Scottish Environment Protection Agency
Buidheann Dìon Àrainneachd na h-Alba

CLEANER AIR FOR SCOTLAND – NATIONAL MODELLING FRAMEWORK

Low Emission Zone
Aberdeen Evidence Report

October 2021

Scope of Report

Air Quality modelling for Aberdeen has been ongoing, supporting the Scottish Government Cleaner Air for Scotland strategy (CAFS). This report follows on from the previous SEPA report 'Aberdeen Emissions Analysis Report' which focused on calculated tail-pipe emissions of Nitrogen Oxide (NO_x). This work represents the final stages of the National Modelling Framework (NMF), providing modelled NO_2 concentrations to support Aberdeen City Council's (ACC) proposed Low Emission Zone (LEZ). Traffic modelling has been carried out by SYSTRA to predict changes in vehicle flows and fleet compositions, which was then used to calculate pollutant emissions and air quality concentrations. This report presents the results of air quality modelling work to examine the changes on emissions and concentrations associated with the implementation of the proposed LEZ. Calculated changes in Particulate Matter (PM_{10}) emissions are also presented.

Main Points to Note

- Air quality model results are based on traffic flow and fleet composition data collected in May 2019 and so incorporate any changes following the completion of the Aberdeen Western Peripheral Route in February 2019.
- Earlier modelling identified that the highest annual-average concentrations of NO_2 occurred in the City Centre where vehicle emissions were dominated by buses, whilst diesel car emissions dominated other key routes around the city.
- Traffic model outputs for the LEZ Case indicate general reductions in traffic levels within the proposed LEZ area with relatively low levels of traffic displacement elsewhere. A stretch of South Anderson Drive experienced the largest increase in total traffic as traffic approaching the city from the south-west follow routes that avoid the city centre.
- SEPA's emissions report (SEPA, 2021) identified that key bus routes within the LEZ boundary will experience the largest reductions in NO_x emissions, due to the implementation of an LEZ. On the sections of Union Street where only buses and taxis are permitted as part of the City Centre Master Plan (CCMP) Union Street Scheme, there is an average reduction of 87% in NO_x emissions. Along the remaining sections of Union Street there is a reduction in NO_x emission rates of 57% on average (ranging between 34% and 72%).
- Air quality modelling results indicate that, if an LEZ is implemented, the majority of current NO_2 exceedances inside the LEZ will be removed.

- Localised and isolated exceedances may remain on some streets and at the Westburn Road/Berryden Road/Hutcheon Street/Caroline Place, Skene Street/Rosemount Viaduct and Beechgrove Terrace/Rosemount Place junctions despite small decreases in NO_2 concentrations due to the LEZ.

- Further detailed modelling was carried out to predict concentrations at a selection of building façades agreed with ACC. One exceedance was identified close to the junction of Caroline Place and Hutcheon Street. This suggests that the risk of exceedances when an LEZ is implemented is limited to receptors in the immediate vicinity of the Caroline Place junction, and that the risk of exceedances at other locations is low.

- The LEZ is also expected to lead to substantial reductions in tailpipe emissions of PM10, most notably on bus routes inside the LEZ. However, increases are predicted on routes outside of the LEZ.

List of Abbreviations

AADT	Annual Average Daily Traffic
ACC	Aberdeen City Council
ADMS	Atmospheric Dispersion Modelling System
ADMS	Urban Atmospheric Dispersion Modelling System for Urban Environments
ANPR	Automatic Number Plate Recognition
AQMA	Air Quality Management Area
AWPR	Aberdeen Western Peripheral Route
ATC	Automatic Traffic Counters
CAFS	Cleaner Air for Scotland
CERC	Cambridge Environmental Research Consultants
DfT	Department for Transport
DEFRA	Department for Environment Food & Rural Affairs
DVLA	Driver and Vehicle Licensing Agency
EFTv10	Emissions Factors Toolkit v10.0
EMIT	CERC Emissions Tool
HGV	Heavy Goods Vehicle
JTC	Junction Turn Counts
LAQM	Local Air Quality Management
LEZ	Low Emission Zone
LGV	Light Goods Vehicle
NAEI	National Atmospheric Emissions Inventory
NLEF	National Low Emission Framework
NMF	National Modelling Framework
PDT	Passive Diffusion Tube
SEPA	Scottish Environment Protection Agency
SG	Scottish Government
TS	Transport Scotland

List of Chemical Abbreviations

NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxides
PM_{10}	Particulate Matter less than 10µm in diameter

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Introduction

Background

As part of the National Modelling Framework (NMF) and National low Emission Framework (NLEF) process within the Cleaner Air for Scotland (CAFS) strategy, an air quality model was built using good quality data and it's performance was validated against air quality monitoring data. The principals and methodology underpinning the model development is set out in the SEPA Aberdeen Pilot Project (SEPA, 2017). A consistent approach to air quality model development has been taken across all four cities implementing Low Emission Zones (LEZs).

Following on from the initial air quality modelling and evidence presented to Aberdeen City Council (SEPA, 2018a) and SYSTRA (SYSTRA, 2020) during the early stages of the LEZ development, the next step was to model LEZ scenarios. As part of this, further traffic surveys were carried out to identify if there are any significant changes in traffic flows and to detect improvements in the fleet composition due to fleet turnover. ACC commissioned SYSTRA consultants to carry out traffic modelling and predict changes to traffic flows in response to the introduction of an LEZ; the traffic model data was used to run the Air Quality models to assess potential changes in pollutant concentrations.

SEPA Cyberattack

On Christmas Eve 2020, SEPA was subject to a serious and complex criminal cyber-attack that significantly impacted our internal systems and our Air Quality modelling capabilities.

As part of our recovery plan, SEPA implemented a phased rollout programme to restore critical services, re-establish critical communication systems to continue providing our priority regulatory, monitoring, flood forecasting and warning services. Our priority regulatory work programme included the delivery of our NMF obligations to assist in the final assessments of the LEZ options for each city.

Due to SEPAs inability to carry out Air Quality modelling, an alternative approach to allow for local authorities to report to committee in Spring 2021 was discussed at the LEZ Leadership Group meeting held on the 3rd of February 2021. The following steps were recommended by Scottish Government and SEPA on a way forward:

- Continuation of traffic modelling to define potential LEZ options or a preferred LEZ option for each city.

- SEPA to carry out emissions analysis on the traffic model outputs using the established NMF methodology, assessing the impact of the LEZ by comparing traffic and emissions between the 2019 Base, and 2024 Reference and LEZ options.
- SEPA to continue detailed AQ modelling during the consultation phase over the summer of 2021 to support the local authorities in finalising the preferred LEZ scheme for Ministerial approval.

Since July 2021, SEPA's air modelling capacity has been restored and the original modelling data for Aberdeen has been recovered though this has resulted in a significant delay to work plans.

National Modelling Framework

Modelling work presented here continues to follow the NMF approach and methods outlined in previous reports (SEPA, 2017) ensuring a consistent approach in air quality modelling. These include:

- The use of ADMS-Urban and EMIT as used in previous NMF work.
- Processing traffic model outputs in the same way that detailed data from traffic data collection surveys was processed earlier in the NMF process.
- Running the air quality models of each city using identical methods and default model settings as used previously.
- Using the same sources of data for input into the model, such as road layout, road width and building heights.
- Using appropriate meteorological and background emission data obtained from a common source.
- Combining traffic data with published emission information to derive consistent emission estimates.
- More accurate emission information, if available, will be applied in a consistent way.
- Ensure that observations and lessons learned from one city are applied in other cities.
- Process, visualise and report on modelling output in a consistent and informative way.

The model continues to be assessed against measurement data to ensure the model is performing well, which includes updating emission calculations based on Automatic Number Plate Recognition (ANPR) data to account for fleet turnover and localised bus fleet data.

It's important to note that some differences in methodology between the cities have arisen due to different approaches in traffic modelling for each city. ACC, along with Dundee and Glasgow City Councils, commissioned SYSTRA to carry out traffic modelling using Paramics (a microsimulation traffic model), whilst City of Edinburgh Council commissioned Jacobs to carry out traffic modelling using the VISUM model (a strategic traffic model). There are some differences in how the traffic data is processed into Annual Average Daily Traffic (AADT) as required by the air quality modelling. However, from that point the traffic data is treated in the same way when calculating emissions and processing within ADMS.

The ADMS-Urban software has been updated recently. The main difference compared to the previous version is an update to the way ADMS-Urban deals with canyons, which may lead to some differences between ADMS-Urban model versions. However, the new version of ADMS-Urban (version 5) has been used for air quality modelling in Aberdeen.

Modelling Methodology

Scope of Traffic Modelling

The initial base traffic model development is detailed in the *Aberdeen City Centre Paramics Model Upgrade 2019 Report* (SYSTRA, 2019a) and the development of the future year Reference Case model is detailed in the *Aberdeen City Centre: Future Year (2024) Model Development Report.* (SYSTRA, 2020a).

The future year Reference Case traffic model for Aberdeen includes infrastructure changes and committed Local Development Plan forecasts to 2024 as identified by ACC. Following discussion with ACC, it was determined that the Union Terrace, South College Street Junction, Berryden Corridor and Haudagain Improvement schemes, along with any committed changes related to the Roads Hierarchy would be included in the Reference Case model. The Reference Case model has been built with the expectation that there will be background traffic growth of 6 to 8% over the 2019 traffic levels (SYSTRA, 2020a).

Aberdeen City Council's proposed City Centre Master Plan (CCMP) includes several transport related projects. The CCMP Union Street Scheme involves limiting traffic to buses, taxis and pedal cycles only along the section of Union Street between the north end of Market Street and Bridge Street, and the whole of Union Terrace. As part of the same scheme the southern end of Rose Street will be pedestrianised.

In the Interim NLEF Stage 2 report (SYSTRA, 2021b), 8 potential LEZ boundary options were considered. The traffic model was utilised to identify if any elements of the CCMP would reduce traffic further to support the LEZ in meeting its objectives. Additional testing identified that a revision to the operation of the Milburn Street/South College Street junction would also manage displaced traffic from the City Centre in the area to the south and west of the LEZ and limit the routing of all traffic through the Milburn Street and the Ferryhill corridor. The CCMP Union Street Scheme and Milburn Street traffic management measures were predicted to significantly reduce emissions on roads where most exceedances were observed in 2019 and it was recommended that including these as part of the LEZ would be viewed as a combined package of measures to meet the LEZ objectives.

Due to concerns regarding harbour access, 2 additional LEZ boundary variants were tested where the LEZ boundary was altered along the eastern edge (Figure 1). These are:

- Option 1: Exclusion of East North Street and Commerce Street from the LEZ
- Option 2: Exclusion of East North Street, Commerce Street, Virginia Street, Trinity Quay and Market St (South of Guild St) from the LEZ

This was to assess how these changes would affect traffic flows through the NO_2 exceedance areas adjacent to the harbour

Figure 1: Maps showing the LEZ options with routes excluded from LEZ highlighted in black. The extent of the LEZ is shown in blue.

The CCMP Union Street Scheme and Milburn Street traffic management measures were retained in both options. Model predictions showed that Option 2 resulted in large increases in predicted NO_2 concentrations along the northern end of Market Street and Virginia Street, therefore Option 1 became the preferred option (Figure 2) and was taken forward for detailed air quality modelling.

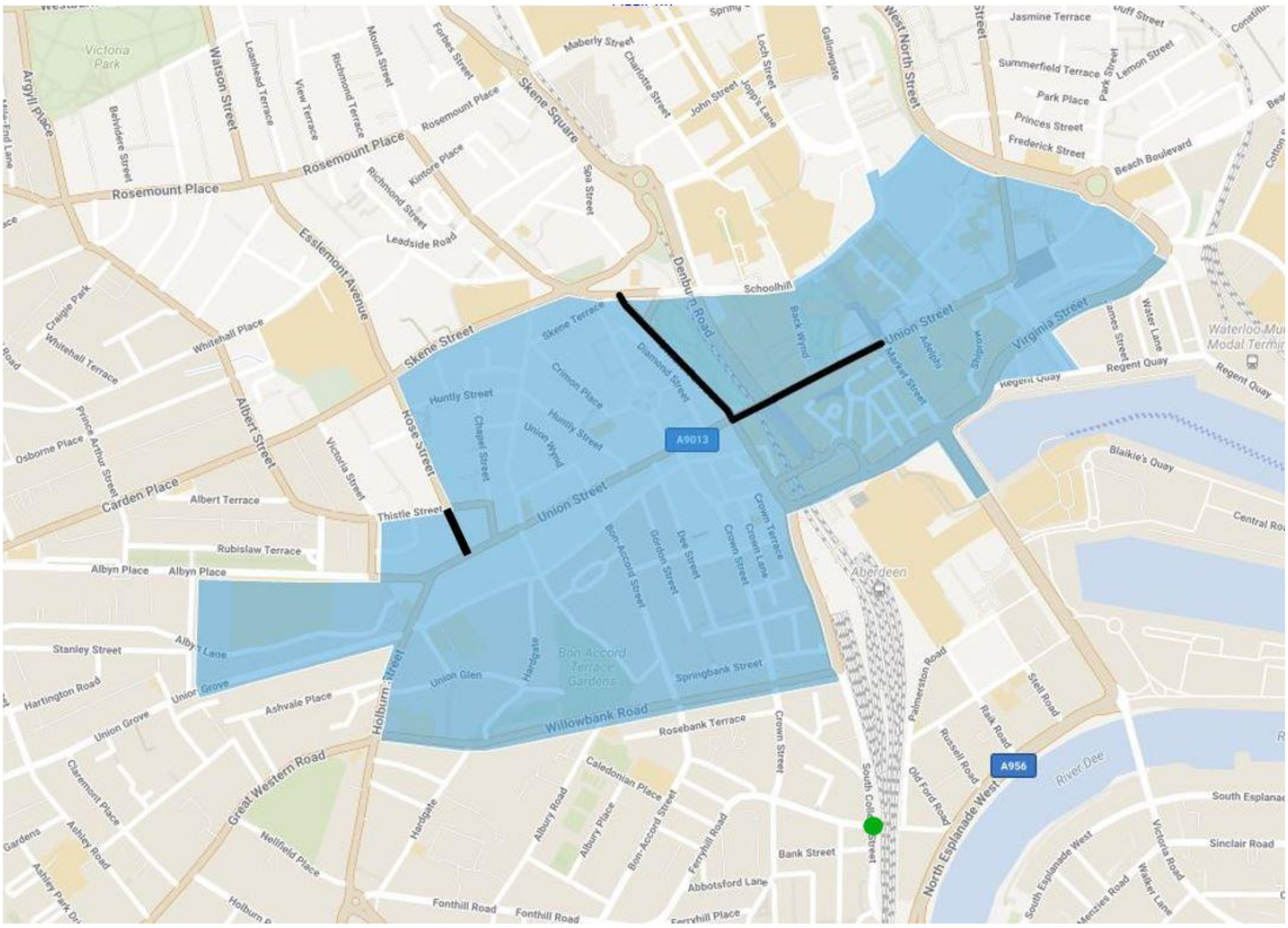

Figure 2: Extent of the LEZ covering the area of Aberdeen City Centre with key elements of the CCMP Union Street Scheme shown in black and the location of the Milburn Street junction improvements shown by the green marker. East North Street and Commerce Street have been excluded from the LEZ. The extent of the LEZ is shown in blue.

Due to concerns raised by the Trinity Centre regarding access to the shopping centre, the traffic model was run with LEZ Option 1 (Figure 2) but with the Wapping Street gyratory excluded to see what impact this would have upon predicted traffic flows. Traffic modelling predictions suggested that the impact on traffic flows to be almost negligible (e.g. less than 10 vehicles per hour increase to two way flows on College Street). It was therefore considered unlikely that exclusion of the Wapping Street gyratory would result in any significant changes to predicted NO_2 concentrations, so this option was taken forward as the final LEZ boundary option (Figure 3). Due to time constraints this boundary has not been incorporated into the detailed air quality modelling, but as stated before given the negligible change in traffic flows the current air quality model parameters would be sufficient to determine potential concentration changes.

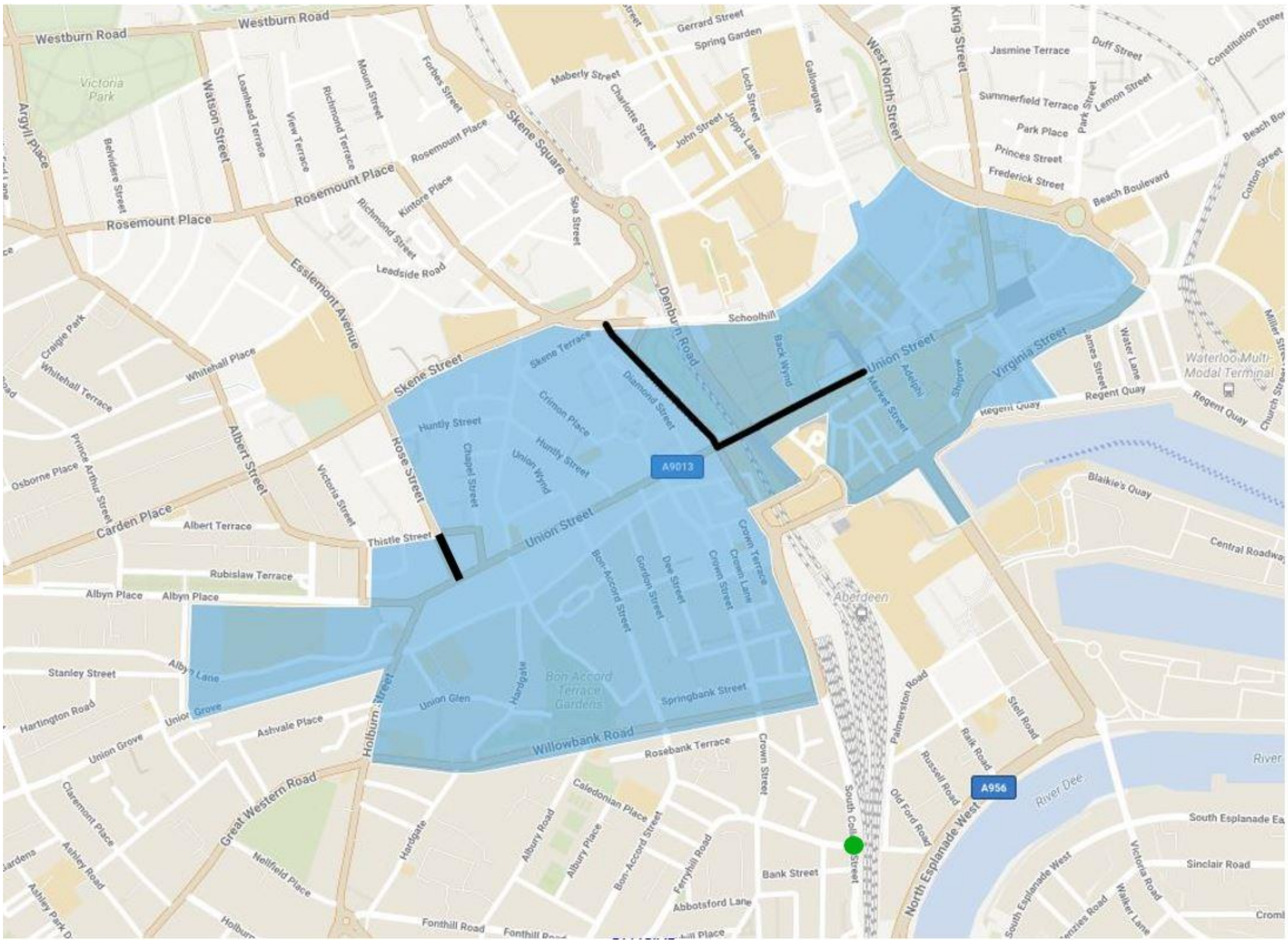

Figure 3: Final LEZ boundary covering the area of Aberdeen City Centre with the Wapping Street gyratory, and East North Street and Commerce Streets excluded. The CCMP Union Street Scheme is shown in black and the location of the Milburn Street junction improvements is shown by the green marker. The extent of the LEZ is shown in blue.

The existing air quality model domain was considered adequate for this piece of work as it covers the city centre in detail, where local displacement of traffic will need to be considered as part of the city centre LEZ. The LEZ rules also needed to be considered when planning this stage of the modelling work, where it is noted that regulations for petrol cars are different from all other vehicles (Table 1). This is because NO_x emissions from petrol vehicles are much lower than diesel vehicles.

Table 1: LEZ rules for Vehicle Categories.

Vehicle category	Compliant	Non-Compliant
Cars (Petrol)	Euro 4, 5, 6	Euro 3 or earlier
All Vehicles (except Cars (Petrol))	Euro 6, Electric	Euro 5 or earlier

Traffic Modelling Methodology

The traffic modelling was carried out by SYSTRA using the Paramics microsimulation model. It is important to note that the traffic modelling carried out for Aberdeen (along with that carried out for Dundee and Glasgow) is a different approach to that used for Edinburgh which utilised the VISUM strategic traffic model. The traffic model was run for 3 cases:

1. 2019 Base Case
2. 2024 Reference Case
3. 2024 LEZ Case

Results of air quality modelling using the 2019 Base Case traffic flows were compared against air quality observations, in order to assess the performance of the model. The results of this verification are presented in Appendix 1.

For the Base Case and Reference Case the traffic model has 7 vehicle categories represented; Car, Light Goods Vehicle (LGV), Medium Goods Vehicle (MGV), Heavy Goods Vehicle (HGV), Bus, Coach and Taxi. The MGV category in the Paramics model is split across the 3 Rigid-HGV classes and the HGV category is split across the 3 Artic-HGV classes.

For the LEZ Case, 4 vehicle categories; Car, LGV, MGV and HGV were further split to provide Compliant and Non-Compliant sub-categories resulting in a total of 11 vehicle categories in the model. Traffic entering, leaving, or travelling within the LEZ is 'Compliant'. Traffic which is 'Non-Compliant' is forced to divert around the LEZ. This may result in 'Compliant' traffic taking advantage of quieter roads within the LEZ and changing their route accordingly. Only the displacement of Cars, LGV's, MGV's and HGV's are considered in the LEZ Case.

It is assumed bus routes will remain unchanged and all bus vehicles will become compliant. Regulations affecting taxi compliance is being carried out separately through the ACC taxi licencing scheme.

Traffic Flow

Traffic and air quality models must be underpinned by good quality traffic data to ensure traffic flows and the distribution of vehicle categories are represented as accurately as possible (SEPA, 2017). Two detailed traffic data surveys were carried out in 2017 and again in 2019 (following completion of the AWPR) with additional Junction Turn Count (JTC) sites to support the development of the traffic model. In the Base, Reference and LEZ cases traffic flows are based on those observed in 2019. Overall, there was a small increase in total traffic flows in the 2019 survey (Figure 4).

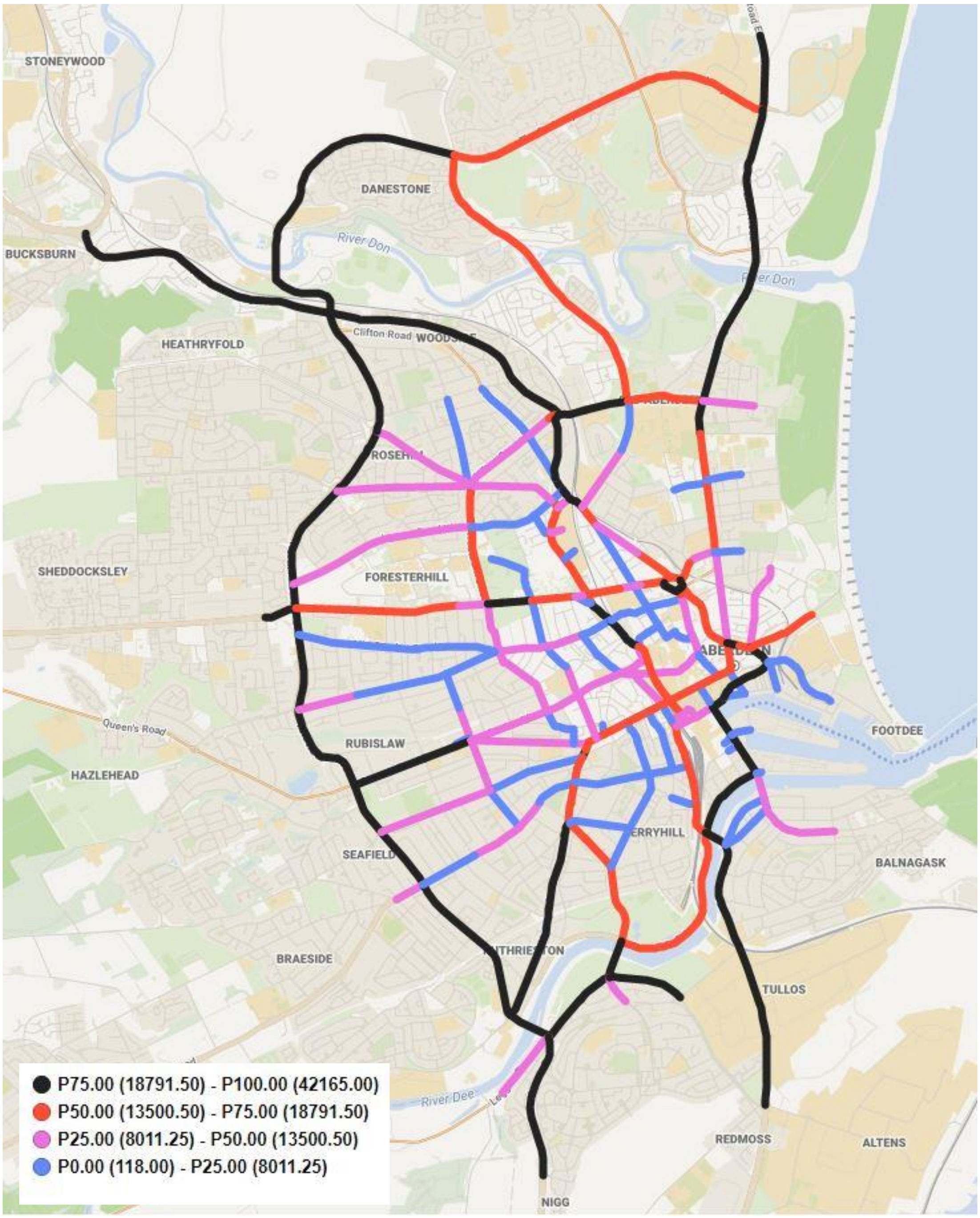

Figure 4: Total AADT traffic flows based on the 2019 traffic data survey. Roads are coloured by total traffic flow.

ANPR and Fleet Composition

ANPR survey data provides information linking vehicle number plates to information on the DVLA database such as vehicle type, weight, engine size and fuel type. The DVLA also provide estimated Euro class, based on the age of the vehicle. This information can be processed to derive fleet composition tables, which are required to calculate the emission rates for each road link in the CERC emission database tool, EMIT.

Predicting future fleet composition introduces a level of uncertainty and the National Fleet projections that are published by the DfT are widely considered to be optimistic. The vehicle fleet composition used for the 2024 modelling scenarios is based on the predicted trends in national fleet composition/compliance (2019-2024) which was applied to locally observed ANPR data gathered in 2019. Note that changes in compliance in the national fleet tables from one year to the next are not linear. As these predictions are known to be optimistic and, in reality are likely to occur later than 2024. COVID has added another level of uncertainty, and fleet prediction data does not account for this. Therefore, this fleet composition scenario should be considered as one possible 'future scenario'. It is expected that over time, the fleet will become cleaner as older vehicles are scrapped and new vehicles enter the fleet.

Buses are significant emitters of NO_x and it is important that the bus fleet is represented appropriately in the model. For the Base Case, bus operator data and ANPR surveys showed that only 21% of buses were compliant (13.9% of buses are Euro VI and 6.6% are hydrogen fueled) (Table 3). In the Reference Case and LEZ Case, the bus fleet is assumed to be fully compliant with 89% of bus journeys made by Euro VI buses and 11% of bus journeys made by hydrogen fuel cell vehicles based on the 2021 fleet as agreed with ACC.

Within the traffic model, Cars, LGV's and HGV's were split into 2 categories, compliant and non-compliant using the values in Table 2 . The values are derived from the 2019 ANPR survey adjusted to 2024:

Table 2: Compliant and Non-compliant percentages used in the 2019 (Base) and 2024 (Reference and LEZ) case in the traffic modelling.

Vehicle Type	Compliance	Fuel Type	Percentage by Vehicle Class	
			2019	2024
Cars	Compliant	Petrol	51.5%	63%
		Diesel	18.6%	23%
	Non-Compliant	Petrol	3.9%	2%
		Diesel	26%	12%
LGV's	Compliant	Petrol	0.5%	0.6%
		Diesel	39.8%	69%
	Non-Compliant	Petrol	0.2%	0.3%
		Diesel	59.5%	30.1%
Buses	Compliant	Diesel	13.9%	89.4%
	Non-Compliant	Diesel	79.5%	0%
	Compliant	Hydrogen	6.6%	10.6%
Rigid HGV 2-Axle	Compliant	Diesel	69.2%	91.9%
	Non-Compliant	Diesel	30.8%	8.1%
Rigid HGV 3-Axle	Compliant	Diesel	71.9%	94.6%
	Non-Compliant	Diesel	28.1%	5.4%
Rigid HGV 4+-Axle	Compliant	Diesel	74.6%	87.3%
	Non-Compliant	Diesel	25.4%	12.7%
Artic HGV 3&4 Axle	Compliant	Diesel	63.8%	76.5%
	Non-Compliant	Diesel	36.2%	23.5%
Artic HGV 5 Axle	Compliant	Diesel	66.7%	79.4%
	Non-Compliant	Diesel	33.3%	20.6%
Artic HGV 6+ Axle	Compliant	Diesel	80.1%	92.8%
	Non-Compliant	Diesel	19.9%	7.2%

Table 3: Percentage of Bus Euro Class used in the 2019 Base Case taken from the Bus Operators fleet and 2019 ANPR Survey.

Bus Class	Percentage of Bus Fleet
Euro III	10%
Euro IV	29.6%
Euro V	39.9%
Euro VI	13.9%
Hydrogen	6.6%

The main bus routes within the LEZ boundary are shown in Figure 5. This was taken from the Aberdeen Bus Operators' tool that was used to develop the bus fleet composition for the Base Case. The provided a more accurate bus operator fleet data that was based on bus frequency and Euro class across the network, rather than just total static fleet composition.

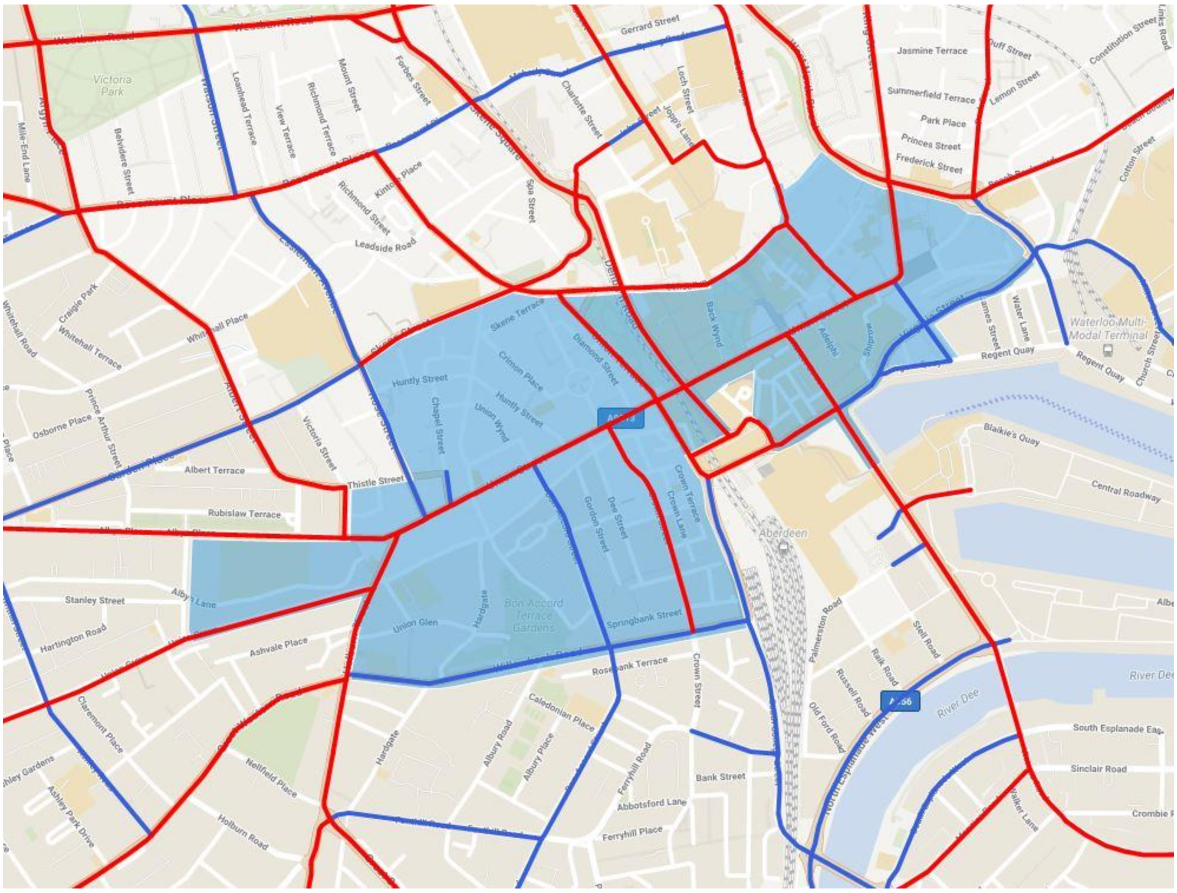

Figure 5: Main bus routes (shown in red) across Aberdeen city centre taken from the SEPA Bus Operator tool (pre-Covid 2019).

Each case was run over 3 time periods within the traffic model, with the flows for each period summed to provide a 12-hour flow:

- AM: 07:00 – 10:00
- Interpeak: 10:00 -16:00
- PM: 16:00-19:00

The road network in the traffic model consists of approx. 7000 links and is much more detailed than the network in the air quality model consisting of approx. 255 links (Figure 6). Links in the traffic model road network that did not overlap with links in the air quality model road network were removed and the remaining traffic model links were mapped and associated with the appropriate links in the air quality model. The road networks shown in Figure 6 include the Haudagain, Berryden and South College Street road layout changes that will be complete and operational in 2024. In the road network that was used in the 2019 Base Case models these changes were absent.

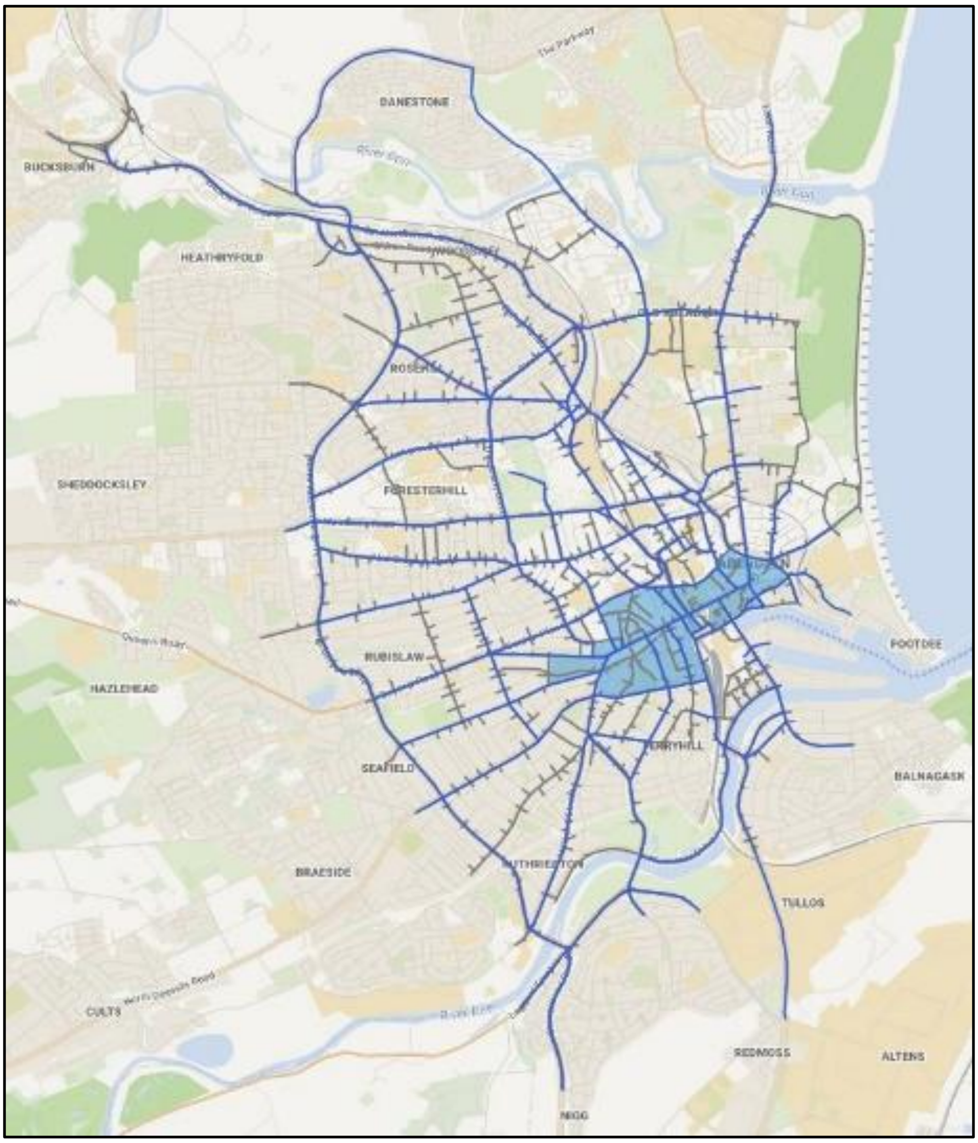

Figure 6: Aberdeen Paramics road network in grey, with the ADMS road network (2024 Reference Case and LEZ Case) overlaid in blue.

In most cases there were multiple traffic model links associated with one air quality model link so the maximum flow for each vehicle type in each direction along the traffic model links were summed to provide a two-way flow and assigned to the appropriate link in the air quality model. This is considered a precautionary approach. The average of each vehicle type's average speed in each direction in the traffic model links were also assigned to the appropriate link in the air quality model.

Calculating Emission Inputs for Air Quality Modelling

The Emission Factor Toolkit version 10.1 (EfT10) emission factors (Defra, 2020) within the CERC database tool EMIT have been used to calculate emission rates in this analysis which is the most up to date at this time.

Vehicle categories from the Paramics model were converted into 11-vehicle classes required by EMIT:

- Motorcycle
- Car
- LGV
- Bus/Coach
- Rigid HGV 2 axle
- Rigid HGV 3 axle
- Rigid HGV 4 axle
- Artic HGV 3 and 4 axle
- Artic HGV 5 axle
- Artic HGV 6 axle
- Taxi

To generate fleet composition tables for EMIT, the heavy goods vehicles were split in line with the proportions identified in the 2019 observed (ANPR) fleet data and vehicle numbers for buses and coaches were combined. During the 2019 traffic survey taxis were counted as cars as they are not the Black Cab type vehicles and are not easily distinguished in the traffic data, therefore taxis are included in the petrol/diesel car categories in EMIT. In the LEZ Case all taxis are assumed to be compliant.

To calculate emission rates, 24-hour traffic flows (known as Annual Average Daily Traffic, or AADT) are required, which is not provided by the traffic model. In previous modelling work, traffic flows were calculated using 12-hour and 24-hour JTC data. The junctions that had 24-hour data were already AADT flows. Where data was collected over a 12-hour period, these values were factored up to AADT using conversion factors derived from the 24-hour JTC data, with different factors used for each traffic category.

Finally, the 2019 fleet composition tables and traffic flow data were used in the CERC EMIT database tool to generate NO_x, NO_2 and PM_{10} emission rates for each road link. These emission rates were analysed to provide information on emission rate changes for each road and were also ready to import into ADMS-Urban to predict NO_x and NO_2 concentrations.

Air Quality Modelling Methodology

The Aberdeen Pilot Project Technical report (SEPA, 2017) outlines the air quality modelling methodology and this remains the same to maintain consistency with previous modelling unless outlined in more detail below, which is mainly focused on the use of traffic model data to examine the effect on introducing an LEZ.

The following Air Quality modelling parameters were used:

- Meteorology: The model was run using meteorology from Aberdeen Dyce Airport for 2019. Figure 7 shows the annual average wind speed (in metres per second: m/s) at this site for each year from 2006 to 2019. In 2019 the average wind speed was 4.3 m/s and ranks amongst the lowest four average wind speed years of the fourteen analysed. The lower wind speed will result in less dispersion of air pollutants in 2019, thus resulting in higher concentrations. Therefore the choice of using 2019 data is a precautionary approach.

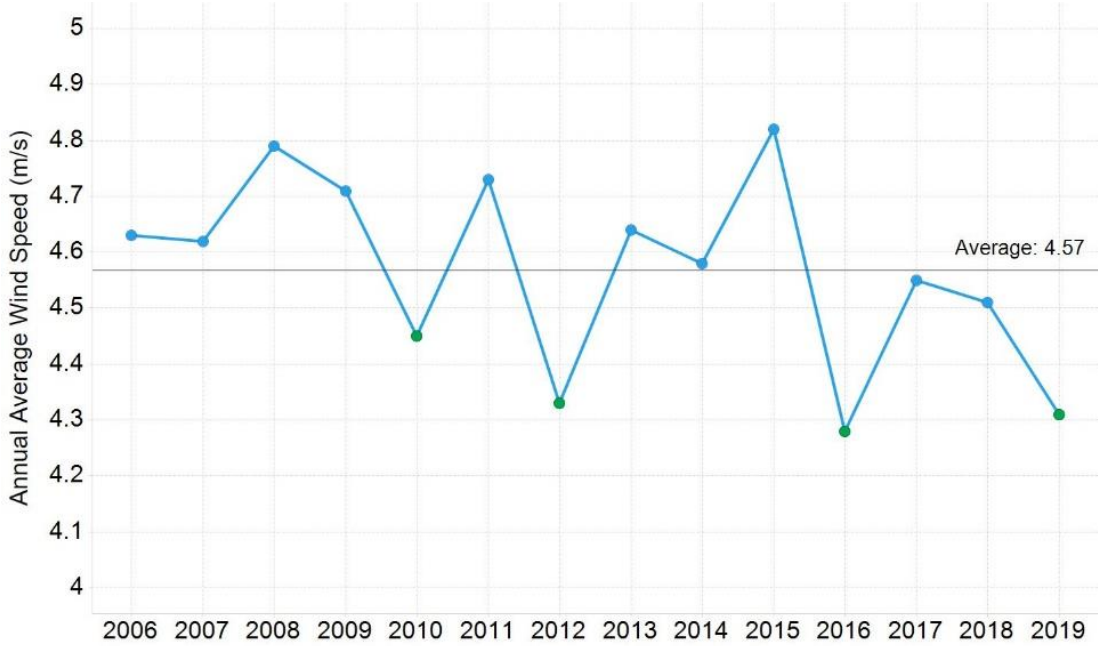

Figure 7: Annual Average Wind Speed (m/s) at Aberdeen Dyce from 2006 to 2019. The lowest four wind speed years are highlighted with the green markers.

- Background data: 2017 Gridded Background Emissions and Rural Background Concentrations from the Bush Estate monitoring station. This method uses estimated gridded area emissions data compiled by the National Atmospheric Emissions Inventory (NAEI). The Gridded Emissions come in raster format on a 1km x 1km grid resolution for many pollutants and different sectors (e.g. road transport) and subsectors (e.g. major roads, minor roads, shipping). As the major roads and shipping were being modelled explicitly in the model these sectors were removed from the background emissions.

- Traffic Speed: These are based on output from the traffic model as discussed above.
- Street Geometry (road widths and canyons): These features were re-calculated from Mastermap using the established NMF methodology **(SEPA, 2017)**.
- 12-hr traffic flows were converted to 24-hr flow using JTC data.

Aberdeen is considered relatively unique in the UK with regard to the close proximity of a major harbour to the city centre, so it is important that this emission source is represented as accurately as possible in the model. Shipping emissions are represented by 26 point sources. Stack emission parameters are based on those reported by (Meneses, 2004) and NO_x emission rates are based on the shipping emission grids published by NAEI (2017). Previous modelling explored the relative contribution of NO_x from background, (gridded emissions and rural background), road traffic and shipping sources to the annual average total NO_x at a selection of roadside points in and around the city centre close to the harbour (Figure 8). The results clearly indicate that whilst emissions from shipping do contribute to existing exceedances in the city centre, and to the total regional emissions, they are localised and are not likely to cause an exceedance of the annual mean air quality objectives on their own. Therefore, road traffic followed by gridded emissions are the main sources of emissions near the harbour and should remain the focus of Air Quality Action Planning in the future.

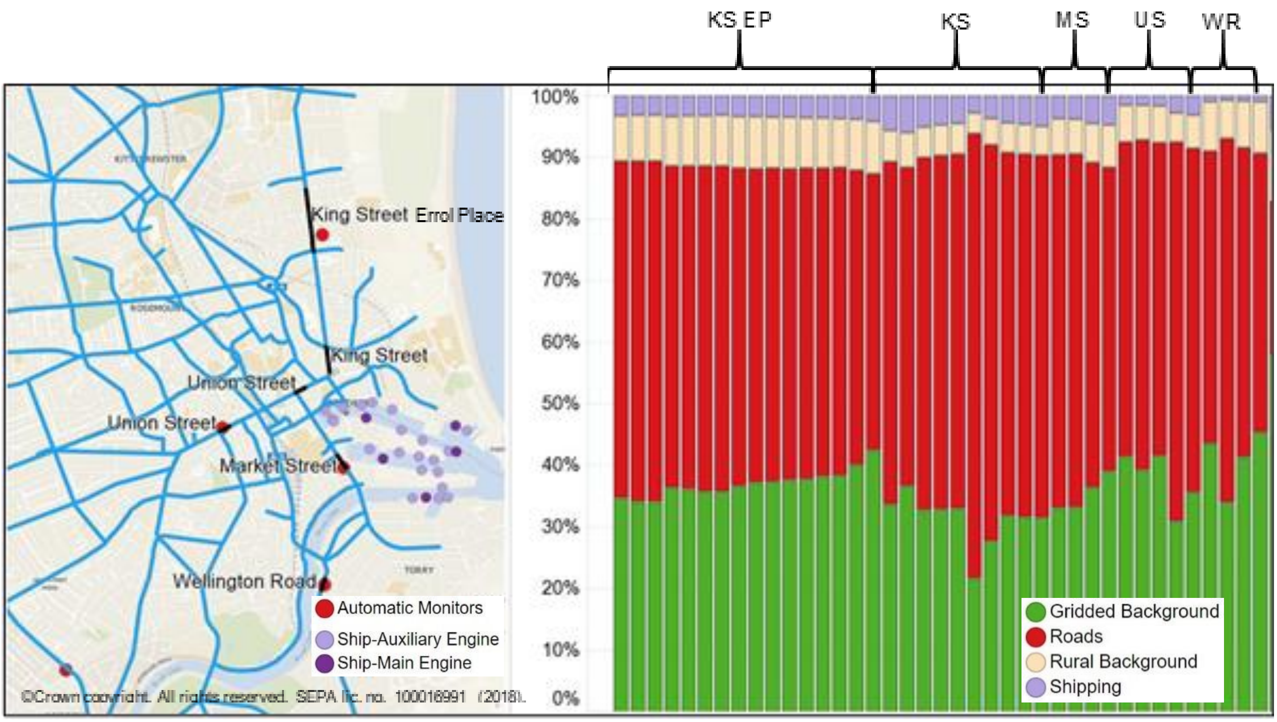

Figure 8: Percentage contribution to annual average total NO_x from background (rural background and gridded emissions), road traffic and shipping sources at a selection of roadside points. Highlighted roads are shown in black. King Street Errol Place (KS EP), King Street (KS), Market Street (MS), Union Street (US) and Wellington Road (WR).

Results

Traffic Model Output

The aim of the traffic model is to predict traffic flow changes in response to the introduction of an LEZ, which is likely to displace non-compliant traffic around the LEZ boundary. The first stage in assessing the effect of these changes on emissions involved processing the Traffic Model outputs to make them compatible with the CERC emissions database tool (EMIT) using conversion factors derived from observed traffic data. Emission rates (g/km/s) were calculated for the vehicle flows along every road in the traffic model for the Reference Case and LEZ Case. Comparing emissions between these 2 scenarios enabled changes due to the LEZ to be identified (SEPA, 2021). Initial findings suggested that there is a significant reduction in NO_x emissions on key bus routes inside the LEZ. For example, on the sections of Union Street where only buses and taxis are permitted as part of the CCMP Union Street Scheme there is an average reduction of 87% of NO_x emissions. The bus fleet in 2024 is considered to be fully compliant in the Reference and LEZ scenarios, so therefore this improvement is due to the removal of all other vehicle categories, mainly diesel cars and goods vehicles. Along the remaining sections of Union Street there is a reduction in NO_x emission rates of on average 57% (ranging between 34% and 72%). The proposed LEZ generally results in low levels of traffic displacement although larger increases in car and LGV flows of up to ~5000 vehicles were noted along Springbank Terrace and Willowbank Road, Rosemount Place and South Anderson Drive.

The emissions generated for each road link using flows in the traffic model, have been imported into the air quality model to predict changes in roadside concentrations due to the LEZ. The absolute differences between Reference and LEZ cases may in some cases be smaller than previously presented in the Aberdeen LEZ Emissions Report. This is a consequence of aggregating the traffic data, whereby the maximum Reference and LEZ flows from the Paramics model are used in ADMS. The air quality modelling results for the LEZ case still represent a worst-case scenario as these are based on maximum traffic flows.

Predicted changes to road emissions

Inside the LEZ

In the 2019 base model, Figure 9 shows all roads in the model network ranked by NO_x emission rate (g/km/s) for the Base, Reference and LEZ cases. In the Base Case only 21% of the bus fleet was compliant (14% Euro VI buses and 7% hydrogen fuel cell vehicles). Bus emissions dominate on the highlighted roads shown in the map where contributions by buses to total NO_x can vary up to 58%. In both the Reference Case and LEZ Case, the bus fleet is assumed to be fully compliant (Table 2). This is based on the predicted 2024 fleet as agreed with ACC. Emissions from buses form a much smaller component of the total NO_x emissions in both these cases when compared to the 2019 base results with diesel cars and LGVs now the dominant sources of NO_x. In the LEZ case the highlighted roads with the lowest emission rates are those contained within the stretch of Union Street where all traffic has been excluded apart from buses and taxis.

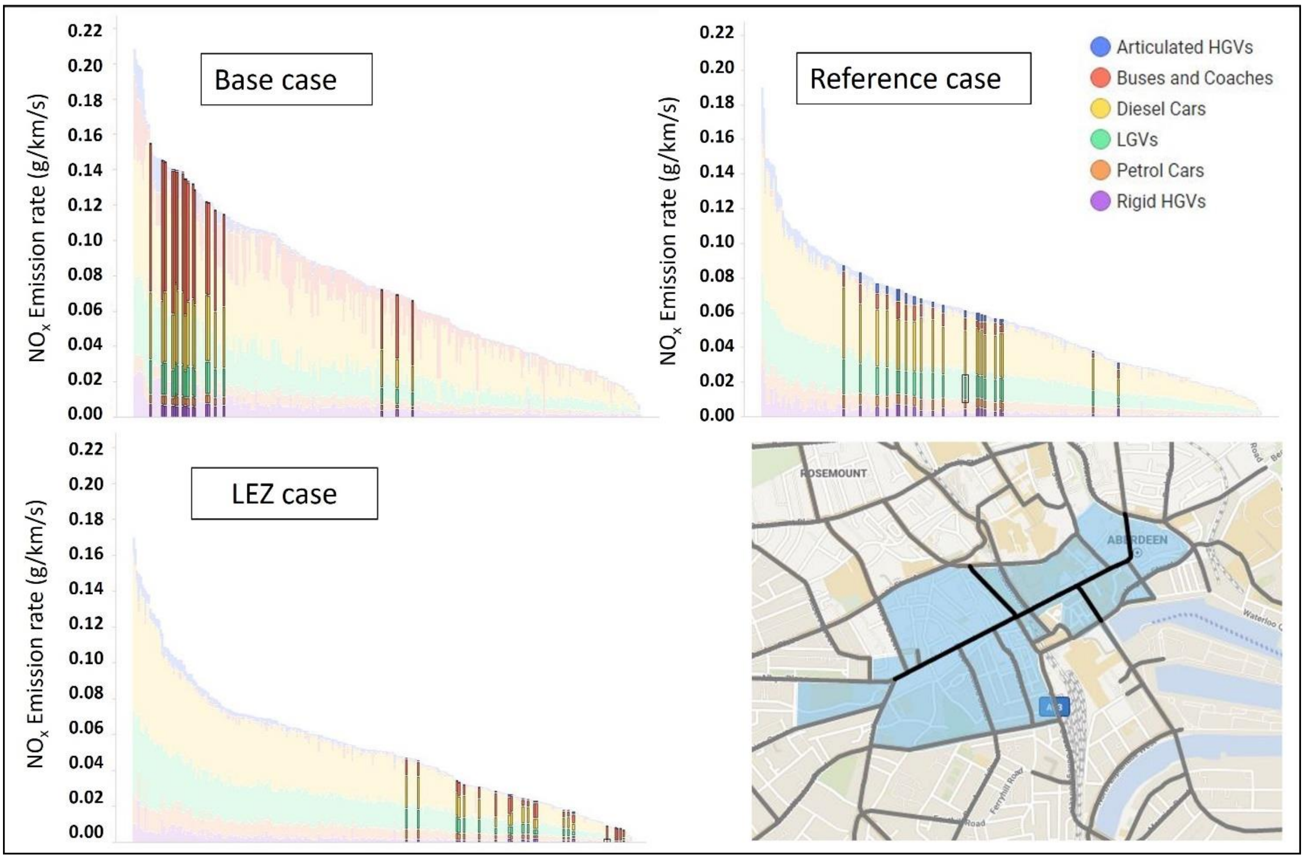

Figure 9: Ranked emissions rates of NO_x (g/km/s) for all roads for the Base, Reference and LEZ cases. Roads inside the LEZ are highlighted to show the contributions from the different vehicle categories.

In addition to lower-emitting vehicles inside the LEZ there are some large reductions in the number of vehicles on some roads within the LEZ. Along the section of Union Street restricted to buses and taxis only, there is a large reduction in total traffic flows decreasing from 13500 vehicles per day in the Reference case to 1700 vehicle per day in the LEZ case, a reduction of 87%. With increasing distance along Union Street away from the restricted section, the differences between the traffic levels in the Reference case and LEZ case diminishes.

There is a large reduction in emissions inside the LEZ due to its implementation. In the Reference case, 9.0 tonnes of NO_x is emitted annually, which reduces to 5.7 tonnes of NO_x in the LEZ case. This is due to all vehicles meeting EURO 6/VI standards. Following implementation of the LEZ, Diesel cars are the largest contributor to NO_x emissions, emitting 2.3 tonnes annually. LGV's are the next largest contributor to annual NO_x (1.5 tonnes/year) followed by buses (0.6 tonnes/year).

Anderson Drive

Following implementation of the LEZ, total traffic increases by approximately 5000 vehicles per day. This corresponds to increases in Car and LGV flows of up to 18% (an additional 4400 cars) and 40% (an additional 1200 LGVs) per day respectively. Similarly, Rigid HGV and Articulated HGV flows increase by up to 20% (110 vehicles) and 13% (49 vehicles) per day respectively.

Figure 10 shows all roads in the model network ranked by NO_x emission rate (g/km/s) for the Reference Case and LEZ Case respectively. Roads between Garthdee Roundabout and Kings Gate are highlighted in black. There is an increase in NO_x emission rates in the LEZ case due to vehicles routing along South Anderson Drive to avoid the LEZ. Emissions from diesel cars and LGVs are the dominant sources of NO_x. In the Reference case there are 10.1 tonnes of NO_x emitted annually, compared with 14.1 tonnes of NO_x in the LEZ case. Following implementation of the LEZ just over half of emissions (7.3 tonnes of NO_x) are expected to be from non-compliant vehicles.

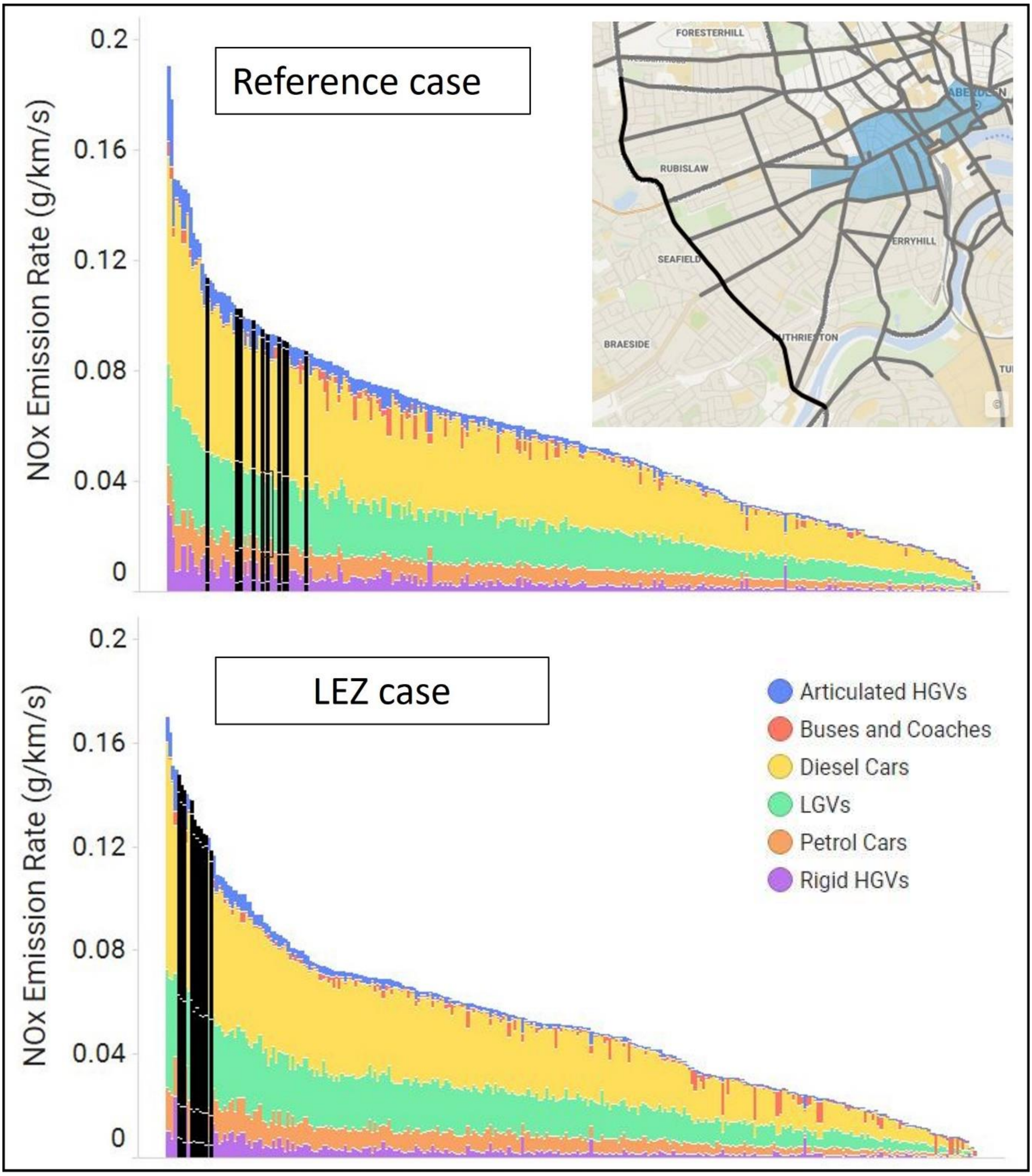

Figure 10: Ranked emission rates of NO_x (g/km/s) for all roads for the Reference and LEZ cases. Sections of South Anderson Drive are highlighted in black.

Market Street to Commerce Street

Figure 11 shows all roads in the model network ranked by NO_x emission rate (g/km/s) for the Reference Case and LEZ Case respectively. Virginia Street and the section of Market Street highlighted on the map are included within the LEZ. Overall, there is a reduction in traffic flows along Virginia Street and Market Street. In the Reference Case there is a maximum traffic flow of around 33000 vehicles per day on the section of Market Street. This reduces to 29400 vehicles per day in the LEZ Case which is a reduction of 11%. This reduction is mainly achieved by fewer cars entering the LEZ.

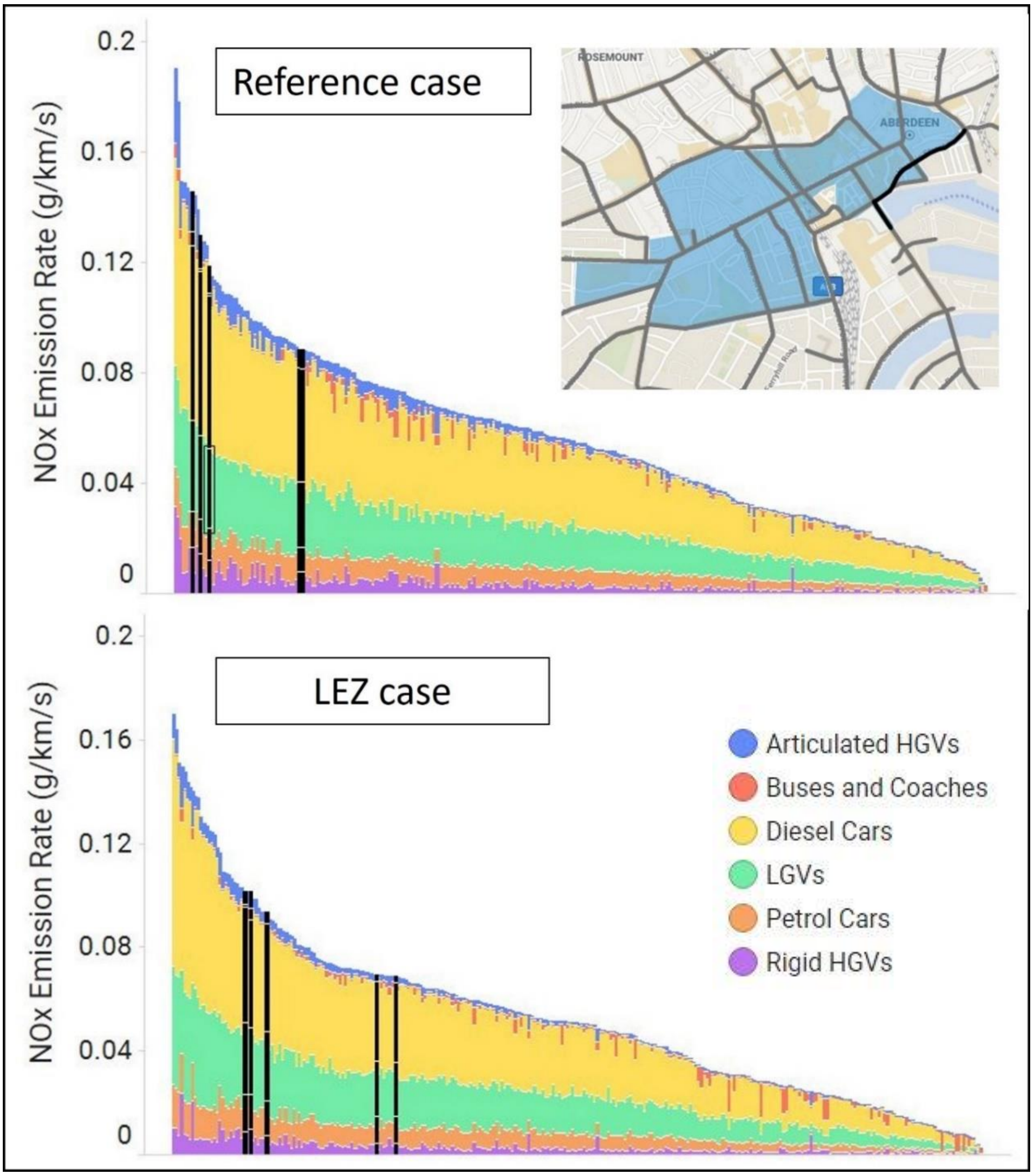

Figure 11: Ranked emissions rates of NO_x (g/km/s) for all roads for the Reference and LEZ cases. Sections of Market Street and Virginia Street are highlighted in black.

The reduced flows combined with the change to fully compliant vehicles in the LEZ Case results in reductions in NO_x emission rates of up to 30% on the highlighted roads. Emissions from diesel cars and LGVs are the dominant sources of NO_x. In the Reference Case there are 2.4 tonnes of NO_x emitted annually, compared with 1.8 tonnes of NO_x in the LEZ case.

Rosemount Place

There is an increase in traffic flows along Rosemount Place. Figure 12 shows all roads in the model network ranked by NO_x emission rate (g/km/s) for the Reference Case and LEZ Case respectively.

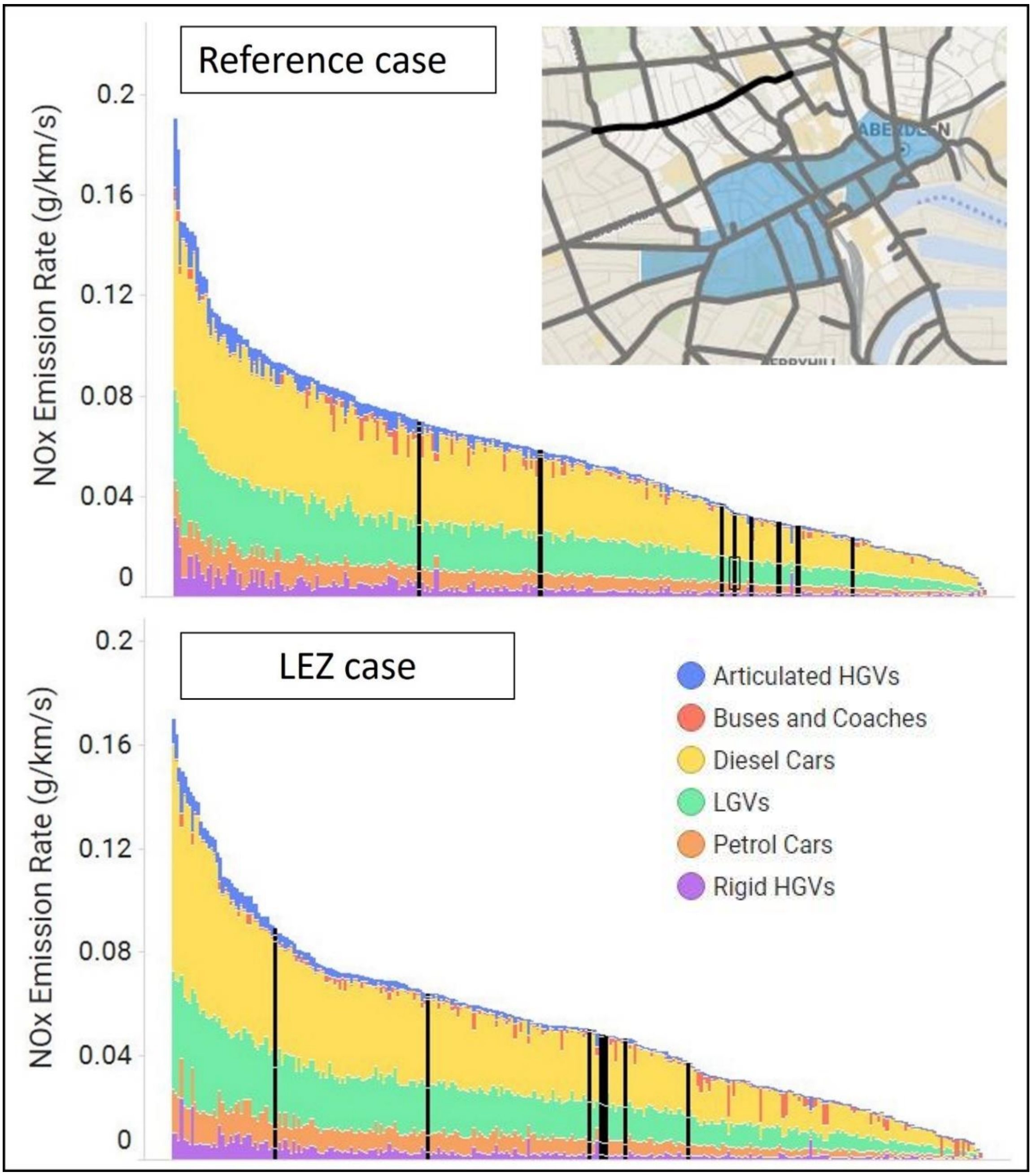

Figure 12: Ranked emissions rates of NO_x (g/km/s) for all roads for the Reference and LEZ cases. Sections of Rosemount Place are highlighted in black.

On one road section highlighted in the map shown in Figure 12, there is a maximum traffic flow of around 8900 vehicles per day in the Reference Case which increases to 12000 vehicles per day in the LEZ Case which is an increase of 36%. This increase is mainly due to cars along this route with just under half of these vehicles being non-compliant.

The increased flows in the LEZ Case results in increases in NO_x emission rates of up to 60% on the highlighted roads although the increases are relatively small in absolute terms. Emissions from diesel cars and LGVs are the dominant sources of NO_x. In the Reference Case there are 1.3 tonnes of NO_x emitted annually, compared with 1.9 tonnes of NO_x in the LEZ Case.

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Predicted changes in NO_2 concentration due to the LEZ

The emissions described in the previous section have been used in the air quality model to predict roadside concentrations of NO_2 and NO_x across the city.

The model has been run for 3 different scenarios which are presented in Figure 13. The 2019 base Case corresponds to the traffic fleet as it was observed in 2019, with 21% of bus journeys made by compliant buses (Euro VI or hydrogen).

In the 2024 Reference Case, all buses are fully compliant (89% Euro VI and 11% hydrogen). The 2024 LEZ case includes the fully compliant buses and the intervention of the LEZ boundary and the CCMP.

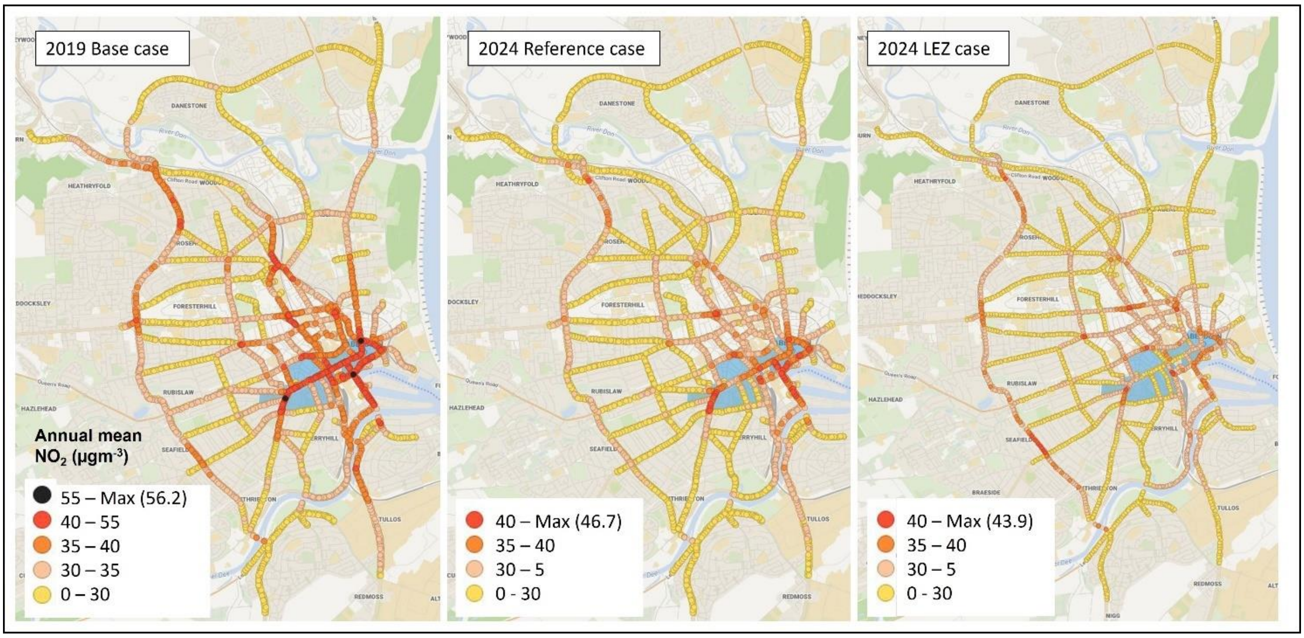

Figure 13: Predicted NO_2 concentrations at kerbside receptors for Base 2019, Reference 2024 and LEZ 2024.

The concentration data shown in the maps in Figure 13 has been ranked from high to low for each of the 3 scenarios. Figure 14 shows concentrations from across the whole city, and Figure 15 focuses on kerbside points inside the LEZ boundary only. Data from these plots are also summarised in Table 4.

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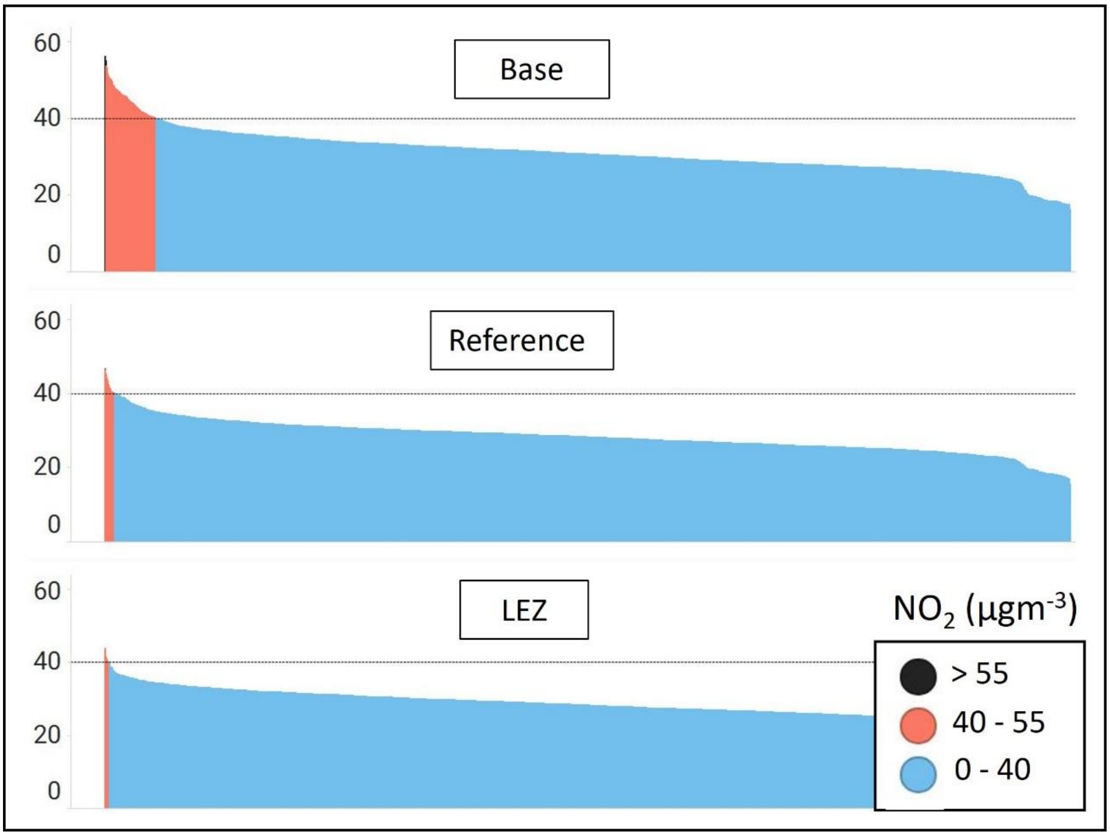


Figure 14: Ranked modelled concentrations of NO_2 (ugm^{-3}) at all kerbside points across the model domain, for 3 scenarios.

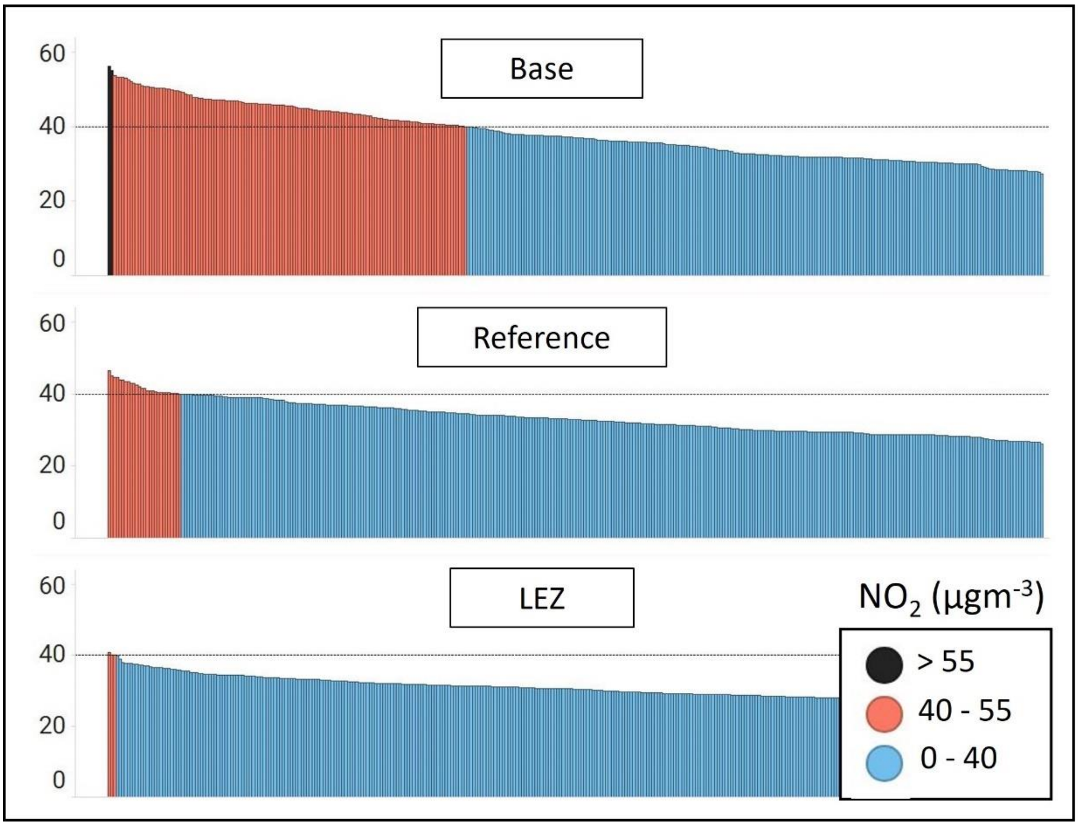


Figure 15: Ranked modelled concentrations of NO_2 (ugm^{-3}) at all kerbside points inside the LEZ boundary, for 3 scenarios.

In the 2019 base case there are exceedances at 218 number of kerbside points, corresponding to 5% of the total model area (Table 4). Inside the LEZ boundary there are exceedances at 128 kerbside points (39% of the LEZ). The predicted concentration at Market Street Automatic monitor was 33 μgm^{-3} and at Union Street Automatic monitor was 39 μgm^{-3}.

In the 2024 Reference case there is no displacement of traffic, but there is a substantial reduction in the number of kerbside points that are predicted to exceed. There are exceedances at 42 number of kerbside points corresponding to 1% of the total model area. This is due to a cleaner bus fleet which is fully compliant and also predicted improvements in the rest of the fleet due to natural turnover. Inside the LEZ boundary there are exceedances at 23 kerbside points.

The introduction of the LEZ restricts vehicles entering the LEZ zone to those which are fully compliant. The implementation of the CCMP further restricts the movement of cars and LGVs on specific roads inside the LEZ. The effects of these two interventions are shown in the 2024 LEZ case in Figure 16 and Figure 17. This has resulted in further reductions to predicted NO_2 concentrations in the city centre, with only 3 roadside points exceeding. However, the displacement of non-compliant traffic to other parts of the city results in some localised increases in kerbside NO_2.

Table 4: The number of kerbside points predicted to exceed 40 μgm^{-3} across 3 scenarios. The total number of kerbside points in each zone (citywide, AQMAs and LEZ) are shown in brackets.

Scenario	City wide (Base=4088) (Ref/LEZ=4116)	AQMA			Within LEZ boundary (326)
		City Centre (272)	Anderson Drive (401)	Wellington Road (43)	
2019 Base	218	173	4	1	128
2024 Reference	42	36	1	0	23
2024 LEZ	17	3	8	0	3

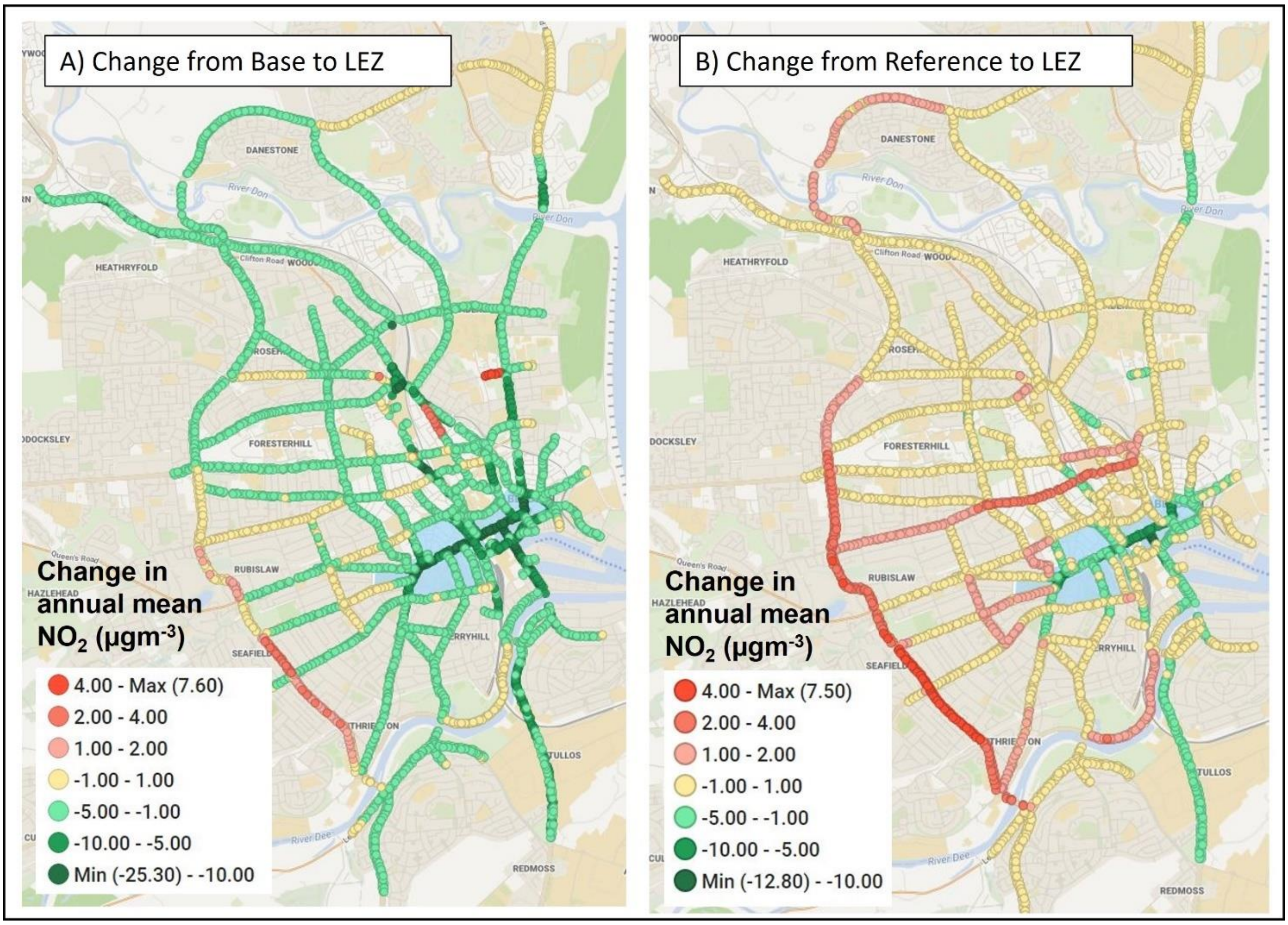


Figure 16: Differences in predicted NO_2 concentrations between the 2019 base and 2024 LEZ scenarios (A), and between the 2024 Reference and 2024 LEZ scenarios (B).

Figure 16 shows the changes in predicted concentrations as a result of:

- A) Bus fleet improvements and displacement of non-compliant traffic due implementing the LEZ and CCMP.
- B) Displacement of non-compliant traffic due to implementing the LEZ and CCMP only.

The introduction of the LEZ and CCMP results in a widespread reduction in NO_2 concentrations across the city. There are small and localised increases in predicted NO2 concentrations along Anderson Drive of 1-4 μgm^{-3}. This increase along Anderson Drive is in part due to a displacement of non-compliant traffic that is unable to enter the LEZ as shown in both cases.

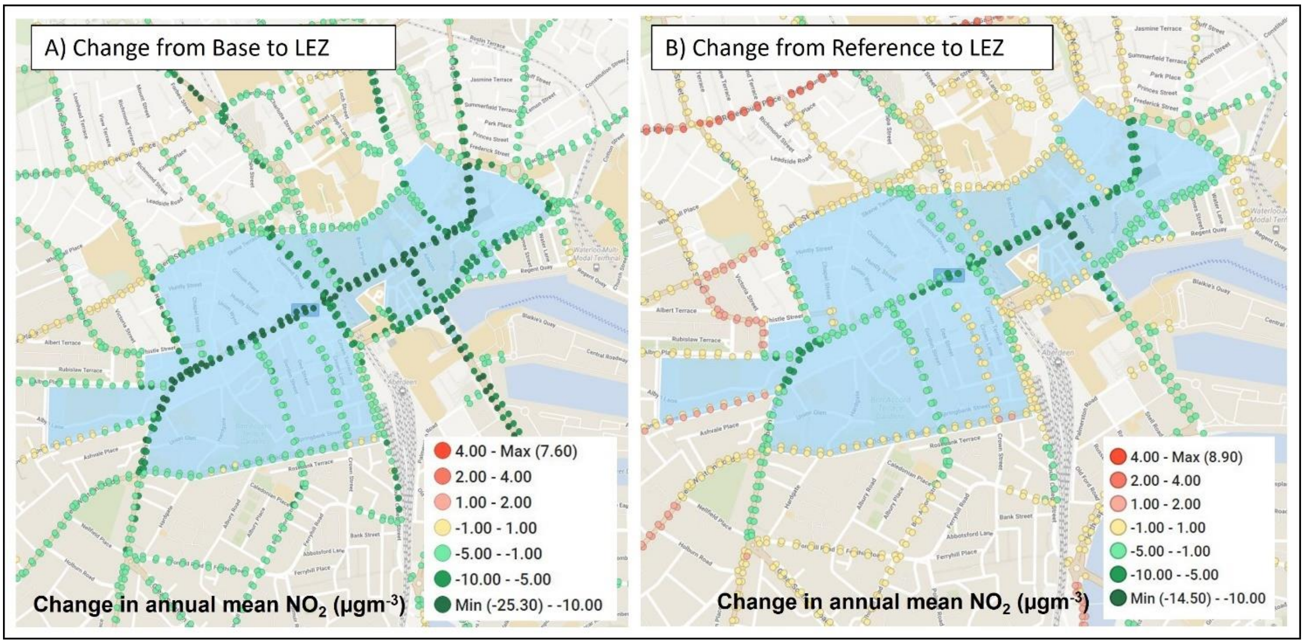


Figure 17: Differences in predicted NO_2 concentrations within the LEZ boundary between the 2019 base and 2024 LEZ scenarios (A), and between the 2024 Reference and 2024 LEZ scenarios (B).

There is an overall reduction of up to 25 µgm^{-3} along Union Street following implementation of the LEZ and CCMP (part A of Figure 17). Restrictions on traffic movements inside the LEZ associated with the CCMP account for average reductions of 9 µgm^{-3} along the restricted section of Union Street and 4 µgm^{-3} along Union Terrace respectively (part B of Figure 17). The remaining improvements in air quality are attributed to improvements in the bus and taxi fleet.

Anderson Drive

The effect of implementing the LEZ and CCMP on Anderson Drive are examined here in more detail. Model predictions of traffic displacement onto Anderson Drive is expected to result in small increases in kerbside NO_2 concentrations. In particular, there is expected to be an additional 5000 vehicles per day. This means that around half of the NO_x concentrations along the section of road highlighted in Figure are attributed to non-compliant vehicles.

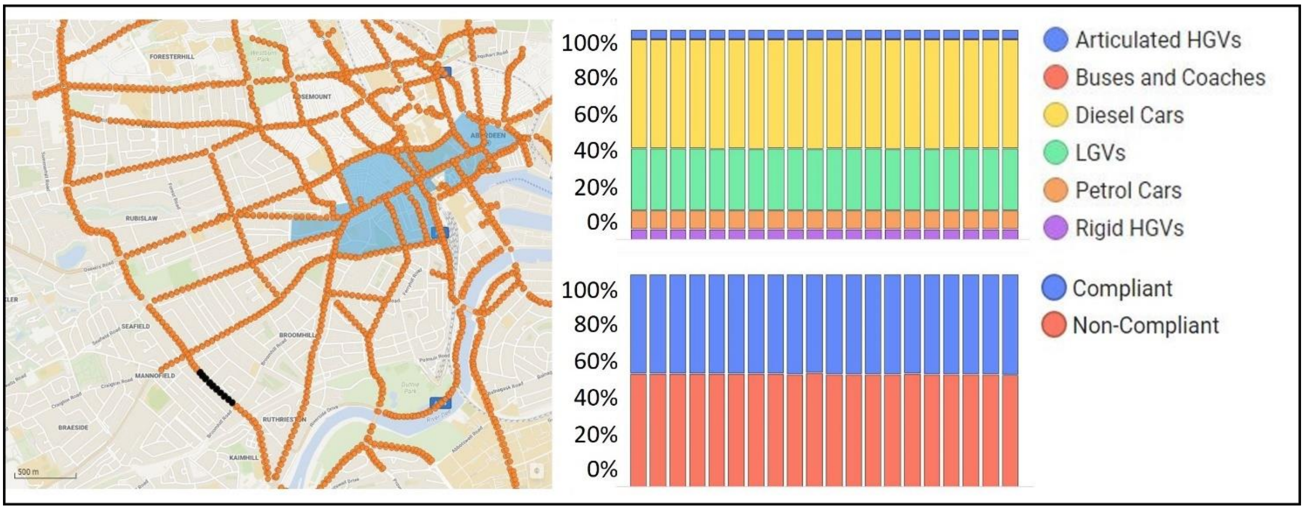


Figure 18: The contribution to modelled NO_x concentrations from different vehicle categories, at kerbside points along a section of Anderson Drive.

The implication of this is that the reduction in NO_2 identified across many parts of the city due to natural fleet turnover is not realised along Anderson Drive. The model predicts a small number of exceedances on South Anderson Drive (Figure 19), however, this is not expected to result in exceedances as the model is known to over-predict in this area (Appendix 1).

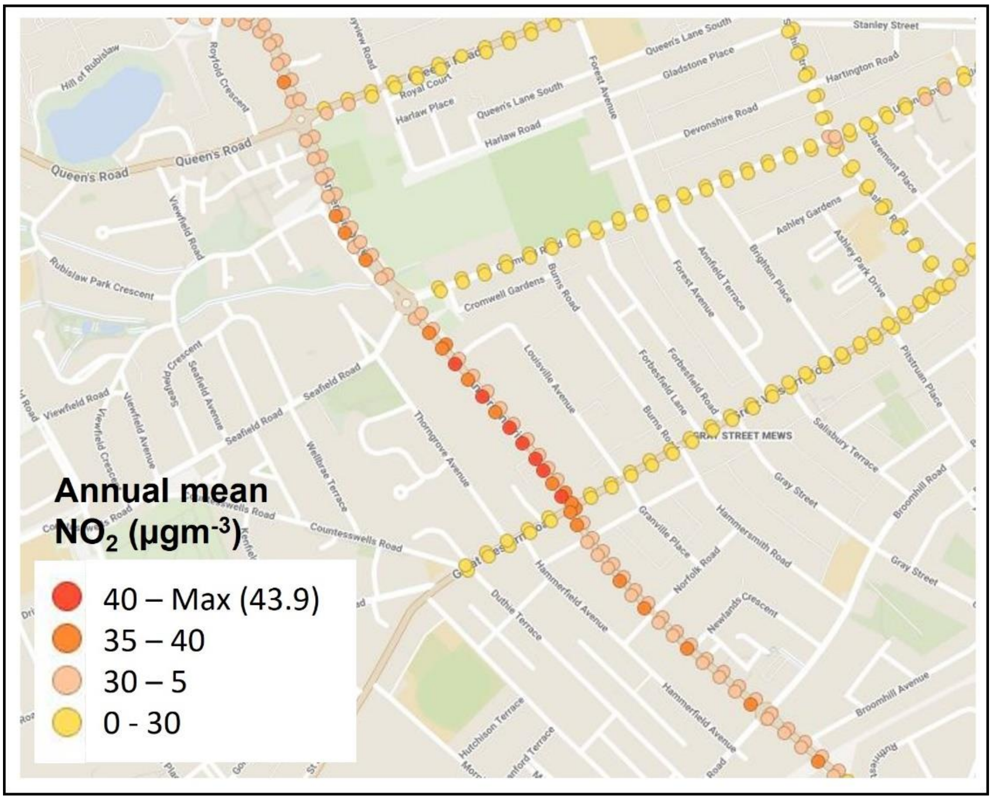


Figure 19: Predicted kerbside concentrations of NO_2 along a section of Anderson Drive for the 2024 LEZ scenario.

City Centre

Predicted concentrations of NO_2 inside the LEZ are substantially reduced following implementation of the LEZ and CCMP. Some of the lowest concentrations inside the LEZ are along Union Street, with an average concentration along the restricted section of 28 μgm^{-3}. Either side of the restricted section NO_2 concentrations average around 31 μgm^{-3} (Figure 20).

Figure 20 shows predicted NO_2 concentrations for the LEZ case, confirming that nearly all predicted exceedances are removed. Some isolated exceedances remain on or near junctions. It should be noted that these air-quality model results are based on a fully compliant Aberdeen fleet predicted for 2024. These improvements will not be realised if the predicted fleet improvements are not achieved.

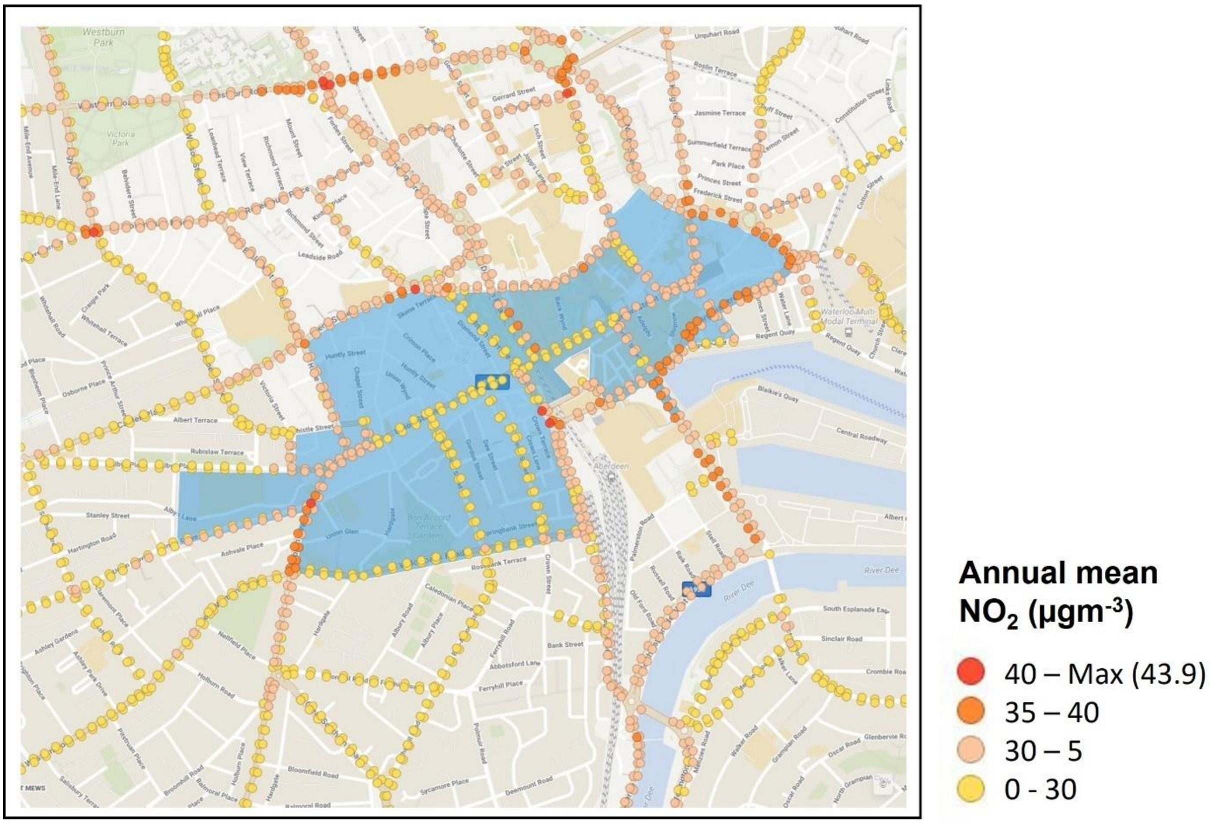


Figure 20: Predicted kerbside concentrations of NO_2 within the LEZ boundary for the 2024 LEZ scenario.

Figure 21 shows that along the restricted section of Union Street the majority of NO_x is attributed to compliant vehicles. In particular, on average 41% is linked to buses, 30% to diesel cars and 17% to LGV's. However, roadside receptors continue to receive a small contribution of NO_x from non-compliant vehicles, outside of the LEZ. Outside of the restrictions there is a greater contribution of NO_x from diesel cars and LGVs.

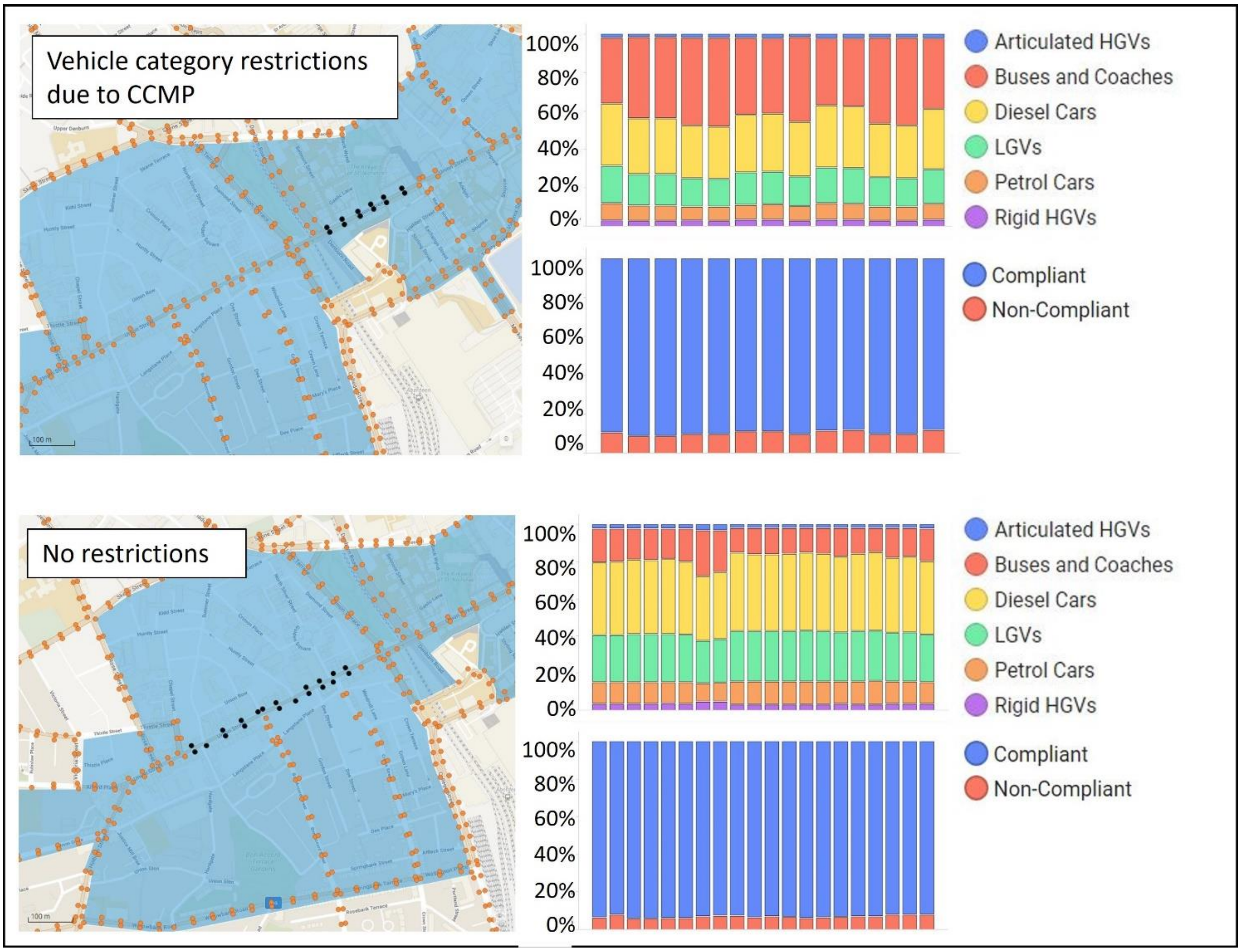


Figure 21: The contribution to modelled NO_x concentrations from different vehicle categories, at kerbside points along two sections of Union Street highlighted in black on the map.

On Virginia Street along the boundary of the LEZ the vast majority of NO_x can be attributed to diesel cars and LGVs (Figure 22).

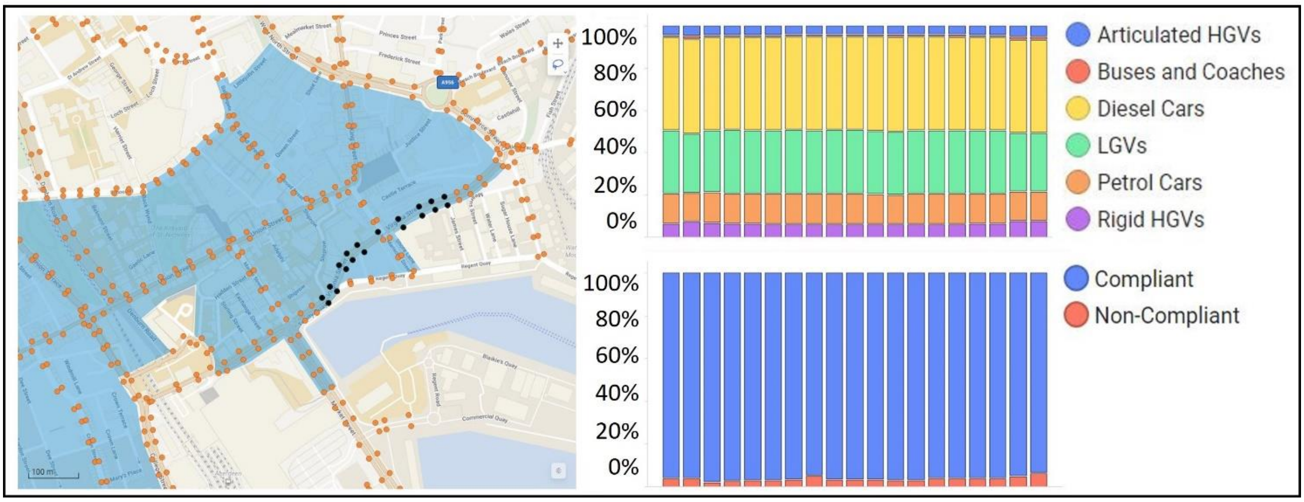


Figure 22: The contribution to modelled NO_x concentrations from different vehicle categories, at kerbside points along a section of Virginia Street highlighted in black on the map.

Façade and Sensitive Receptor Modelling

Further detailed modelling was carried out to predict concentrations at building façades where there was particular concern about air quality predictions. These areas are the central AQMA, Caroline Place and Kittybrewster. These are expected to be lower than the kerbside points. For technical reasons, the point was selected at 1m from the actual building façade, to make sure that the model identified the receptor as being in the street and not within the building Figure 23.

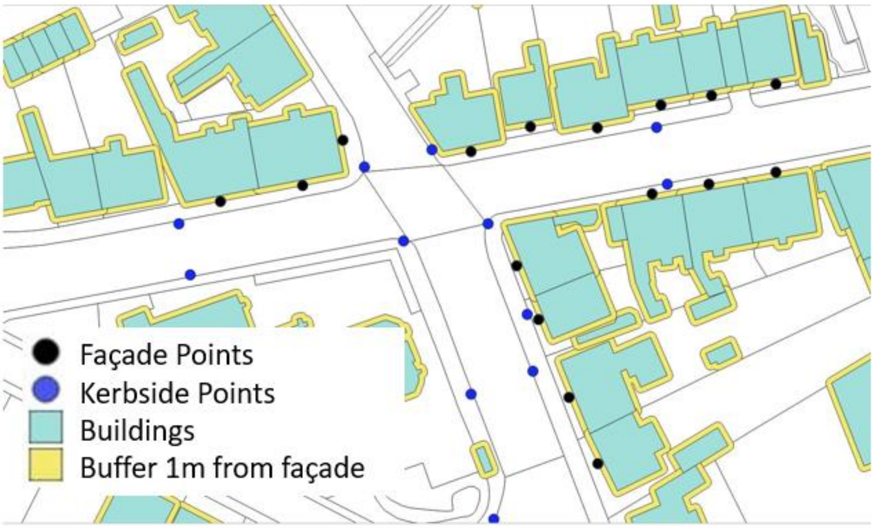


Figure 23: Kerbside points (blue) and facade points (Black) for Caroline Place junction.

This shows that a model exceedance was identified at only 1 façade receptor at the junction of Caroline Place and Hutcheon Street. At all other locations, façade receptor concentrations are predicted to be below the 40 µgm^{-3} threshold (Figure 24).

The Caroline Place junction is shown in greater detail in Figure 25. The predicted concentration of 43.7 µgm^{-3} at 1 façade receptor suggests that the risk of exceedances when an LEZ is implemented is limited to receptors in the immediate vicinity of the Caroline Place junction, and that the risk of exceedances at other locations is low.

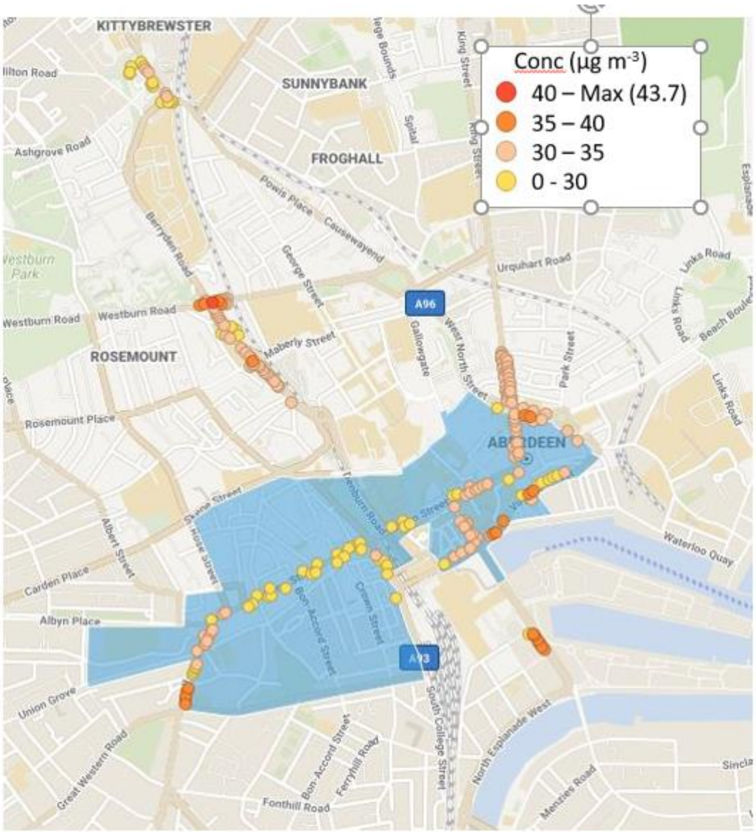


Figure 24: Predicted Concentrations (μgm^{-3}) at building façades (2024 LEZ scenario).

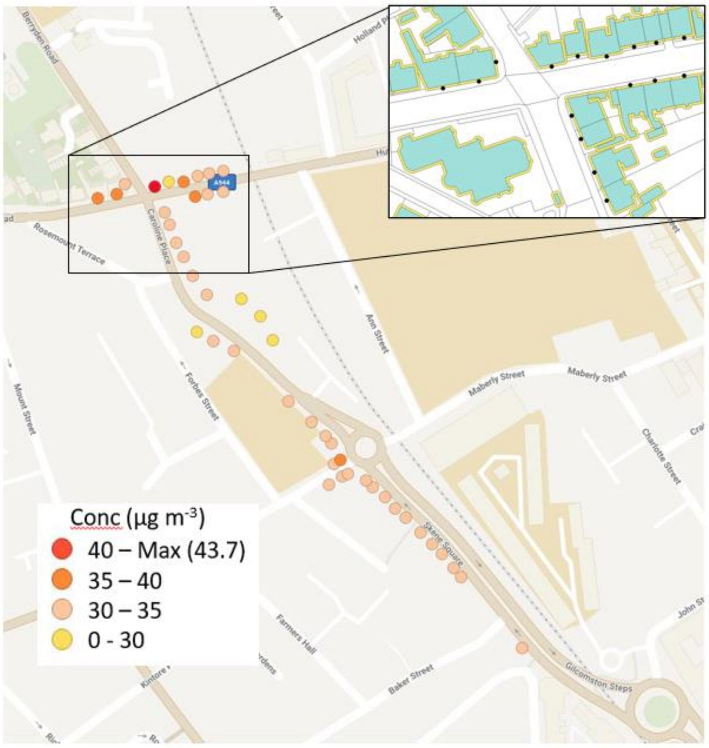
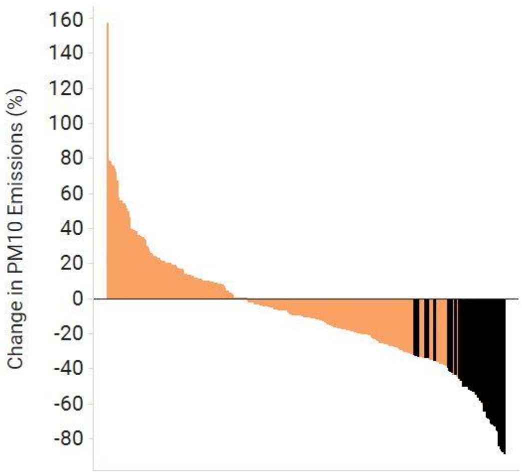


Figure 25: Predicted concentrations at Caroline Place junction.

Predicted changes in PM_{10} emissions due to the LEZ

The predicted change in PM_{10} emissions due to implementing the LEZ have been explored by comparing rates of vehicle tailpipe emissions between the Reference and LEZ cases. However, these emissions have not been used to predict concentrations of PM_{10}. Roadside concentrations of PM_{10} are dominated by non-tailpipe emissions, including brake wear, road wear, tyre wear and dust re-suspension from the road surface. It is estimated that PM_{10} tailpipe emissions make up approximately 27% of total emissions (UK Air Quality Expert Group, 2019), though large uncertainties exist. As it is difficult to quantify the rates of these 'non-tailpipe' emissions, model predictions of PM_{10} concentrations would be associated with high levels of uncertainty.

Large reductions in PM_{10} tailpipe emissions are predicted across many roads in the city as a result of implementing the LEZ at some locations. The largest reductions occur within the LEZ, as shown by the roads highlighted black in Figure 26. Reductions are also predicted on roads surrounding the LEZ, such as the Wellington Road AQMA (Figure 26). This scale of reduction is greater than would be expected to occur in PM_{10} concentration data, due to the contribution of non-tailpipe emissions, as discussed above.



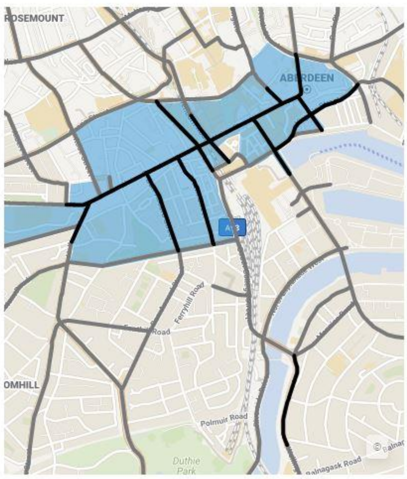


Figure 26: Ranked changes in tailpipe PM_{10} emissions (%) for all roads. The greatest reductions occur inside the LEZ as highlighted in black. Large reductions are also predicted in the Wellington Road AQMA (also highlighted in black).

Figure 27 shows the changes in tailpipe PM_{10} emission rates (g/km/s) between Reference and LEZ cases by vehicle type. This shows that while percentage changes look to be significant, actual changes in emission rates are small.

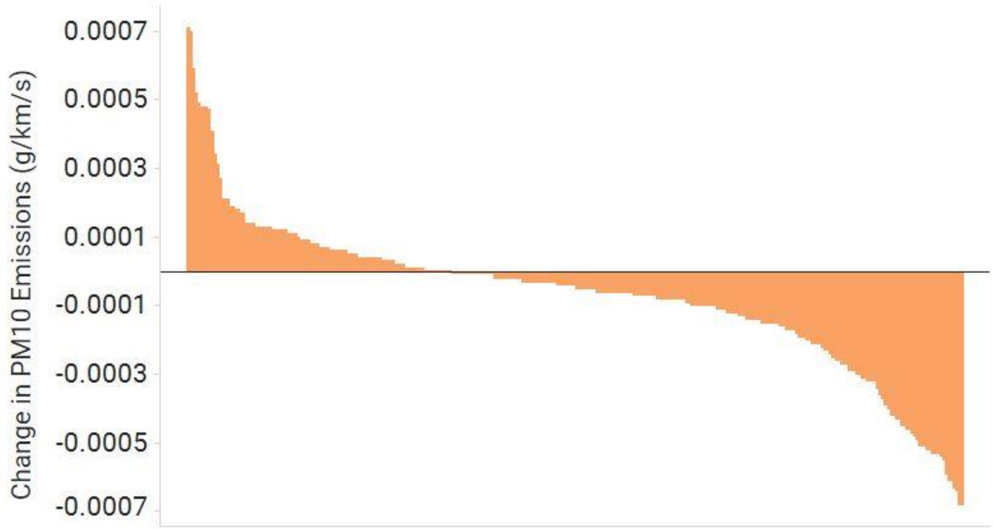


Figure 27: Predicted absolute changes of PM_{10} emissions (g/km/s) following implementation of the LEZ.

However, there are a number of roads where tailpipe PM_{10} emissions are predicted to increase. Significant increases (40-80%) are predicted on Anderson Drive (A92), which is likely to be due to traffic rerouting to avoid the city centre LEZ. The largest increase of ~160% is predicted on Ashgrove Road, close to Berryden Road, though it should be noted that although this relative increase is large, the absolute increase is small (Figure 28).

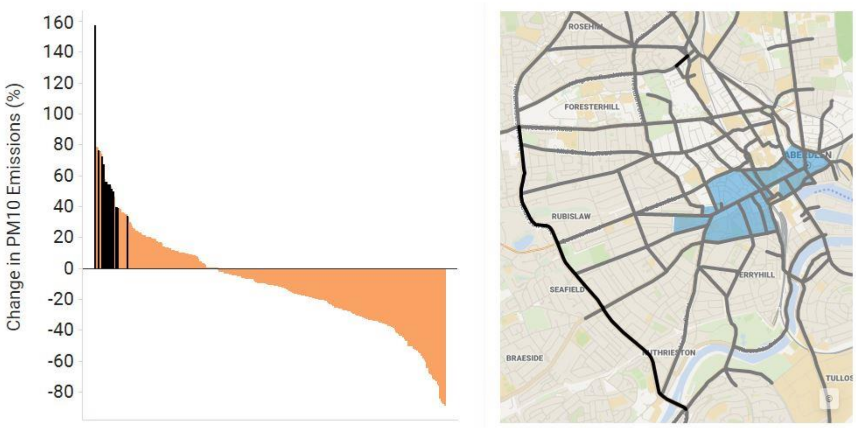


Figure 28: Ranked changes in PM_{10} emissions (%) on all roads. Some of the largest increases occur on the roads highlighted in black.

Consideration of Carbon Dioxide changes within an LEZ scheme

The main aim of the Low Emission Zone (LEZ) is to improve air quality to meet current statutory air quality standards and objectives.

The Euro Classification of vehicles is designed to control Nitrogen Oxides and Particulate emissions, which are by-products of the combustion process. Therefore, the LEZ will restrict access within the zone to lowest emitting Euro Class vehicles. These are Euro 6 for all vehicles, except petrol cars which are Euro 4.

The current European emission standards (up to Euro 6) are for Nitrogen Oxides, Total Hydrocarbons, Non-methyl Hydrocarbons, Carbon Monoxide and Particulate Matter. The introduction of Euro 7 standards by the European Union, expected to come into force in 2025, will include targets to reduce Carbon Dioxide emissions.

CO_2 emissions are linked the quantities of fuel burnt by a vehicle (e.g. miles per gallon), and current reductions in CO_2 emissions are linked to fuel efficiency. New vehicles are more efficient than older vehicles, but this difference is very small. There are no CO_2 abatement systems on vehicles, therefore, significant changes in CO_2 emissions are not expected as a result of the introduction of the LEZ.

Reducing Carbon Dioxide emissions will be achieved by modal shift, introduction of alternative vehicle fuels (e.g. electric, hydrogen) or reducing the number of vehicle journeys using diesel/petrol.

This move to zero carbon emissions could be achieved by actions set out in CAFS2 or the introduction of zero emission zones.

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APPENDIX 1

Air Quality Modelling Verification

The performance of the air-quality model has been examined by comparing model predictions against observed air-quality data.

Figure 29 shows a comparison of modelled annual-average NO_2 against the observed data at the 6 automatic monitoring stations in 2019. Automatic monitors provide high-temporal resolution measurements, and the data is subject to detailed Quality Assurance and Control procedures.

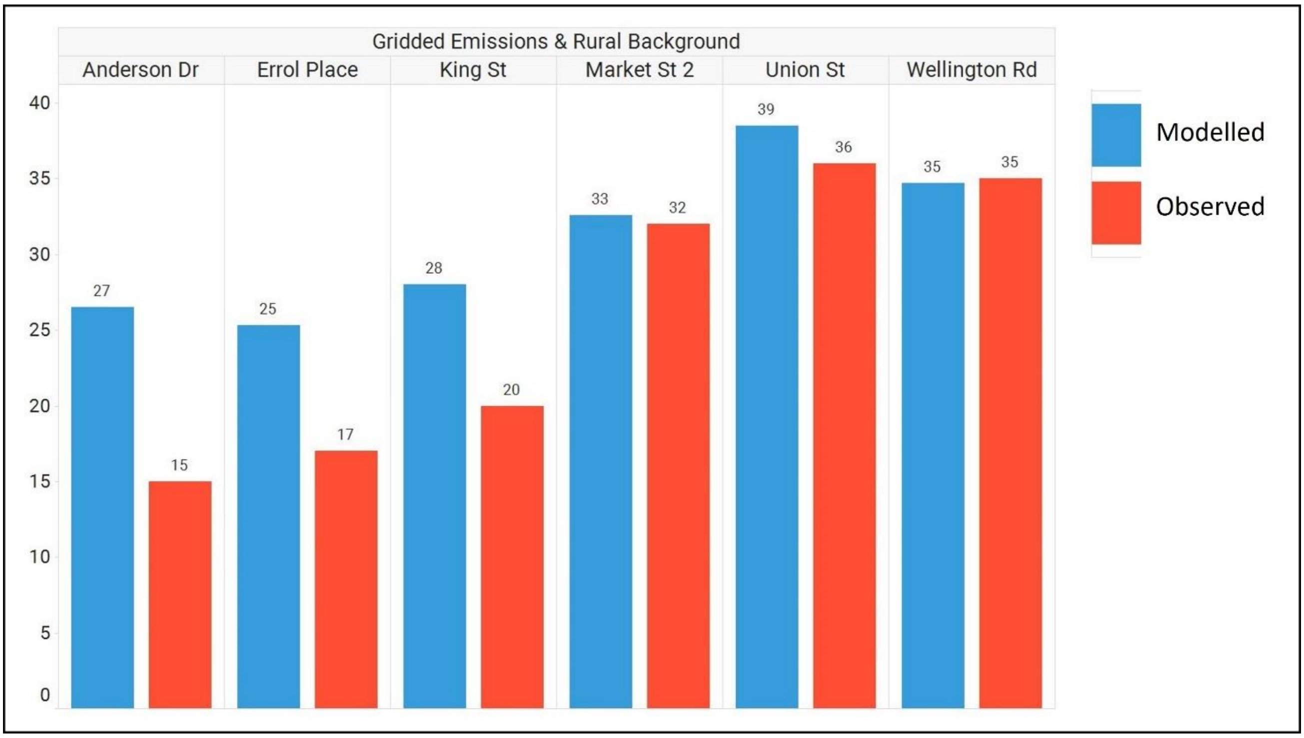

Figure 29: A comparison of modelled and observed NO_2 concentrations at 6 Automatic monitoring locations around the city

When using gridded background emissions and rural background concentrations, the model performs well at most city centre locations. In particular, the annual average NO_2 is reproduced well by the model at Market Street and Wellington Road, and there is a small over-estimate on Union Street of 3 μgm^{-3}. There are larger over-estimates of 8 μgm^{-3} at King Street and Errol Place, and an over-estimate of 12 μgm^{-3} on Anderson Drive.

Measurements of NO_2 from Passive Diffusion Tubes are also subject to detailed Quality Assurance procedures and provide additional data for model evaluation. These monitors are less expensive and easier to locate than automatic monitors and therefore provide greater spatial coverage. However, there are greater uncertainties with the methodology and therefore measurements should be treated with more caution.

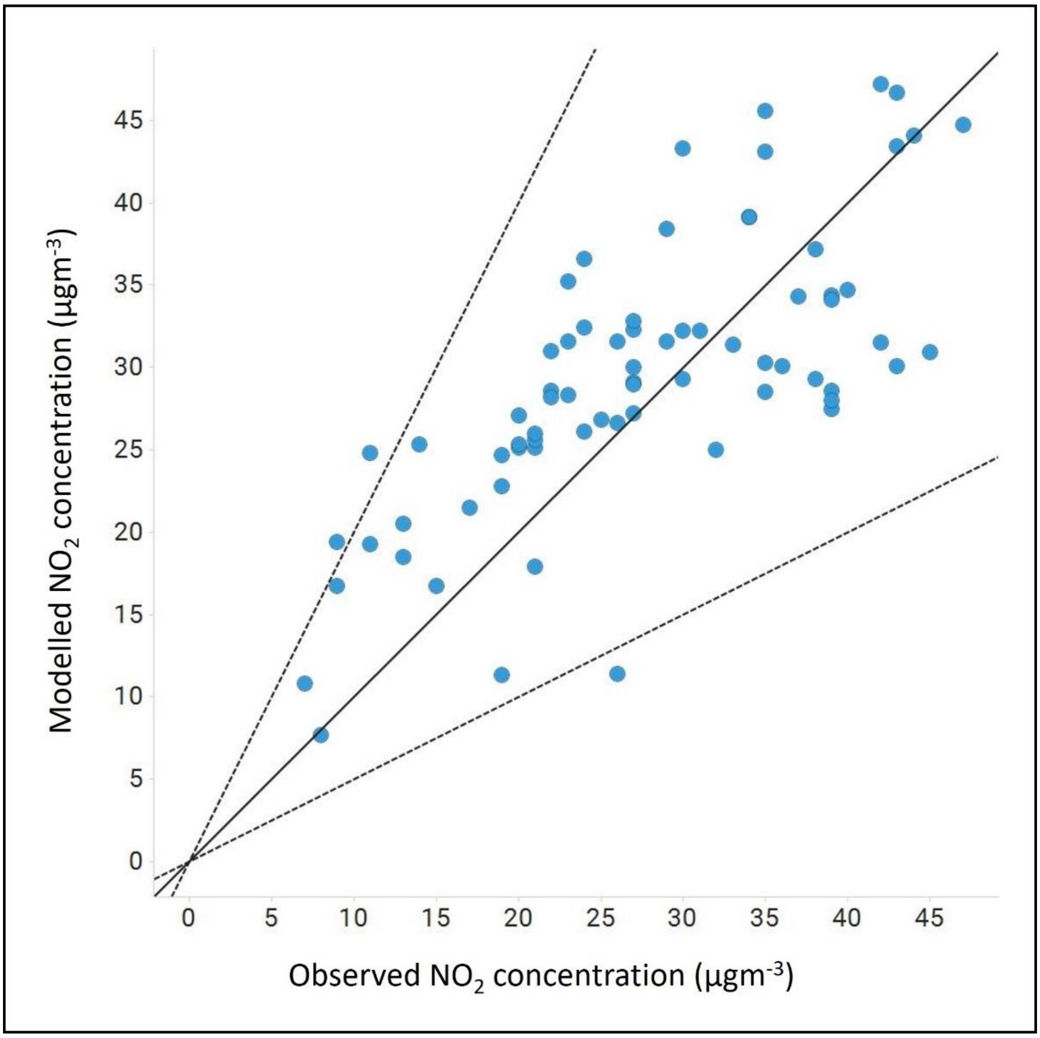

Figure 30: A comparison of modelled and observed NO_2 concentrations at 72 diffusion tube locations around the city.

Figure 30 shows a comparison of modelled annual-average NO_2 against 72 diffusion tubes for the 2019 Base scenario. When using gridded background emissions and rural background concentrations nearly all model predictions are within a factor of 2 of the observed value, as indicated by the dashed lines. A modelling review by DEFRA recommends a model is acceptable when more than half of the model data fall within a factor of 2 of observed values (Defra, 2011).

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