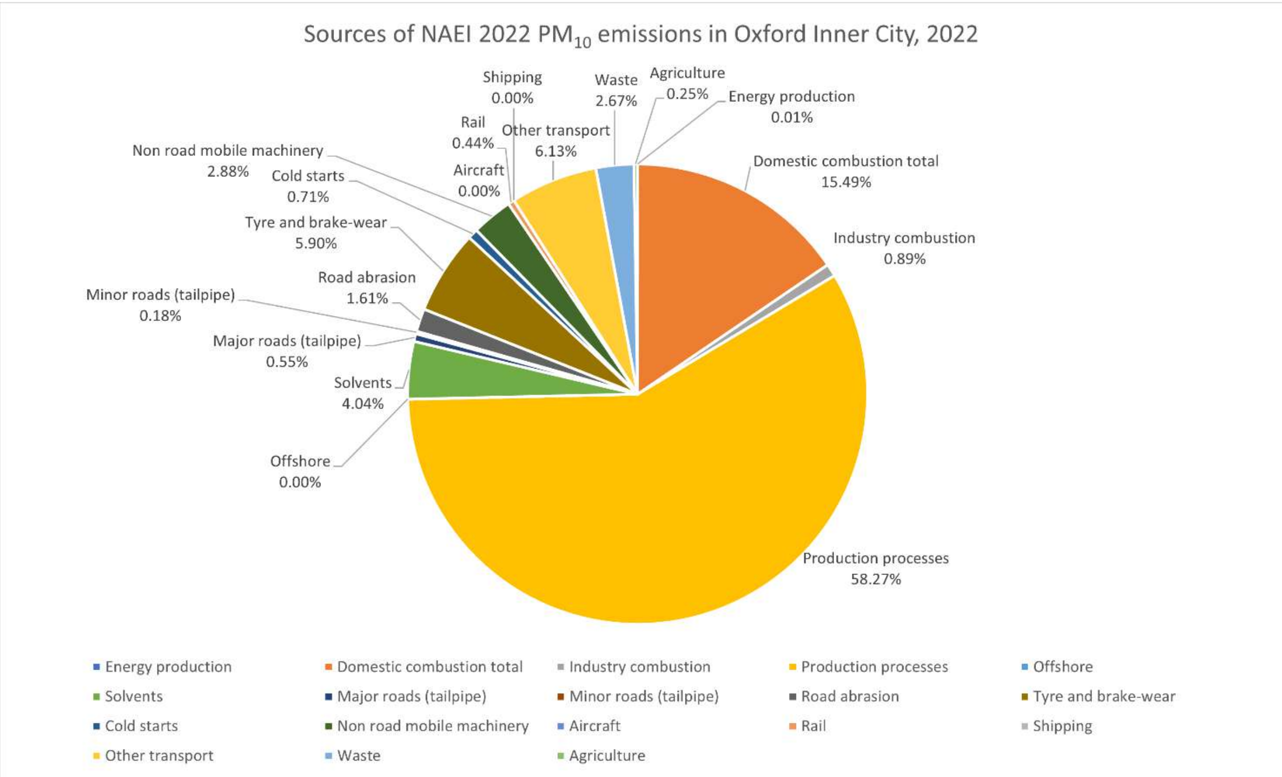
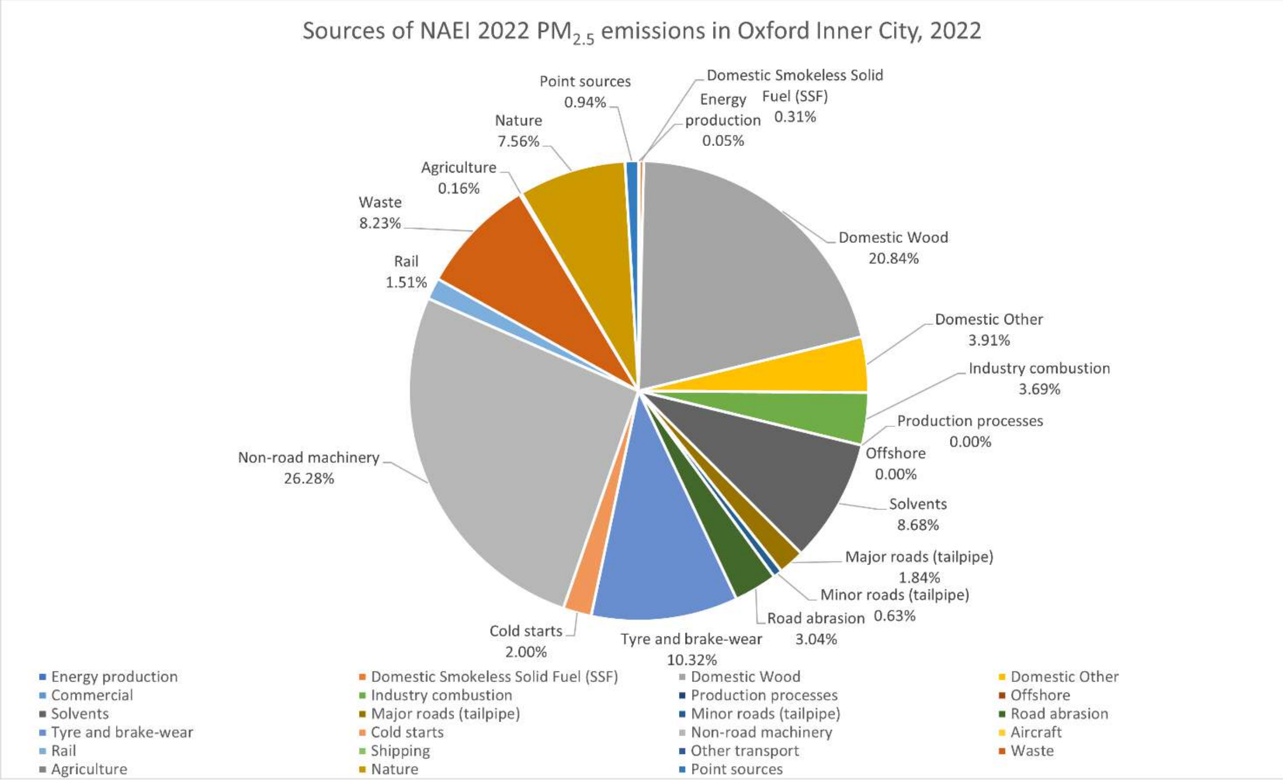


Figure A-5-4 NAEI emissions source apportionment for $PM_{2.5}$ across Oxford Inner City, including distinct major road tailpipe (1.84%), road abrasion (3.04%) and brake and tyre wear (10.32%) contributions.



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