CLEANER AIR FOR SCOTLAND – NATIONAL MODELLING FRAMEWORK

Low Emission Zone Evidence Report – Edinburgh

September 2021

Scope of Report

The Scottish Government's Cleaner Air for Scotland strategy (CAFS) introduced both the National Modelling Framework (NMF) and the National Low Emissions Framework (NLEF). The aim of the NMF is to provide evidence for Local Authorities to inform their decision-making process for implementing a Low Emission Zone (LEZ).

Throughout the development of the LEZ, SEPA have supported the City of Edinburgh Council (CEC) with the provision of detailed air quality modelling ('Air Quality Evidence Report' – Edinburgh), presentations and on-line visualisation tools to inform the selection of the LEZ options.

This report follows on from the previous SEPA report 'Emissions Analysis for Low Emission Zones' which focused on calculating tail-pipe emissions of Nitrogen Oxides (NO_X). This work represents the final stages of the NMF, providing modelled NO_2 concentrations to support the final phase of evidence to support the implementation of CEC's LEZ option. Traffic modelling was carried out by Jacobs, predicting changes in vehicle flows and fleet compositions. Traffic model outputs have been used to calculate pollutant emissions and air quality concentrations associated with the implementation of the LEZ options. Calculated changes in Particulate Matter (PM10) emissions are also presented.

Summary of Findings

This report presents the results of the air quality modelling work examining the potential changes in emissions and air quality concentrations for several LEZ options in Edinburgh. The report provides a detailed insight into the options that were tested and the potential outcomes in relation to changes in air quality concentrations associated with the LEZ implementation.

The introduction of an LEZ in Edinburgh city centre will significantly reduce NO_x and PM_{10} emissions from vehicles, which will result in lower pollutant concentrations within the LEZ. Although concentrations will be reduced, it does not necessarily mean that air quality compliance will be met at all locations, especially on busy roads and junctions.

Non-compliant traffic being re-routed around the LEZ boundary will result in increased emissions on these routes and subsequent increases in NO_2 and PM_{10} concentrations. In some cases, this *may* lead to new exceedances of the Air Quality Standards/Objectives.

Modelled LEZ scenarios were based on the 2019 vehicle fleet and, to represent a 'future scenario', the predicted 2023 vehicle fleet. The future scenario assume more vehicles are compliant, and as a result, fewer vehicles are required to avoid the LEZ and re-route. This allows future air quality concentrations to be predicted.

Both LEZ options are the same, apart from the West side of the city centre. On the East side (e.g. Abbeyhill), small concentration increases are predicted, and these are unlikely to generate new exceedances. On the West side of the city centre, there are 2 options, the Large and the Small LEZ

Large City Centre LEZ

Based on the 2019 Edinburgh traffic fleet, it was found that if the Large LEZ is selected, significant traffic displacement was predicted at the West End. Air quality modelling predicted new exceedances (at kerbsides) on Palmerston Place and Chester Street, however it is shown that at building facades, the main area of concern was on Palmerston Place. On Lothian Road, air quality was predicted to be much improved (though not fully compliant).

Whilst the Large LEZ option may result in new model exceedances on Palmerston Place and Chester Street, these are likely to be short-term exceedances and may not actually occur as the fleet improves closer towards the predicted 2023 scenario when LEZ enforcement starts. The future modelling scenario predicts that the Large LEZ will resolve most model exceedances on Lothian Road.

Small City Centre LEZ

An alternative, Small LEZ option was investigated which curtails the LEZ boundary at Lothian Road. Although the Small LEZ option removes the risk of new exceedances on Palmerston Place and Chester Street, predicted exceedances on Lothian Road are likely to remain for much longer in the future. The Small LEZ will have a very limited impact on the West Side of the city.

City-wide Extended Urban LEZ

A City Wide, or Extended Urban Area LEZ was also investigated, which will not include private vehicles outside of the city centre and thus will only affect a very small proportion of traffic. In this case, air quality improvements will be small and, in these areas, air quality is mostly compliant. Also, the city centre LEZ approach will positively impact on the wider suburban areas. For example, buses which will be required to be compliant to travel through the city centre LEZ, will also emit less pollutants when they travel in suburban areas.

Key Points

- The Large LEZ may result in new exceedances on Palmerston Place and Chester Street, however modelling with the future fleet scenario predicts that these exceedances would not be present (predicted concentrations will actually lower than predicted concentrations in the 2019 ‘do nothing’ scenario). At the time of LEZ implementation and enforcement, it is expected that the risk of new exceedances on Palmerston Place will be low
- The Small LEZ option predicts model exceedances will remain on Lothian Road in the future scenario. At the time of LEZ implementation and enforcement, it is expected that exceedances would remain on Lothian Road

List of Abbreviations

AADT	Annual Average Daily Traffic
ADMS	Atmospheric Dispersion Modelling System
ADMS	Urban Atmospheric Dispersion Modelling System for Urban Environments
ANPR	Automatic Number Plate Recognition
AQMA	Air Quality Management Area
CAFS	Cleaner Air for Scotland
CERC	Cambridge Environmental Research Consultants
CEC	The City of Edinburgh Council
DEFRA	Department for Environment Food & Rural Affairs
DVLA	Driver and Vehicle Licensing Agency
EFTv8	Emissions Factors Toolkit v8.0
EFTv10	Emissions Factors Toolkit v10.1
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
NLEF	National Low Emission Framework
NMF	National Modelling Framework
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) process within the Cleaner Air for Scotland (CAFS) strategy, the initial aim was to build an air quality model which was built using good quality data and which performed well against air quality monitoring data. This is outlined in more detail in the ‘Air Quality Evidence Report – Edinburgh’ report (SEPA, 2018).

Following on from this, the next step is to use the model to predict the impact of introducing a Low Emission Zone (LEZ). As part of this, further traffic surveys were carried out to identify if there were any significant changes in traffic flows and the fleet composition. CEC commissioned Jacobs consultants to carry out traffic modelling using the CEC traffic model to predict changes to traffic flows and fleet compliance rates in response to the introduction of an LEZ; this traffic model data was then used to run the Air Quality models to asses changes in pollutant concentrations.

This process is being carried out for the four Scottish cities implementing LEZs, though it should be noted that there are traffic model methodology differences being used for Edinburgh, when compared to the other cities.

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 a small number of 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. This will assess the impact of the LEZ by comparing traffic and emissions between a/base case 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 modelling data for Edinburgh has been recovered successfully, though this has still resulted in a significant delay to work plans.

National Modelling Framework

Modelling work presented continues to follow the approach and methods outlined in previous reports (SEPA, 2018) to ensure a consistent approach in the air quality modelling. These include:

- Collect high quality and detailed traffic data at a similar resolution in each city. Process these in the same way.
- Build air quality models of each city using the same modelling software with identical methods and model settings, where appropriate.
- Use the same sources of data for input into the model, such as road layout, road width and building heights.
- Use appropriate meteorological and background emission data obtained from a common source.
- Combine 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.

However, some differences in methodology between cities have arisen due to different approaches in traffic modelling for each city. CEC commissioned Jacobs to carry out traffic modelling (Jacobs, 2021) for Edinburgh using the CEC traffic model which is built in VISUM software (a strategic traffic model), whilst SYSTRA have been commissioned by Aberdeen, Dundee and Glasgow city councils to build and run traffic models using Paramics (a microsimulation traffic model). Strategic and microsimulation traffic models work in different ways. The VISUM Edinburgh model is run for three 2-hour periods (6 hours total), whereas Paramics is run for a 12-hour period. Due to this, there are some differences in how the traffic model data is processed into Annual Average Daily Traffic (AADT), which the air quality modelling software requires.

ADMS-Urban and EMIT continue to be the primary software packages used in the NMF work, although there has been an ADMS-version update (to version 5). The main difference is an update to the way ADMS deals with canyons. This may lead to some differences in predicted concentrations between ADMS model versions.

Scope of Air Quality Modelling

Based on the SEPA Evidence report (SEPA, 2018), 3 LEZ options were considered by CEC: (Jacobs, September 2021):

- Large City Centre zone (Figure 1).
- Small City Centre zone (Figure 2).
- Extended Urban Area zone (Figure 3). For this case, a city centre zone would apply to all vehicles, the Extended Urban Area zone would apply to all vehicles (except cars).

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 understood as part of the city centre LEZ, and all AQMA's. Jacobs have advised that traffic modelling for the Extended Urban Area option is technically challenging, so this has not been carried out (Jacobs, September 2021).

The LEZ rules were also considered when planning this stage of the modelling work. As LEZ regulations for petrol cars are different from all other vehicles (Table 1), because NO_x emissions from petrol vehicles are much lower than diesel vehicles, cars were split into petrol/diesel for the traffic modelling.

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 Petrol Cars)	Euro 6, Electric	Euro 5 or earlier

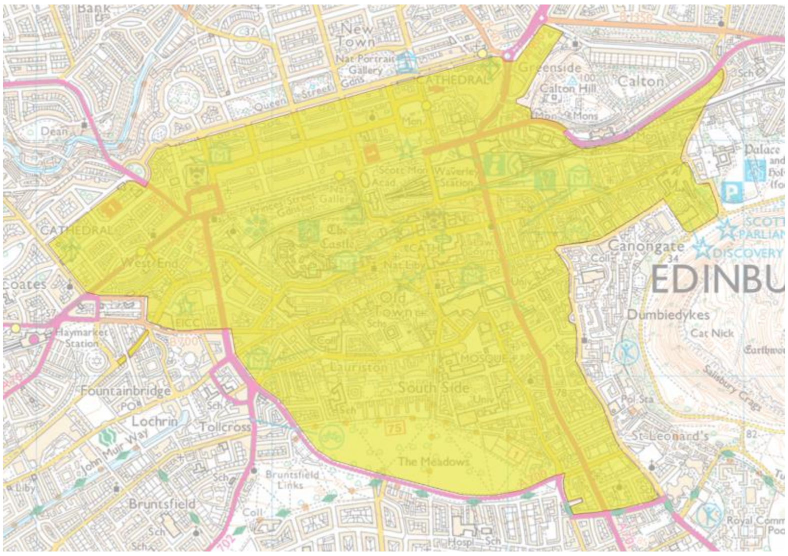

Figure 1: Large City Centre Low Emission Zone option

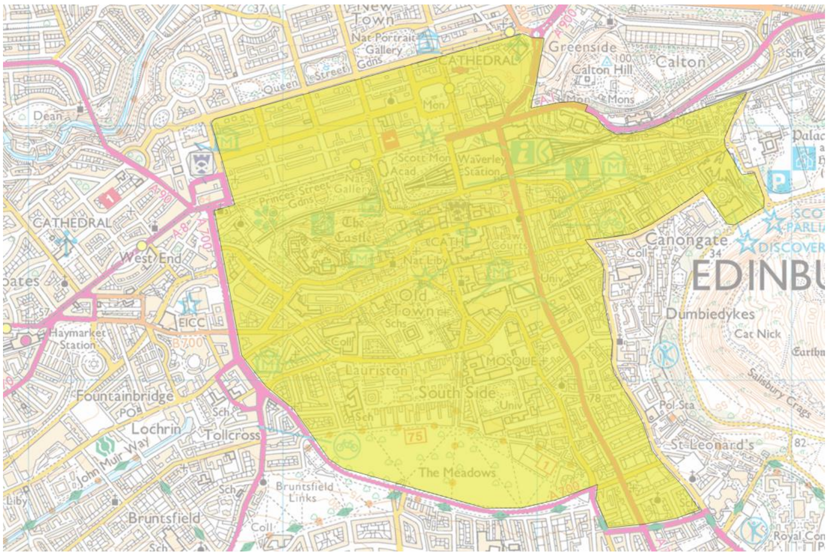

Figure 2: Small City Centre Low Emission Zone option

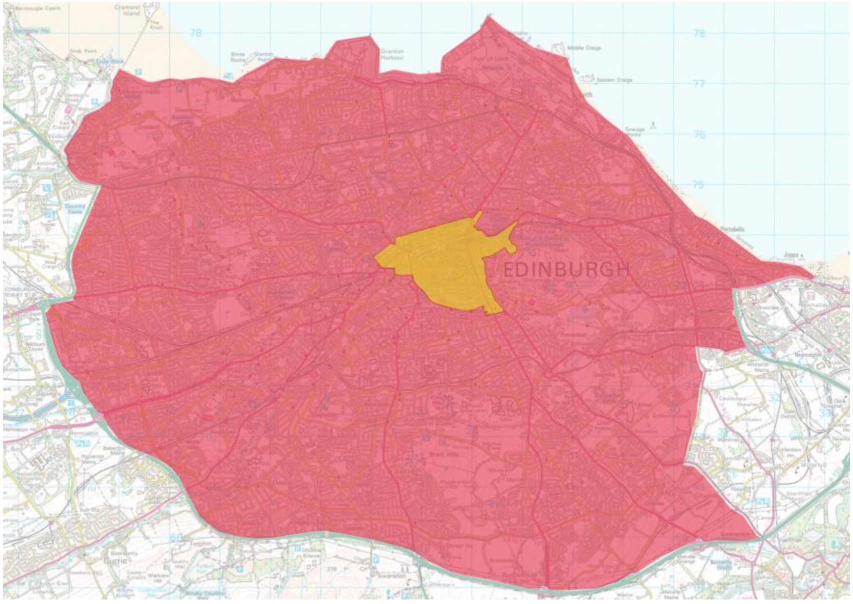

Figure 3: Extended Urban (Red) and Large City Centre (Yellow) Low Emission Zone option

Modelling Methodology

Air Quality Modelling

The Aberdeen Pilot Project Technical report (SEPA, 2017) and Edinburgh Air Quality Evidence Report (SEPA, 2018) outlines the air quality modelling methodology. This remains the same unless outlined in more detail below. Most methodological changes are due to the use of modelled traffic data to examine the effect on introducing an LEZ.

Traffic Data – 2019 Survey

Accurate traffic data is important for the traffic and air modelling to be robust, as discussed in previous reports (SEPA, 2017; SEPA, 2018). A further detailed traffic survey was carried out in June 2019 for a comparison to made with the November 2016 survey. This included 4 additional Junction Turn Counts (JTC's) and 2 new ANPR locations. This survey is a snapshot on a particular day and roadworks and road closures on a particular day can affect traffic flows. It should be noted that this survey was carried out before tram works started. Without continuous traffic monitoring it is difficult to detect daily and seasonal trends, but it has been considered that this data is high quality and robust as discussed previously (SEPA, 2018).

Traffic Flows

This survey found that across all roads, total traffic volumes had slightly decreased (~1.5%), though there was variability across individual roads. Roads where total traffic flows had increased in the 2019 survey by more than 10% are shown in Figure 4, though some of these roads had been closed during the 2016 survey (e.g. Viewforth, George Street (West)).
However, there are also roads where traffic flows were found to be lower in the 2019 survey; Figure *5* shows roads where total traffic flow was more than 10% lower.

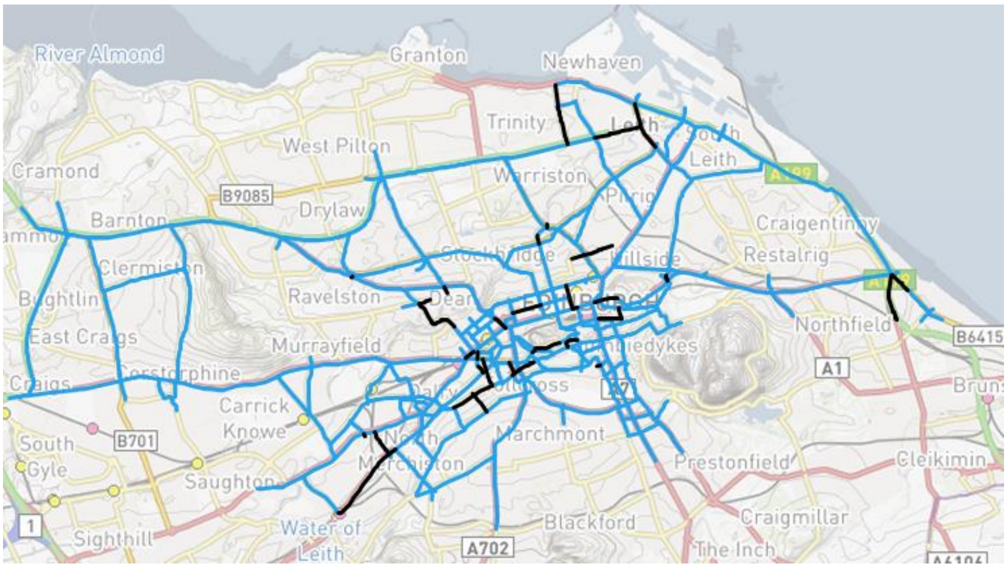

Figure 4: Roads highlighted in black where 2019 traffic flows were more than 10% higher than 2016 survey

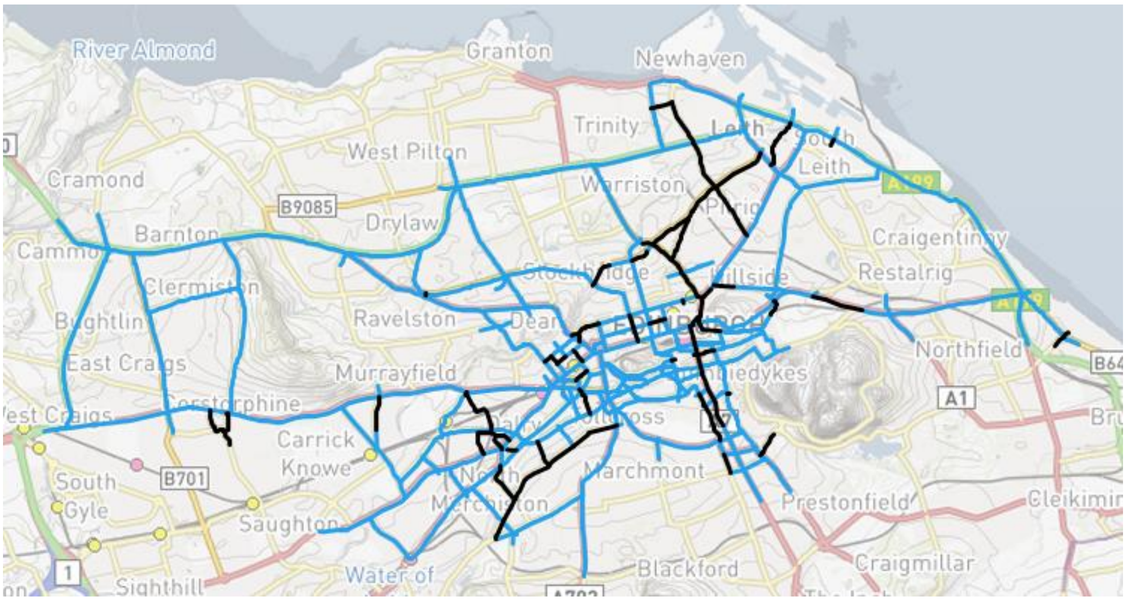

Figure 5: Roads highlighted in black where 2019 traffic flows were more than 10% lower than 2016 survey

Overall, car traffic was ~5% lower, Rigid HGV's were ~29% lower and Artic HGV's were ~7% lower. In contrast, LGV traffic was found to be ~1% higher.

Taxi traffic was found to be 58% higher (particularly on the route between the city centre and the airport where there was a 134% increase). Bus/Coach traffic was 13% higher (particularly in the city centre). This is likely to be due to seasonal factors due to an increase in summer tourist traffic.

In the 2019 survey, it was decided to categorise public service buses and coaches separately. There is a good understanding of public service bus routes and the vehicles deployed on each route, but less so on tourist and other coaches. The survey shows that most coaches are in the city centre and west side of the city (Figure 6), whereas large bus flows (Figure 7) are found on most key routes into the city (except Queensferry Road).

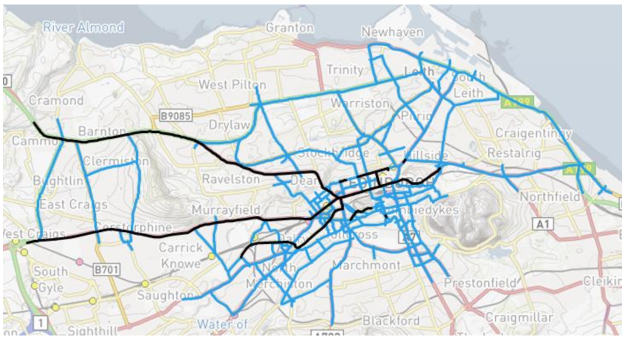

Figure 6: Routes where number of Coaches exceeds 200

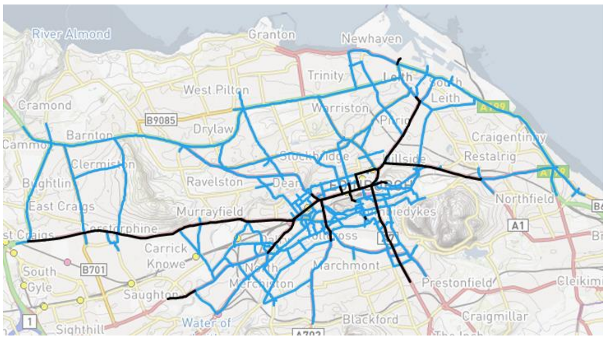

Figure 7: Routes where number of Buses exceeds 1000

It was decided that, as the LEZ traffic modelling will focus primarily on Cars, LGVs and HGVs, and that traffic flows for these vehicles are generally higher in the 2016 survey, the 2016 traffic data would continue to be used for the LEZ modelling scenarios. This was also preferred as the Edinburgh traffic model was populated with 2016 traffic data and updating with 2019 traffic data would be time consuming and have little benefit.

ANPR and Fleet Composition

ANPR survey data provides details on individual vehicles from the DVLA database such as vehicle type, weight, engine size, fuel type for each vehicle observed. The DVLA also provide an estimate of the vehicle Euro class, based on the vehicle age. This information can be processed to derive a fleet composition table (i.e. the percentage of vehicles with a specific Euro class), which is required to calculate the pollutant emission rates for each road link in EMIT (the CERC emission database tool). The data from the ANPR survey is used in preference to the National fleet composition data which is published by the Department for Transport, and does not accurately represent the local fleet.

The 2019 ANPR survey provided updated data on the Edinburgh specific vehicle fleet composition and can be compared to the 2016 ANPR survey.

It is expected that over time, the fleet will become less polluting as older vehicles are scrapped and new vehicles enter the fleet. This can be seen in Table 2 where the percentage of cars which are Euro 5 and earlier is declining throughout whilst the percentage of Euro 6/6c/6d vehicles are gradually increasing in each survey.

Car fuel type is also an important factor, especially as diesel cars emit about 10 times more NO_x than petrol cars. This shows the percentage of diesel cars in the fleet is declining whilst other fuel types are increasing in share (Table 3).

Table 2: Percentage of Car Euro Class in 3 ANPR surveys (2016 and 2019)

Car Class	% of Car Fleet in 2016 ANPR	% of Car Fleet in 2019 ANPR
Pre-Euro 1	0.07%	0.00%
Euro 1	0.08%	0.13%
Euro 2	0.77%	0.55%
Euro 3	7.5%	6.6%
Euro 4	26.7%	19.1%
Euro 5	42.6%	32.2%
Euro 6	22.1%	32.1%
Euro 6c	0%	9.0%
Euro 6d	0%	0%
Electric*	0%	0.42%
***Note: These are electric only cars and do not include Hybrid Electric Cars**		

Table 3: Percentage of Car Fuel Types in 3 ANPR surveys (2016 and 2019)

Car Fuel Type	% of Car Fleet in 2016 ANPR	% of Car Fleet in 2019 ANPR
Diesel	45.0%	44.6%
Petrol	53.4%	52.1%
Hybrid Electric	1.4%	2.8%
Electric	0.17%	0.42%
Other fuel types	0.10%	0.06%

Bus fleets need to be accurately represented in the model and it has been shown (SEPA, 2018) that there are large differences between the Euro Class estimated by the DVLA (provided in the ANPR data) and the actual Euro Class for each bus (which has kindly been provided by the main local bus operators). Therefore, in this analysis we have used the local bus operator Euro Class data in the analysis to represent the bus fleet as accurately as possible (this accounts for over 90% of buses in detected in the ANPR survey; where buses belong to a company other than the main local operators, the DVLA estimated Euro class has been used). The percentage of Euro VI buses has been increasing since the first survey in 2016 from 24% to 51% (Table 4).

Table 4: Percentage of Bus Euro Class in 3 ANPR surveys (2016 and 2019)

Bus Class	% of Bus Fleet in 2016 ANPR	% of Bus Fleet in 2019 ANPR
Euro I	0.02%	0%
Euro II	0.09%	0.16%
Euro III	20.7%	9.3%
Euro IV	5.4%	0.7%
Euro V	49.8%	37.8%
Euro VI	24.1%	51.4%
Electric*	0.00%	0.7%
***Note: These are electric only Buses and Coaches and do not include Hybrid Electrics Buses**		

The average fleet composition from ANPR survey sites has been used to represent the entire city, however, it should be noted that there is some fleet variation across the city which will introduce some uncertainties into the modelling on specific roads.

The Emission Factor Toolkit version 8 (EfTv8) emission factors within the EMIT tool have been used to calculate NO_x emission rates in this analysis. This was the most up to date version of NO_x emission factors in EMIT that was available at the time of modelling; EfT version 10 (EfTv10) has been used to calculate Particulate emissions.

LEZ Traffic Modelling Methodology

The traffic modelling was carried out by Jacobs and is described in more detail in the report 'Edinburgh Low Emissions Zone, Revised Fleet Composition, Transport Modelling Report' (Jacobs, 2021).

In summary, the CEC Edinburgh traffic model was used which uses the VISUM software package. It is important to note that this is a different approach to the other Scottish cities and has resulted in a divergence in methodologies (prior to SEPA receiving the data). The traffic model assumes that all traffic entering, leaving, or travelling within the LEZ is 'Compliant'. Traffic which is 'Non-Compliant' is forced to divert around the LEZ. The traffic may then assume that 'Compliant' traffic may re-route through the LEZ (taking advantage of capacity on roads that would have previously been taken by 'Non-Compliant' traffic.

The traffic model includes all vehicle sectors; however it is only considering the displacement of Cars, LGV's and HGV's. It is assumed bus routes will remain unchanged. Regulations affecting taxi compliance is being carried out separately through the CEC taxi licencing scheme.

The traffic model was run for 2 fleet scenarios:

- **2019:** Using 2019 ANPR data and 2016 traffic flows.
- **2023 'future':** Using 2023 forecast National Fleet predictions and 2016 traffic flows.

Note that whilst the 2023 National fleet prediction is used, predicting future fleet compositions is very uncertain. These predictions are known to be optimistic and in reality is likely to occur later than 2023. COVID has added another level of uncertainty, and fleet prediction data does not account for this. Therefore, this scenario should be considered as a 'future scenario'.

Car fuel split

Due to different LEZ rules for petrol and diesel cars, they are treated separately within the traffic model and subsequent data analysis.

To enable the traffic model to be run with cars split into petrol/diesel, the car flows were split accordingly. It was assumed that, for traffic modelling purposes, all cars were either petrol or diesel.

The EfTv8 National Fleet predicts that the diesel/petrol fuel ratio in 2019 and 2023 are similar, however the 2019 ANPR data shows that for Edinburgh, the proportion of diesel cars is lower than the National Fleet (Table 5). In the absence of other data, the assumption was made to use the 2019 ANPR petrol/diesel split for 2023 'future' scenario traffic modelling.

Table 5: Percentage of Cars which are Petrol or Diesel

	ANPR	2019 National Fleet (EfTv8)	2023 National Fleet (EfTv8)
Diesel	44%	47.7%	47.8%
Petrol	56%	52.3%	52.2%

Within the traffic model, Cars, LGV's and HGV's were split into 2 categories (compliant and non-compliant) using the values in Table 6. The 2019 values are derived from the 2019 ANPR survey, the 2023 'future scenario' values are derived from the National Fleet predictions. Note that predicting future fleet compositions is uncertain, these predictions are likely to be optimistic and are likely to occur later than 2023.

Table 6: Compliant and Non-compliant percentages used in traffic modelling

	2019		2023 'future' scenario	
	Compliant	Non-Compliant	Compliant	Non-Compliant
Cars (Diesel)	42.6%	57.4%	78.1%	21.9%
Cars (Petrol)	88.4%	11.6%	99.6%	0.4%
LGV's	41.2%	58.8%	81.6%	18.4%
HGV's	64.4%	25.6%	91.6%	8.4%
Note: 2019 values derived from ANPR. 2023 values derived from EfTv8 National Fleet predictions				

Traffic Model Scenarios

The Edinburgh traffic model was run by Jacobs for 4 scenarios for each of the 2 fleet scenarios (2019 and 2023 'future') described above:

1. Base
2. Large City Centre LEZ
3. Large City Centre LEZ (including City Centre Transformation changes)
4. Small City Centre LEZ (including City Centre Transformation changes)

City Centre Transformation (CCT) changes include measures such as closure of Bank Street and parts of George Street to general traffic.

The traffic model was run for these 4 scenarios for each of the fleet scenarios, over 3 time periods:

- AM: 07:00 – 09:00
- Interpeak: 10:00 -12:00
- PM: 16:00-18:00

The road links in the traffic model are mostly smaller than those in the air quality model. To maintain consistency and to keep road links in the air quality model the same as in previous modelling, the maximum traffic flow from any of the traffic model road links which represents an air quality model road link was used for the air quality modelling. For example, if 4 traffic model road links represented 1 air quality model road link, the maximum flow from any of the 4 traffic model road links was used.

Traffic flows for each of the 4 vehicle classes in Table 6, split into compliant/non-compliant, for each LEZ and fleet scenario and for each time-period was provided by Jacobs to SEPA for the air quality modelling.

Calculating Emission Inputs for Air Quality Modelling

The CERC database tool EMIT has been used to calculate the emission rates for each toolkit as discussed in the SEPA 2018 Evidence report (SEPA, 2018). However, based on advice from CERC, a slightly different approach is required to calculate emissions from the traffic model output Emissions are generated in EMIT for each of the 4 compliant/fuel categories (using same method as before) and then summed to obtain total emissions for input into ADMS.

Traffic Flow

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. Previously, AADT traffic flows were calculated from the Junction Turn Counts (JTC) data, by deriving 12 to 24 hour conversion factors based on data from 24-hour JTC sites (SEPA, 2018).

In this case, new conversion factors were derived to convert traffic model output from 6-hours (07:00-09:00; 10:00-12:00; 16:00-18:00) to 24 hours (AADT) for all road links in the air quality model.

For technical reasons in the traffic model set up, absolute traffic flows from the traffic model could not be used in the air quality modelling. Based on advice from Jacobs, ratios of traffic flows between each of the LEZ traffic model scenarios and the Base traffic model scenario were calculated for each vehicle sector. These ratios were then applied to the 2016 traffic survey data to generate traffic flows for each of the 8 compliant/fuel categories (4 traffic categories in Table 6 split into compliant/non-compliant).
For example, if the traffic model predicts that the LGV flow increases by 5% on a road when an LEZ is introduced, in the air quality model, the LGV flow from the 2016 traffic survey increased by 5% is used.

There are some minor roads not in the traffic model that are in the air quality model, and for completeness in these cases, the 2016 traffic survey flow data was used.

Bus and Taxi traffic flows from the 2016 Survey were used in the air quality model (as this is the bus and taxi data which is included in the traffic model), as 2 options:

1. Buses and Taxis fully compliant within the relevant LEZ only; outside the LEZ, Buses and Taxis were split into compliant/non-compliant flows at the same ratio as the 2019 ANPR survey, or 2023 National Fleet composition data

2. Buses and Taxis were fully compliant across the whole city.

It was assumed that all non-car traffic is 100% diesel (ANPR data shows that only a very small proportion of LGV's are electric or petrol).

This results in having 4 traffic flow tables: Diesel Compliant, Diesel Non-compliant, Petrol Compliant, Petrol Non-Compliant.

Fleet Composition

Fleet composition tables were generated to represent each of the 4 traffic flow tables above. These tables represent the percentage of each of vehicle category in a specific Euro class.

Diesel Compliant:

- All Vehicles (excluding cars): All Non-Compliant categories were set to 0% and compliant categories (including electric) were weighted accordingly to sum to 100%.
- Cars: All Petrol and Diesel Non-compliant set to 0%. Compliant diesel car categories weighted to sum to 100%.

Diesel Non-Compliant:

- All Vehicles (excluding cars): All Compliant categories were set to 0% and Non-Compliant categories were weighted accordingly to sum to 100%.
- Cars: All Petrol and Diesel Compliant set to 0%. Non-Compliant diesel car categories weighted to sum to 100%.

Petrol Compliant:

- All Vehicles (excluding cars): All categories set to a zero emissions category.
- Cars: All Petrol Non-Compliant and Diesel set to 0%. Petrol compliant categories weighted to sum to 100%.

Petrol Non-Compliant:

- All Vehicles (excluding cars): All categories set to a zero emissions category.
- Cars: All Petrol Compliant and Diesel set to 0%. Petrol Non-compliant categories weighted to sum to 100%.

This process was carried out for the 2019 ANPR fleet and the 2023 National Fleet predictions to match the compliance percentages used in the traffic modelling.

Emissions Calculations

Finally, the fleet composition and traffic flow data generated using the above methodology was used in the 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 used in ADMS-Urban to predict NO_x and NO_2 concentrations.

Air Quality Modelling Methodology

To maintain consistency with previous modelling, the methodology and key inputs outlined were unchanged and the justifications are described in the Air Quality Evidence Report **(SEPA, 2018)**. Some key points are outlined below:

- Meteorology: 2016 data from the Edinburgh Gogarbank Met Office weather station was used as described in the Air Quality Evidence Report to maintain consistency. Additional model runs were also carried out using 2019 data as a sensitivity test, which was selected as it is the same year as the ANPR survey data used in the traffic modelling.
- Background data: Urban Background data from the St Leonards monitoring station was used for 2016 and 2019 to match with the relevant meteorology scenario.
- Street Geometry (road widths and canyons): It is noted that since the modelling was carried out for the Air Quality Evidence report **(SEPA, 2018)**, there have been several changes in the street geometry.
    - Road Widths: Some road widths have changed due to the CEC Spaces for People programme, in response to the COVID-19 pandemic. These are still classed as temporary (though some may become permanent). Road layouts in other locations have been modified (e.g. Picardy Place roundabout).
    - Street Canyon characteristics: Over time in every city, new buildings appear, and others are removed. Most of the time, this will not result in significant changes to the street canyon characteristics, however, some changes are significant (e.g. St James centre replacement and new development at Haymarket). These changes, if large, may affect the dispersion characteristics in the nearby vicinity, and this may change the predicted pollutant concentrations.
    - To maintain consistency with previous modelling and remove a variable when analysing model predictions, it was decided not to update the road widths or canyon characteristics in the model at this stage, but to review this and update the model at a later date. It should be noted that the modifications to the air quality model (e.g. model upgrades) can change the way the model interprets current street geometry data, which suggests that modelling uncertainties may have a larger impact on model predictions than changes to street geometry data files.

Traffic Model Output

Detailed results of the traffic modelling can be found in the Edinburgh Low Emission Zone modelling transport report (Jacobs, February 2021), however, a summary is useful here. The aim of the traffic model is to predict traffic flow changes in response to the introduction of an LEZ. This is likely to displace non-compliant traffic around the LEZ boundary.

Within the LEZ’s, traffic flows are expected to be lower and all vehicles are expected to be compliant.

On the West side of the city centre, the Large LEZ is predicted to lead to displacement of non-compliant traffic onto Palmerston Place and Chester Street. In the 2019 fleet scenario, traffic flows are expected to increase significantly, and compliance rates will fall to very low levels which is important for calculating emissions. In the 2023 ‘future’ fleet scenario, traffic displacement is not as significant and compliance rates are higher. This is an indication that as more compliant vehicles enter the fleet, traffic displacement of non-compliant vehicles around the LEZ is reduced.

If the Small LEZ is selected, no significant displacement of traffic is predicted onto Palmerston Place and Chester Street. However, as there is little difference in predicted flows between the 2019 and 2023 ‘future’ fleet scenarios in the West End, it seems that traffic flow changes are due to CCT changes (e.g. Bank Street closure) and not the LEZ. Therefore, the Small LEZ may only have a very small impact on improving air quality in the West End of the city centre and improvements will be due to fleet turnover.

On the East side of the LEZ (e.g Abbeyhill), the LEZ boundary is the same for both options. Increased traffic flows are predicted, and compliance rates will fall slightly due to non-compliant traffic being diverted, but it is not as significant as on the west side of the city centre.

More information can be found in Appendix 2.

Emissions

Emissions were calculated using the EMIT tool and were analysed and reported in detail in the Edinburgh Emissions Analysis for Low Emissions Zone report (SEPA, 2021), where the changes in emission rates for each road link were detailed. In this report, more detail is presented on source attribution of NO_x emissions.

NO_x Emissions Source Attribution

Within Large LEZ

Within the Large LEZ for the 2019 and 2023 'future' scenario, the introduction of the LEZ is predicted to reduce emissions from the bus sector significantly (in 2019 this would fall from 42.4% to 12.5% of all emissions). As a result, the percentage contribution from other sectors (especially diesel cars, LGV's and Taxis) will increase (Figure 8), with diesel car emissions becoming the main contributor to NO_x emissions.

Total emissions from all vehicle sectors within the Large LEZ will fall significantly, (~30 tonnes per year), based on 2019 values (Figure 9). The most significant emissions reduction is expected from the bus sector (accounting for 20 tonnes of NO_x removed within the LEZ). Although it appears that there is a large percentage reduction for HGV's, total emissions from this sector are low (Figure 10, Figure 11).

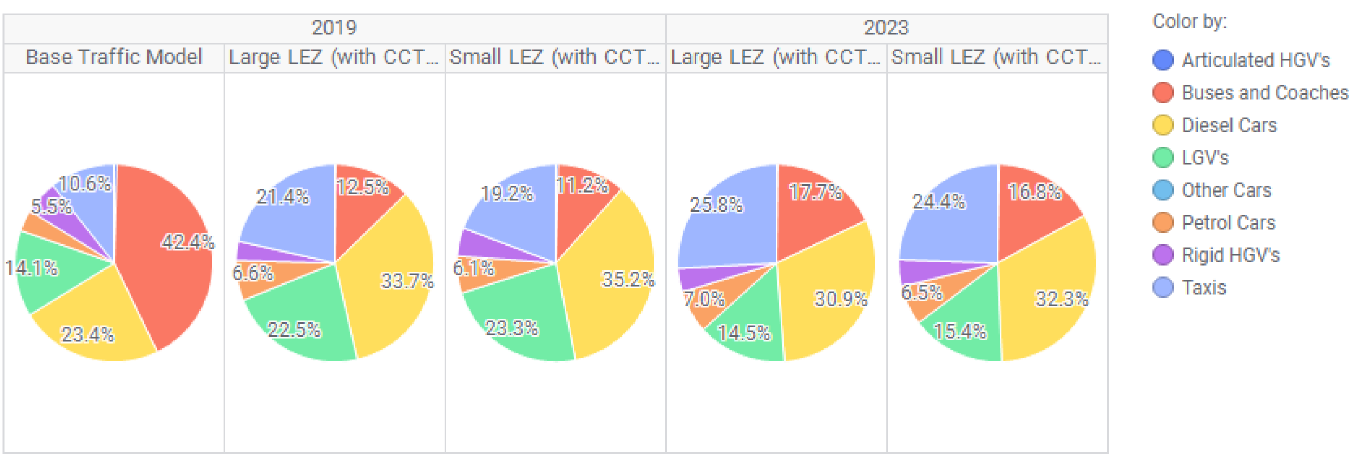

Figure 8: Percentage NO_x emissions from each vehicle sector for different LEZ scenarios (for the Large LEZ zone area)

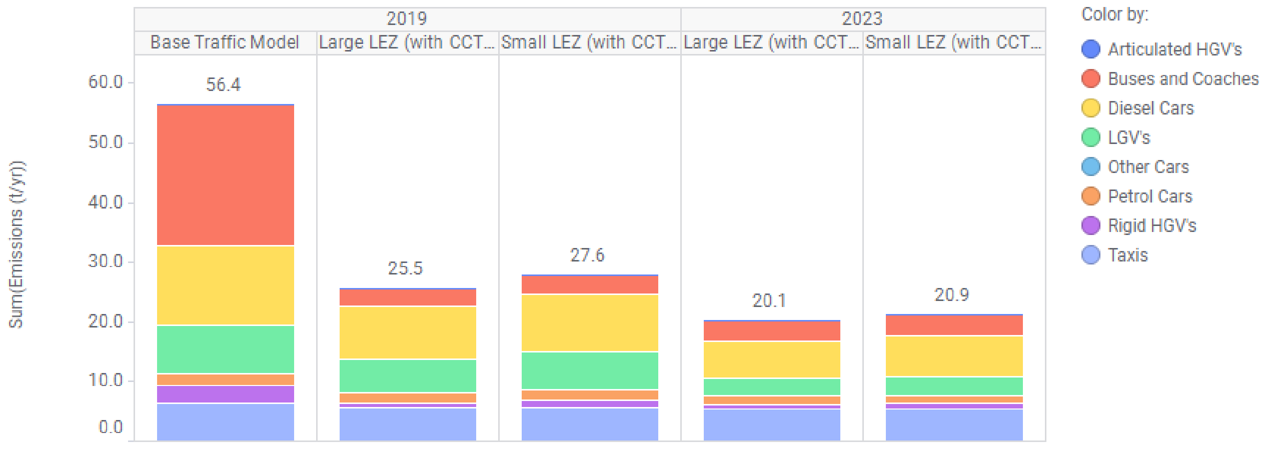

Figure 9: NO_x emissions (tonnes/yr) source attribution for different LEZ scenarios (for the Large LEZ zone)

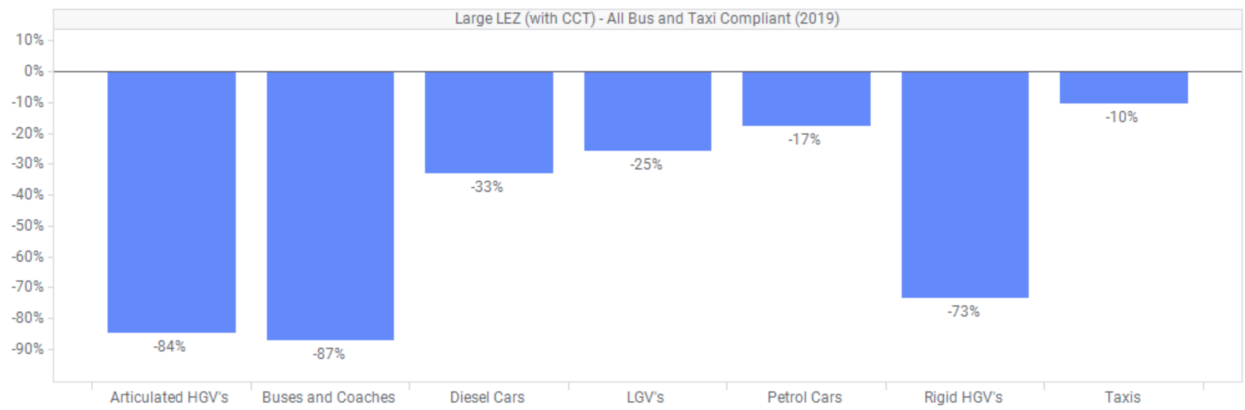

Figure 10: Percentage Change in Emissions from each vehicle sector for the Large LEZ compared to Base 2019 scenario

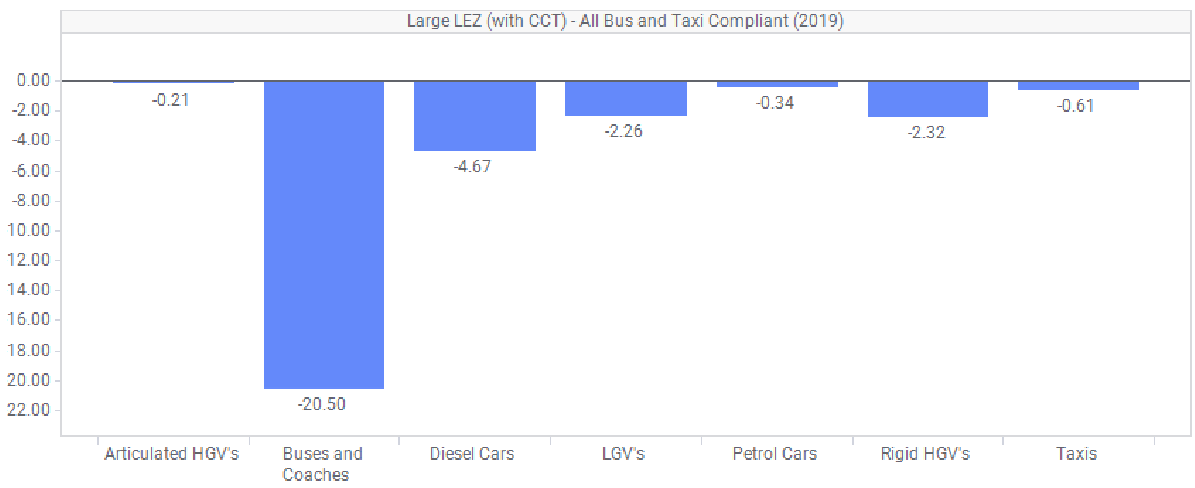

Figure 11: Emissions (tonnes/yr) change from each vehicle sector for Large LEZ compared to Base 2019 scenario

Within the LEZ – North Bridge/South Bridge/Clerk Street corridor

Within the LEZ, there will be differences on a street-by-street basis and the North Bridge/South Bridge/ Clerk Street corridor is a good example (Figure 12). In this case the LEZ will apply in both Large or Small LEZ options, so only the Large LEZ results have been shown.

In the 2019 Base scenario, over 50% NO_x emissions were attributed to the bus sector, but this would fall to 16% if an LEZ was in place. In the future, as emissions from other vehicle sectors decline, the relative contribution from buses will steadily increase, however total emissions will continue to fall (Figure 13, Figure 14).

Significant reductions are predicted from all vehicle sectors, except for petrol cars, which are predicted to increase emissions by 4% or 0.01 tonnes on this route (Figure 15, Figure 16). This is very small compared to reductions in other vehicle sectors and is due to an increase of petrol cars (which are mostly compliant) travelling through the LEZ, whilst most other sectors are forced to re-route around the LEZ.

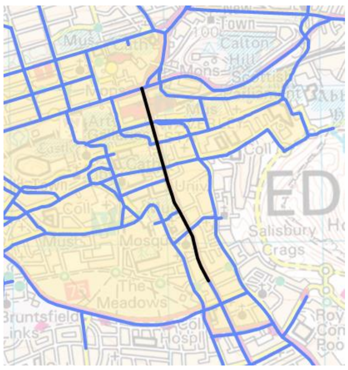

Figure 12: North Bridge/South Bridge/Clerk Street corridor

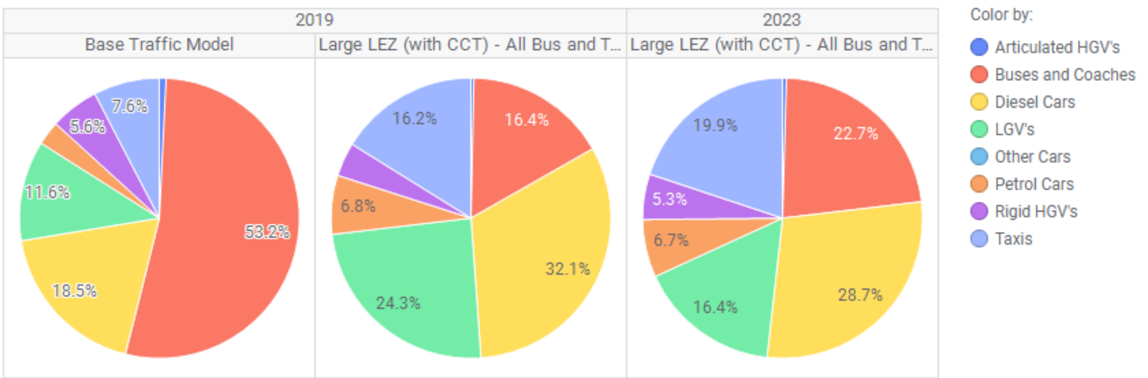

Figure 13: Percentage NO_x emissions from each vehicle sector for North Bridge/South Bridge/Clerk Street

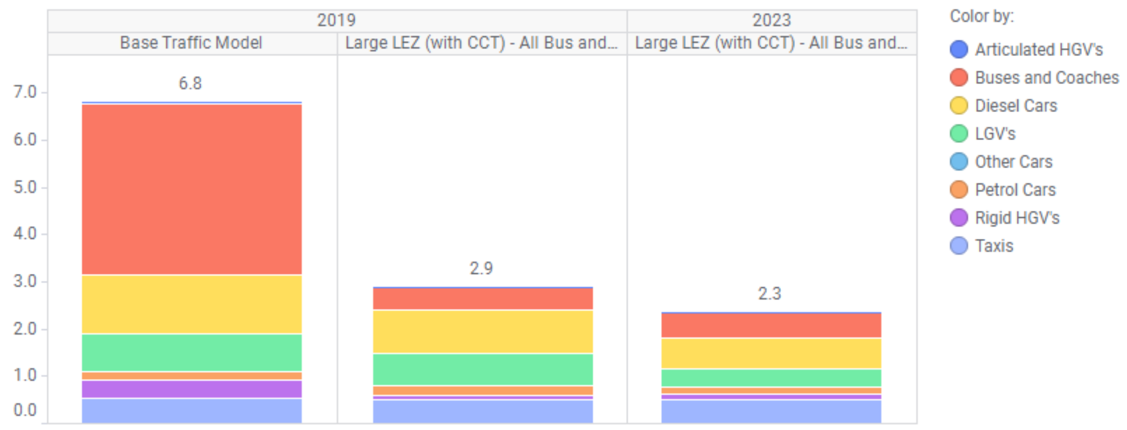

Figure 14: NO_x emissions (tonnes/yr) source attribution for each LEZ scenario for North Bridge/South Bridge/Clerk Street

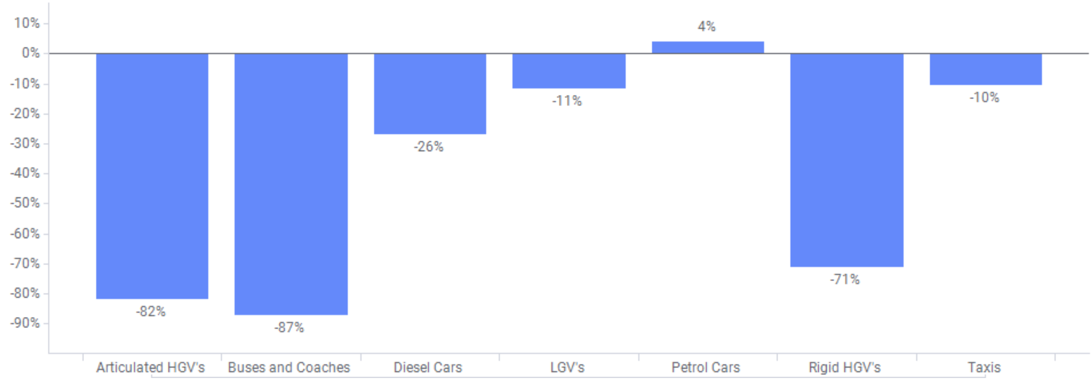

Figure 15: Percentage Change in Emissions from each vehicle sector for North Bridge/South Bridge/Clerk Street (LEZ 2019) compared to Base 2019 scenario

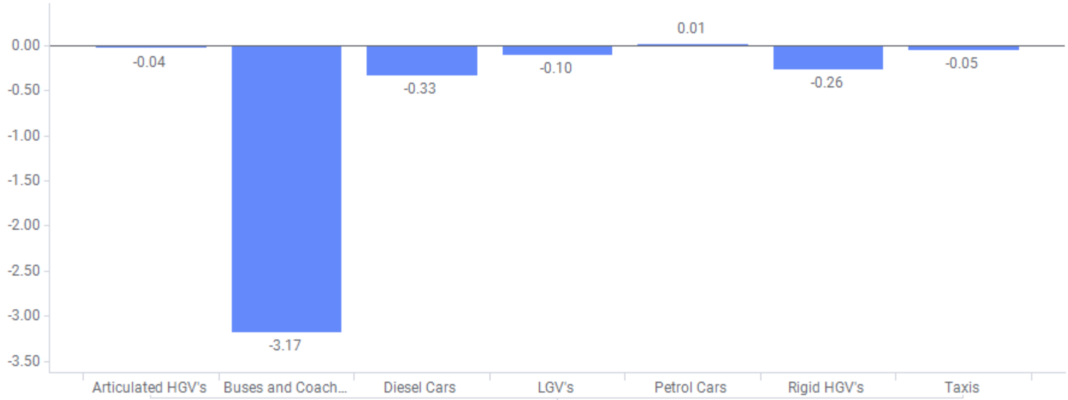

Figure 16: Emissions (tonnes/yr) change from each vehicle sector for North Bridge/South Bridge/Clerk Street (LEZ 2019) compared to Base 2019 scenario

LEZ Boundary - Palmerston Place/Chester Street

On the Palmerston Place and Chester Street corridor (highlighted in Figure 17), increases in traffic flow is predicted if the Large LEZ is implemented. The source attribution of NO_x emissions from each vehicle sector does not change significantly for each of the 2019 or 2023 'future' LEZ scenarios. Diesel cars (45-51%) and LGV's (26-29%) are the biggest contributors, with Petrol cars contributing around 5-7% (Figure 18).

However, as discussed in the Emissions Report (SEPA, 2021), the Large LEZ will result in actual emissions almost doubling (based on the 2019 fleet), though this is expected to decline as the fleet progresses toward the 2023 predicted scenario (Figure 19).

When looking at each vehicle sector, the largest emissions increases are from the Diesel Car, LGV and Rigid HGV sector (Figure 20, Figure 21). It is important to note that if the Small LEZ option was selected, total emissions will also increase by a small amount due to increased emissions from cars and LGVs (Figure 19, Figure 20, Figure 21).

Figure 17: Palmerston Place/Chester Street

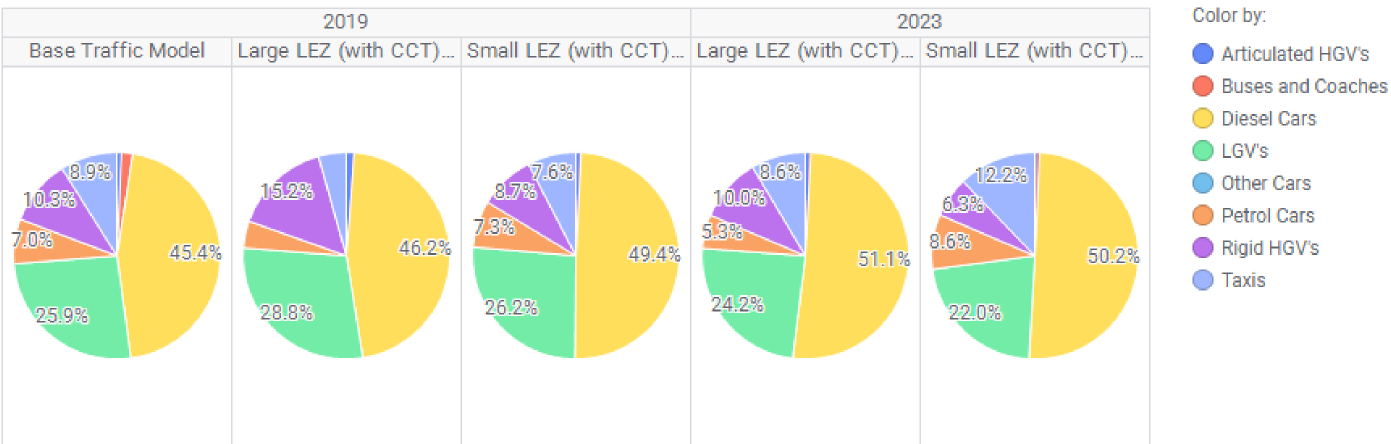

Figure 18: Percentage of Total NO_x emissions for each vehicle sector for Palmerston Place/Chester Street

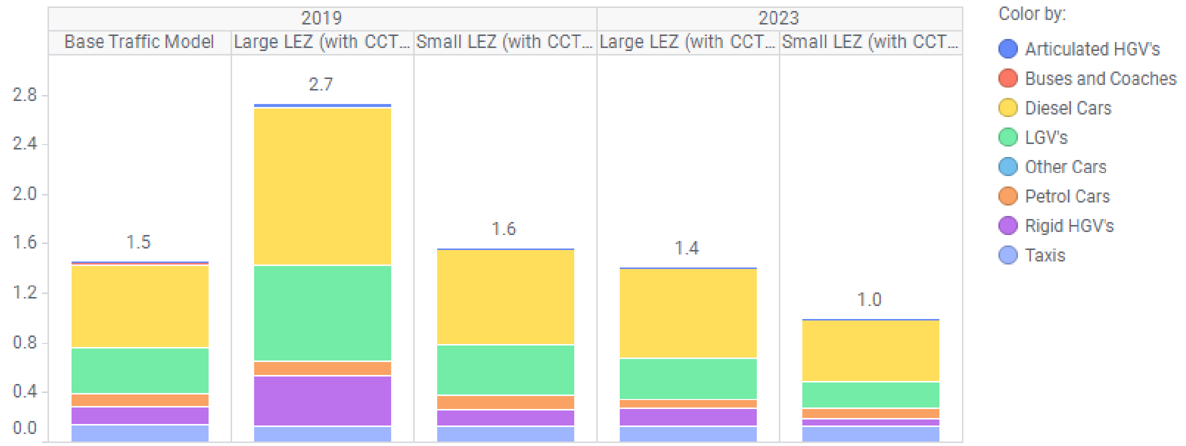

Figure 19: NO_x emissions (tonnes/yr) source attribution for each LEZ scenario for Palmerston Place/Chester Street

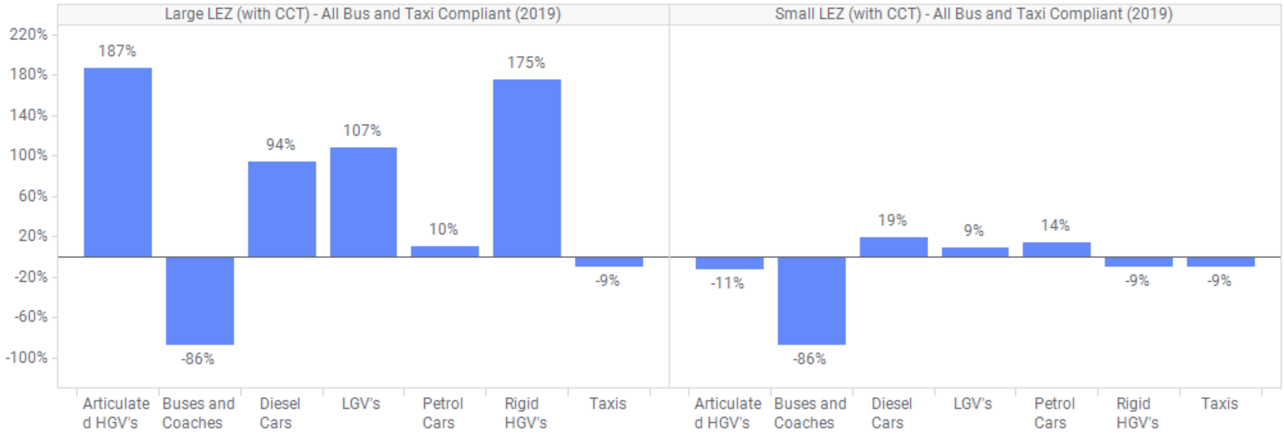

Figure 20: Percentage Change in Emissions (Large and Small LEZ 2019 options) from each vehicle sector for Palmerston Place/Chester Street compared to Base 2019 scenario

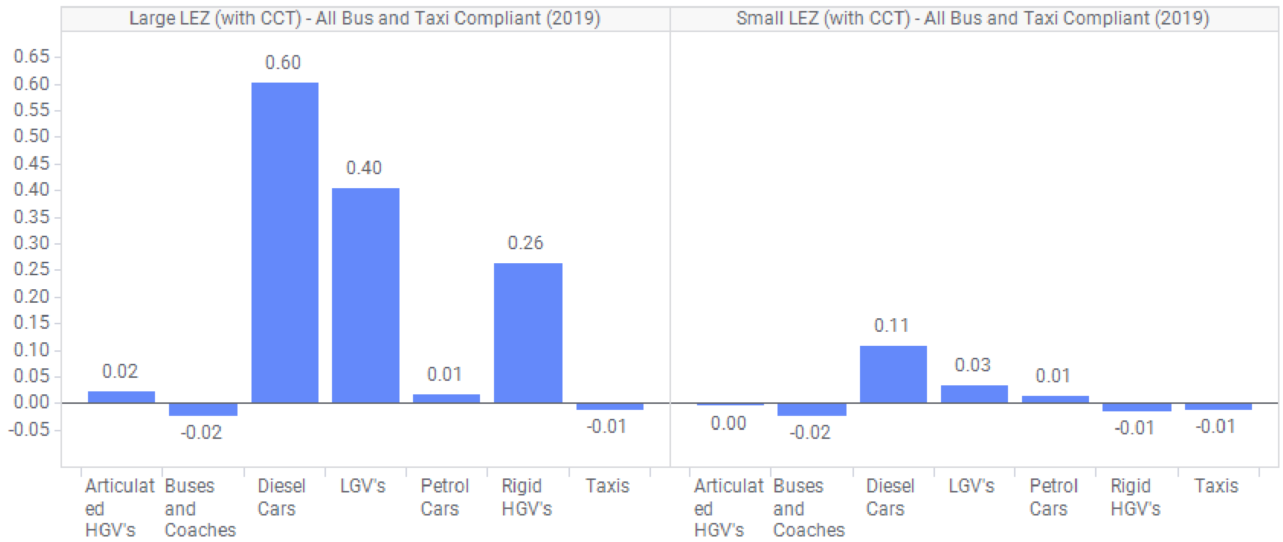

Figure 21: Emissions (tonnes/yr) change (Large and Small LEZ options 2019) from each vehicle sector for Palmerston Place/Chester Street compared to Base 2019 scenario

Lothian Road

Lothian Road is one of the most polluted streets in Edinburgh, and depending on the choice of City Centre LEZ, will either sit inside the Large LEZ, or on the boundary of the Small LEZ. The section of Lothian Road being considered is highlighted in Figure 22.
Bus emissions will decline, regardless of the choice of Small or Large LEZ, as the bus sector will be fully compliant. In both Large and Small LEZ options, Diesel Cars and LGV's will be the biggest contributor of NO_x emissions (Figure 23).

Total NO_x emissions are predicted to decline in the 2019 fleet scenario by 27% if the Small LEZ is selected and by 50% if the Large LEZ is selected (Figure 24). This is expected to decline further in the 'future' 2023 scenario as cleaner vehicles join the fleet.

When looking at individual vehicle sectors (Figure 25, Figure 26), for the Large LEZ option, emissions are reduced from all vehicle sectors. However, if the Small LEZ is selected, although total emissions are lower than the Base scenario (due to large emission reductions from buses), emissions from Cars, HGV's and LGV's will increase, which will delay air quality improvements on this road.

Figure 22: Section of Lothian Road in Analysis

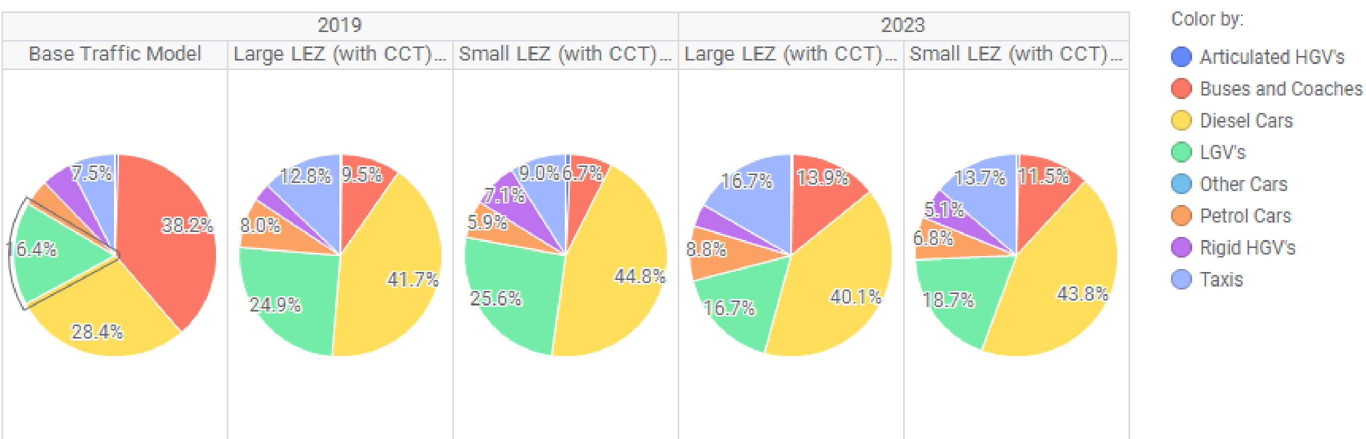

Figure 23: Percentage of Total NO_x emissions for each vehicle sector for Lothian Road

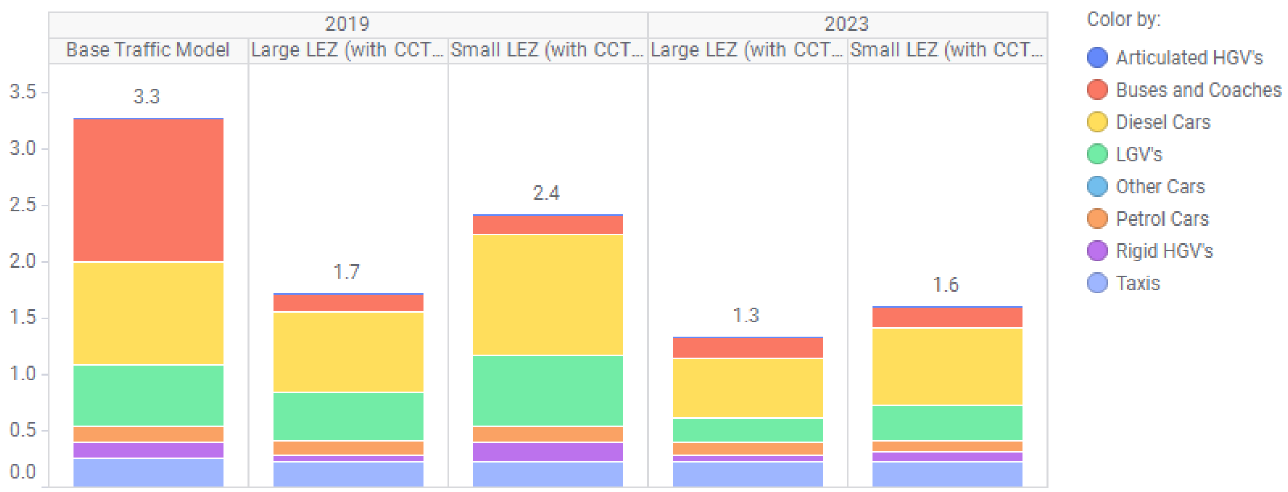

Figure 24: NO_x emissions (tonnes/yr) source attribution for each LEZ scenario for Lothian Road

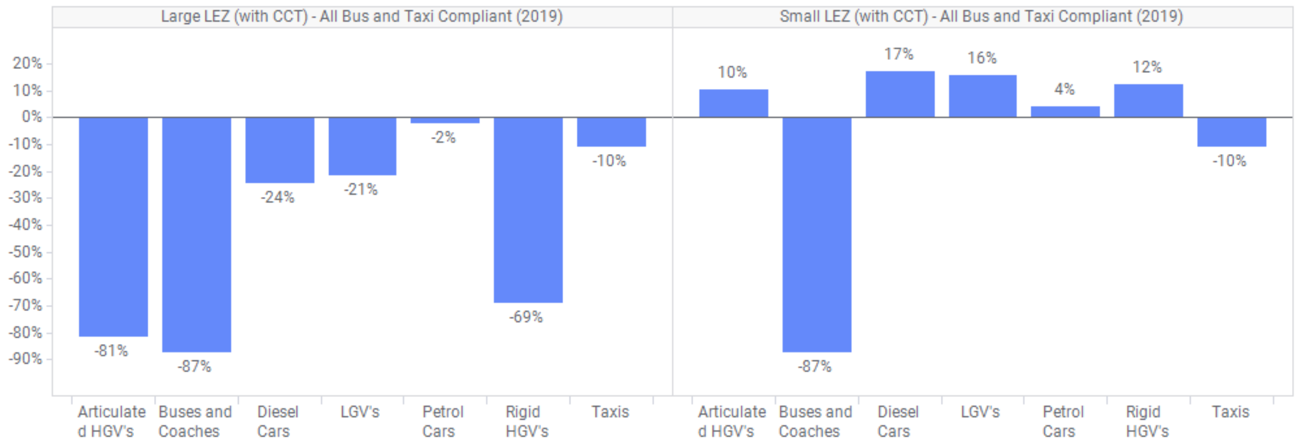

Figure 25: Percentage Change in Emissions (Large and Small LEZ options 2019) from each vehicle sector for Lothian Road compared to Base 2019 scenario

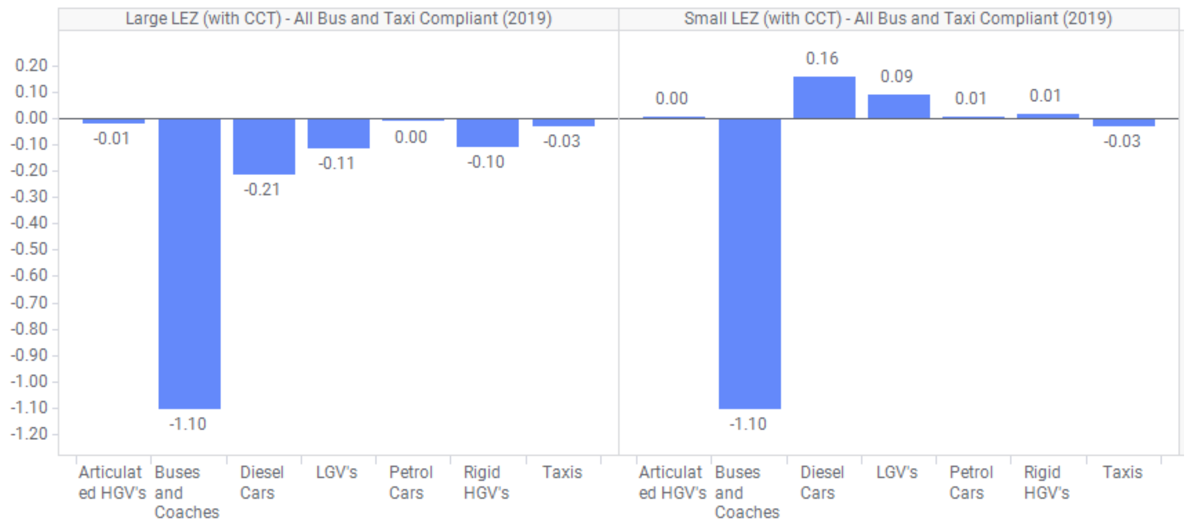

Figure 26: Emissions (tonnes/yr) change (Large and Small LEZ options 2019) from each vehicle sector for Lothian Road compared to Base 2019 scenario

Particulate Emissions

PM_{10} emissions have been calculated for the Large LEZ option only using the EMIT tool (EfTv10 emission factors); this is because at the time of analysis, the Large LEZ option had been selected as the preferred option. It should be noted that the PM_{10} emissions shown represent tailpipe emissions and do not include other particulate emission sources such as road wear, tyre wear, brake wear and resuspension of particulates. 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.

The introduction of the LEZ is predicted to significantly reduce particulate emissions within the Large LEZ and on surrounding streets. There are, however, some streets where PM_{10} emissions increase (Figure 27), based on the 2019 fleet. On Palmerston Place/Chester Street, it is predicted that in the 2019 scenario, tailpipe PM_{10} emissions would double, however it should be noted that despite these increases, emissions would still be relatively lower than on other roads and, like NO_2, emissions will decline over time as the fleet improves (Figure 28, Figure 29, Figure 30).

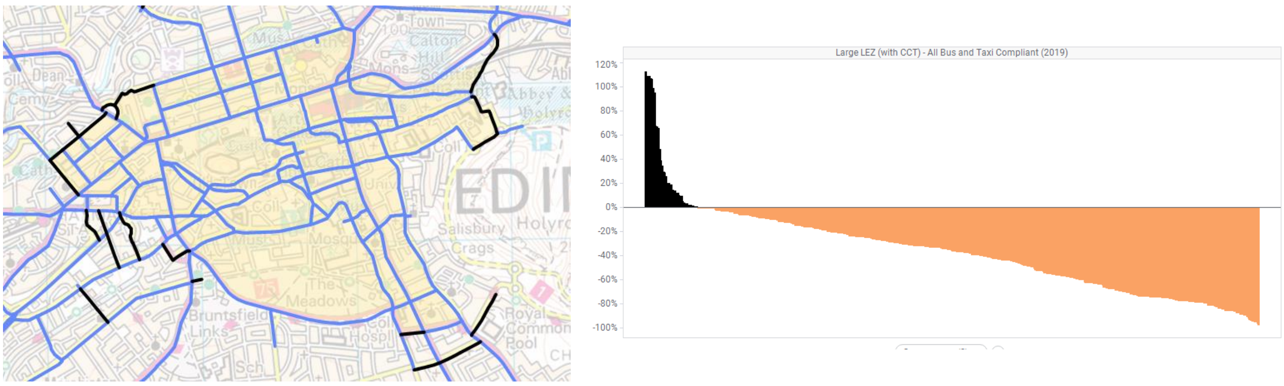

Figure 27: Relative changes to PM_{10} emissions when comparing the Base 2019 scenario and Large LEZ 2019 option. Street highlighted are those where an increase in emissions is predicted

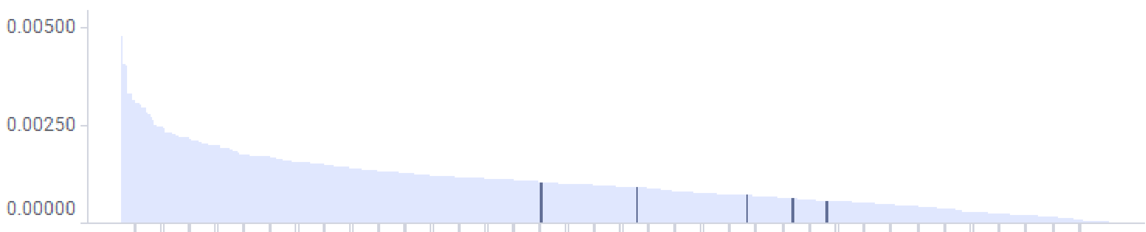

Figure 28: Base 2019 PM_{10} emission rates (g/km/s) for all roads, with Palmerston Place and Chester Street highlighted

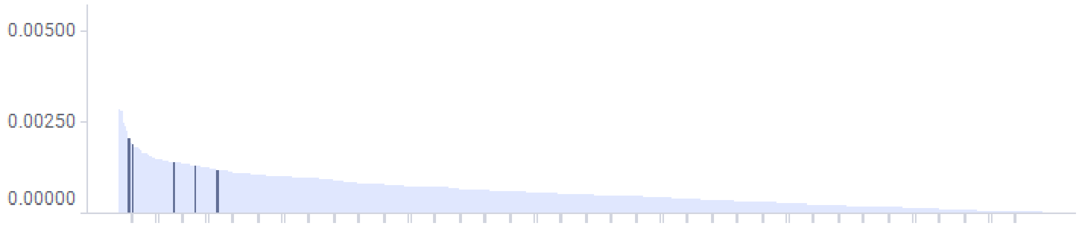

Figure 29: Large LEZ 2019 PM_{10} emission rates (g/km/s) for all roads, with Palmerston Place and Chester Street highlighted

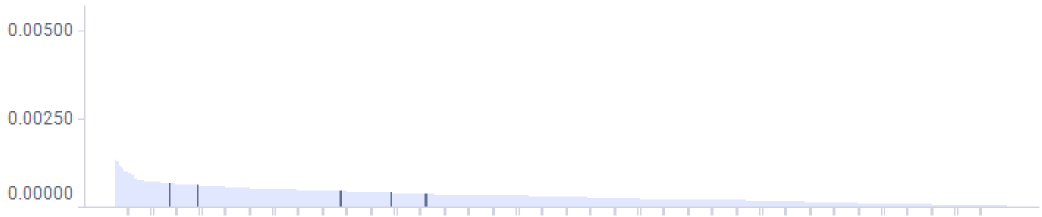

Figure 30: Large LEZ 'future' 2023 PM_{10} emission rates (g/km/s) for all roads, with Palmerston Place and Chester Street highlighted

In the 'future' 2023 scenario, it is predicted that tailpipe PM_{10} emissions rates on all roads will fall below Base 2019 (Figure 31) and Base 2023 (Figure 32) emissions. On Palmerston Place and Chester Street, emissions are expected decline by 33-36% compared to Base 2019 scenario and 15% lower when compared to Base 2023 levels, so despite an initial increase, this is expected to be short term.

Figure 31: Relative changes to particulate emissions when comparing the Base 2019 scenario and Large LEZ 2023 'future' option for each street

Figure 32: Relative changes to particulate emissions when comparing the Base 2023 scenario and Large LEZ 2023 'future' option for each street

Particulate Emissions Source Attribution

All Model Roads

For the Base 2019 scenario, it is predicted that diesel cars (38%) and buses (26%) are the largest sources of PM_{10} from tailpipe emissions (Figure 33).

The introduction of the Large LEZ is predicted to reduce tailpipe PM_{10} emissions significantly. In the 2019 scenario, it is predicted that 1.5 tonnes (Figure 34) will be removed (mostly attributed to the bus sector), which is a reduction of 34%. In the 'future' 2023 scenario, emissions will be 2.9 tonnes lower (Figure 34), which is a reduction of 66%, as emissions from the non-bus sector fall.

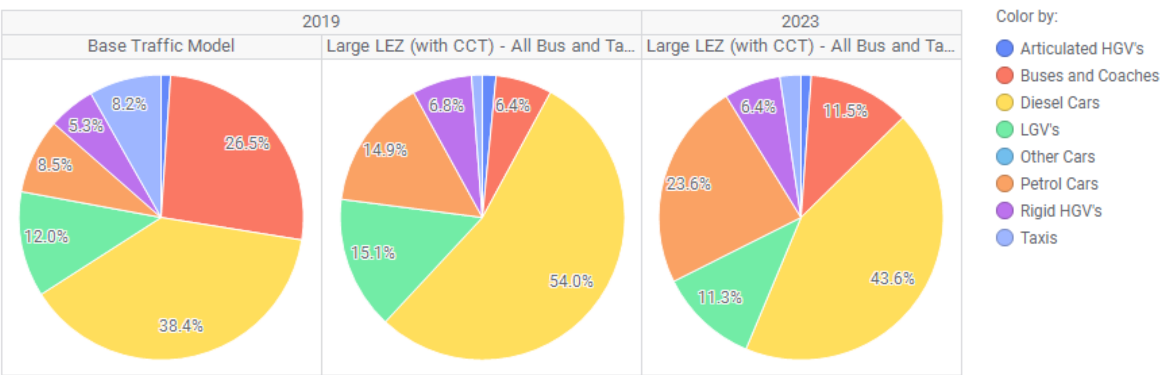

Figure 33: PM_{10} relative source attribution for Base 2019 and Large LEZ (2019 and 2023) for all model roads

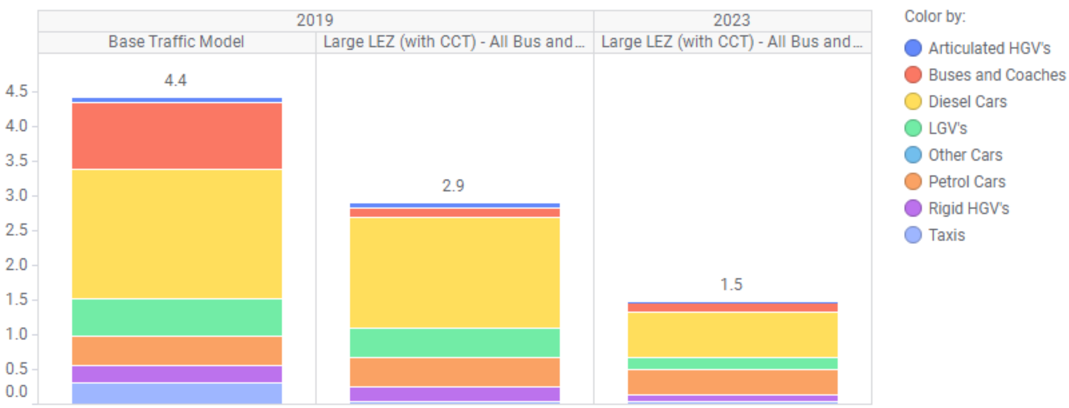

Figure 34: PM_{10} source attribution (tonnes/yr) for Base 2019 and Large LEZ (2019 and 2023) for all model roads

Within the LEZ

The source attribution analysis for PM_{10} emissions (tailpipe only) shows that in the Base scenario 41% of emissions are from the bus sector, but this would fall to 28% with the introduction of either LEZ. The relative contribution from Diesel cars increases slightly (25 to 30%), and there is a large relative increase from petrol cars, from 5% to 25% (Figure 35). Total PM_{10} emissions (from tailpipe) will fall by 85% from 0.7 tonnes to 0.1 tonnes per year (Figure 36).

Within each vehicle sector, significant reductions in emissions are predicted for all vehicle sectors, with the exception of petrol cars, which will stay the same (Figure 37, Figure 38), which is why petrol cars become a relatively larger emission sector with an LEZ.

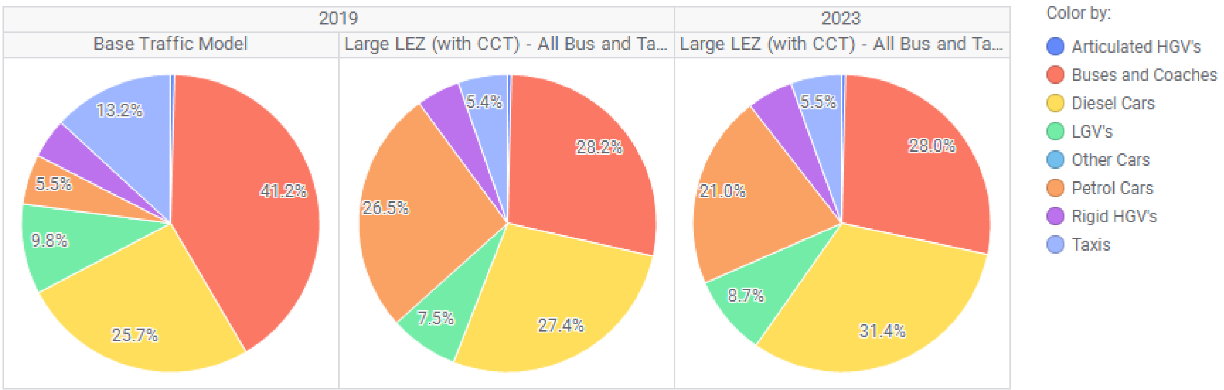

Figure 35: PM_{10} relative source attribution for Base 2019 and Large LEZ (2019 and 2023) within the Large LEZ area

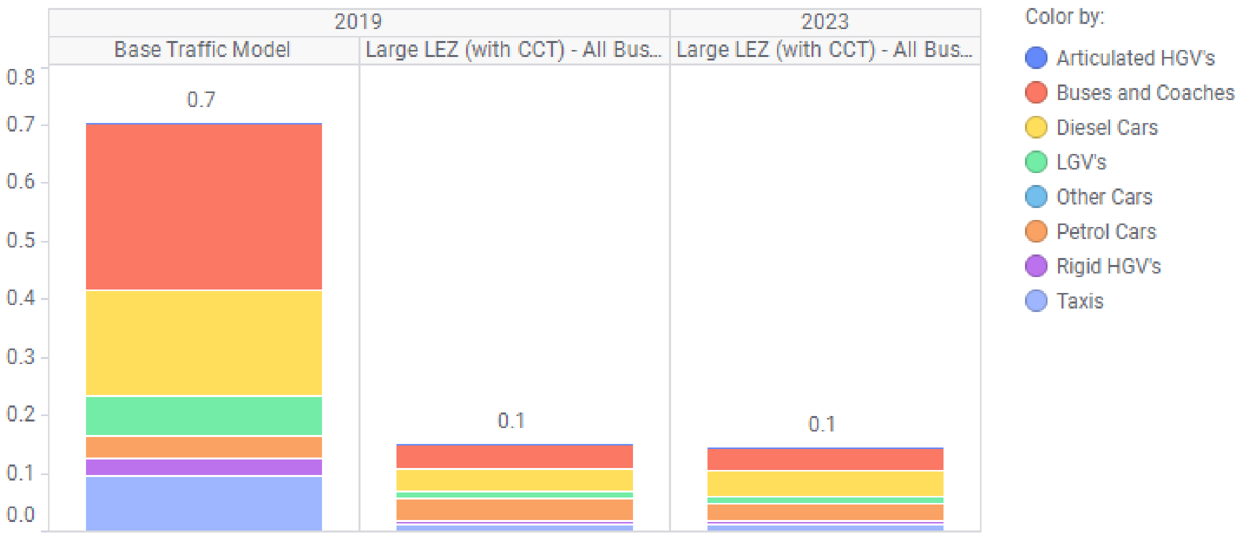

Figure 36: PM_{10} source attribution (tonnes/yr) for Base 2019 and Large LEZ (2019 and 2023) for within the Large LEZ area

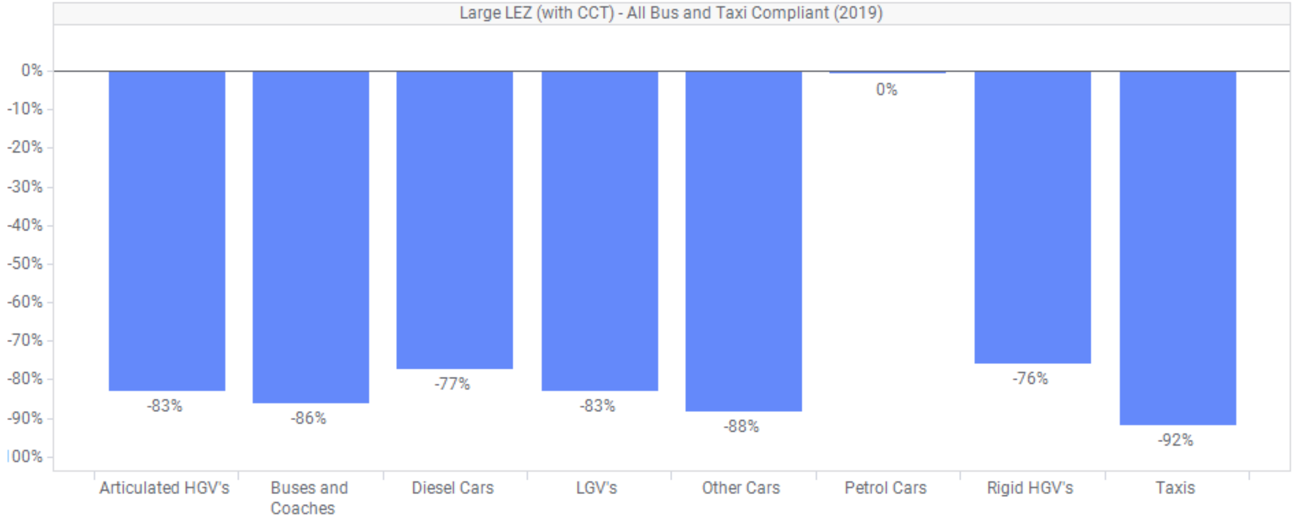

Figure 37: Percentage Change in PM_{10} Emissions (Large LEZ option) from each vehicle sector for within the LEZ when compared to Base 2019 scenario

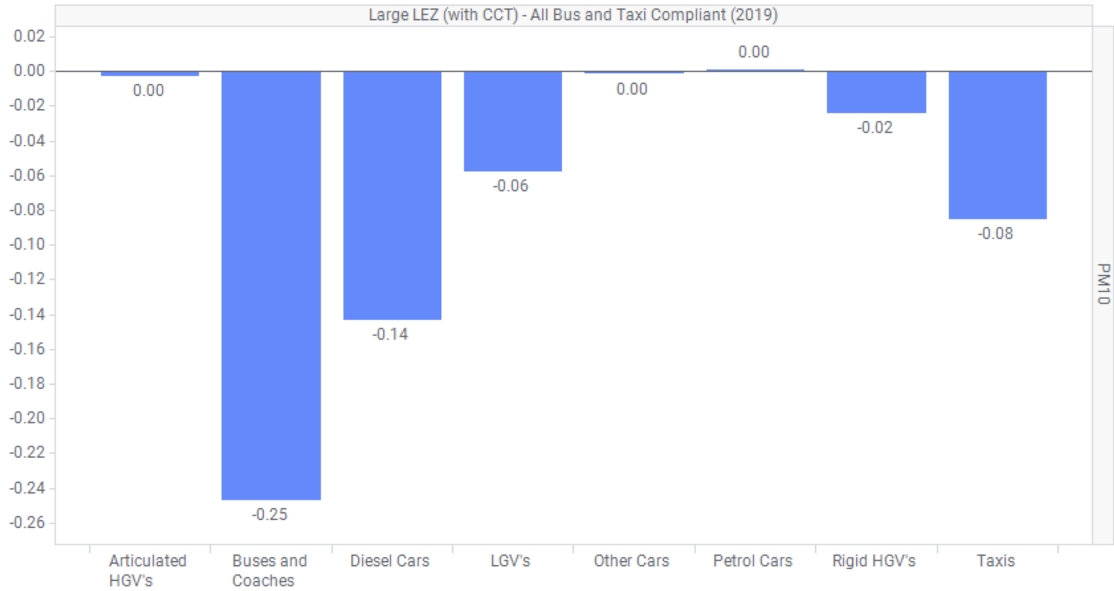

Figure 38: Changes in PM_{10} Emissions (Large LEZ option) from each vehicle sector for within the LEZ when compared to Base 2019 scenario (tonnes/yr)

Palmerston Place/Chester Street

Like NO_x emissions, in the Large LEZ 2019 fleet scenario there is a predicted to be an increase in tailpipe PM_{10} emissions which is predominantly attributed to increases in LGV and Diesel Car traffic, which has been displaced by the LEZ (Figure 39). However, this increase is likely to be short term as total emissions are predicted fall below Base 2019 levels in the 'future' 2023 scenario, though Diesel cars will still be responsible for over 50% of emissions (Figure 39, Figure 40).

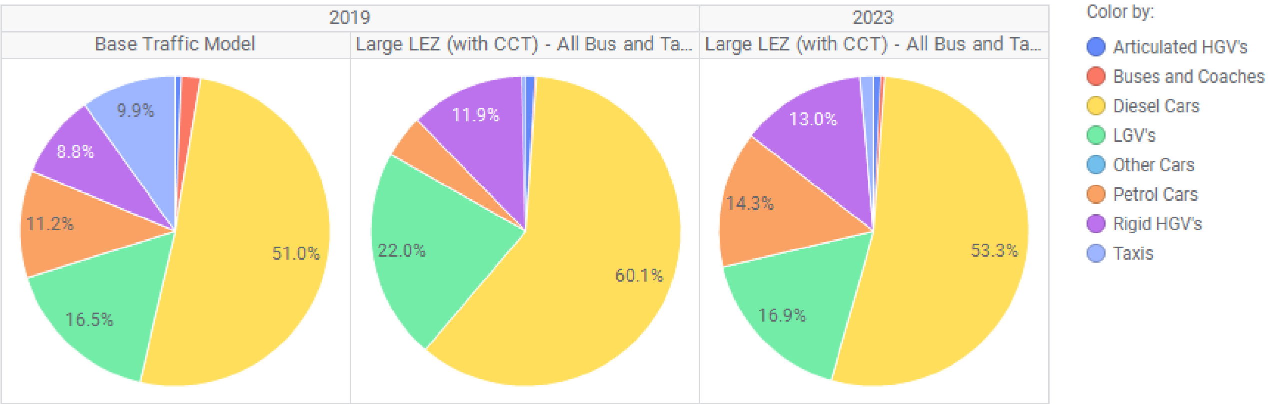

Figure 39: PM_{10} relative source attribution for Base 2019 and Large LEZ (2019 and 2023) for Palmerston Place/Chester Street

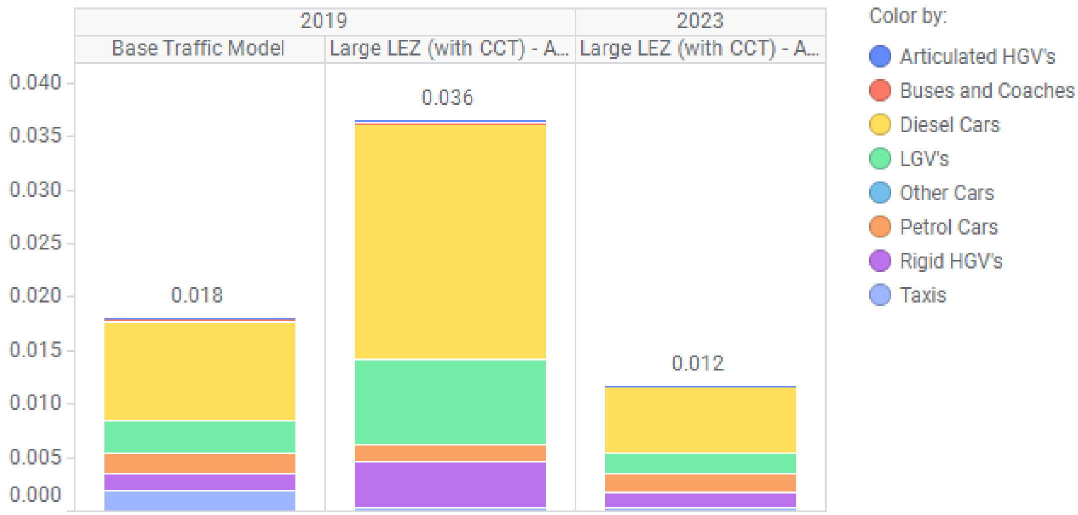

Figure 40: PM_{10} source attribution (tonnes/yr) for Base 2019 and Large LEZ (2019 and 2023) for Palmerston Place/Chester Street

Model Results

NO_2 Concentration Predictions

A summary of NO_2 concentration predictions was provided in the SEPA March 2021 Interim Presentation Summary (SEPA, 2021), though this relied on limited information due to the cyber-attack. This report expands on this information that was included in the previous report.

The air quality model was run for 3 options using 2 fleet scenarios (2019 'worst case' and 2023 'future'):

1) Base – the 'No LEZ' or 'Do Nothing' approach

2) Large City Centre LEZ (Figure 1)

3) Small City Centre LEZ (Figure 2)

The model was run using the methodology outlined in the SEPA Evidence report (SEPA, 2018), with changes described above, due to the way the traffic model data was supplied.

In this section we will refer to **model exceedances**. These are exceedances (concentrations greater than 40 µg m^{-3}) predicted by the model at kerbside points.

2019 'Worst Case' Scenarios

The air quality model predicts for the Base scenario that model exceedances are predicted **within** the proposed LEZ's at 43% of kerbside points for both LEZ options, and **across the whole city** at 24% of kerbside points (Table 7, Figure 41).

Table 7:Summary of Percentage of Model Exceedances for 2019 scenarios

Percentage of Kerbside Points exceeding 40µg/m^3	Model Scenarios		
	Base	Large LEZ	Small LEZ
All City	24%	12%	12%
In Large LEZ area	43%	10%	12%
In Small LEZ area	43%	8%	9%
Outside Large LEZ area	19%	13%	n/a
Outside Small LEZ area	20%	n/a	13%

If there was an LEZ in place for the 2019 fleet scenario, the number of model exceedances predicted within the LEZ falls from 43% to 10-12% (Table 7). There is also a reduction in model exceedances outside of LEZ zones from ~20% to 13% (Table 7).

However, it should be noted that, if an LEZ was in place in 2019, although there is an overall improvement, model exceedances are predicted in some areas:

- **New** model exceedances are predicted on Palmerston Place and Chester Street if the Large LEZ option is selected (Figure 42).

- **Existing** model exceedances with concentrations greater than 55 µg m^{-3} will persist on the Lothian Road/Charlotte Square corridor if the Small LEZ option is selected (Figure 43).

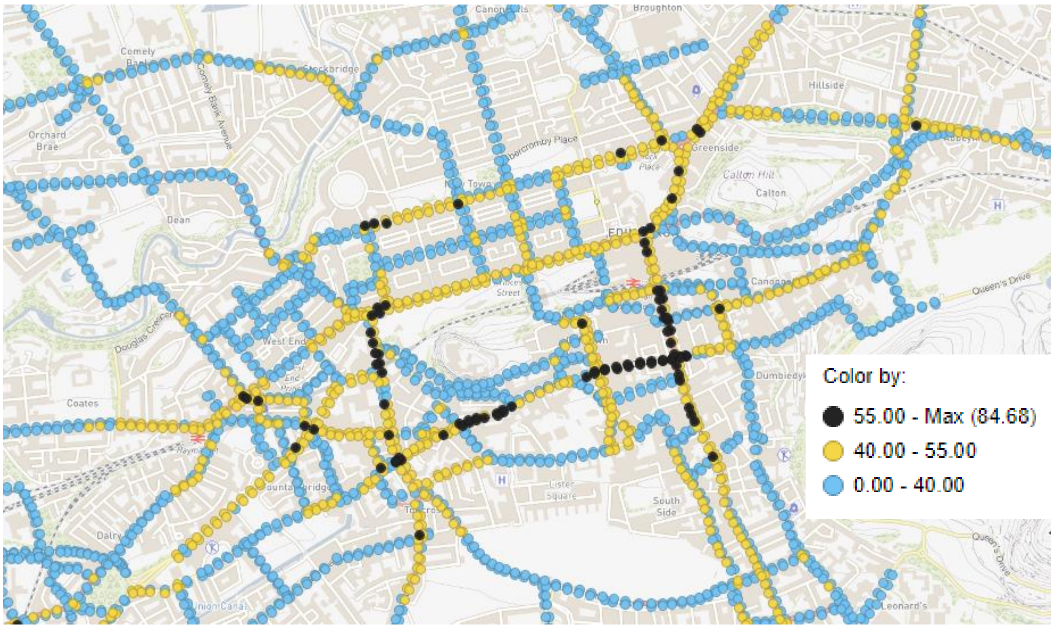

*Figure 41: **Base** 2019 NO_2 predicted concentrations (µg m^{-3})*

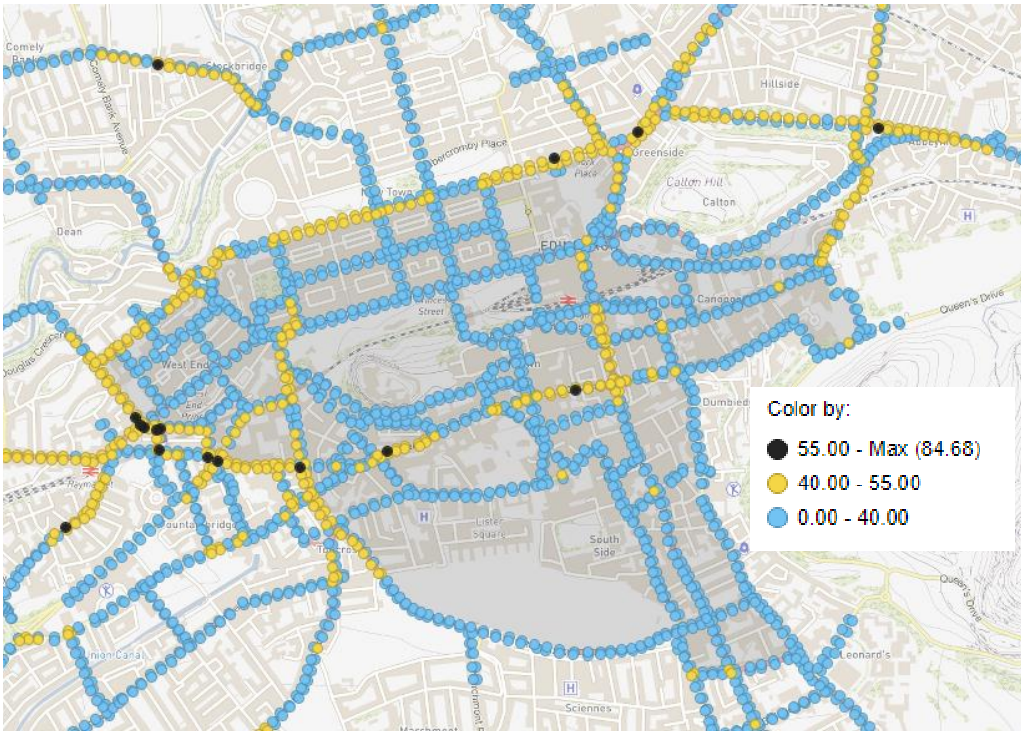

*Figure 42: **Large LEZ** 2019 NO_2 predicted concentrations (µg m^{-3}). Large LEZ is shaded area*

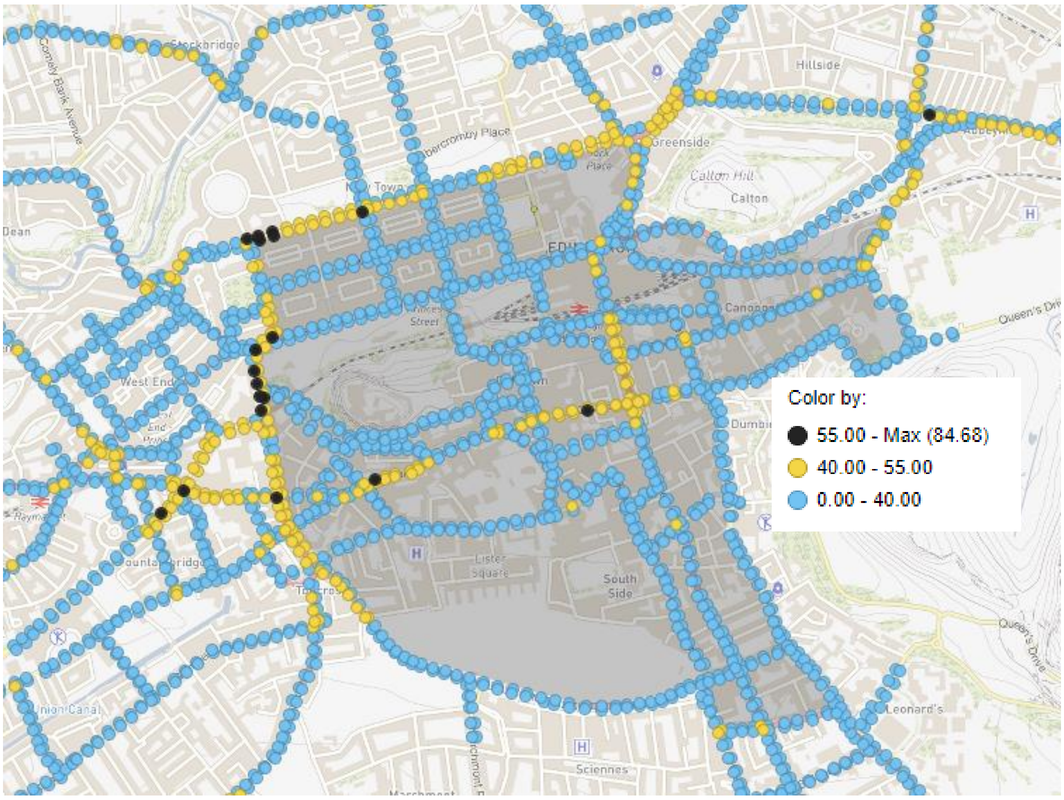

*Figure 43: **Small LEZ** 2019 NO_2 predicted concentrations (µg m^{-3}. Small LEZ is shaded area*

NO_2 Modelling Predictions (2019 'worst case' scenarios)

Large LEZ

The introduction of the Large LEZ (based on the 2019 fleet) is predicted to reduce concentrations at over 90% of kerbside points across the whole city (points coloured with blue shades in Figure 44). However, there are some areas where kerbside concentrations are predicted to increase (Palmerston Place, Chester Street, Grove Street, Gardiners Crescent, Abbeyhill, Horse Wynd, Holyrood Park Road, West Preston Street, Salisbury Road and Salisbury Place).

Most of these predicted increases in NO_2 concentrations are relatively small (less than 2 µg m^{-3}); however, there is predicted to be large increases on Palmerston Place and Chester Street of between 6 to 12 µg m-3 (Figure 45).

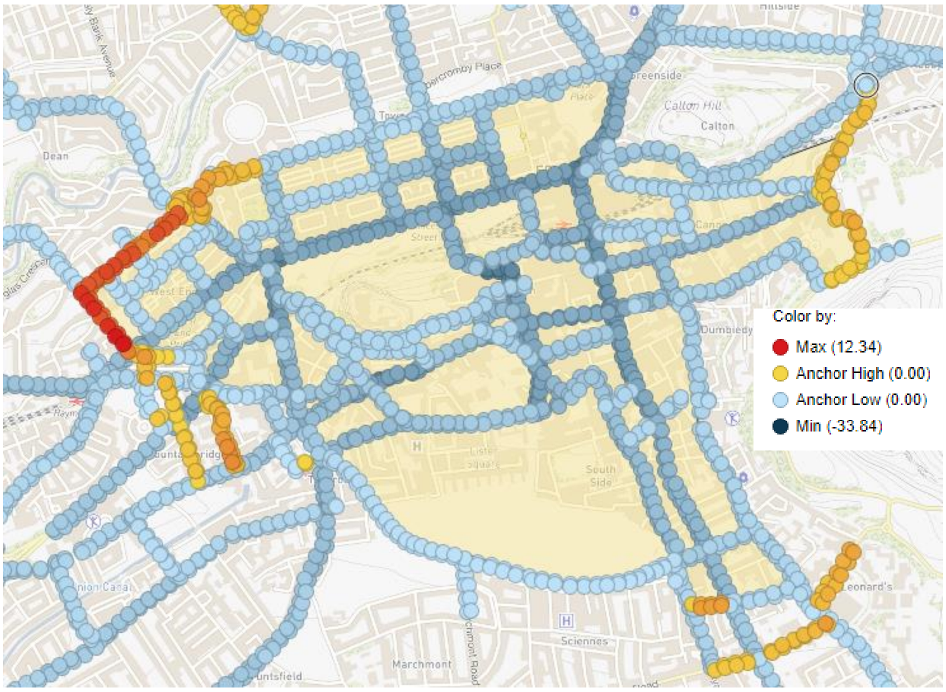

Figure 44: Predicted Changes in NO_2 concentration (µg m^{-3}) due to introduction of Large LEZ (2019), when compared to 2019 Base scenario

Model exceedances are still predicted at ~10% of kerbside points within the LEZ (Table 7), with the highest concentrations predicted at the junction of West Maitland Street, Palmerston Place and Shandwick Place (Figure 46). High concentrations are also predicted in the Cowgate, West Port and Morrison Street.

The introduction of the Large LEZ may create new model exceedances on Palmerston Place/Chester Street/Drumsheugh Gardens, Great Stuart Street and Abbeyhill (Figure 47).

- Palmerston Place: Model exceedances were predicted at 37% of kerbside points in the Base Run. For the Large LEZ (2019), model exceedances are predicted at all kerbside points (concentrations range from 43 to 54 µg m^{-3}).
  Although the largest concentration increases are predicted here, higher concentrations are predicted in other parts of the city, including some locations within the LEZ (e.g. Lothian Road) (Figure 48).

- Chester Street/Drumsheugh Gardens: New model exceedances are predicted at all kerbside points on Chester Street and the east section of Drumsheugh Gardens. Concentration increases of up to 9 µg m^{-3} (Figure 45) are predicted resulting in concentrations of between 44 and 46 µg m-3 (Figure 46, Figure 47).

- Abbeyhill and Great Stuart Street: Although new model exceedances are predicted in the model, this is because concentrations were just below the 40 µg m^{-3} threshold in the Base scenario, and a small increases of 1-2 µg m^{-3} (Figure 45) due to the LEZ results in a concentration just above the 40 µg m^{-3} threshold (Figure 46, Figure 47).

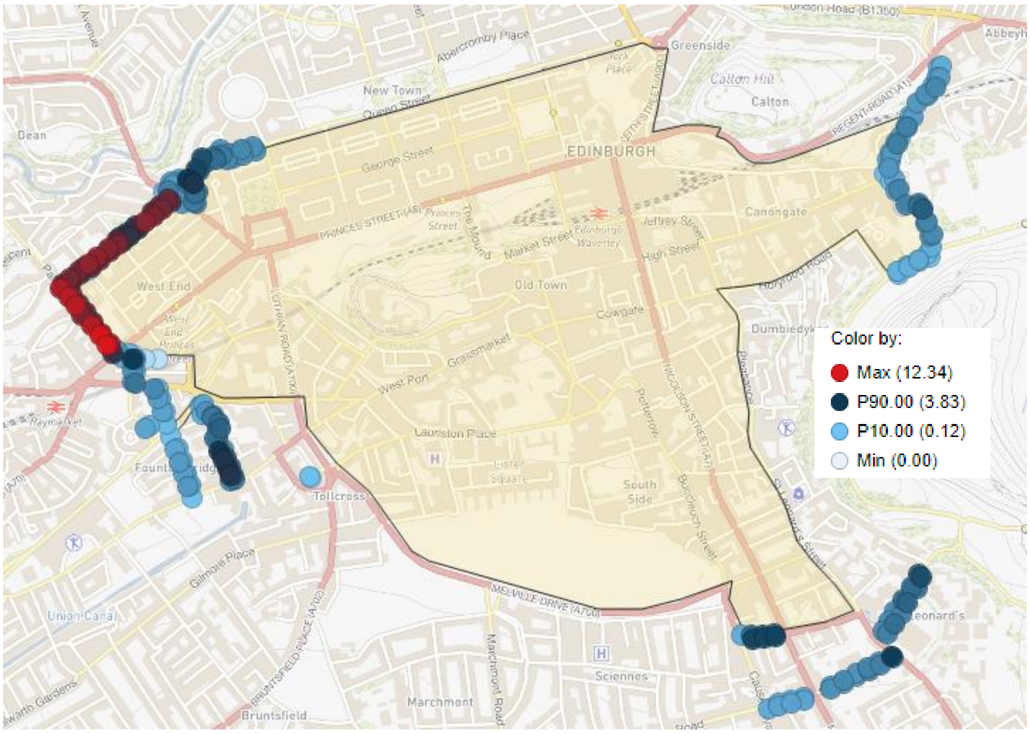

Figure 45: Predicted NO_2 increases (µg m^{-3}) due to introduction of Large LEZ (2019), when compared to 2019 Base scenario

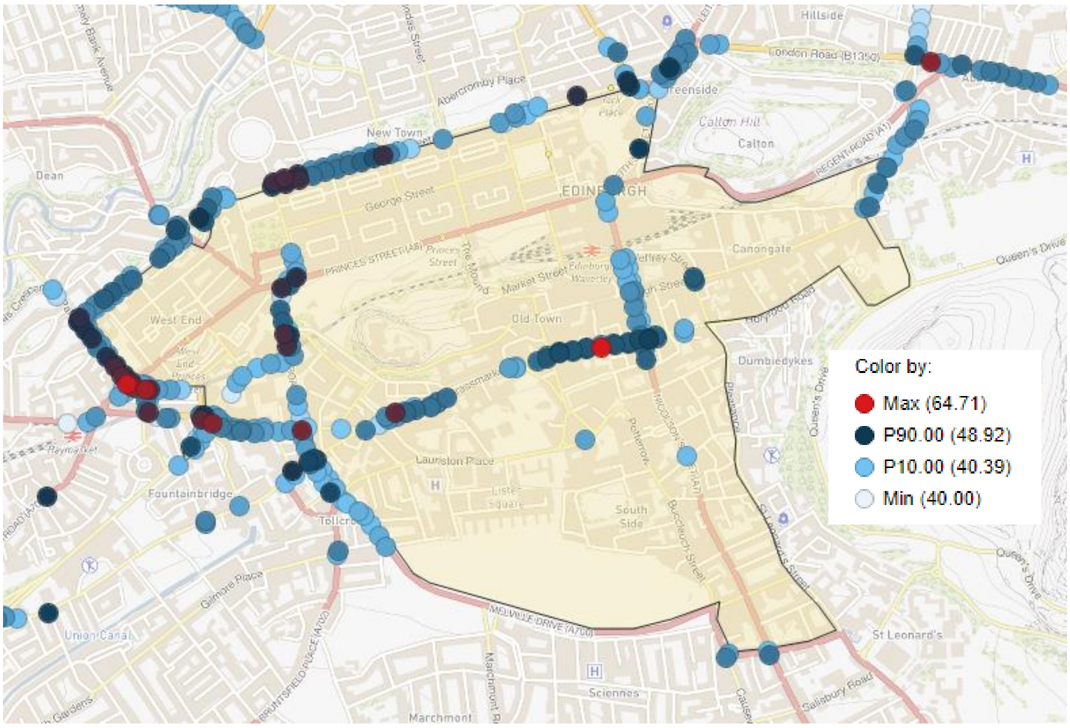

Figure 46: Predicted model exceedances (µg m^{-3}) after introduction of Large LEZ (2019)

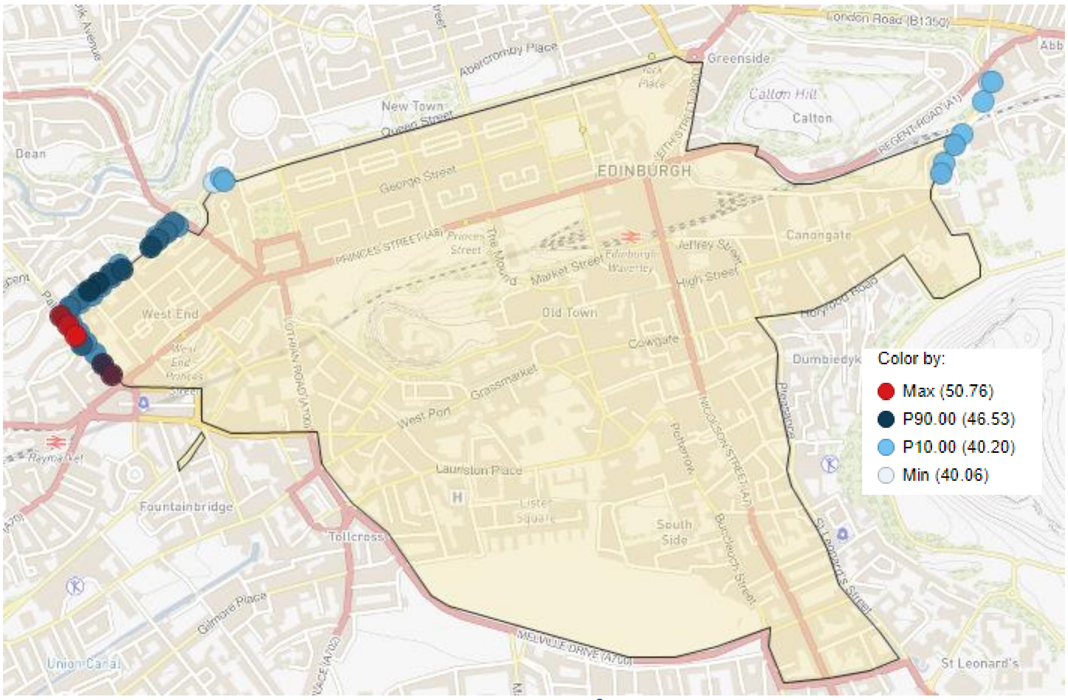

Figure 47: Predicted new exceedances (µg m^{-3}) introduction of Large LEZ (2019)

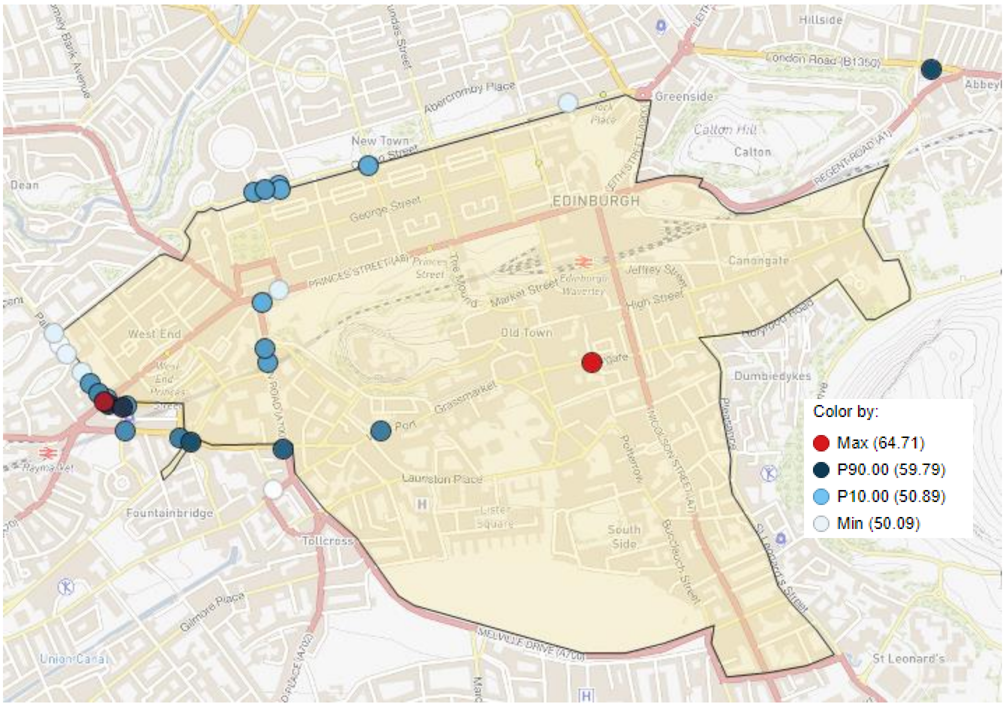

Figure 48: Predicted concentrations > 50 µg m^{-3} due to introduction of Large LEZ (2019)

Small LEZ

As there was concern that the Large LEZ option would result in new model exceedances in Palmerston Place and Chester Street, a smaller LEZ option was explored (Figure 2).

For the Small LEZ option (2019 fleet), like the Large LEZ, NO_2 concentrations are expected fall in most kerbside points (Figure 49), though they are predicted to increase on some roads coloured in yellow and red. It is important to note that the maximum increase is 3.8 µg m^{-3}, which is significantly lower than the maximum increase of 12 µg m^{-3} in the Large LEZ option.

Concentration increases due to the introduction of the Small LEZ would not lead to many new model exceedances (Figure 50), and where they do, predicted increases are very small and just cross above the 40 µg m^{-3} threshold.

The largest predicted increases are on West Preston Street, increases on other roads are very small (less than 1 µg m^{-3}; Figure 51).

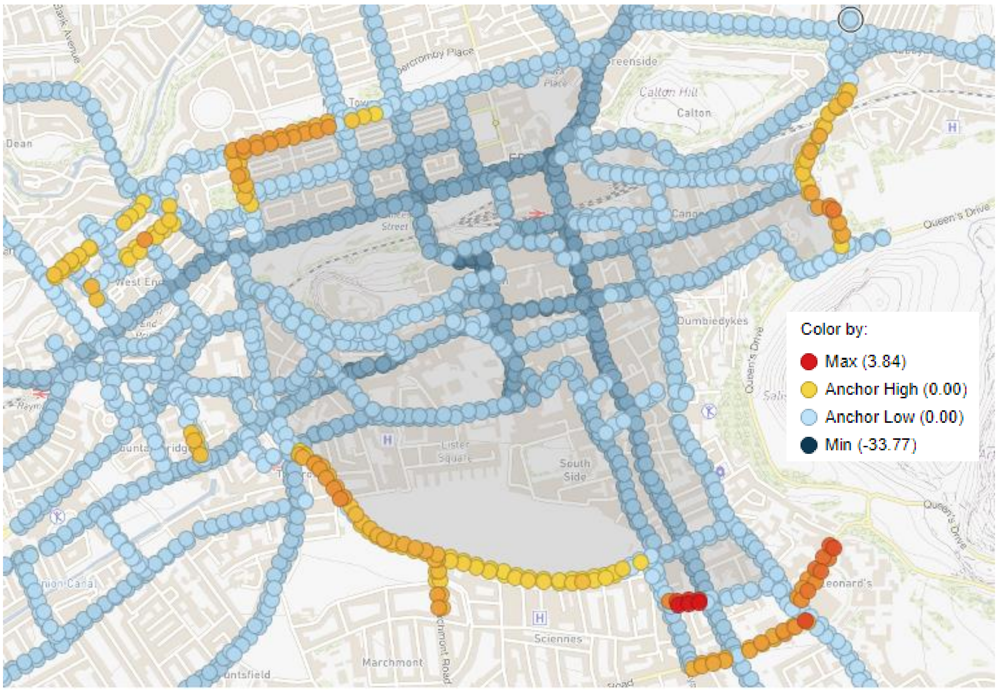

Figure 49: Predicted Changes in NO_2 concentration (µg m^{-3}) due to introduction of Small LEZ (2019), when compared to Base 2019 scenario

The highest concentrations are predicted on Lothian Road, Queen Street and Cowgate (Figure 52) and model exceedances will occur at 8% of kerbside points within the Small LEZ. On Lothian Road, predicted concentrations are still likely to exceed 50 µg m^{-3} and possibly over 60 µg m^{-3} (Figure 53).

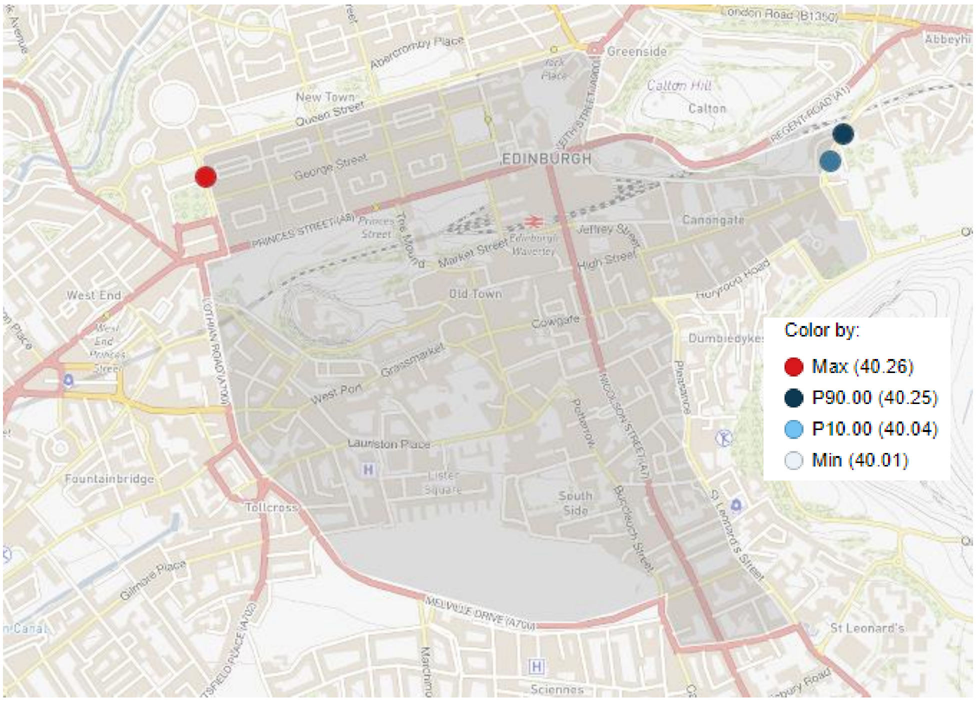

Figure 50: Predicted new NO_2 exceedances introduction of Small LEZ (2019)

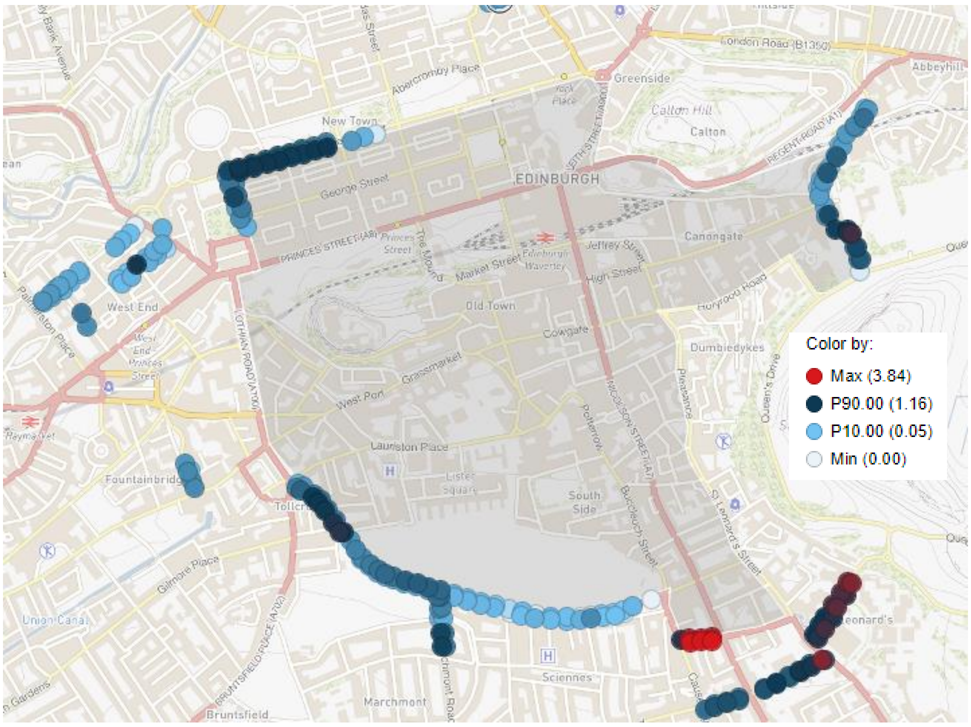

Figure 51: Predicted NO_2 increases ($\mu g\ m^{-3}$) due to introduction of Small LEZ (2019), when compared to 2019 Base scenario

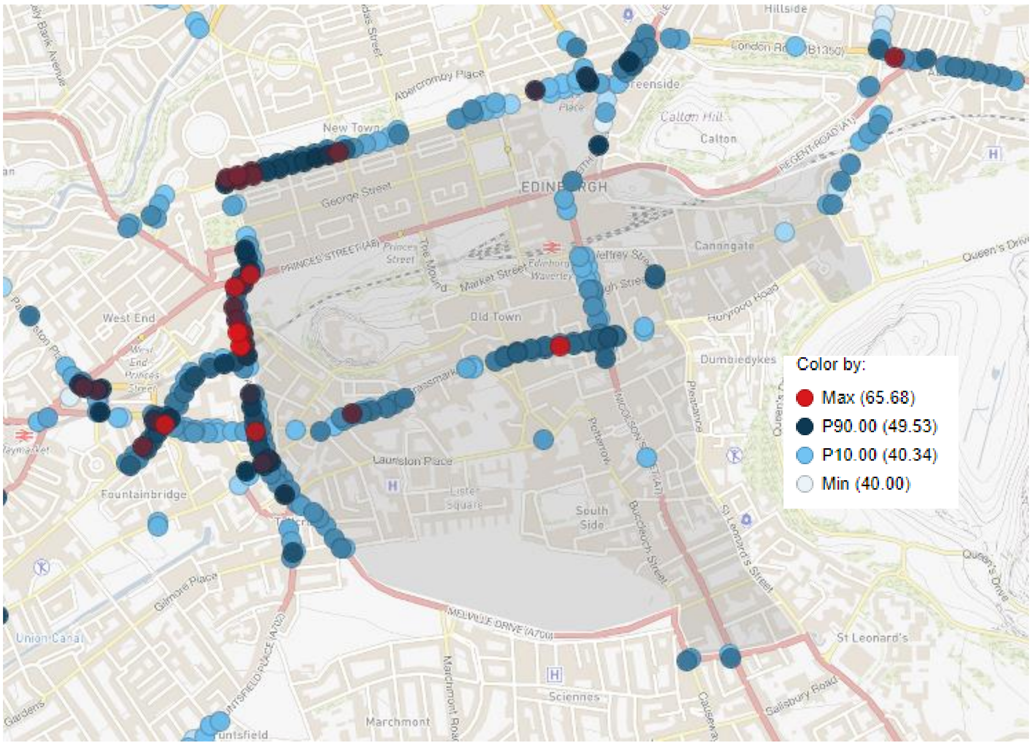

Figure 52: Predicted NO_2 exceedance concentrations (µg m-3) after introduction of Small LEZ (2019)

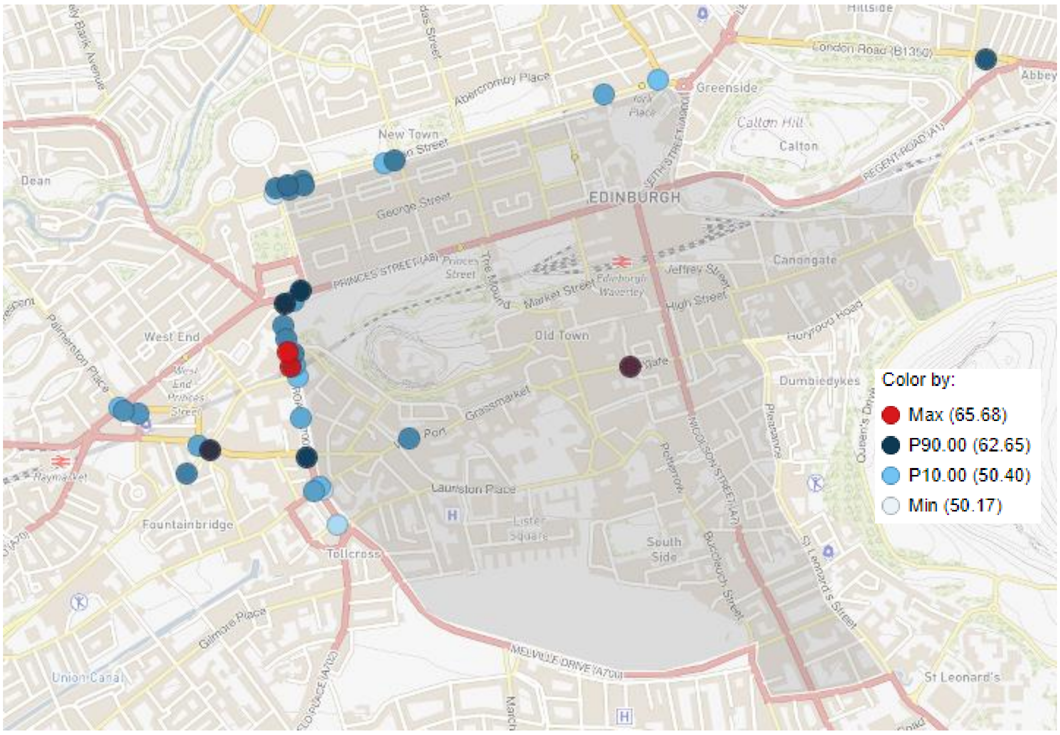

Figure 53: Predicted NO_2 concentrations >50 µg m^{-3} due to introduction of Small LEZ (2019)

Summary (2019 scenarios)

Based on 2019 fleet scenarios, the Large LEZ option is predicted to create new model exceedances have on Palmerston Place and Chester Street. Although the Small LEZ option would avoid creating these new exceedances, existing model exceedances (with higher concentrations than is predicted on Palmerston Place/Chester Street with the Large LEZ) would remain on Lothian Road.

Across the whole city, when looking at the ranked (high to low) values for all kerbside points, both LEZ options significantly reduce NO_2 concentrations (Figure 54) and model exceedances fall from 23.5% to 12% (Table 8).

For kerbside points within the Central AQMA area (Figure 55), the Large LEZ will result in slightly lower concentrations than the Small LEZ. For kerbside points not in any AQMA, both LEZ options will reduce the number of model exceedances from 15% to 8% (Table 8).

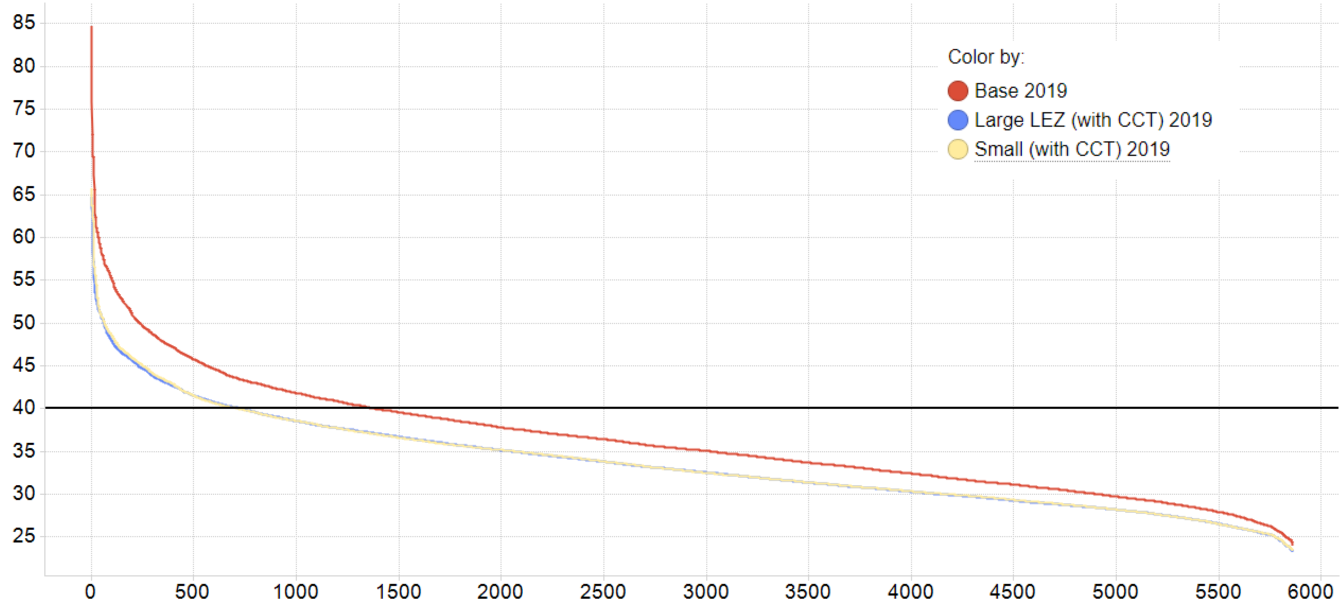

Figure 54: Ranked Concentrations for Base, Large LEZ and Small LEZ options (2019) for All City

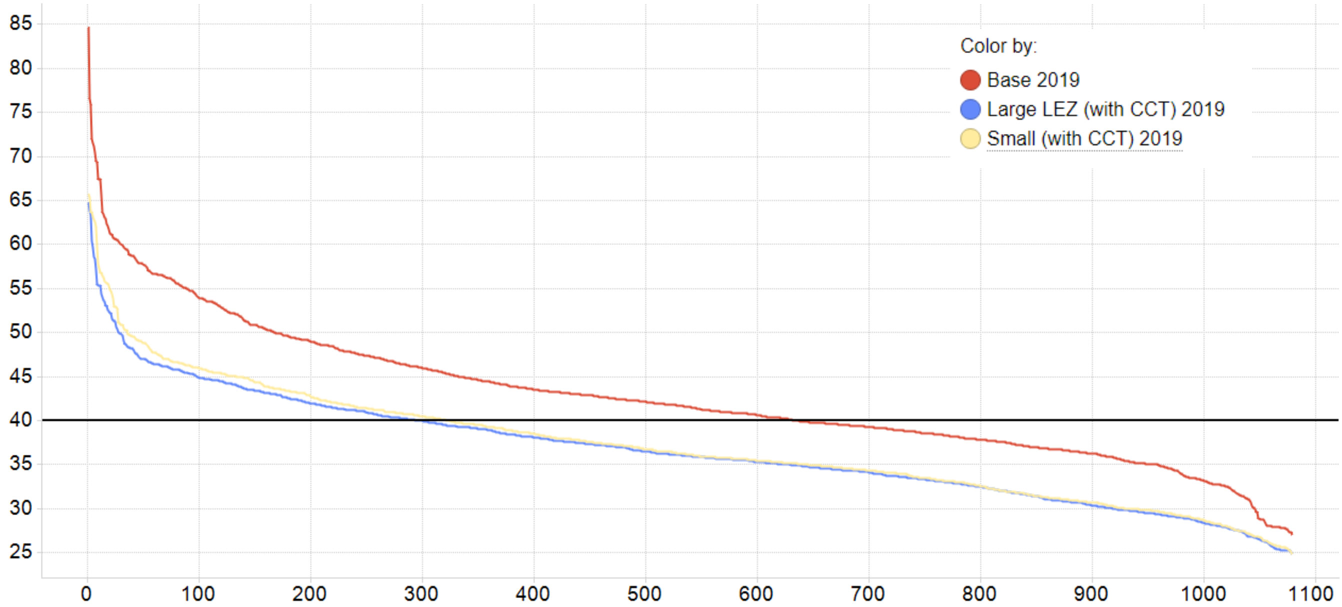

Figure 55: Ranked Concentrations for Base, Large LEZ and Small LEZ options (2019) for the Central AQMA

Table 8: Percentage of Model Exceedances in AQMA's

Area of City	Base	Large LEZ	Small LEZ
All City	23.5%	12.4%	12.2%
All AQMA's	55.1%	26.5%	28.3%
Central AQMA only	58.7%	27.5%	30.0%
Not in AQMA	14.8%	7.7%	8.5%

NO_2 Model Predictions (2023 'future' scenario)

There are many uncertainties in predicting future pollution concentrations, due to large uncertainties on what the fleet composition will be and how COVID will affect future fleet changes. However, it was agreed with CEC and Jacobs to use the 2023 National Fleet predictions to predict future concentrations. It is important to note that as it has been found these fleet predictions tend to be optimistic, this is likely to occur later than 2023.

The 2023 fleet compliance vales can be found in Table 5 and Table 6. The traffic flow data used in the modelling remains unchanged from the 2019 model scenarios.

2023 'future' Scenarios

For the Base 2023 scenario, model exceedances are predicted at 11% of kerbside points within the Large LEZ area, and at 3.2% of kerbside points across the whole city (Table 9) and are predicted to found on Lothian Road, Bridges, Cowgate, West Port and Leith Street (Figure 56).

Table 9: Summary of Percentage of Model Exceedances for 2023 scenarios

Percentage of Kerbside Points exceeding 40µg/m^3	Model Scenarios		
	Base Run	Large LEZ	Small LEZ
All City	3.2%	0.8%	1%
In Large LEZ area	11.2%	2.2%	2.7%
In Small LEZ area	10.8%	1.9%	1.8%
Outside Large LEZ area	1.6%	0.6%	0.6%
Outside Small LEZ area	2.0%	0.7%	0.8%

If an LEZ was in place for the 2023 'future' fleet scenario, model exceedances within the LEZ are predicted to fall from 11% to 2-3%%. A reduction in model exceedances is also predicted outside of the LEZs (from ~1.6% to ~0.6%. This shows that even in the future, an LEZ will still be effective.

However, it should be noted that although there is a significant overall improvement in pollution levels, model exceedances are still predicted in some areas (Figure 57, Figure 58) such as Cowgate (dispersion on this road is very poor due to the deep canyon). Other roads where model exceedances are predicted are Lothian Road, Princes Street (West End) and Queen Street (by Charlotte Square).

For the Large LEZ option, no model exceedances are predicted on Palmerston Place and Chester Street. This suggests any new model exceedances created on this road by the introduction of an LEZ will be a short-term issue and may not even occur depending on what the fleet composition is when the LEZ is enforced. It is likely that in 2024, when LEZ enforcement is scheduled to begin, the actual fleet will be closer to the 'future' 2023 fleet scenario than the 2019 fleet scenario.

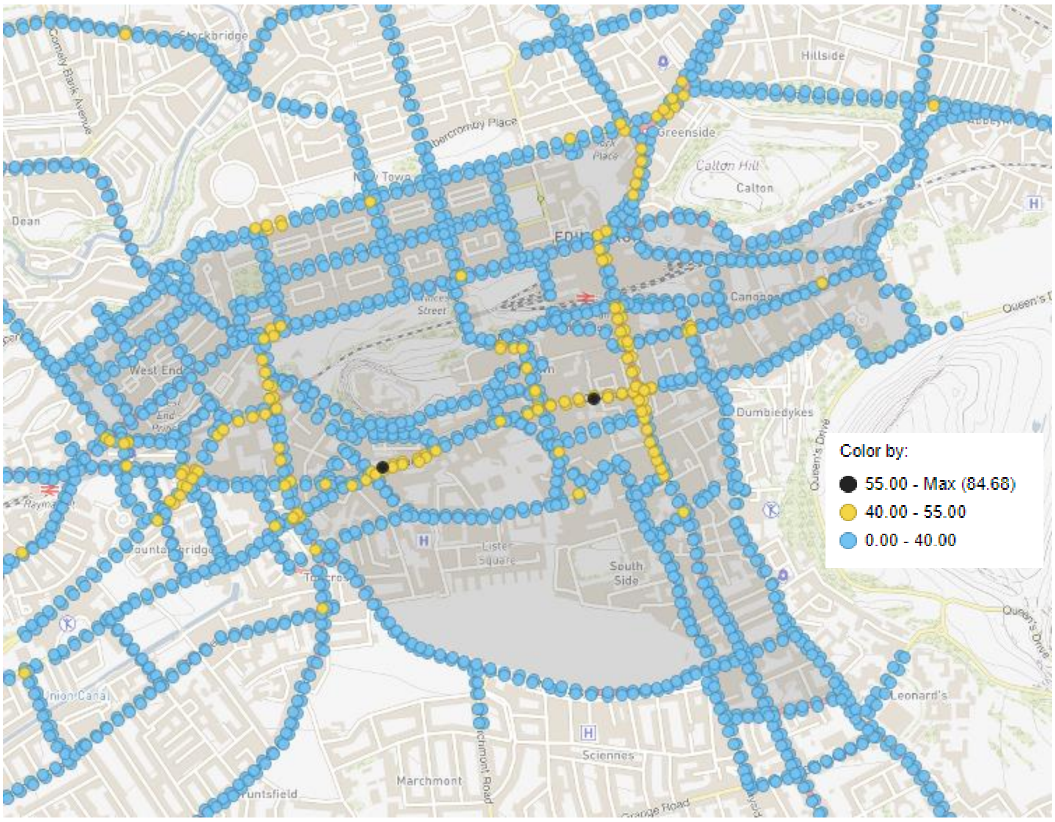

Figure 56: Base 2023 'future' scenario NO_2 predicted concentrations (µg m^{-3})

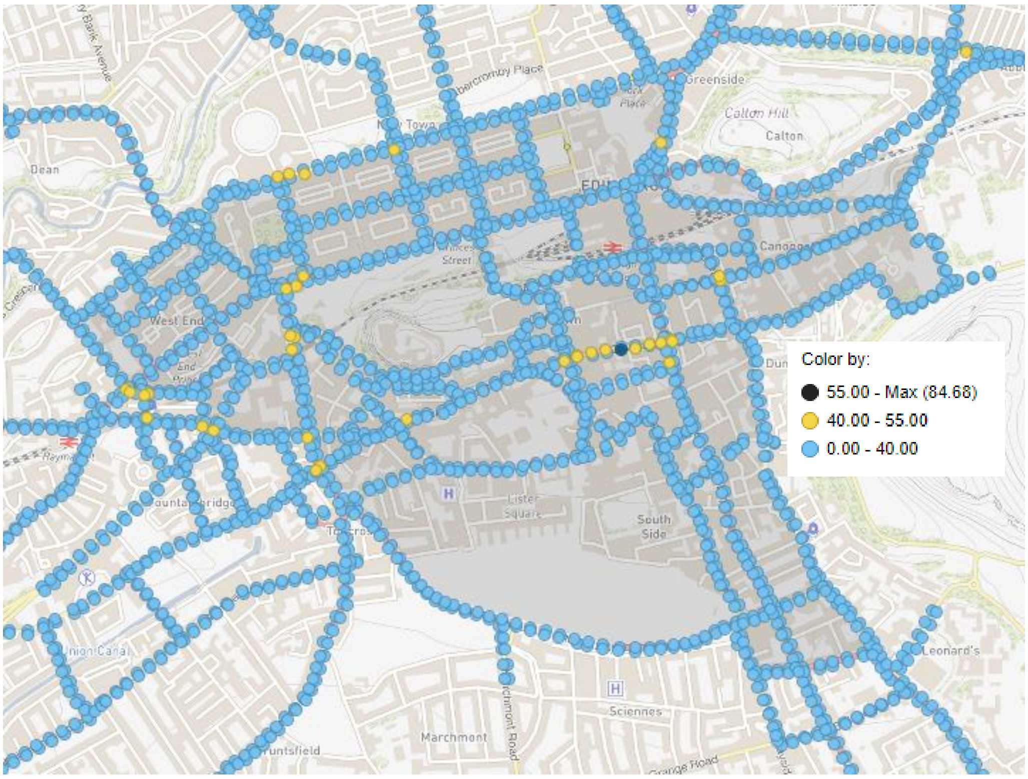

Figure 57: Large LEZ 2023 'future' scenario NO_2 predicted concentrations ($\mu g\ m^{-3}$). LEZ is shaded area

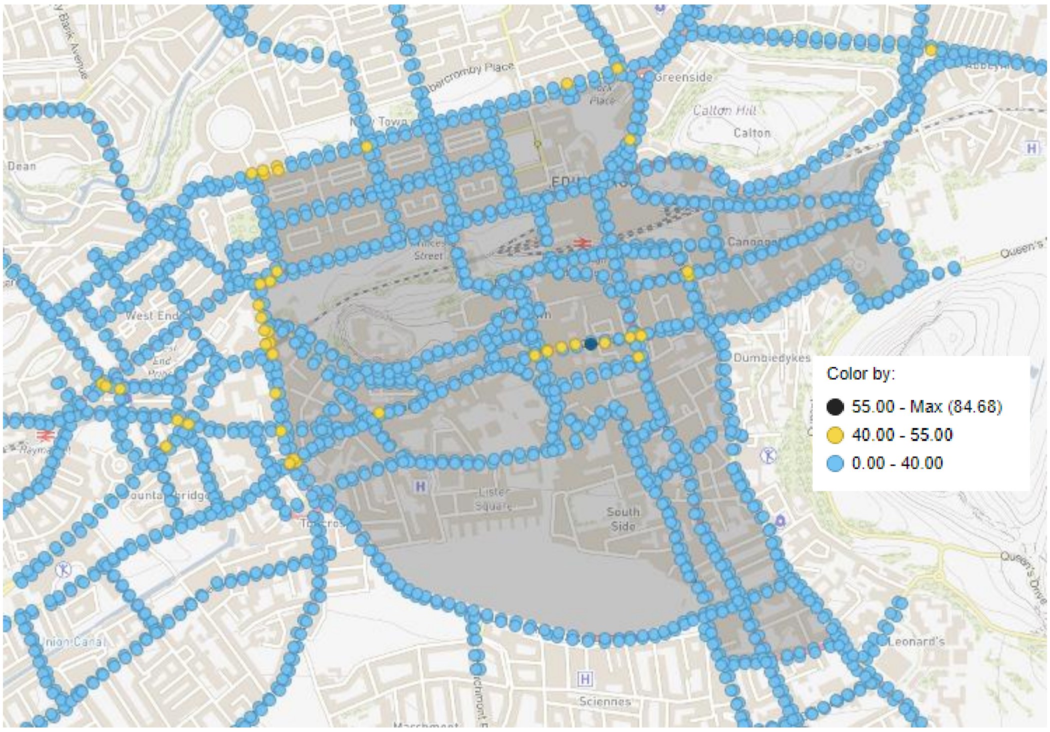

Figure 58: Small LEZ 2023 'future' scenario NO_2 predicted concentrations ($\mu g\ m^{-3}$). LEZ is shaded area

Large LEZ

Model exceedances are still predicted for the Large LEZ ‘future’ 2023 scenario (Figure 57). Although the Base 2023 ‘future’ scenario suggests that concentrations will fall when compared to the Base 2019 scenario, the impact of the Large LEZ with the ‘future’ 2023 fleet will reduce concentrations further (Figure 59, Figure 61).

There will still be displacement of non-compliant traffic, with Palmerston Place/Chester Street remaining the streets with the highest increases. The predicted concentration increases are much lower than in the Large LEZ 2019 scenario (4 µg m^{-3} increase in 2023 ‘future scenario) **and** no new model exceedances are predicted (concentrations are predicted to be 34 – 36 µg m^{-3}).

On Lothian Road, Torphichen Street and Morrison Street, model exceedances are predicted (~44 µg m^{-3}), though not at all kerbside points (Figure 57).

On all modelled roads, no new model exceedances are predicted, and there is only 1 kerbside point on Cowgate where concentrations are predicted to exceed 50 µg m^{-3} (Figure 62).

When compared to the Base 2019 scenario, concentrations at kerbside points are predicted to be lower across the whole city centre. At some kerbside points, the model predicts concentrations to be up to 34 µg m^{-3} lower (Figure 60).

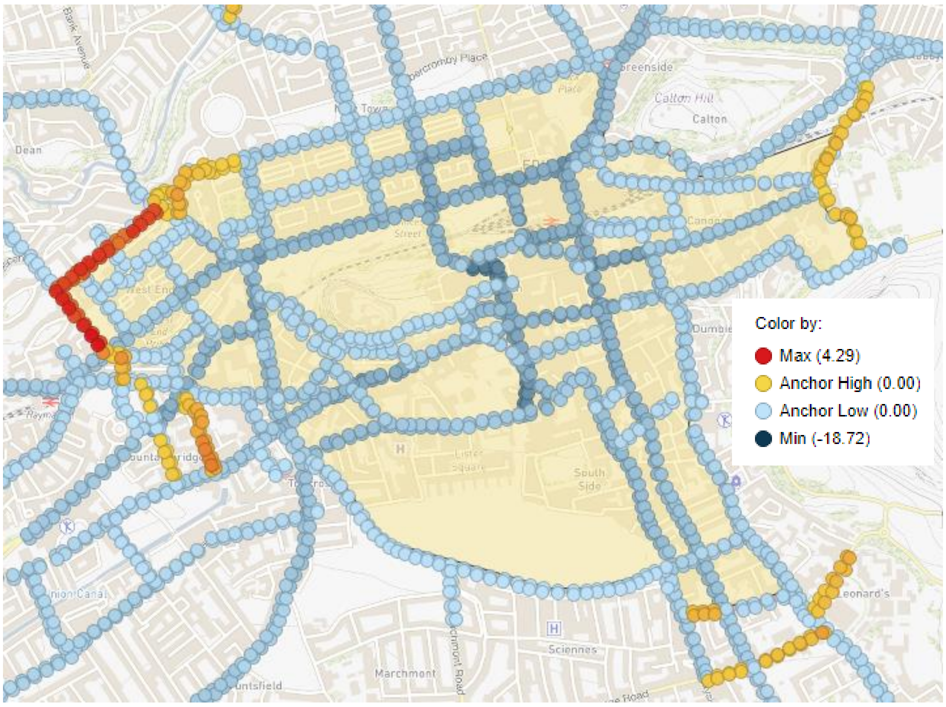

Figure 59: Predicted Changes in NO_2 concentration (µg m^{-3}) due to Large LEZ (2023), when compared to 2023 Base scenario

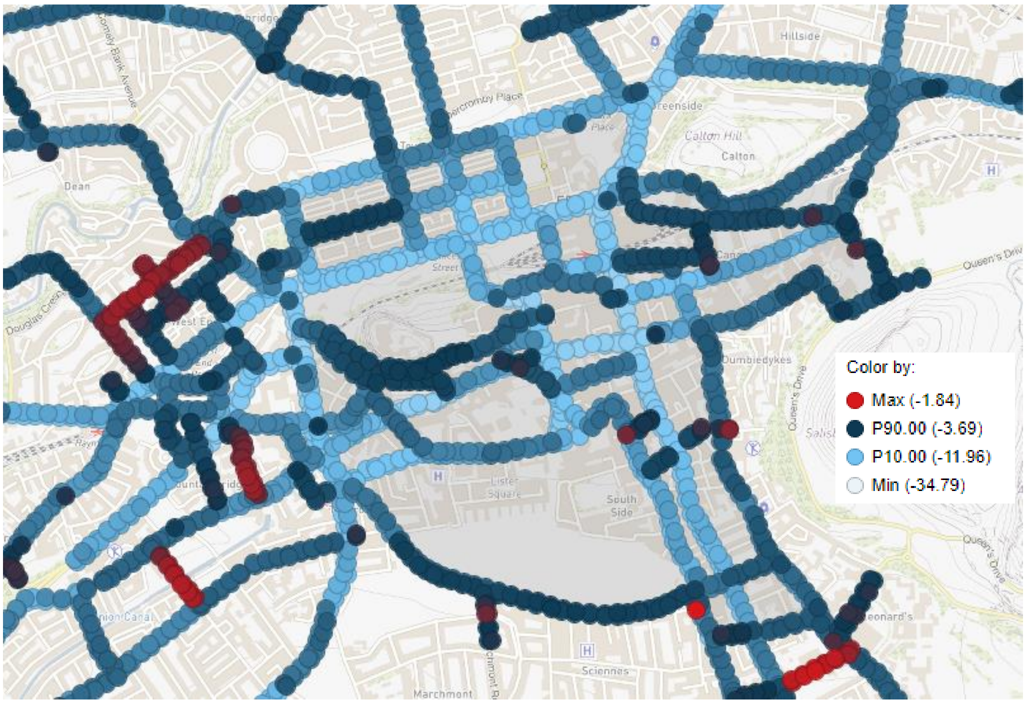

Figure 60: Predicted Changes in NO_2 concentration (µg m^{-3}) due to Large LEZ (2023), when compared to 2019 Base scenario

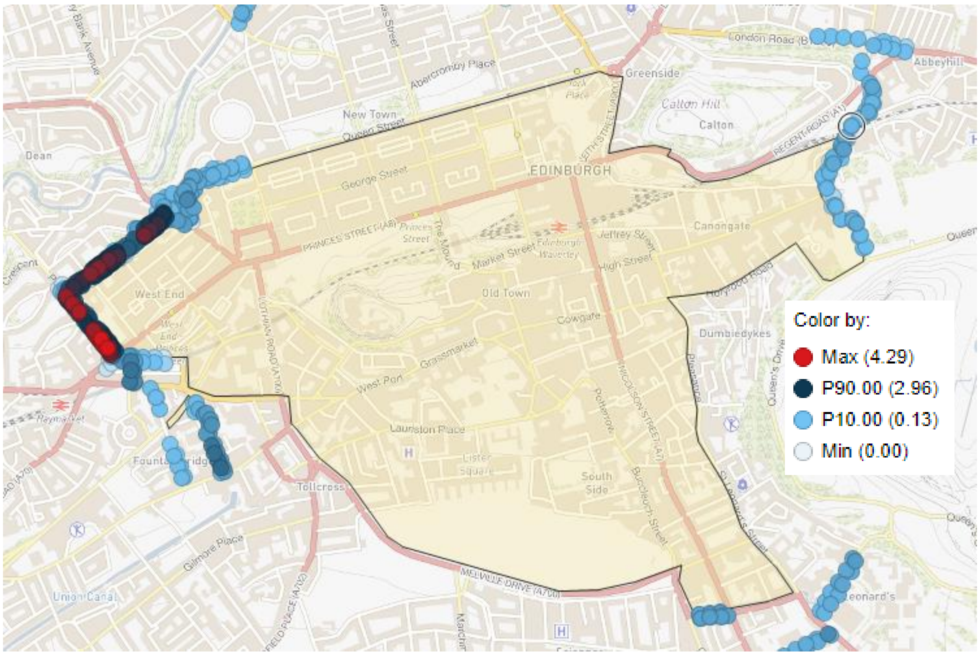

Figure 61: Predicted NO_2 increases (µg m^{-3}) due to Large LEZ (2023), when compared to 2023 Base scenario

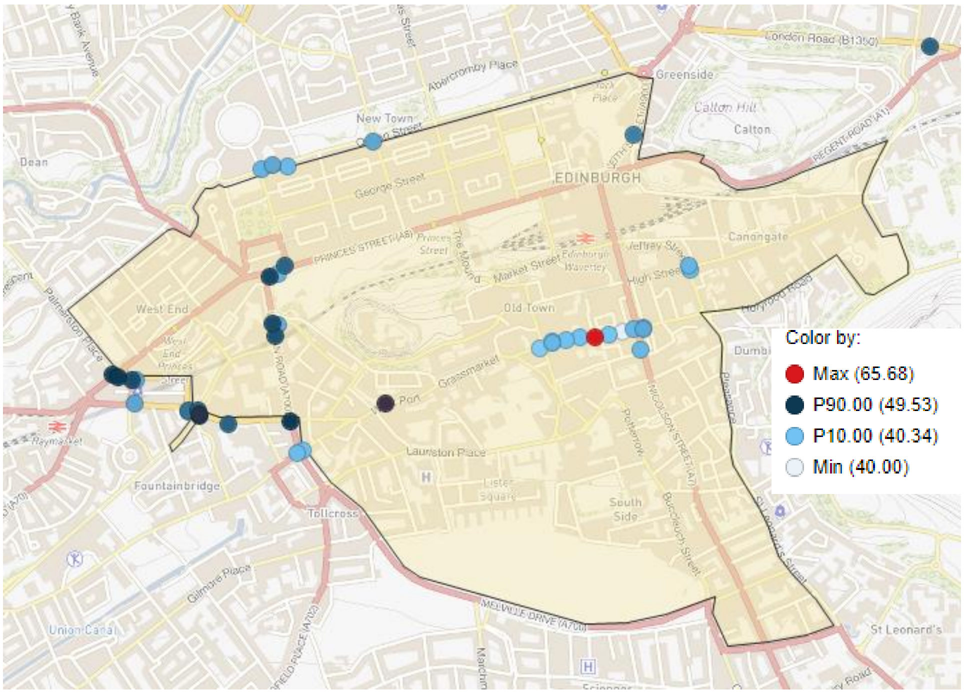

Figure 62: Predicted NO_2 exceedance ($\mu g\ m^{-3}$) concentrations due to Large LEZ (2023)

Small LEZ

Model exceedances are also still predicted in the ‘future’ 2023 scenario if the Small LEZ option was selected. When compared to the Base 2023 scenario, concentrations decline at most kerbside points (Figure 63). Increased concentrations are predicted at some locations, though these are predicted to be 1µg m^{-3} or less (Figure 64).

When compared to the Base 2019 scenario, concentrations will be lower at all kerbside points (Figure 65).

Model exceedances are predicted at similar locations to the Large LEZ option. The exception of Lothian Road, where concentrations of up to 50 µg m^{-3} are predicted at most kerbside points. This is around 5 µg m^{-3} higher than the Large LEZ option, due to non-compliant vehicles being allowed to use this route (Figure 66).

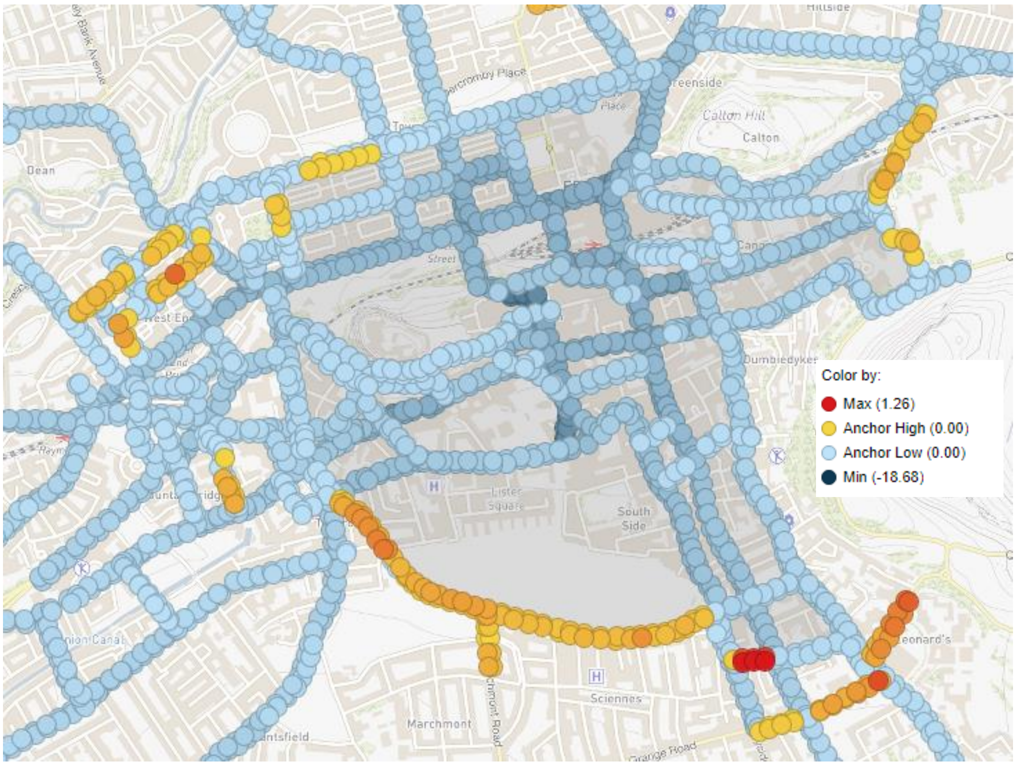

Figure 63: Predicted Changes in NO_2 concentration (µg m^{-3}) due to introduction of Small LEZ (2023), when compared to 2023 Base scenario

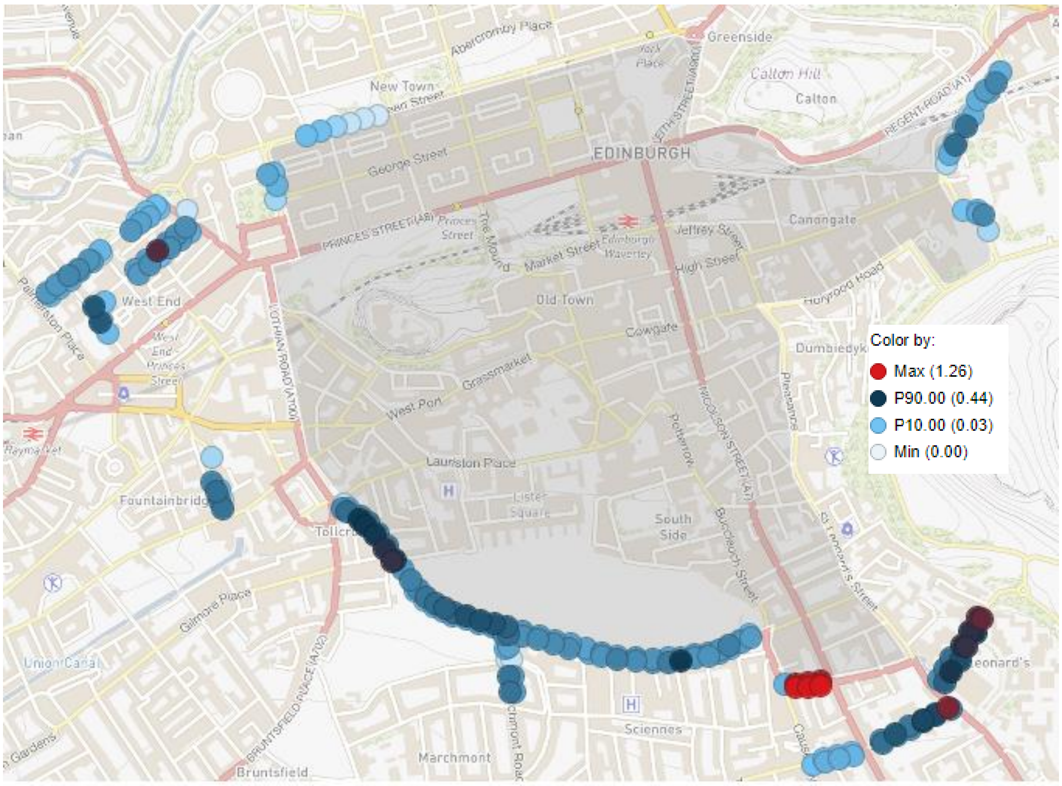

Figure 64: Predicted NO_2 increases due to introduction of Small LEZ (2023), when compared to 2023 Base scenario (µg m^{-3})

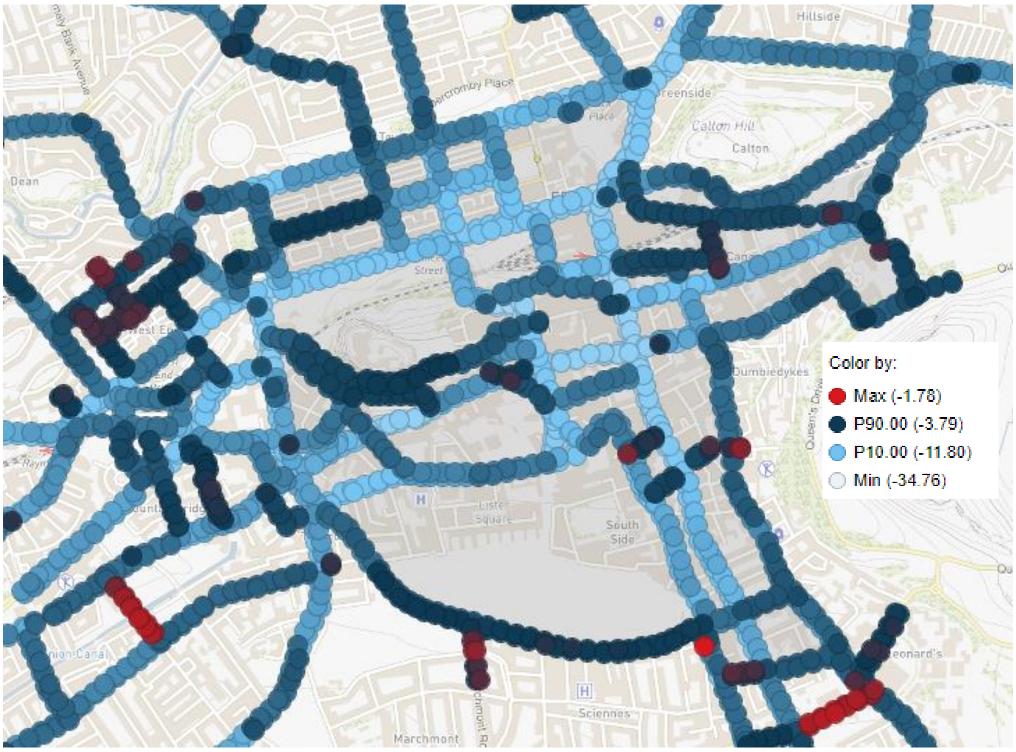

Figure 65: Predicted Changes in NO_2 concentration (µg m-3) due to introduction of Large LEZ (2023), when compared to Base 2019 scenario

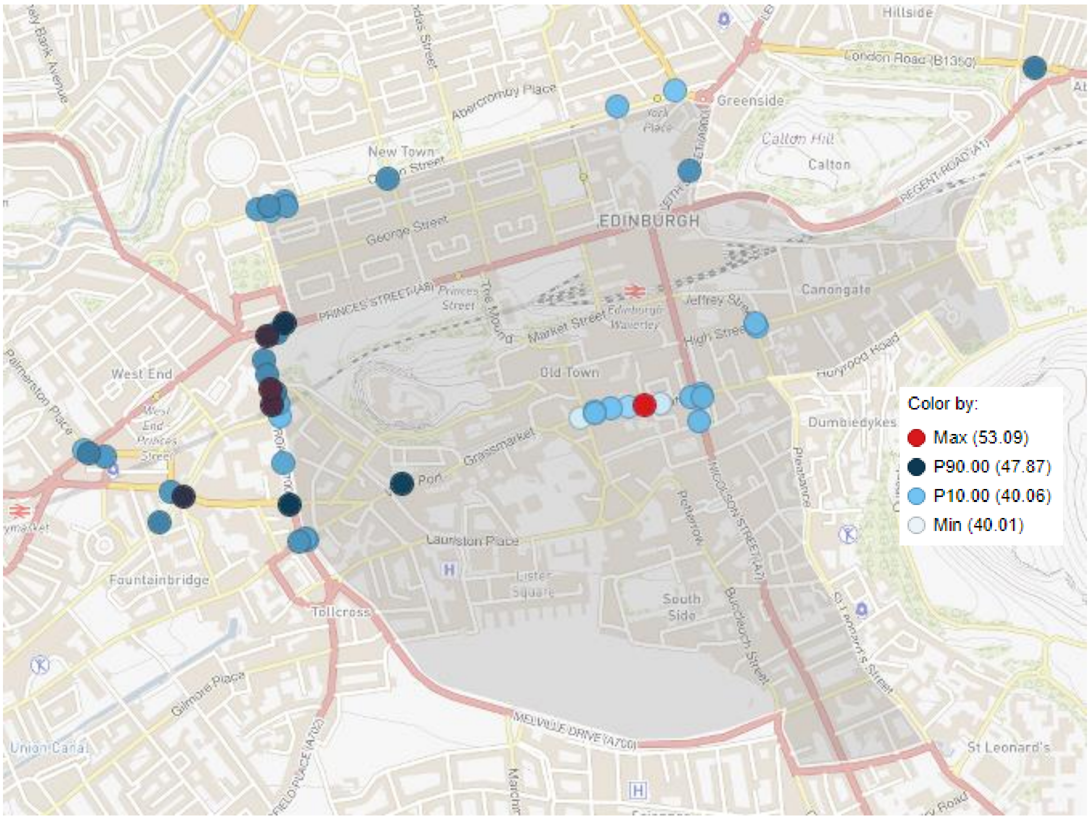

Figure 66: Predicted exceedance concentrations after introduction of Small LEZ (2023) (µg m^{-3})

Summary (2023 'future' scenarios)

Using the predicted 2023 National Fleet data to predict 'future' concentrations, the model predicts that the LEZ will still have an impact on reducing NO_2 concentrations (Figure 67) within the LEZ and on most surrounding areas.

No new model exceedances are predicted and concentrations at all kerbside points would be lower than the Base 2019 scenario. Within the Central AQMA, the effect of the LEZ is clear (Figure 68), with a reduction of model exceedances from 8.3% to 3.2% (Table 10).

Traffic displacement of non-compliant traffic is still expected, though will be much less than the 2019 scenarios. On Palmerston Place and Chester Street, model exceedances are not predicted, and concentrations are predicted to be lower than Base 2019 levels. However, on Lothian Road, Torphichen Street, parts of Queens Street and Cowgate (Figure 66), model exceedances are still predicted.

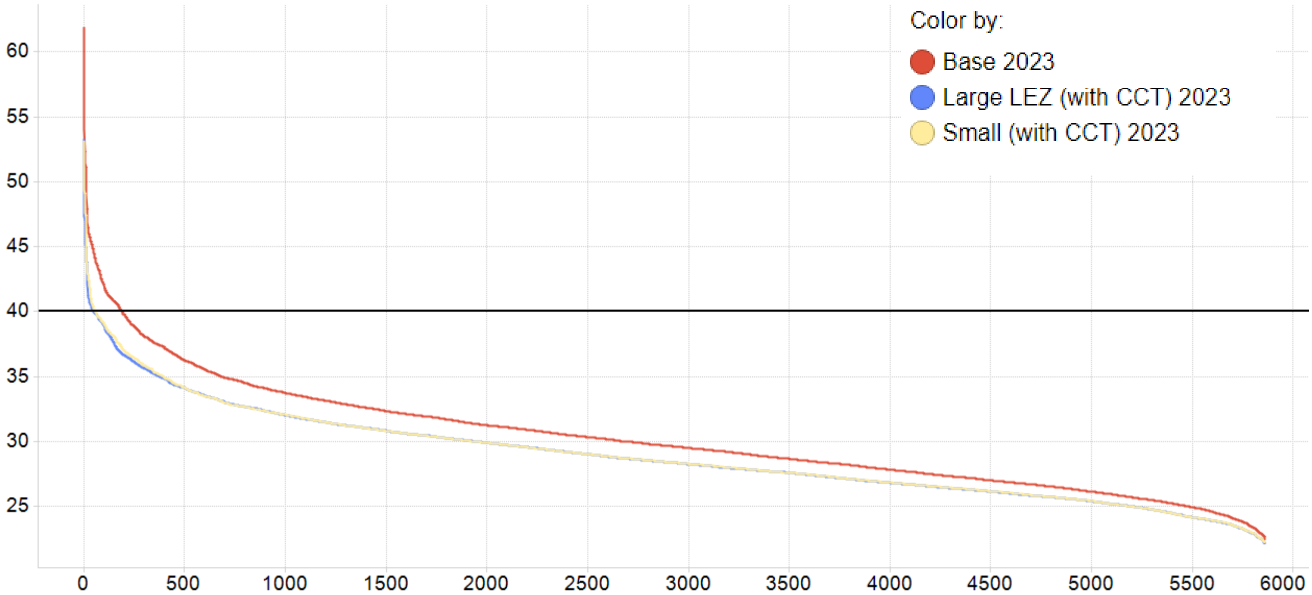

Figure 67: Ranked Concentrations for Base, Large LEZ and Small LEZ options (2023) for All City

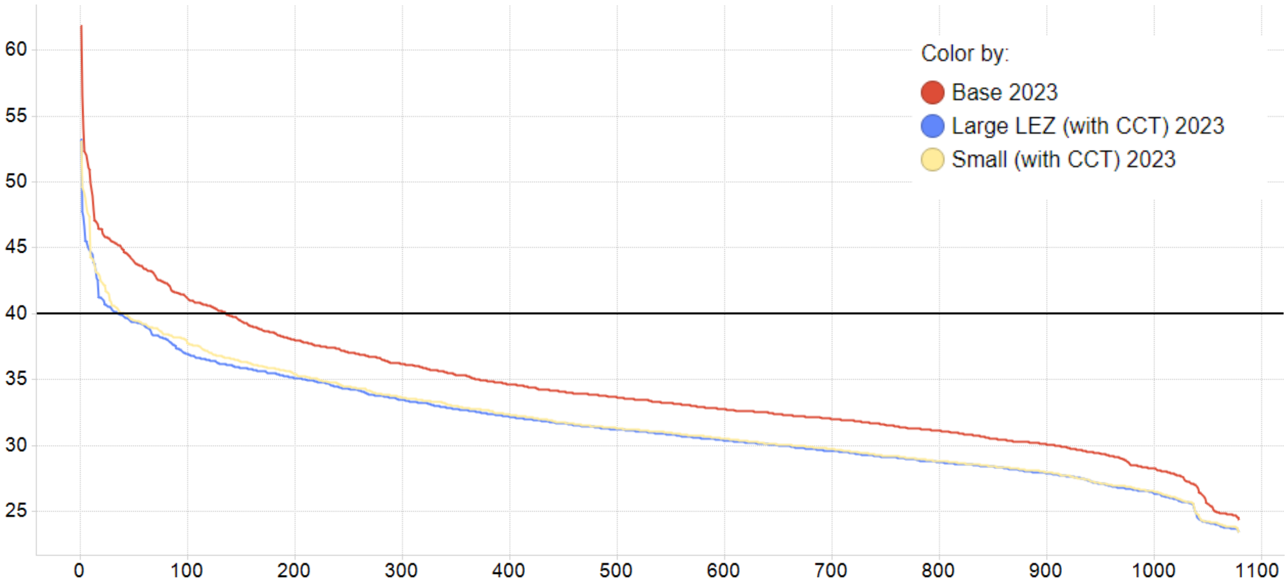

Figure 68: Ranked Concentrations for Base, Large LEZ and Small LEZ options (2023) for the Central AQMA

Table 10: Number of Kerbside points exceeding 40 µg m^{-3} for AQMA's (2023)

Area of City	Base	Large LEZ	Small LEZ
All City	2.1%	0.84%	0.97%
All AQMA’s	7.2%	2.9%	3.5%
Central AQMA only	8.3%	3.2%	3.8%
Not in AQMA	0.63%	0.26%	0.28%

Comparing effects of Large LEZ option in 2019 and 2023

It is useful to look at the effects of the Large LEZ on a histogram plot which shows the number of kerbside points within a concentration group. We want to see the peak of the curve as far to the left as possible (where concentrations are lower). The LEZ has the effect of pushing the curve to the left, which means there are fewer model exceedances (Figure 69, Figure 70).

Due to model uncertainties, there is a risk that kerbside points which are just below the 40 µg m^{-3} threshold may, in reality, be above it, and vice versa.

The 2019 fleet scenario predicts that there are many kerbside points close to the 40 µg m^{-3} line, and there is a risk that model exceedances may, in reality, exist at more locations.

However, the 2023 scenario predicts that the majority of kerbside points are less than 35 µg m^{-3}, and so the risk of incorrectly predicting that model exceedances will not occur at these kerbside points is low.

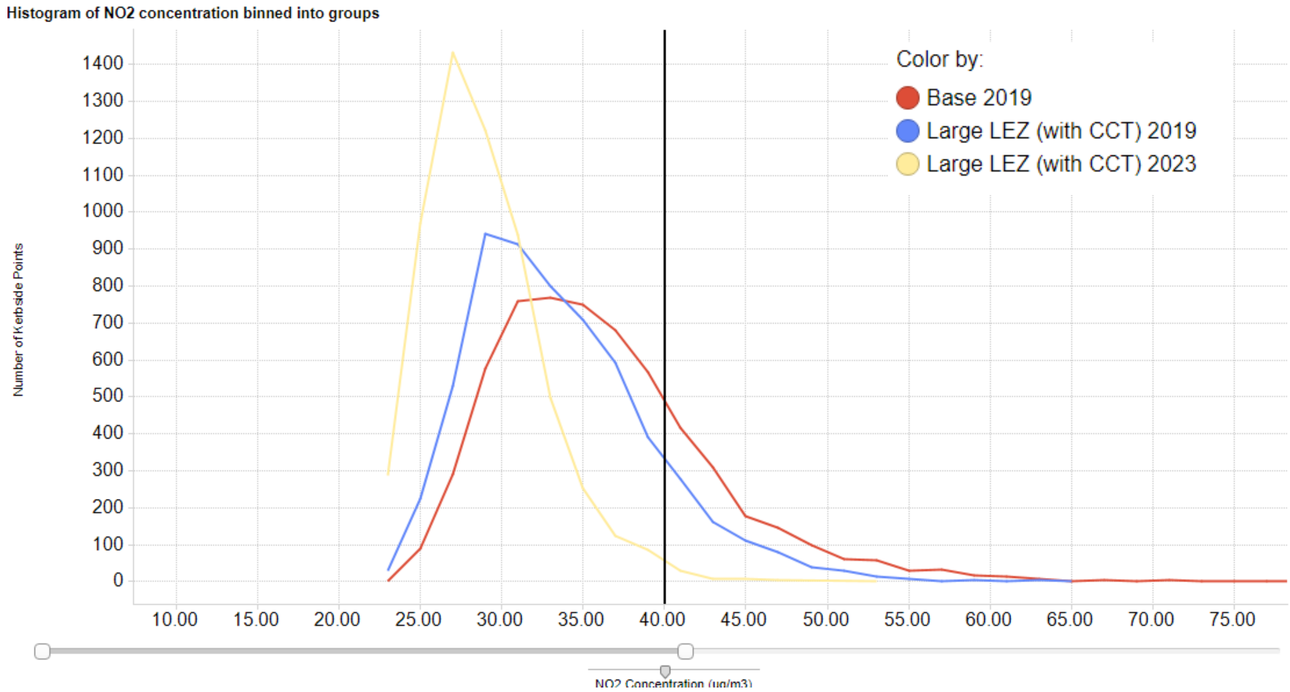

Figure 69: Concentration histogram for Base, Large LEZ (2019 and 2023) for All City

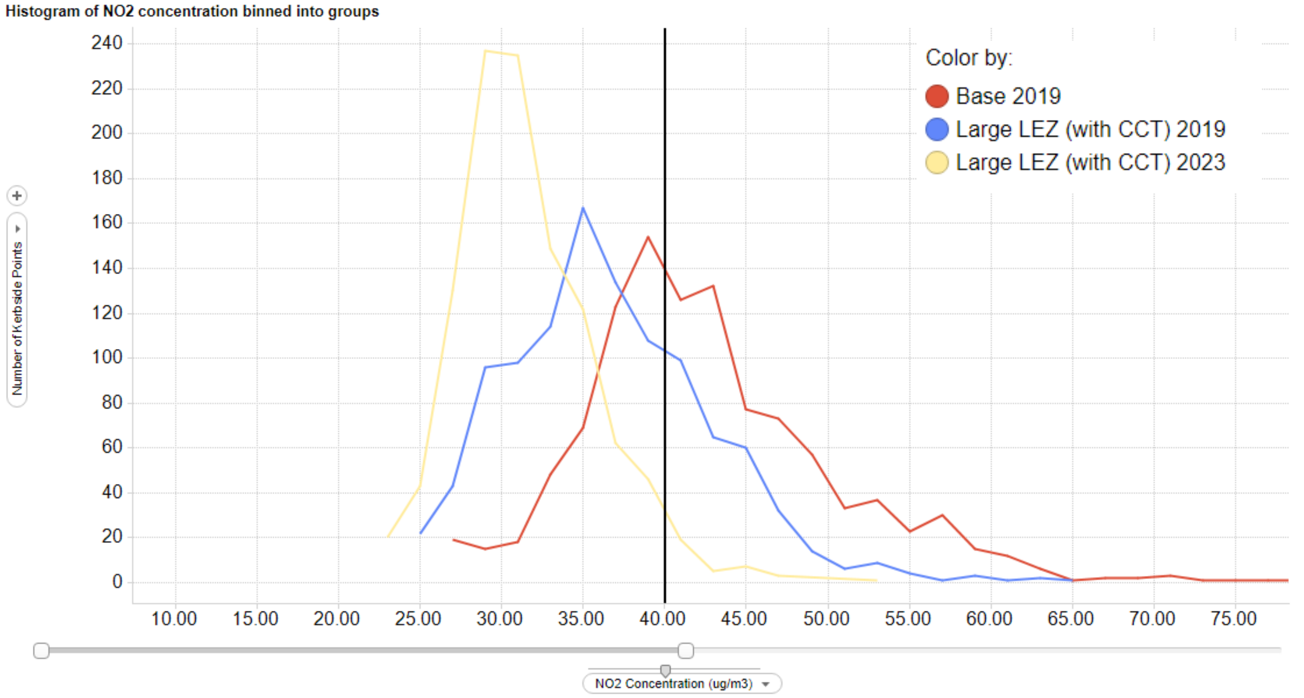

Figure 70: Concentration histogram for Base, Large LEZ (2019 and 2023) for Central AQMA

Detailed Street Analysis

In this section, the average concentrations for each street are analysed.

On Palmerston Place/Chester Street/Drumsheugh Gardens, the Large LEZ 2019 scenario predicts large increases in concentrations that would lead to new model exceedances, however in the Large LEZ 2023 scenario, concentrations are less than 40 µg m^{-3} and are lower than the Base 2019 scenario (Table 11).

On Lothian Road, the average concentration only falls below the 40 µg m^{-3} threshold for the Large LEZ 2023 scenario, although concentrations are declining (Table 11).

On Abbeyhill, the introduction of either LEZ has increased concentrations by a small amount. Concentrations are close to the 40 µg m^{-3} threshold in the 2019 scenarios, but no model exceedances are expected in any of the 2023 'future' scenarios (Table 11).

Table 11: Average kerbside Concentrations (µg m^{-3}) on selected streets. ***Bold*** *numbers represent a model exceedance*

	Average NO_2 Concentrations (µg m^{-3})					
	2019 'worst case'			2023 'future'		
	Base	Large LEZ	Small LEZ	Base	Large LEZ	Small LEZ
Palmerston Place (South)	39.4	**49.5**	38.9	33.1	37.6	32.8
Palmerston Place (North)	38.4	**46.9**	38.1	30.7	35.1	31.8
Chester Street	35.3	**42.6**	35.4	28.6	32.7	29.9
Drumsheugh Gardens (East)	34.7	**43.2**	34.7	28.3	32.2	29.4
Lothian Road (North)	**56.6**	**44.7**	**50.7**	**41.1**	37.3	**41.2**
Abbeyhill	39.6	**40.9**	**40.1**	31.8	32.9	32.7

Façade and Sensitive Receptor Modelling

Due to concerns about increased concentrations and new exceedances on Palmerston Place and Chester Street, further detailed modelling was carried out to predict concentrations at building façades and sensitive points around the LEZ boundary. 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 71, Figure 72).

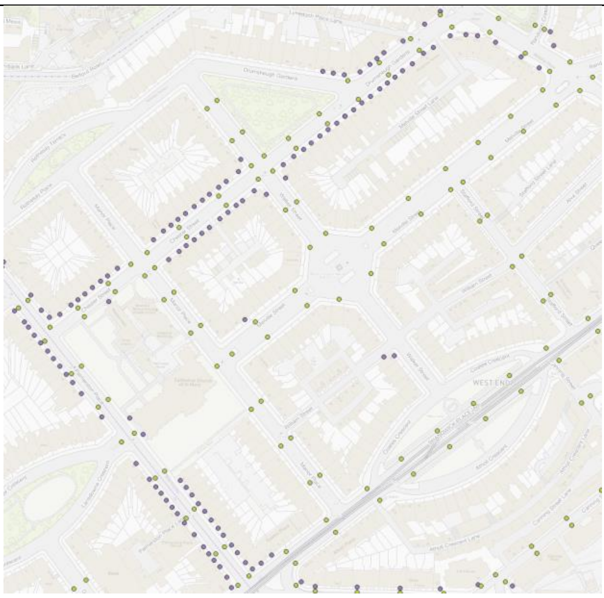

Figure 71: Kerbside points (green) and façade points (blue) for West End (including Palmerston Place/Chester Street)

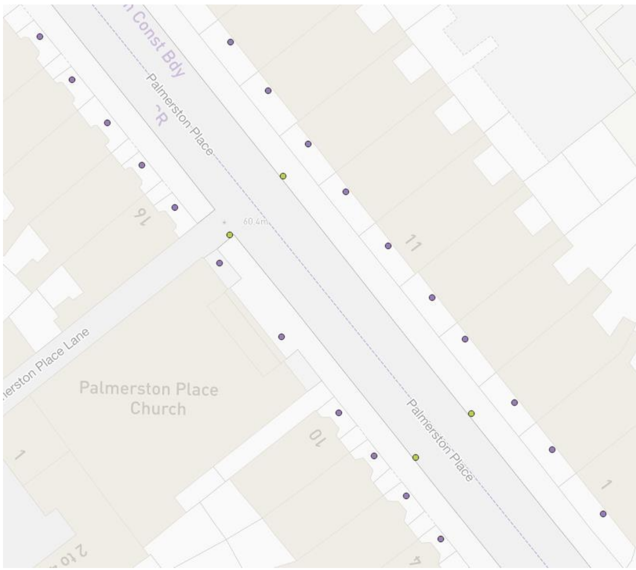

Figure 72: Kerbside points (green) and façade points (blue) for close up on Palmerston Place

Palmerston Place/Chester Street

The model predicts lower concentrations at the façade points of around 5 µg m^{-3} on Palmerston Place and 3 µg m^{-3} on Chester Street/Drumsheugh Gardens.

On Palmerston Place (South), average concentrations at facades are predicted to be 45 µg m^{-3}, though this is expected fall to 34 µg m^{-3} in the 2023 scenario (Table 12).

Façade exceedances are not predicted on Chester Street and concentrations are on the 40 µg m^{-3} threshold on Drumsheugh Gardens (East). No model exceedances are predicted on the section of Drumsheugh Gardens which has a park on the north side of the road (Figure 73).

No exceedances at the kerbside or façade are predicted in the 2023 'future' scenario (Figure 74).

*Table 12: Comparison of predicted NO_2 façade/kerbside concentrations at West End LEZ boundary (with LEZ). **Bold** is an exceedance*

	Average NO_2 Concentrations (µg m^{-3})			
	2019		2023	
	Kerbside	Façade	Kerbside	Façade
Palmerston Place (South)	**50**	**45**	36	34
Palmerston Place (North)	**48**	**42**	35	33
Chester Street	**41**	39	33	31
Drumsheugh Gardens (East)	**44**	**40**	33	31

Figure 73: Predicted Concentrations at building façades (2019 LEZ scenario)

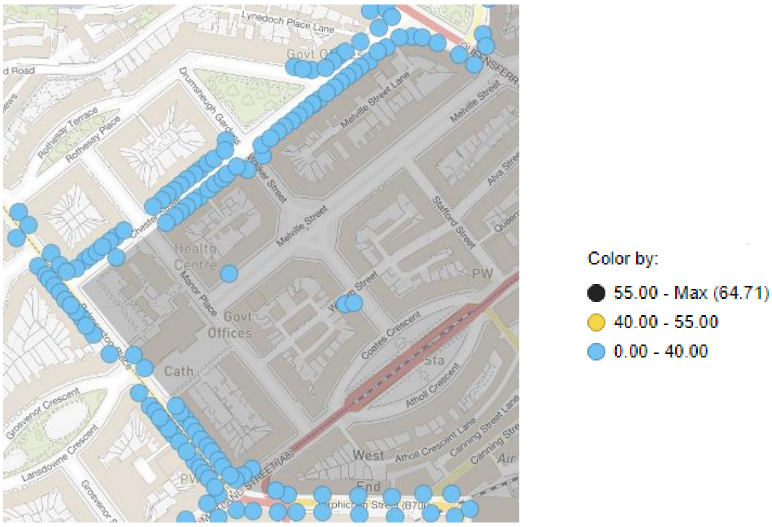

Figure 74: Predicted Concentrations at building façades (2023 LEZ scenario)

Around the LEZ boundary

Façade and sensitive receptor modelling also included other locations around and close to the LEZ boundary at a lower density than Palmerston Place and Chester Street. These included schools and nurseries and were agreed with CEC.

This shows that exceedances are predicted at façades in the Base 2019 scenario (Figure 75) and Large LEZ 2019 scenario (Figure 76) on the west and north sides of the LEZ. If an LEZ was in place in 2019, new exceedances at façades would be predicted on Palmerston Place and Chester Street. In the 'future' 2023 scenario (Figure 77), façade exceedances are only predicted on Morrison Street (the pavement is very narrow at some locations on Morrison Street).

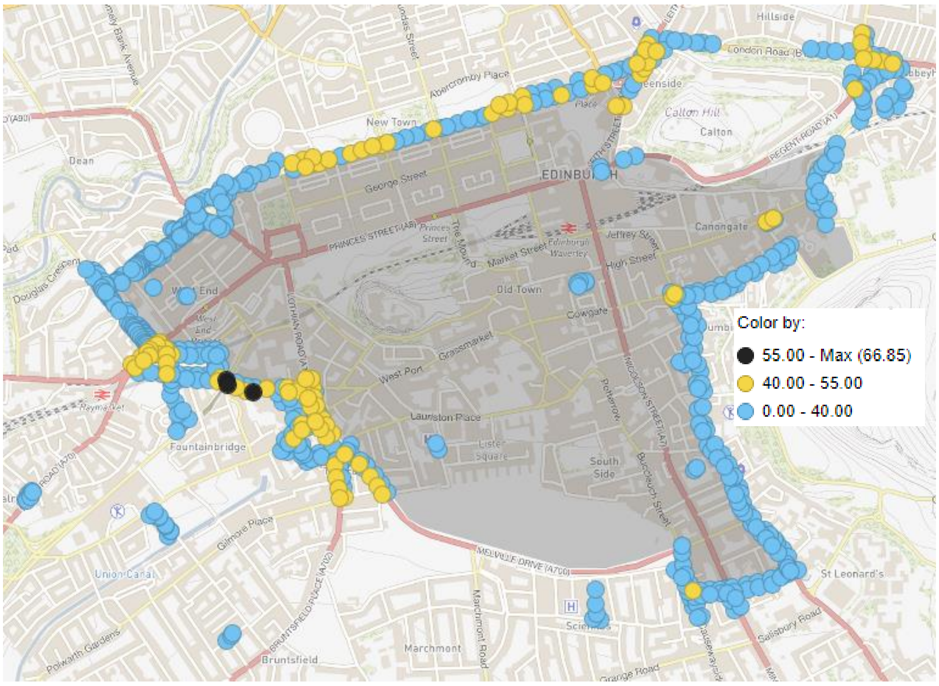

Figure 75: Predicted NO_2 concentrations (µg m^{-3}) at façade receptors (Base 2019)

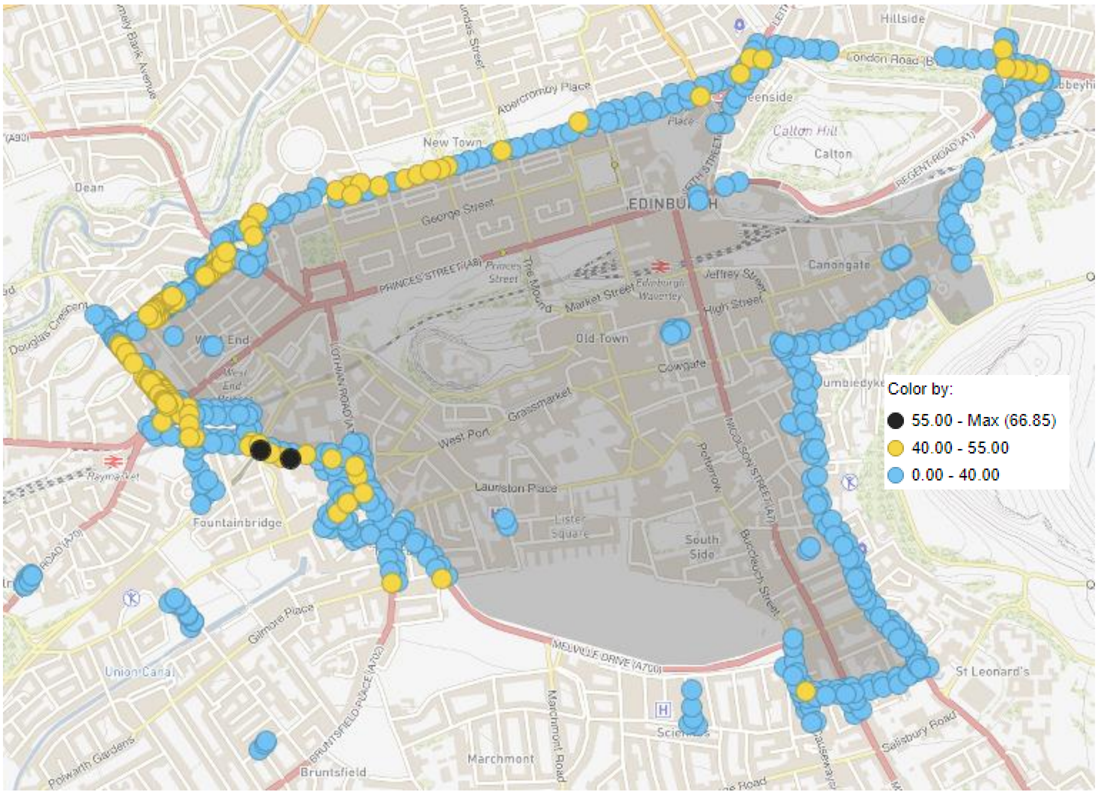

Figure 76: Predicted NO_2 concentrations ($\mu g\ m^{-3}$) at façade receptors (Large LEZ 2019)

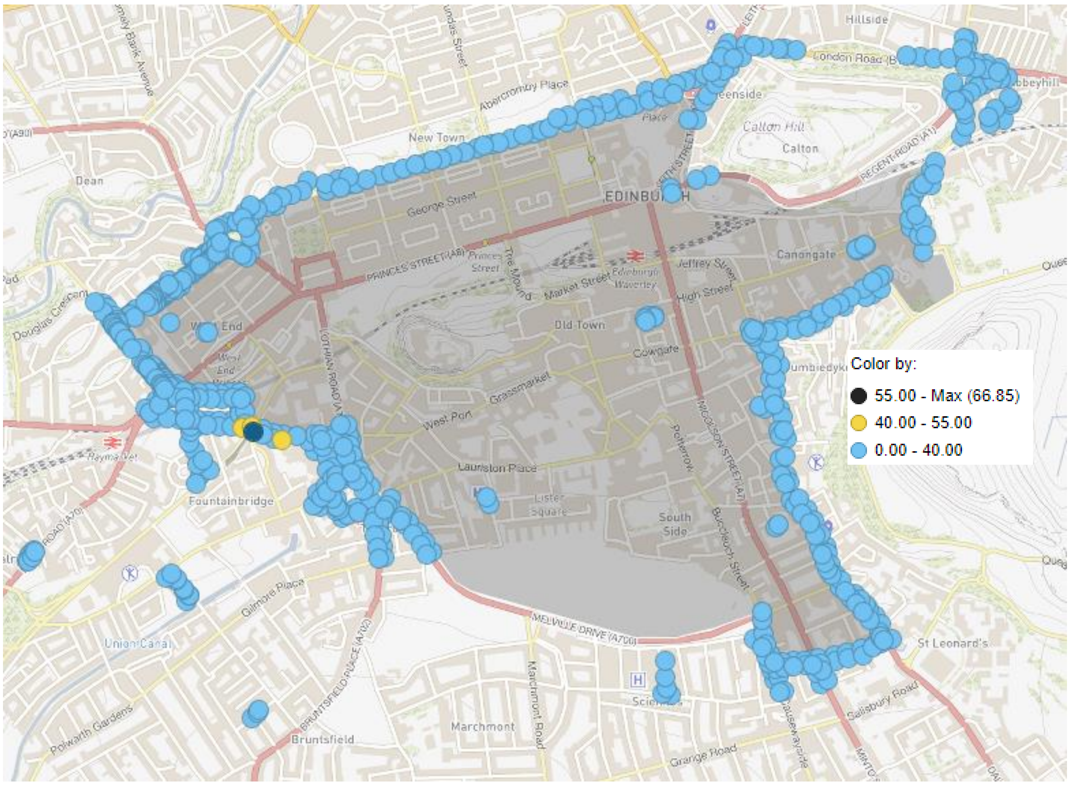

Figure 77: Predicted NO_2 concentrations ($\mu g\ m^{-3}$) at façade receptors (Large LEZ 2023)

Extended Urban Area LEZ Modelling

As outlined previously, traffic modelling for an Extended Urban Area LEZ is technically challenging and has not been carried out (Jacobs, September 2021). An attempt to run the air quality model for the Extended Urban Area LEZ was made, though the following assumptions should be noted:

- 2016 traffic survey data has been used. As modelled traffic data is unavailable, this is the only suitable data that can be used.
- The model assumes that the LEZ rules apply to all vehicles, except cars.
- If this scenario was taken forward, the LEZ rules would still apply to cars in the city centre. There are therefore large uncertainties about vehicle behaviour around the City centre boundary, as only cars would be displaced, whilst LGVs and HGVs would not (as the rules would apply to them city wide). Grace periods would also differ. Therefore, using this approach, model results from suburban areas are most useful.

The model predictions have been compared for 4 suburban areas: Queensferry Road (Barnton), Corstorphine, Leith AQMA and Portobello (Figure 78).

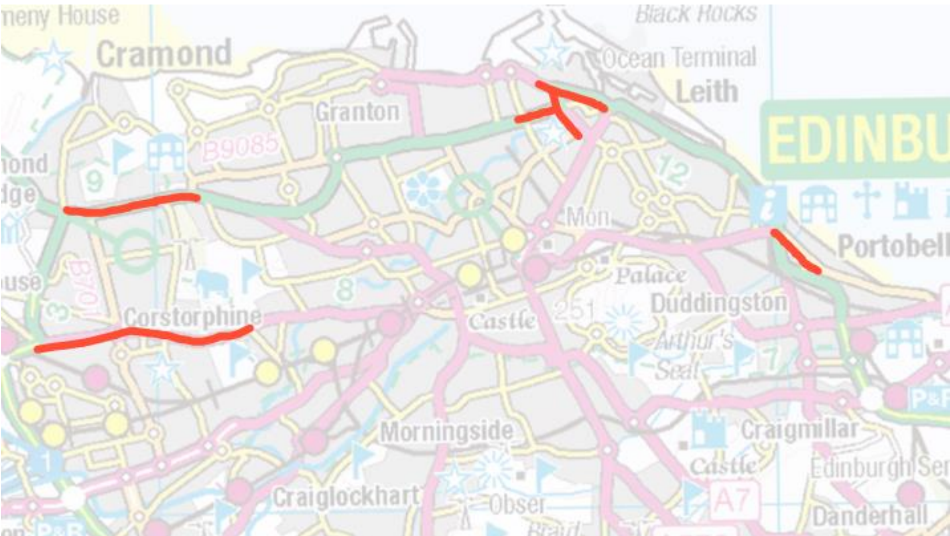

Figure 78: Roads considered in Extended Urban Area LEZ comparison

The results in Table 13 show that although there is a benefit to the Extended Urban Area LEZ option, it is small. Most of these areas are predicted to be already below the 40 µg m^{-3} threshold and the difference in most cases is less than 1 µg m^{-3}. The exception is Queensferry Road (Barnton), where car traffic is dominant and where model exceedances are still predicted.

Table 13: Comparison of NO_2 concentrations (µg m^{-3}) for Extended Urban Area and City Centre LEZ options. Concentrations presented are average kerbside concentrations along roads in Figure 78. ***Bold*** *is an exceedance*

µg m^{-3}	Large City Centre LEZ	Extended Urban Area LEZ
Queensferry Road (Barnton)	**46.5**	**44.9**
Corstorphine	36.2	35.5
Leith AQMA	35.3	33.6
Portobello	31.0	30.3

Concentration Source Attribution

Although emissions within the LEZ are predicted to be from 100% compliant vehicles, emissions from non-compliant vehicles from roads outside the LEZ will still contribute to pollutant concentrations within the LEZ. We can analyse this using NO_x emissions for each vehicle sector (**Note**: this does only look at NO_x emissions from modelled traffic sources and does not include emissions from non-traffic sources).

North Bridge/South Bridge/Clerk Street

Source attribution analysis for concentrations at kerbside points on the Bridges/Clerk Street corridor show that, for the Large LEZ 2019 scenario, emissions from non-compliant traffic (or traffic from outside of the LEZ) will account ~5% of concentrations on this route (Figure 80). Diesel cars are the largest contributor at ~33%, LGV's contribute ~24% and buses contribute ~15% (Figure 79).

In the 2023 'future' scenario, ~2% of NO_x concentrations can be attributed to non-compliant vehicles (Figure 82). Diesel cars remains the largest contributor at 30%, though bus contributions have increase to 21% (Figure 81). It is important to note that total emissions are lower in the 2023 scenario compared to the 2019 scenario.

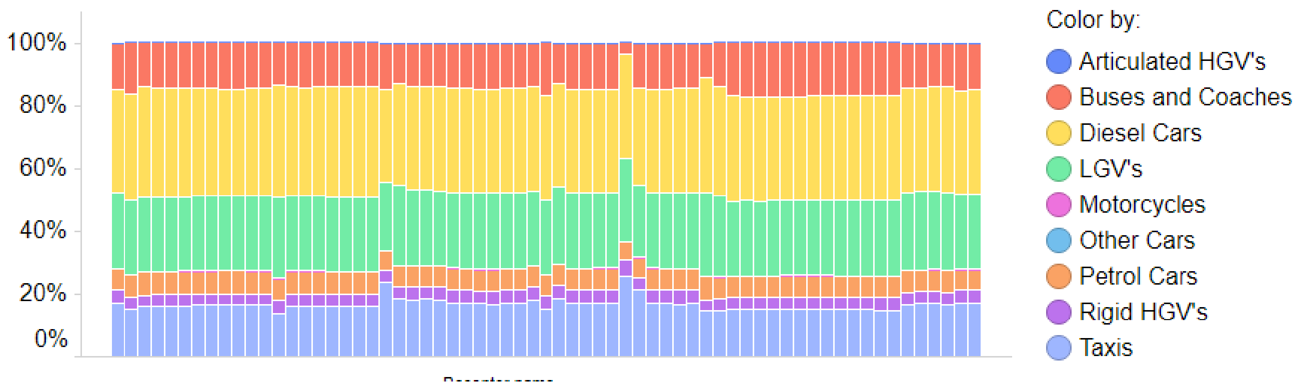

Figure 79: Percentage contribution from each vehicle sector at kerbside points on Bridges/Clerk Street (Large LEZ; 2019)

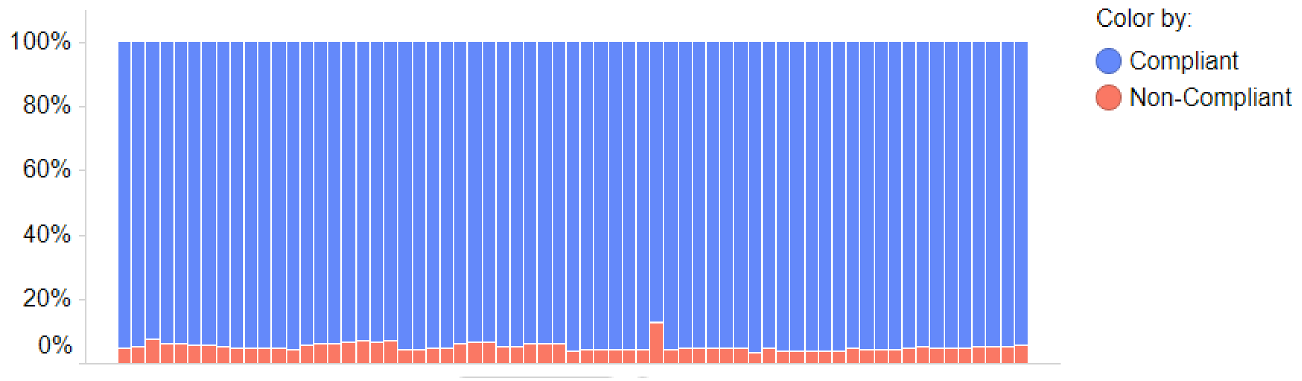

Figure 80: Percentage contribution for compliant at kerbside points highlighted on Bridges/Clerk Street (Large LEZ; 2019)

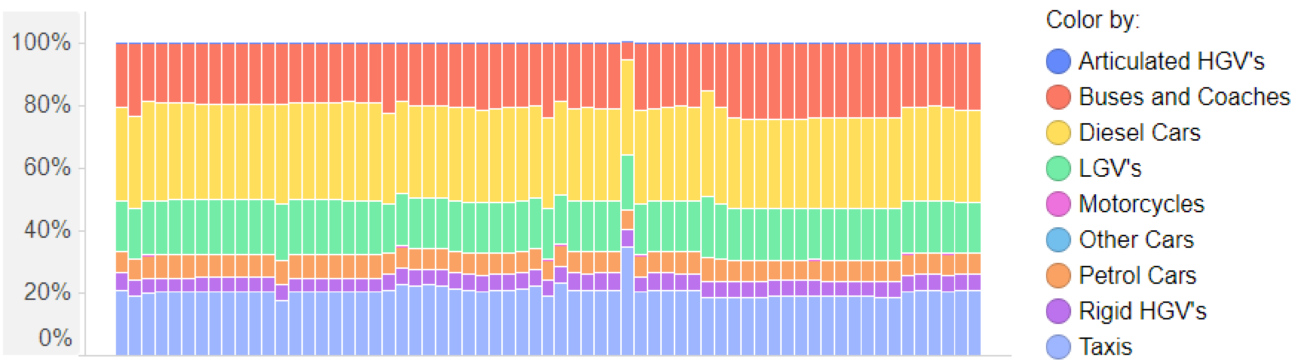

Figure 81: Percentage contribution from each vehicle sector at kerbside points on Bridges/Clerk Street (Large LEZ; 2023 'future')

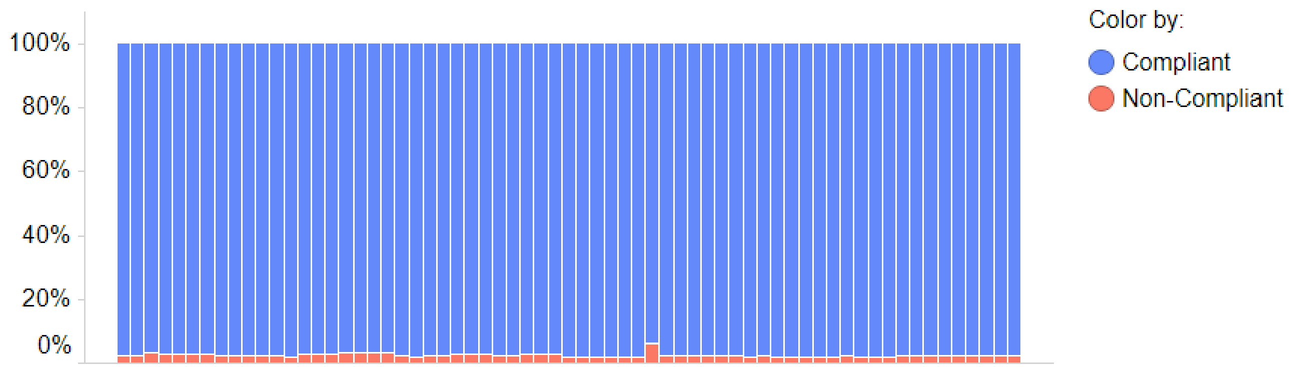

Figure 82: Percentage contribution for compliant at kerbside points highlighted on Bridges/Clerk Street (Large LEZ; 2023 'future')

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Appendix 1: Model Verification

It is important that model predictions are checked against monitored data. Since the SEPA evidence report (SEPA, 2018) was published, ADMS-Urban has been updated to version 5, which includes some changes to the way dispersion in canyons is calculated. Further information is available on the CERC website (www.cerc.co.uk). This analysis is based on fleet composition derived from the 2016 and 2019 ANPR data, supplemented by information gratefully provided by local bus operators.

Variation in model predictions is always expected and can be for many reasons (local dispersion conditions may be complex, variation in local fleet composition etc). For both years, the same emission factor database has been used (EfTv8). It is worth noting that the effect of meteorology is important, and even if emissions decline, if the average wind speed is lower than for other years, concentrations may not fall at the same rate.

Automatic Monitors

At the Automatic Monitors, model performance is generally good. For 2016, both model versions perform well and are broadly consistent, except for Salamander Street which may be due to local factors (Figure 83, Figure 84).

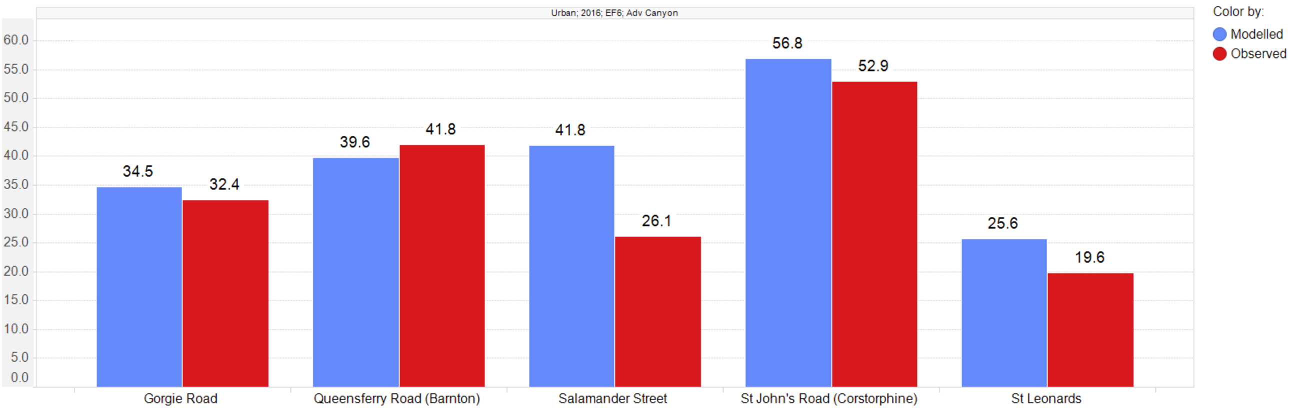


Figure 83: Modelled and Measured 2016 NO_2 Concentrations at Automatic Monitors (ADMS-Urban 4.2)

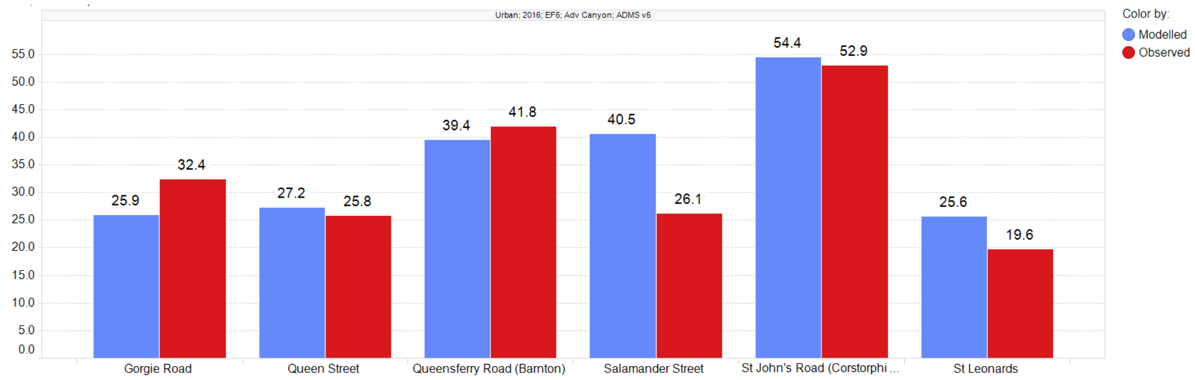


Figure 84: Modelled and Measured 2016 NO_2 Concentrations at Automatic Monitors (ADMS-Urban 5.0)

For 2019, observed and modelled concentrations have fallen (Figure 85, Figure 86). Note that 2016 traffic flow data has been retained as this has been used in traffic modelling.

At the Gorgie Road monitor a difference in model predictions is observed between the 2 ADMS-Urban model versions. The only difference is the model version, and this suggests that the changes in the way ADMS-Urban deals with canyons may be the reason. This is an example of model uncertainties, especially where flows may be complex as is the case at the Gorgie Road monitor. ADMS-Urban version 5 performs well for Gorgie Road.

At Queensferry Road, the ADMS-Urban performs well for both years and model versions (this is more open, with no canyon effects to account for).

At the St John's Road monitor, ADMS-Urban predicts NO_2 concentrations to be marginally lower in 2019, despite NO_2 and NO_x emissions used in the model being 12% and 16% lower respectively than in 2016.
This may be due to 2 factors:

- Meteorological and chemistry effects (if there is available Ozone and NO, secondary NO_2 will be formed).
- Fleet composition, derived from ANPR, used to calculate emissions is an average for all of Edinburgh. Local bus operators (e.g. Lothian, Citylink) who use the St John's Road corridor placed Euro VI buses on this route in response to high concentrations at this monitor.

Therefore, on this road, bus emissions may be lower than has been calculated for 2019, thus leading to a model overestimate.

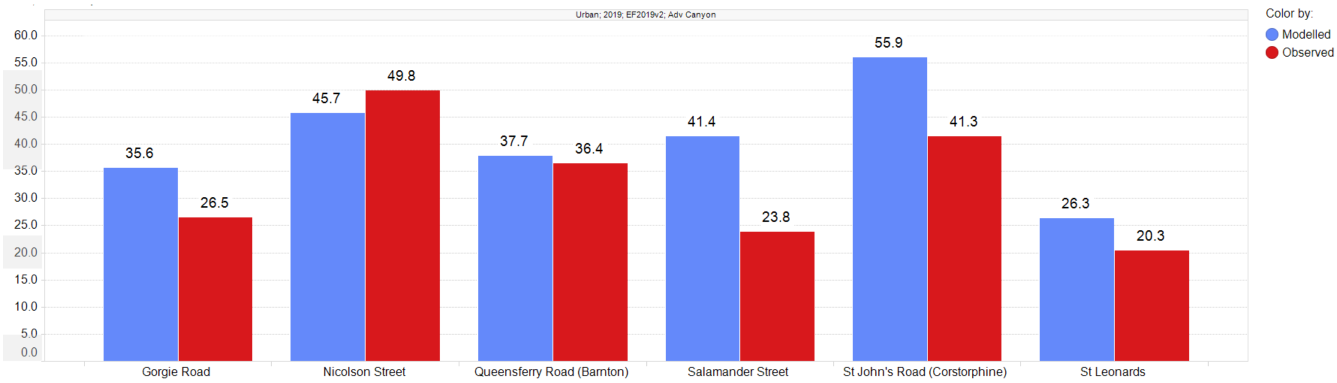


Figure 85: Modelled and Measured 2019 NO_2 Concentrations at Automatic Monitors (ADMS-Urban 4.2)

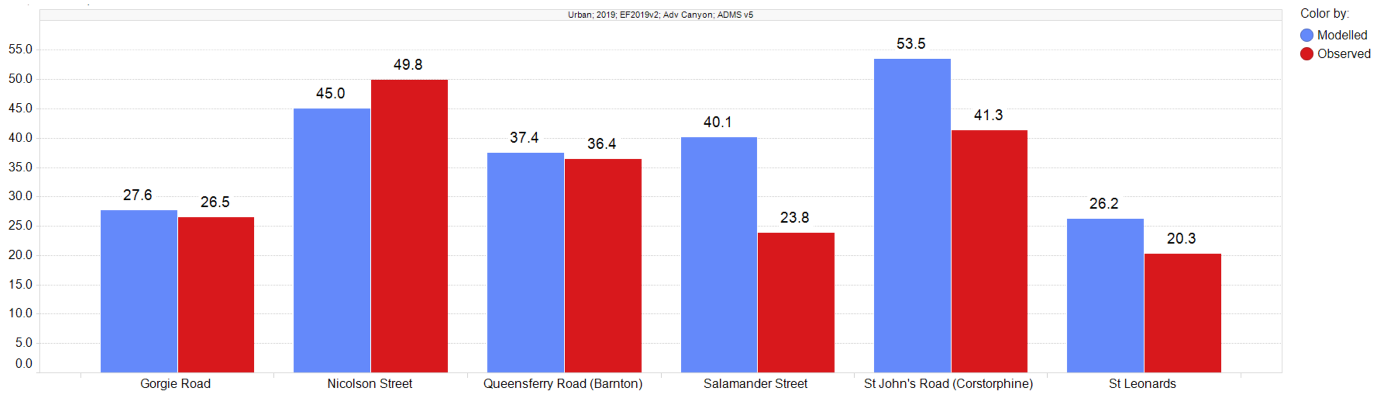


Figure 86: Modelled and Measured 2019 NO_2 Concentrations at Automatic Monitors (ADMS-Urban 5.0)

Diffusion Tubes

Monitoring using Diffusion Tubes has the advantage that they can be put in many locations for minimal cost, however reported diffusion tube concentrations have greater uncertainties than the automatic monitors. It is still important to test the model performance against the diffusion tube data. These data are reported by City of Edinburgh Council in their Annual Air Quality Report (City of Edinburgh Council, 2020).

Almost all model predictions are within a factor of 2 of the measured diffusion tube concentrations and many are close to the 1:1 line (Figure 87), though more points are above the 1:1 line than below which suggest the model may be slightly over-estimating. Further work will be carried out on model performance.

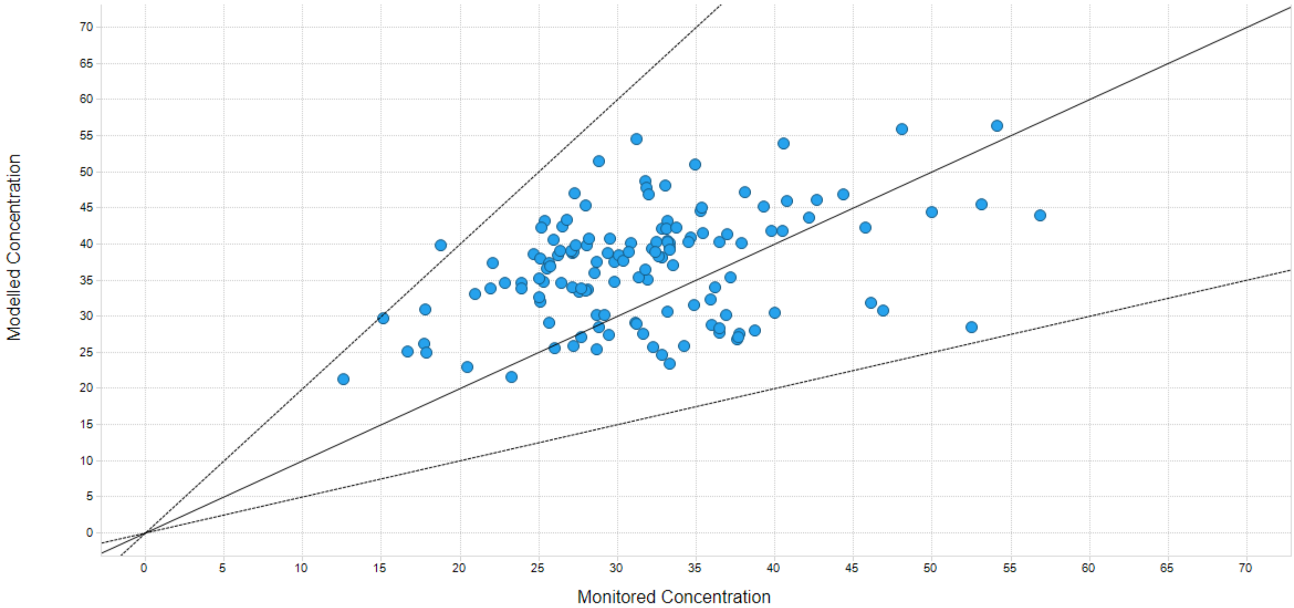


Figure 87: Modelled v Monitored NO_2 Concentration Scatter Plot for Diffusion Tube Locations for 2019 (ADMS v5; Urban Background; Bias-adjusted diffusion tube data)

Appendix 2: Traffic Model Data for Air Quality Modelling

A fuller summary is provided here on the modelled traffic data which is a key input for the air quality modelling work.

Large LEZ Option

Diesel Cars

- **2019**
  - **Within the LEZ:** Diesel Car flows decline on most roads (Table 14, Figure 89) and are 100% compliant (Figure 91).
  - **On the LEZ boundary:** Large increases in flows are predicted at the West End (75-90%), and compliance rates will fall to between 8 and 23% (Table 14). On the East side of the boundary, the impact is not as significant, where flows increase by 36% and compliance rates fall to 38% (Figure 91).
- **2023 'Future':**
  - **Within the LEZ:** Diesel Car flows increase on Lothian Road compared to the Base 2019 scenario. This is likely to be due to increased numbers of compliant diesel cars, and CCT changes forcing diesel cars to re-route.
  - **On the LEZ boundary:** At the West End, increases in flows are still predicted (Table 14) when compared to the 2019 Base scenario (34-45%), but it is not as large as the 2019 LEZ scenario. Compliance levels have risen from 8-23 % to 52-61%.

Petrol Cars

- **2019:**
  - **Within the LEZ:** Petrol car flows increase and decrease within the LEZ (Figure 90). As a higher proportion (88%) of petrol cars are compliant (Table 6), they are likely to travel through the LEZ, and avoid routes where non-compliant cars are forced to take. Petrol car compliance within the LEZ is 100% (Figure 92).
  - **On the LEZ boundary:** At the West End LEZ boundary, petrol car flows are predicted to be lower (up to 31% less) and compliance rates are also predicted to fall to between 44 and 72% (Table 14). On the East side of the boundary, there is an increase in petrol traffic, though compliance rates remain high (Figure 90, Figure 92).

- **2023 'Future'**:
    - **On the LEZ boundary:** At the West End LEZ boundary, a small increase in petrol car flow is predicted on Palmerston Place, but flows are still predicted to be lower on Chester Street (Table 14). Compliance levels are predicted to be high on both roads.

LGV's

- **2019:**
    - **Within the LEZ:** LGV flows are expected to decline as non-compliant LGV's divert around the LEZ. Compliance will be 100% (Table 15, Figure 93, Figure 94).
    - **On the LEZ boundary:** At the West End LEZ boundary, LGV flows are predicted to double (94-107% increases) and compliance rates will fall to between 13 and 19% (Table 15). On the East side of the boundary (Abbeyhill), although a 20% flow increase is predicted, compliance rates also increase from 41% to 50% (Table 15).
- **2023 'Future'**:
    - **On the LEZ boundary:** At the West End LEZ boundary, LGV flows are still predicted to be 27-38% higher than the Base 2019 scenario, however compliant rates have also increased (Table 15).

HGV's

- **2019:**
    - **Within the LEZ:** HGV flows are expected to decline (Figure 95) and compliance is 100% (Figure 96).
    - **On the LEZ boundary:** At the West End LEZ boundary, HGV flows are predicted to increase (Figure 95) by up to 113%, with compliance rates falling to 38% (Table 15).
- **2023 'Future':**
    - **On the LEZ boundary:** At the West End LEZ boundary, HGV flows are still predicted to be higher than the Base 2019 scenario, however, compliant rates are predicted to be 77% (Table 15).

*Table 14: Changes in Car traffic and compliance rates for the **Large** LEZ option when compared to the 2019 Base scenario*

	Diesel Cars						Petrol Cars					
	% change		Flow Change		Compliance (%)		% change		Flow Change		Compliance (%)	
	2019	2023	2019	2023	2019	2023	2019	2023	2019	2023	2019	2023
Palmerston Place	+75%	+34%	+4716	+2122	23%	61%	-2%	+1%	-182	+77	72%	99%
Chester Street	+90%	+45%	+2783	+1384	8%	52%	-37%	-7%	-1430	-268	44%	99%
Lothian Road	-10%	+5%	-790	+468	100%	100%	+22%	+20%	+2342	+2047	100%	100%
Abbeyhill	+36%	+26%	+2096	+1521	38%	75%	+8%	+13%	+623	+1004	85%	100%

*Table 15: Changes in LGV and HGV traffic and compliance rates for the **Large** LEZ option when compared to the 2019 Base scenario*

	LGV						HGV					
	% change		Flow Change		Compliance (%)		% change		Flow Change		Compliance (%)	
	2019	2023	2019	2023	2019	2023	2019	2023	2019	2023	2019	2023
Palmerston Place	+107%	+38%	+1701	+601	19%	61%	+113%	+35%	+513	+161	38%	77%
Chester Street	+94%	+27%	+1145	+330	13%	57%	+46%	+14%	+165	+50	32%	78%
Lothian Road	-11%	+4%	-328	+138	100%	100%	+16%	+19%	+87	+106	100%	100%
Abbeyhill	+22%	+12%	+431	+239	51%	84%	+18%	+9%	+68	+33	68%	92%

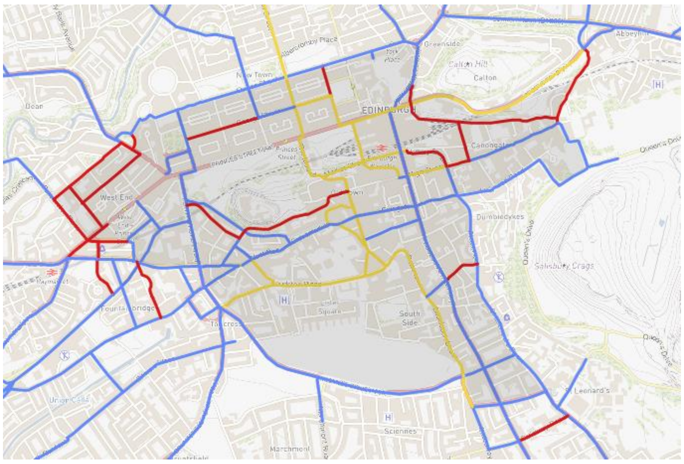


Figure 88: Total Car Flow Relative Differences (2019) for Large LEZ option, when compared to Base scenario

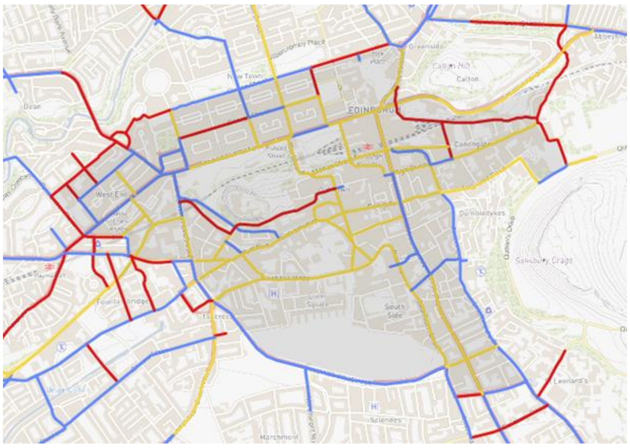


Figure 89: Total Diesel Car Traffic Flow Relative Differences (2019) for Large LEZ option, when compared to Base scenario

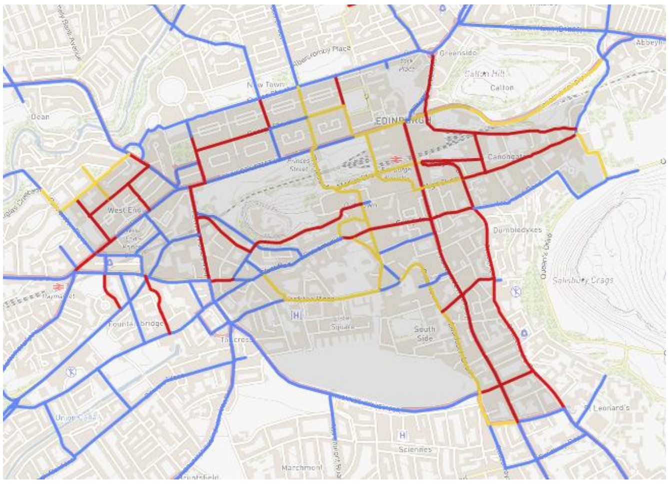
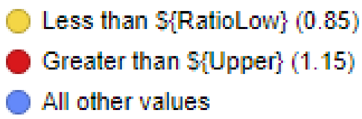


Figure 90: Total Petrol Car Traffic Flow Relative Differences (2019) for Large LEZ option, when compared to Base scenario



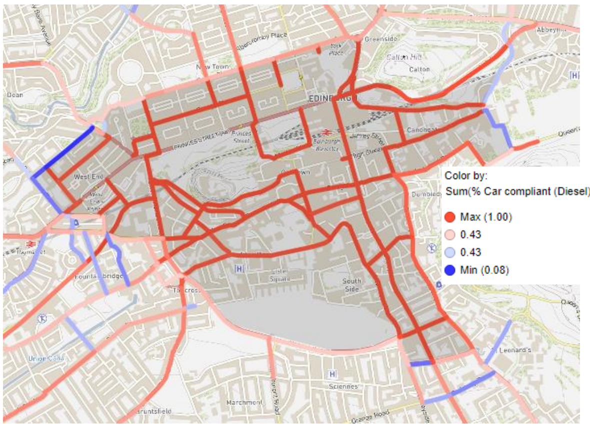


Figure 91: Compliance % of Diesel Cars on each road link for the Large LEZ option (2019). 43% is Base 2019 compliance value

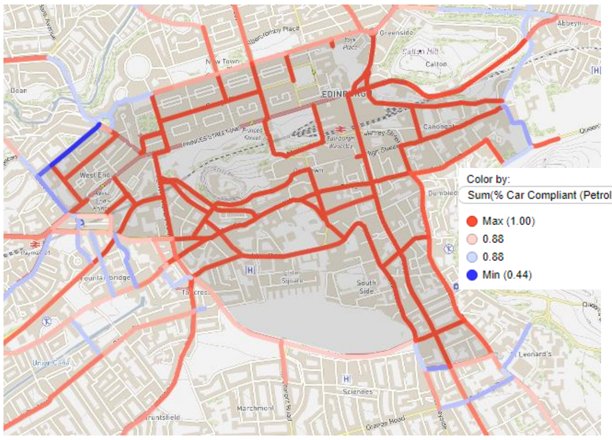


Figure 92: Compliance % of Petrol Cars on each road link for the Large LEZ option (2019). 88% is Base 2019 compliance value

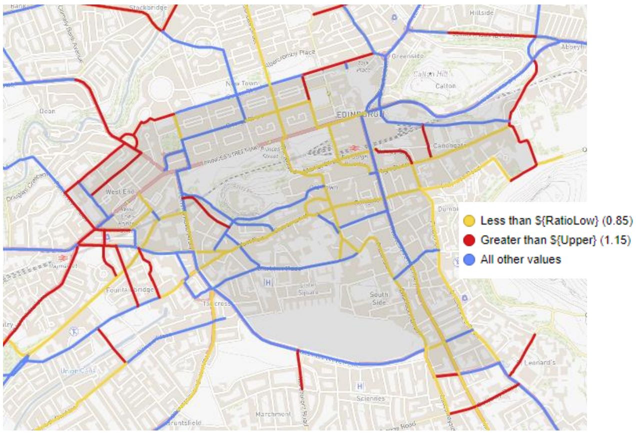


Figure 93: LGV Flow Relative Differences (2019) for Large LEZ option, when compared to Base scenario

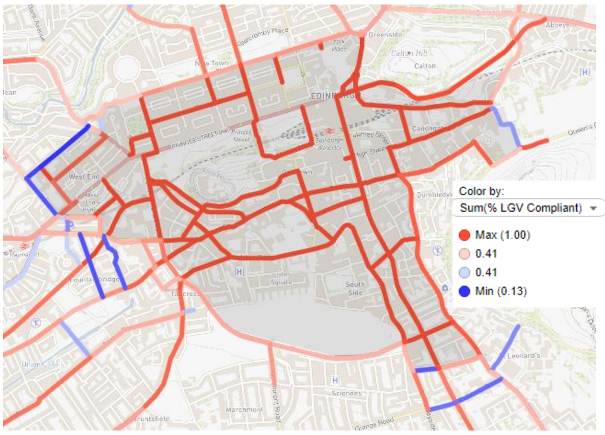


Figure 94: Compliance % of LGV's on each road link for the Large LEZ option (2019). 41% is the 2019 compliance value for LGV's

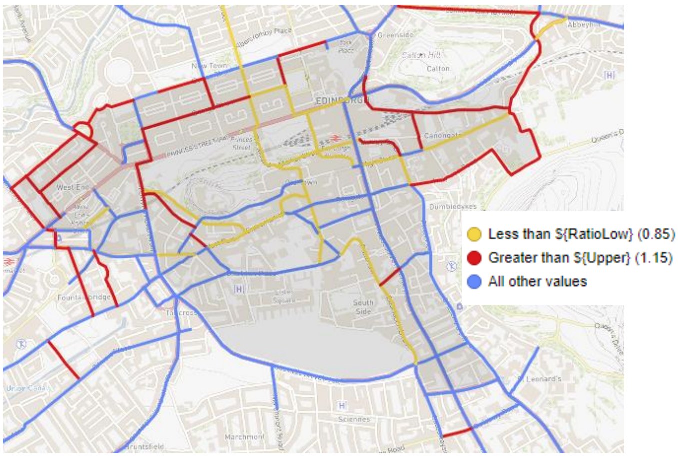


Figure 95: HGV Flow Relative Differences (2019) for Large LEZ option, when compared to Base scenario.

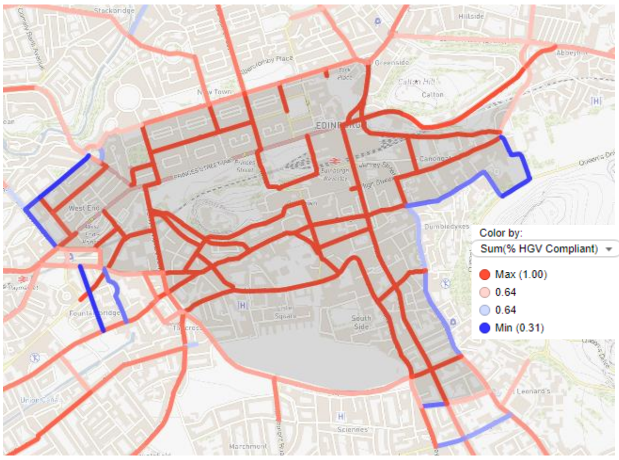


Figure 96: Compliance % of HGV's on each road link for the Large LEZ option (2019). 41% is the 2019 compliance value for HGV's.

Small LEZ Option

The Small LEZ option has the West End boundary on Lothian Road (Figure 2). In this case, displacement around the west side of the LEZ is more likely to be influenced by CCT changes than the LEZ. On the East side of the LEZ, the boundary is the same as the Large LEZ option, so the focus below is the West side of the LEZ boundary.

Diesel Cars

- **2019:**
    - **Lothian Road:** On Lothian Road (not in LEZ), diesel car flows increase by 20%. The compliance rate is 56% (Table 16), which is higher than the Base 2019 scenario (42.6%, Table 6), but lower than 100% compliance which would occur if the Large LEZ was selected.
    - **Palmerston Place/Chester Street:** On Palmerston Place and Chester Street, 13-25% flow increases are predicted, which is much smaller than the Large LEZ scenario (Table 16). Compliance rates are also much higher (46-49%).
- **2023 'Future':**
    - **Lothian Road:** Diesel Car flow is expected to be 15% higher than the Base 2019 scenario, however, compliance rates are much higher at 82% (Table 16).
    - **Palmerston Place/Chester Street:** Only a small change in traffic flows when compared to 2019 LEZ scenario, though compliance rates will be around 80% (Table 16). This suggests that the LEZ is having a small impact on traffic flows on the west side of the small LEZ, and that CCT changes have a larger influence.

Petrol Cars

- **2019:**
    - **Lothian Road:** A 10% increase in petrol car flows is predicted though compliance rates are 90% (Table 16; Figure 99).
    - **Palmerston Place/Chester Street:** A 13-15% increase in petrol car flows is predicted though compliance rates are 90% (Table 16; Figure 99).
- **2023 'Future':** There is little difference in petrol flows, though compliance rates are expected to be 100% (Table 16).

LGV's

- **2019:**
  - **Lothian Road:** A 21% increase in flow is predicted, though compliance is expected to increase to 56% (Table 17, Figure 100, Figure 101).
  - **Palmerston Place/Chester Street:** A 7-9% increase in flow is predicted, though compliance rates are expected to increase to 56% (Table 17, Figure 100, Figure 101).
- **2023 'Future':**
  - **Lothian Road:** A 13% increase in flow is predicted, though compliance is expected to increase to 85% (Table 17).
  - **Palmerston Place/Chester Street:** Flows are expected to be 10-11% higher than the Base 2019 scenario, though compliance is predicted to increase to around 85% (Table 17).

HGV's

- **2019:**
  - **Lothian Road:** A 29% increase in flow is predicted, though compliance is expected to increase to 76% (Table 17, Figure 102, Figure 103).
  - **Palmerston Place/Chester Street:** A 15% increase in flow is predicted on Palmerston Place, though only 2% increase is predicted on Chester Street (Table 17, Figure 102, Figure 103).
- **2023 'Future':** There is little difference in HGV flows, though compliance rates are expected to increase to 93% (Table 17)**.**

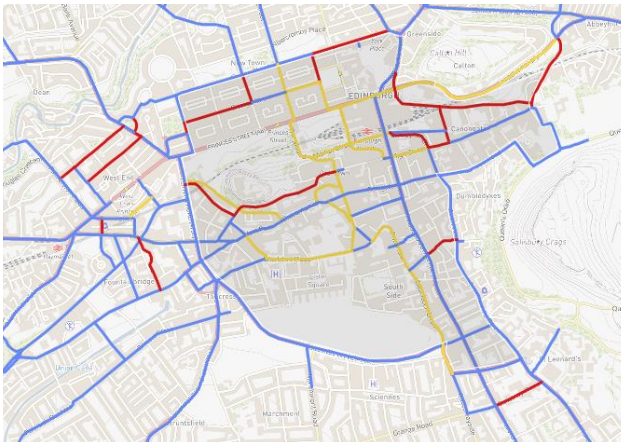


Figure 97: Total Car Flow Relative Differences (2019) for Small LEZ option, when compared to Base scenario.

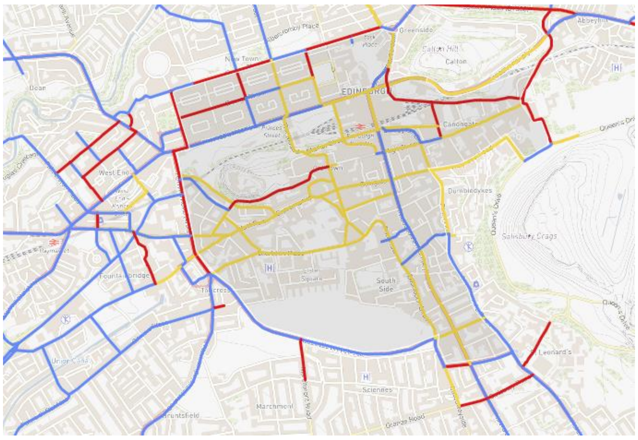


Figure 98: Total Diesel Car Traffic Flow Relative Differences (2019) for Small LEZ option, when compared to Base scenario.

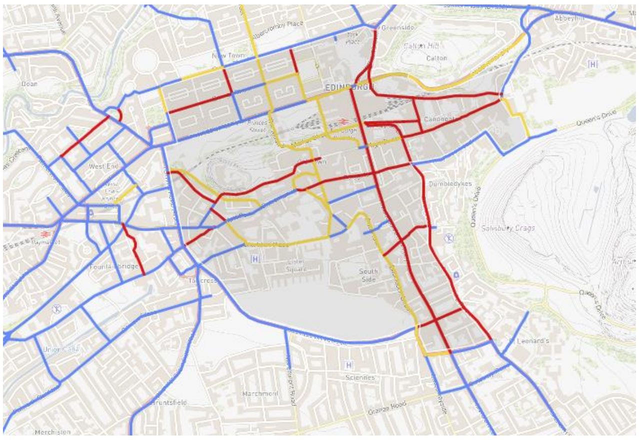


Figure 99: Total Petrol Car Traffic Flow Relative Differences (2019) for Small LEZ option, when compared to Base scenario.

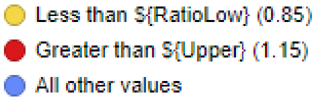


*Table 16: Changes in Car traffic and compliance rates for the **Small** LEZ option*

	Diesel Cars						Petrol Cars					
	% change		Flow Change		Compliance (%)		% change		Flow Change		Compliance (%)	
	2019	2023	2019	2023	2019	2023	2019	2023	2019	2023	2019	2023
Palmerston Place	+13%	+10%	+790	+625	49%	80%	+15%	+10%	+525	+785	90%	100%
Chester Street	+25%	+18%	+706	+539	46%	79%	+13%	+14%	+992	+529	88%	100%
Lothian Road	+20%	+15%	+1666	+1280	56%	82%	+10%	+12%	+1036	+1265	90%	100%
Abbeyhill	+32%	+24%	+1869	+1420	42%	77%	+12%	+14%	+917	+1091	87%	100%

*Table 17: Changes in LGV and HGV traffic and compliance rates for the **Small** LEZ option*

	LGV						HGV					
	% change		Flow Change		Compliance (%)		% change		Flow Change		Compliance (%)	
	2019	2023	2019	2023	2019	2023	2019	2023	2019	2023	2019	2023
Palmerston Place	+9%	+11%	+145	+180	51%	84%	+15%	+12%	+68	+53	74%	94%
Chester Street	+7%	+10%	+88	+121	48%	83%	+2%	+1%	+7	+4	71%	93%
Lothian Road	+21%	+13%	+661	+410	56%	85%	+29%	+21%	+157	+113	76%	94%
Abbeyhill	+15%	+10%	+286	+206	56%	86%	+10%	+8%	+38	+29	74%	94%

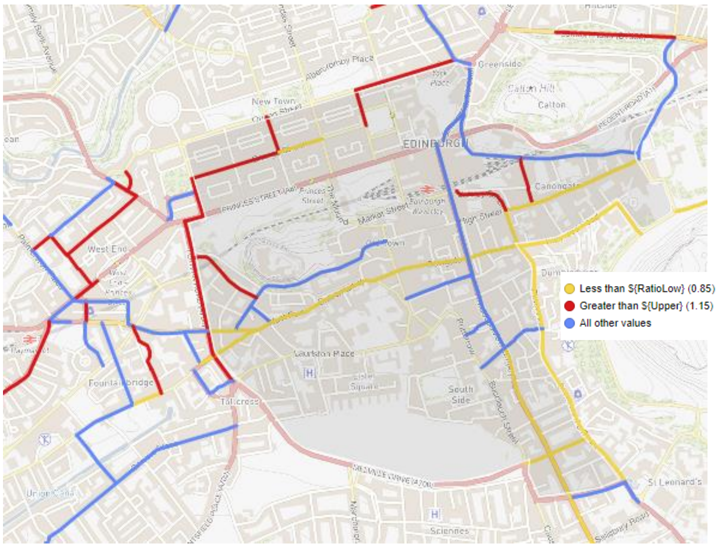


Figure 100: LGV Flow Relative Differences (2019) for Small LEZ option, when compared to Base scenario.

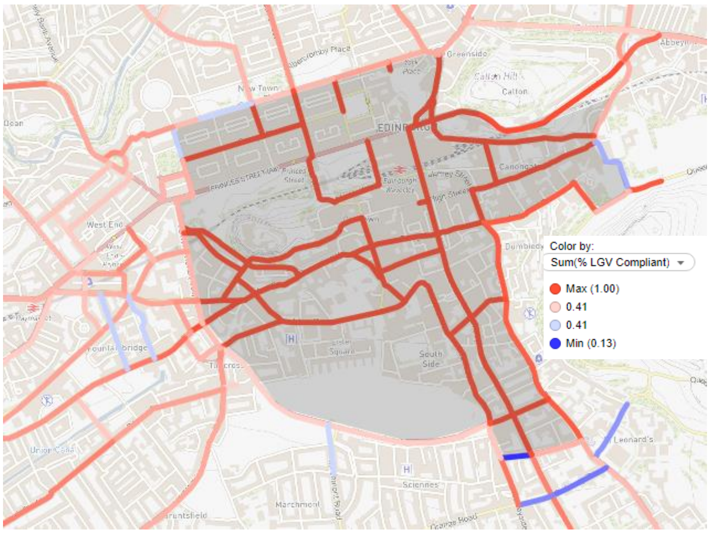


Figure 101: Compliance % of LGV's on each road link for the Small LEZ option (2019). 41% is the 2019 compliance value for LGV's.

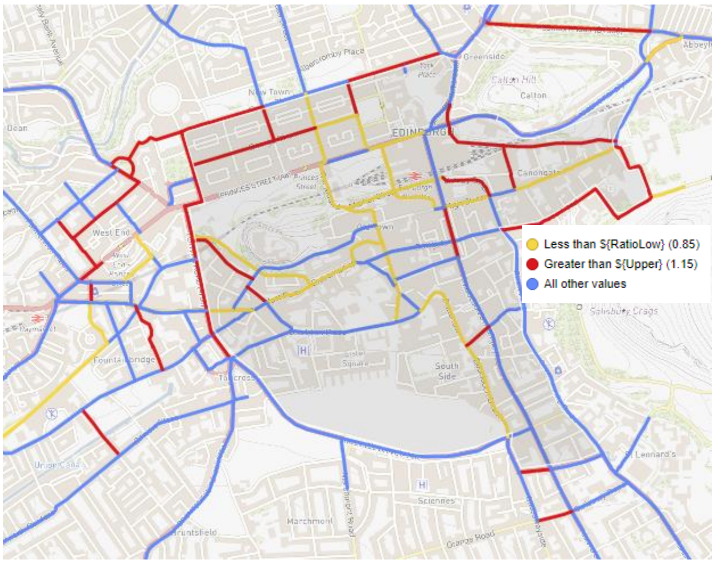


Figure 102: HGV Flow Relative Differences (2019) for Small LEZ option, when compared to Base scenario.

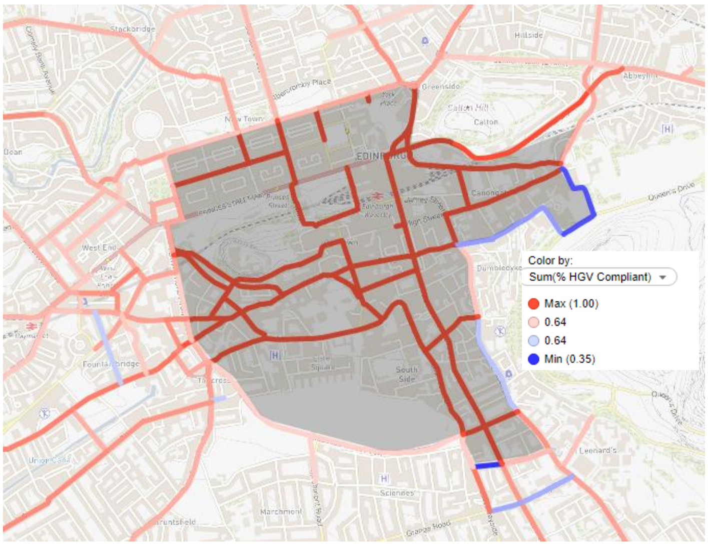


Figure 103:Compliance % of HGV's on each road link for the Small LEZ option (2019). 64% is the 2019 compliance value for HGV's.

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