Emissions Analysis for Low Emission Zones - Edinburgh

May 2021

Main Points to Note

- Introducing a Low Emission Zone (LEZ) within Edinburgh City Centre will reduce NO_x emissions from traffic sources, within either LEZ option, by 55% (equivalent to 25-30 tonnes/year), when compared to 2019 levels.
- For areas that are not in the LEZ, it is predicted that NO_x emissions from traffic sources will decline by 15%, when compared to 2019 levels.
- Overall, NO_x emissions across the model domain will decline by 20% (or 72 tonnes/year), when compared to 2019 levels.
- On several roads within the LEZ, NO_x emissions are predicted to decline by over 50%. On Princes Street NO_x emissions are predicted to decline by over 75%.
- The LEZ will force some non-complaint traffic to re-route around the LEZ boundary, increasing emissions on some of these roads by over 50%, when compared to 2019 levels.
- It is predicted that selecting the Large LEZ option would increase NO_x emissions on Palmerston Place and Chester Street by 85% (compared to 2019 levels), which would generate new exceedances at kerbsides and may result in new exceedances of Air Quality Standards at receptors. However, these new exceedances may be short lived as the 'future' scenario predicts that as new LEZ compliant vehicles enter the fleet, fewer vehicles will be required to re-route, resulting in NO_x emissions falling below 2019 levels. The large emission increases are a worst-case scenario, as the scheme will not be fully implemented and enforced until 2024, any emission increases will be lower than this. Further detailed air quality modelling work will be undertaken to assess potential compliance levels.
- Selecting the Small LEZ is unlikely to create new exceedances at kerbsides, though it is likely to slow down air quality improvements in the West End zone (between Lothian Road, Torphichen Street, Palmerston Place and Chester Street), and it may take longer to achieve compliance in these areas.

Introduction and Background

Air quality monitoring and management activities in Scotland is primarily driven by the 2008 ambient air quality directive (2008/50/EC), which was incorporated into Scottish law through the Air Quality Standards (Scotland) Regulations 2010. At a local level, The Environment Act 1995 and Regulatory Reform (Scotland) Act 2014 sets out the Local Air Quality Management (LAQM) regime to assist Local Authorities in achieving air quality standards and objectives to protect human health.

The Cleaner Air for Scotland (CAFS) strategy, released in 2015, sets out how Scottish Government and its partner organisations propose to further reduce air pollution to protect human health and fulfil Scotland's legal responsibilities as soon as possible. The strategy includes commitments to ensure a consistent approach to the appraisal, design and implementation of Low Emission Zones (LEZ) through the application of the National Low Emission Framework (NLEF), in conjunction with the National Modelling Framework (NMF).

In September 2017, the Scottish Government's Programme for Government committed to the introduction of Low Emission Zones in Scotland's four biggest cities (Glasgow, Edinburgh, Aberdeen and Dundee) by 2020, with the first introduced in Glasgow in 2018. COVID-19 and the subsequent lock-down restrictions have temporarily paused the implementation of LEZ's and the Scottish Government have set a new timetable for LEZs to be introduced across all four cities between February and May 2022.

CAFS is currently under review, with an updated strategy (CAFS2) expected later in 2021. The initial findings of the review identified that Scotland was performing well on Air Quality, with the major pollutants continuing to fall as a result of actions taken to date. However, the review also recommended that Scotland must take a precautionary public health approach to air quality reductions.

The analysis presented here has been carried out in line with the NMF, which has the aim to deliver a detailed and consistent approach to urban air quality modelling. The methodology was developed during a pilot project in Aberdeen and has been peer reviewed.

The NMF methodology is based on using high quality and detailed traffic data to calculate vehicle emissions, appropriate meteorology and background concentration data. Models are built using the same software (ADMS Urban for dispersion modelling and EMIT for emissions calculations); consistent methods and model settings are used, where appropriate. Street geometry data (e.g. road layout, road width and building heights) are derived from the same sources. The results of the modelling are processed, visualised and reported in a consistent and informative way.

An earlier report (SEPA Air Quality Evidence Report – Edinburgh; November 2018) shows that the NMF Edinburgh model performs well when compared against observed air quality data, highlights how fleet composition changes can improve air quality on a city-wide basis and looks at source apportionment for different vehicle sectors.

An interim report (SEPA Air Modelling Results - Interim Presentation Summary) was issued by the Scottish Environment Protection Agency (SEPA) in April 2021 based on an interim data which was only available at that time due to the SEPA cyber-attack. This report focussed on how changes in traffic flow and fleet composition will change air quality concentrations due to the proposed introduction of both City Centre LEZ options.

SEPA Cyber Attack – and the Alternative Approach Taken

On Christmas Eve, 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 the reference/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.

Low Emission Zone options:

Within this document, the LEZ options are referred to as the 'Large LEZ' and 'Small LEZ':

- **Large LEZ**: This is the LEZ option which includes Morrison Street, Torphichen Street, Palmerston Place and Chester Street as the Western boundary (Figure 1).

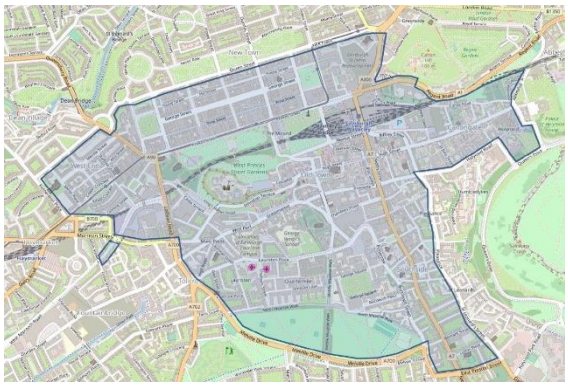


Figure 1: Large Low Emission Zone option

- **Small LEZ**: This LEZ option has Lothian Road and Charlotte Square as the western boundary (Figure 2).

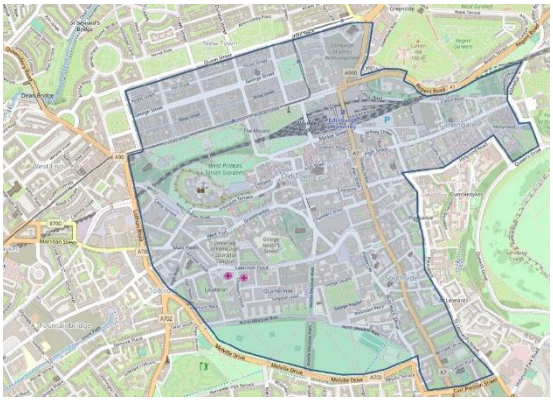


Figure 2: Small Low Emission Zone option

Traffic Modelling:

The LEZ traffic modelling predicts traffic flows numbers and the percentage of traffic which is compliant with LEZ rules for each road in the air quality model, by implementing an LEZ to force traffic to re-route according to the LEZ rules.

The traffic modelling, carried out by Jacobs (Edinburgh Low Emission Zone Transport Modelling Report, Jacobs, February 2021), has been run for a 2019 and a 2023 scenario. The 2019 scenario is based on ANPR data collected in Edinburgh. The 2023 scenario represents a plausible 'future' scenario that is likely to occur later than 2023.

The traffic models incorporate committed future City Centre Transformation (CCT) plans for the LEZ scenarios, such as closing Bank Street to general traffic.

Assumptions:

The analysis and results in this report assume all Taxis and Buses are LEZ compliant across the whole city. Emissions are calculated from 24-hour annual average flows.

Emission Calculations:

The EMIT software package, distributed by CERC, incorporates emission rates from the Emission Factor Toolkit, and has been used to calculate emission rates for NO_x and NO_2.

Emissions are calculated using fleet composition data (i.e. % of vehicles with a particular Euro Class), vehicle flow numbers and published emission factors. Emission rates (grams per kilometre per second or g/km/s) are used to compare emissions on each road, as this is a fair comparison between roads of different lengths.

NO_x and NO_2

Nitrogen Oxides (NO_x) is the sum of Nitrogen Dioxide (NO_2) and Nitrogen Oxide (NO). They chemically interact with each along with Ozone (O_3) and sunlight.

Vehicles directly emit both NO and NO_2 (known as primary NO and primary NO_2). When primary NO chemically reacts to for NO_2, this is known as secondary NO_2.

Due to this chemical interaction, there may not be a direct relationship between an increase in road traffic emissions and NO_2 concentrations. We also need to consider background concentrations, which are due to emissions from other (non-traffic) sources, and which make up a significant percentage of total NO_2 and NO_x concentrations.

Therefore, in this report we focus on total NO_x emissions from traffic sources.

Model Exceedances and Air Quality Standards:

This report refers to 'model exceedances' which are based on the predicted concentrations at kerbside points. This differs from the legal Air Quality Standards exceedances which refers to concentrations at relevant receptors. The Nitrogen Dioxide (NO_2) 40 micrograms per metre cubed ($\mu g/m^3$) threshold is used for both.

All NO_2 predictions used in the report are modelled and are from the detailed Edinburgh Air Quality model.

NO_x Emission Predictions (2019 Scenario)

- NO_x Emission rates for 2019 were calculated for 3 scenarios:
  - Base (No LEZ or 'do nothing' approach)
  - Large LEZ option
  - Small LEZ option
- An ANPR survey in 2019 provided comprehensive data on the vehicle fleet composition, which includes each vehicles Euro Class, so that compliance percentages can be calculated (Table 1). This is needed to calculate emission rates.

Table 1:LEZ Compliance (%) for each Vehicle Class (2019 Edinburgh Fleet from ANPR)

Vehicle Class	Compliant (%)	Non-compliant (%)
Car (Diesel)	42.6	57.4
Car (Petrol)	88.4	11.6
LGV	41.2	58.8
HGV	64.4	35.6

- Traffic flow data from the detailed Edinburgh 2016 traffic survey has been used (this is to maintain consistency with the Jacobs traffic model which uses this data).
- The Emission Rate colour scheme is:
  - Black: Highest emissions rates (> 0.15 g/km/s).
  - Red: Mid-level emission rates between 0.08 - 0.15 g/km/s.
  - Blue: Low emission rates (< 0.08 g/km/s).
- It is important to note that high emission rates do not necessarily correspond to high NO_2 concentrations, as this also depends on the dispersion characteristics for each road (e.g. buildings and street canyons).

All Roads in Model

- Base Scenario Emissions Rates are shown in Figure 3 and Figure 9. This shows roads with the highest emission rates are on Princes Street, Lothian Road, Bridges, Leith Street, London Road, Queensferry Road and St John's Road/Glasgow Road.

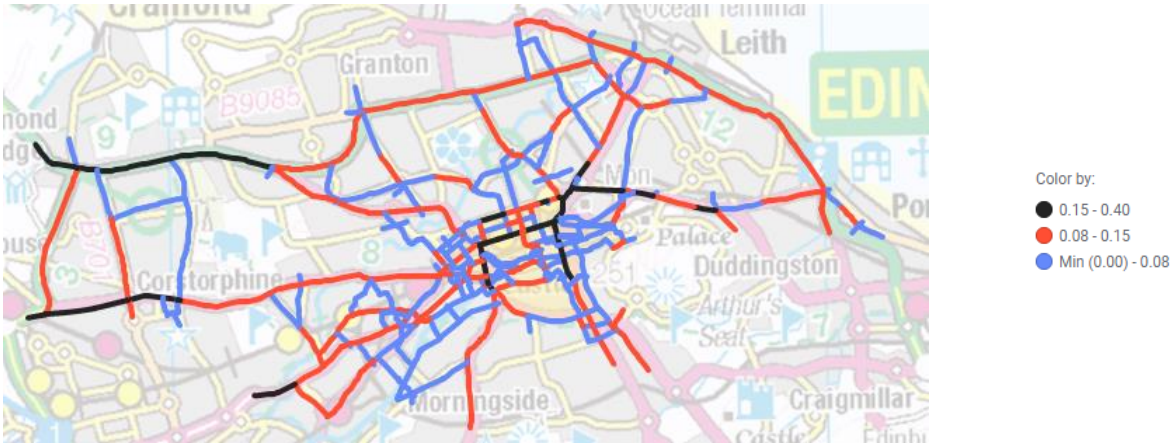


Figure 3: Base NO_x Emission Rates 2019 (g/km/s)

Figure 4: Large LEZ Option (with CCT) NO_x Emission Rates 2019 (g/km/s)

Figure 5: Small LEZ Option (with CCT) NO_x Emission Rates 2019 (g/km/s)

- A comparison of predicted emission rates across the whole city for both the Large LEZ option (Figure 4) and Small LEZ option (Figure 5) shows that emissions rates are predicted to decline for both LEZ options in many areas across the city.
- There are wider benefits to air quality across the city as a result of a City Centre LEZ (e.g. emission reductions in Corstorphine, Gorgie, Bruntsfield, Newington, London Road and Leith). This is due to all buses and taxis becoming compliant with LEZ rules over the whole city.
- Emission Rates can also be viewed on a histogram (Figure 6 - Figure 8), which shows the ranking of emission rates for each road section in the model. For both LEZ options, the number of roads coloured black (> 0.15 g/km/s) is significantly lower than the Base Scenario.
- The Large LEZ has a slightly fewer number of roads with a high emission rate (those coloured black).
- The magnitude of predicted emission rates generally declines over the whole city as a result of the introduction of both LEZ options, though there are some roads where emission rates increase (e.g. Large LEZ option: Palmerston Place and Chester Street).

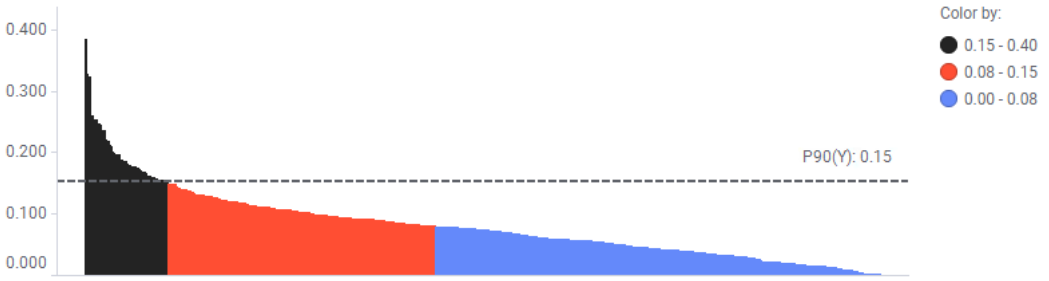


Figure 6: Base NO_x Emission Rates histogram 2019 (g/km/s)

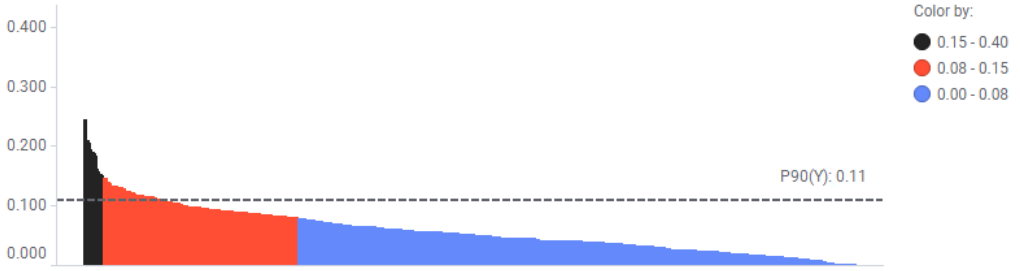


Figure 7: Large LEZ (with CCT) Option NO_x Emissions Rates histogram 2019 (g/km/s)

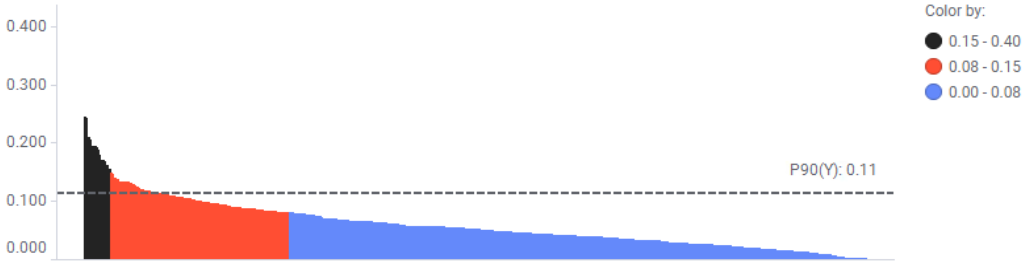


Figure 8: Small LEZ (with CCT) Option NOx Emission Rates histogram 2019 (g/km/s)

- Total NO_x emissions are predicted to decline by around 55% within the LEZ boundaries. For roads not in the LEZ, total NO_x emissions are predicted to decline by around 15%.
- In the West End Zone (this is the area which is within the Large LEZ, but not the Small LEZ), emission reductions would be:
    - Small LEZ option (LEZ rules do not apply): 32%
    - Large LEZ option (LEZ rules apply): 49%
    - This is the equivalent of 2 tonnes/year fewer NO_x emissions in the West End Zone if the Large LEZ option is selected in preference to the Small LEZ option.
- However, it is important to look at the area in and around the LEZ boundaries in more detail, where the Jacobs report indicates that there is traffic displacement due to the LEZ.

City Centre (around the proposed LEZ's)

- Emission rates in the city centre for the Base Run and both LEZ options are shown in more detail in Figure 9 - Figure 11.
- This shows that the introduction of Large or Small LEZ will significantly reduce NO_x emissions in the respective LEZ areas when compared to the Base scenario (Figure 9).
- Increased emissions rates are predicted on some roads around the LEZ boundary due to the displacement of traffic. This is particularly significant for the Large LEZ option on Chester Street and Palmerston Place.
- Roads where increased emissions rates are predicted to increase will be analysed in more detail later in this report.

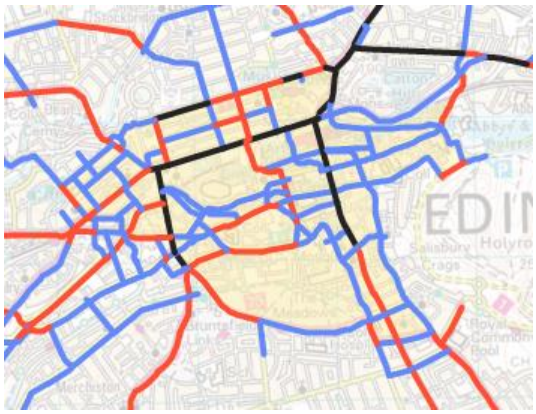


Figure 9: Base NO_x Emissions Rates 2019; g/km/s (Yellow Zone is Large LEZ)

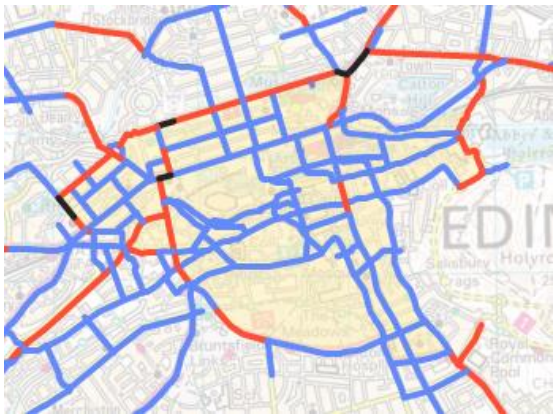
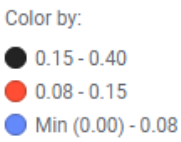


Figure 10: Large LEZ Option (with CCT) NO_x Emission Rates 2019 (g/km/s) (Yellow Zone is Large LEZ)

Figure 11: Small LEZ Option (with CCT) NO_x Emission Rates 2019 (g/km/s) (Yellow Zone is Small LEZ)



Emission Differences between Base and LEZ Options (2019)

Base v Large LEZ

- Ratios of emission differences between the Base and Large LEZ option are shown in Figure 12. This shows emissions declining within the Large LEZ area (except New Street and Walker Street where emission rates are low).
- NO_x emission rate reductions of over 50% are predicted on several roads (Princes Street, Leith Street and Bridges/Clerk Street). Emission rates on Princes Street are predicted to be over 75% lower than Base 2019 levels.
- NO_x emission rate increases are predicted on several roads around the Large LEZ boundary. The largest percentage increases (>50%) are Chester Street, Palmerston Place, Gardiner's Crescent and Grove Street.
- It is important to note that on some roads, while there may be a large percentage increase, the actual emission rate may remain low.

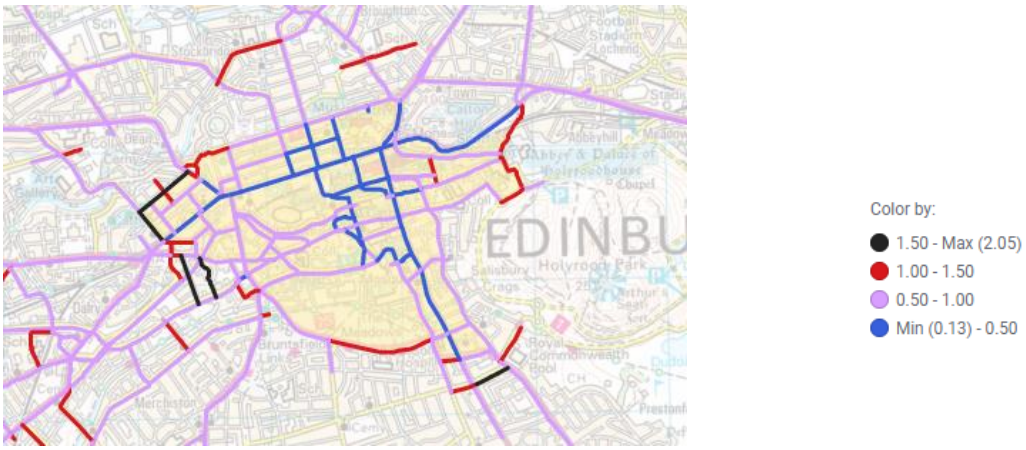


Figure 12: Ratio of NO_x Emission Rate changes (2019) due to introduction of Large LEZ. Black is largest % increase in emissions (> 50%)

Base v Small LEZ

- Ratios of emissions differences between the Base and Small LEZ option are shown in Figure 13. This shows emissions falling within the LEZ (except New Street and the east section of George Street).
- Like the Large LEZ, NO_x emission reductions of over 50% are predicted on several roads, including Princes Street, Leith Street and Bridges/Clerk Street. Emission rates on Princes Street are predicted to be over 75% lower than 2019 levels.
- Also like the Large LEZ, emission increases are predicted on several roads around the Small LEZ boundary. The largest percentage increases (43%) are on Salisbury Place, West Preston Street and Melville Street, however NO_x emission rates are and will remain low on these roads.

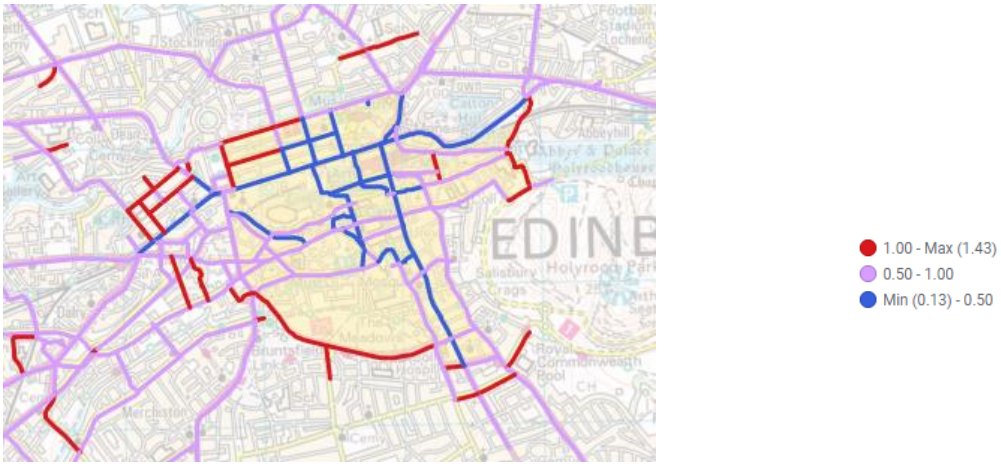


Figure 13: Ratio of NO_x Emission Rate changes (2019) due to introduction of Small LEZ. Red are roads where there is a % increase in emissions

NO_x Emission Predictions (2023 'future' Scenario)

- As for the 2019 scenario, NO_x emission rates for the 2023 'future' scenario were calculated for 3 options:
  - No LEZ or 'do nothing' approach
  - Large LEZ option
  - Small LEZ option
- Predicting future traffic fleet compositions is subject to many uncertainties. The predicted 2023 National Fleet composition (published by the Department for Transport (DfT)) has been used to represent a 'future' scenario for this analysis.
- It has been shown that the DfT National Fleet predictions tend to be optimistic, so it is likely that the published 2023 scenario will occur post-2023, therefore it is called a 'future' scenario. The compliance percentages in the published 2023 scenario are in Table 2. This is needed to calculate emission rates.

Table 2: LEZ Compliance (%) for each Vehicle Class (2023DfT National Fleet)

Vehicle Class	Compliant (%)	Non-compliant (%)
Car (Diesel)	78.1	21.9
Car (Petrol)	99.6	0.4
LGV	81.6	18.4
HGV	91.6	8.4

- Traffic flow data from the 2016 traffic survey is used (this is to maintain consistency with the Jacobs traffic modelling).
- The Emission Rate colour scheme is:
  - Black: Highest emissions rates (> 0.15 g/km/s).
  - Red: Emission rates between 0.08 - 0.15 g/km/s.
  - Blue: Low emission rates (< 0.08 g/km/s).
- It is important to note that high emission rates do not necessarily correspond to high concentrations as this depends on the dispersion characteristics for each road (e.g. buildings and street canyons).

All Roads in Model

- Base Scenario NO_x Emissions Rates (2023) are shown in Figure 14 and Figure 20. This shows roads with the highest emission rates are Princes Street (West End), Leith Street, Queensferry Road and Glasgow Road. When compared to the Base 2019 Scenario (Figure 3), NO_x emissions are predicted to be lower, which is due to lower emitting vehicles entering the fleet.

Figure 14: Base NO_x Emission Rates 2023 (g/km/s)

- It is useful to compare emissions across the whole city for both Large LEZ (Figure 15) and Small LEZ (Figure 16) options. This shows that emissions are predicted to fall for both LEZ options across the city, particularly Queensferry Road, Ferry Road, North/South Bridge and London Road.
- There are also benefits to air quality across the city as a result of the LEZ in the 2023 'future' scenario. The Jacobs LEZ traffic model report notes that traffic displacement around the LEZ will still occur, but will be less than the 2019 scenario.

Figure 15: Large LEZ Option (with CCT) NO_x Emission Rates 2023 (g/km/s)

Figure 16: Small LEZ Option (with CCT) NO_x Emission Rates 2023 (g/km/s)

- NO_x Emission Rates for each road section are shown as a histogram (Figure 17 - Figure 19). For both LEZ options, the number of roads coloured black and red is significantly lower than for the Base 2023 'future' scenario. This shows that the LEZ will still be effective in future years at reducing NO_x emissions across the city.

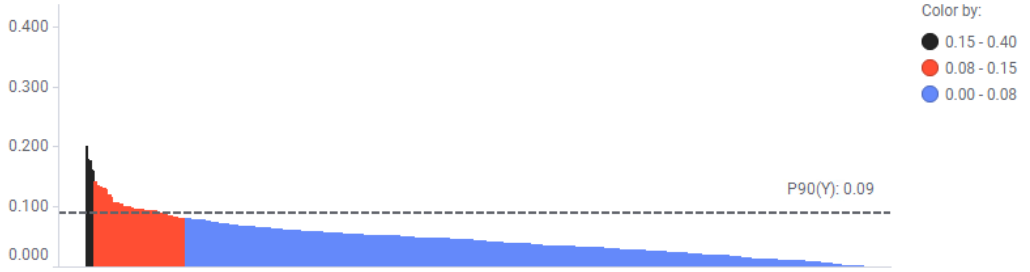


Figure 17: Base NO_x Emission Rates 2023 (g/km/s)

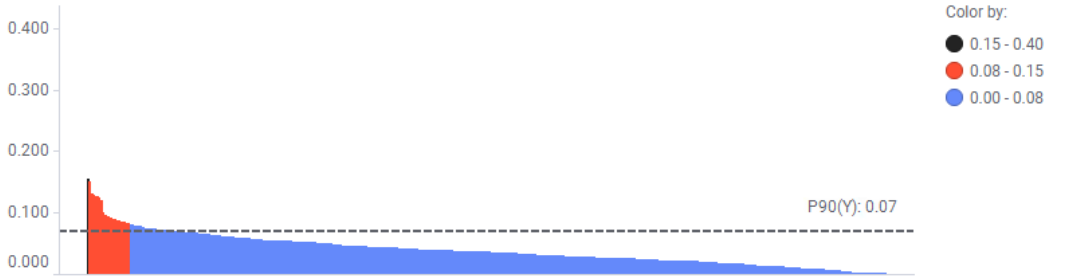


Figure 18: Large LEZ Option (with CCT) NO_x Emissions Rates 2023 (g/km/s)

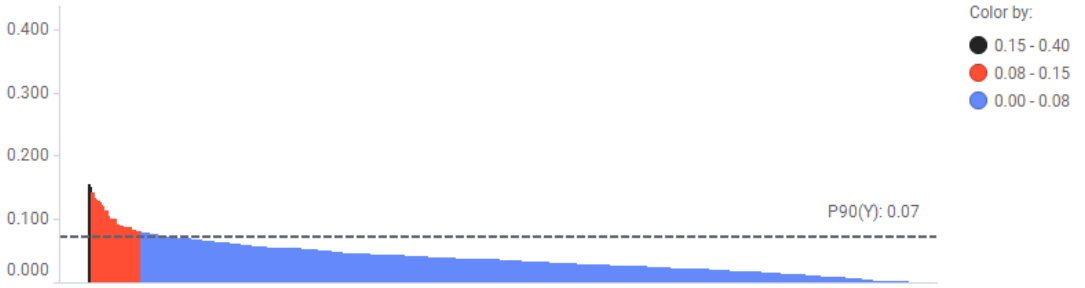


Figure 19: Small LEZ Option (with CCT) NO_x Emission Rates 2023 (g/km/s)

City Centre (around the proposed LEZ's)

- NO_x emission rates for roads in and around the proposed LEZ boundaries can be viewed in more detail in Figure 20, Figure 21 and Figure 22. This shows that in the 2023 'future' scenario, an LEZ will continue to have a positive effect on reducing emissions for both LEZ options when compared to the Base 2023 Scenario (Figure 20).

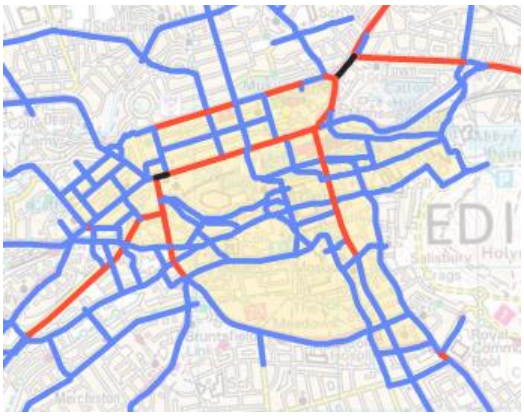


Figure 20: Base NO_x Emission Rates 2023 (g/km/s) (Yellow Zone is Large LEZ)

Figure 21: Large LEZ Option (with CCT) NO_x Emission Rates 2023 (g/km/s)s (Yellow Zone is Large LEZ)

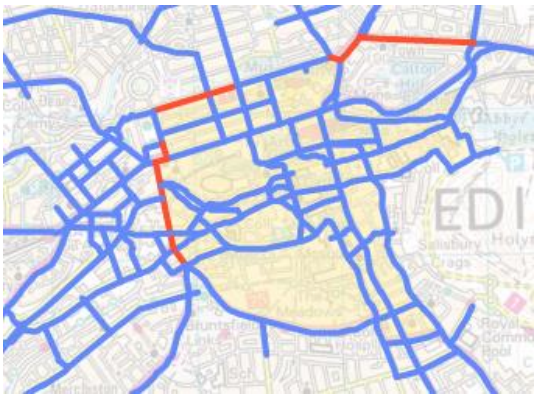
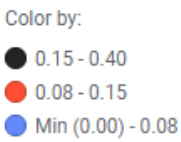


Figure 22: Small LEZ Option (with CCT) NO_x Emission Rates 2023 (g/km/s) (Yellow Zone is Small LEZ)



NOx Emission Comparison between Base and LEZ Options (2023)

- Comparison of NO_x emissions for the 2023 'future' scenario is also useful.
- Ratios of emissions between the Base and each LEZ option are shown in Figure 23 and Figure 24. This shows emissions falling within most of the LEZ. On some roads, NO_x emission rates are predicted to increase, however, these are small increases and emission rates will remain low. These increases are likely to be due to CCT changes (e.g. closure of the Mound resulting in traffic displacement).

Large LEZ

- Emission reductions of over 50% are predicted on several roads, including Princes Street, Shandwick Place, Mound and George IV Bridge. These roads have high emission rates so this represents a significant reduction in emissions. Emission rates on Princes Street are predicted to be over 50% lower than Base 2023 levels.
- Emission increases are predicted on several roads around the Large LEZ boundary; the largest percentage increases (>50%) are Chester Street, Palmerston Place, Gardiner's Crescent and Grove Street, though in most cases, the emission rates on these roads will remain low.

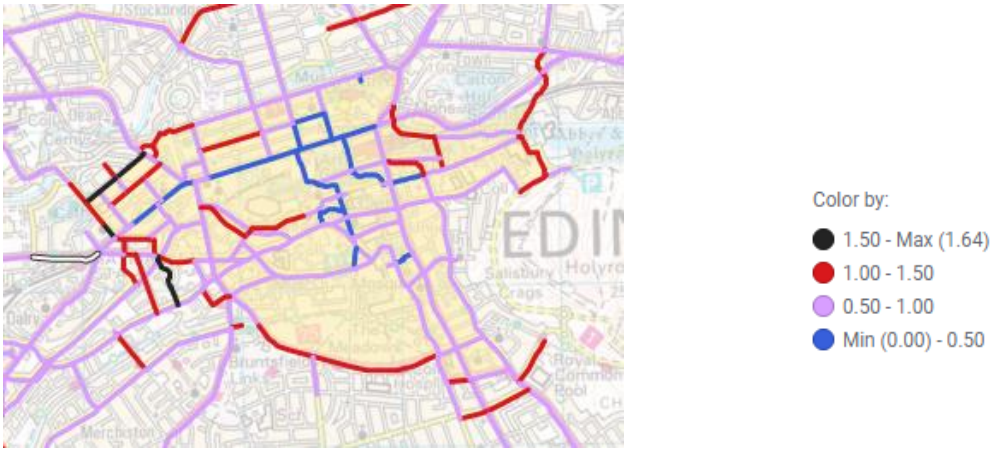


Figure 23: Ratio of Emission Changes (2023) due to introduction of Large LEZ. Black is largest % increase in emissions (> 50%)

Small LEZ

- NO_x Emission reductions of over 50% are predicted on several roads, including Princes Street, Mound and George IV Bridge.
- Small NO_x emissions increases are predicted on several roads around the Small LEZ boundary, including Queen Street (between Charlotte Square and Dundas Street), Charlotte Square (East side), Melville Drive, Horse Wynd and West Preston Street.

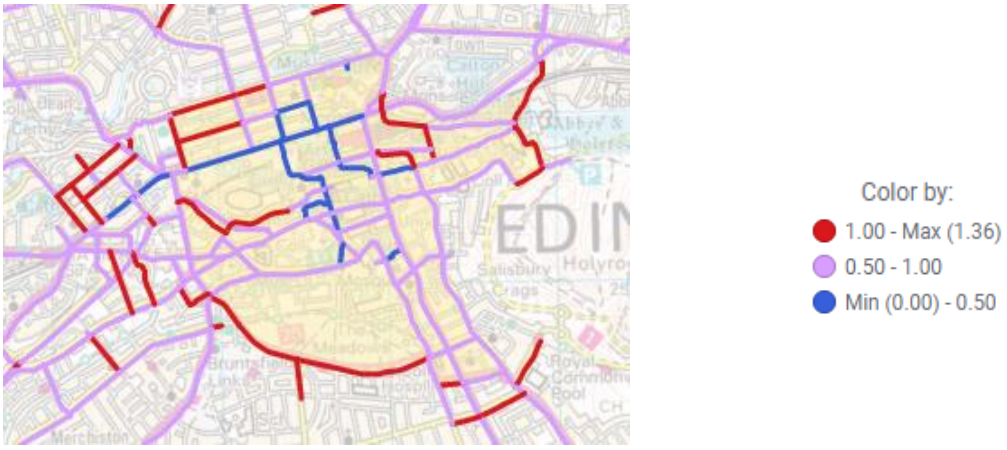


Figure 24: Ratio of Emission Changes (2023) due to introduction of Small LEZ.

Detailed Analysis in Key Areas

Palmerston Place/Chester Street

- Palmerston Place and Chester Street are 2 streets where the Jacobs traffic modelling report indicates that would be significant displacement of traffic to avoid the Large LEZ.
- Ranking histograms (Figure 25 - Figure 30) show the distribution of NO_x emission rates for each road in the city, with Chester Street and Palmerston Place highlighted. This shows emission rates on these roads significantly move up the emission rate rankings with increased emission rates.
- Relative changes in emissions for Chester Street and Palmerston Place, when compared to the Base 2019 scenario can be seen in Figure 31 and Figure 32 respectively.
- 2019 Large LEZ option:
    - NO_x emission rates are predicted to increase by around 85% for Palmerston Place and Chester Street
    - Air Quality modelling predicts NO_2 concentrations which will result in new model exceedances (Chester Street: from ~36 µg m^{-3} to ~45 µg m^{-3}; Palmerston Place: from ~39 µg m^{-3} to ~49 µg m^{-3}).
    - Emission rate increases are due to a combination of increased traffic flows and an increase in non-compliant (higher emitting) vehicles.
- 2019 Small LEZ option:
    - NO_x emission rates are predicted to increase by a comparatively smaller 6%,
    - Air Quality modelling predicts a negligible change to NO_2 concentrations.
- 2023 Large LEZ 'future' option:
    - NO_x emission rates are predicted to be 5-8% higher when compared to the Base 2023 scenario.
    - When compared to the Base 2019 scenario, emission rates are predicted to decline by 4% and 2.7% for Palmerston Place and Chester Street respectively. This is due to a higher percentage of vehicle being LEZ compliant, and so fewer vehicles will need to divert around the Large LEZ boundary.
    - Air Quality modelling predicts NO_2 concentrations of around 34 µg m^{-3} (which is around 2-3 µg m^{-3} lower than current levels).
- 2023 Small LEZ 'future' option:
    - NO_x emission rates are predicted to decrease by 32%
    - Air Quality modelling predicts NO_2 concentrations of around 30 µg m^{-3} (which is around 5-6 µg m^{-3} lower than current levels).
- For the Large LEZ option, although increased NO_2 concentrations and new model exceedances are predicted, these are expected to be short lived. This is because as newer, lower emitting vehicles enter the fleet, the overall percentage of compliant traffic will increase in future years, and hence fewer vehicles will be required to avoid the LEZ.
- Model exceedances (kerbside concentrations) are worst case and further air quality modelling will be carried out for these streets to assess the risk at building façades.

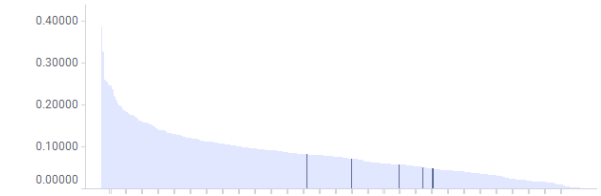


Figure 25: Base Run (2019) Emission Rates ranked for each road, showing Chester Street and Palmerston Place highlighted

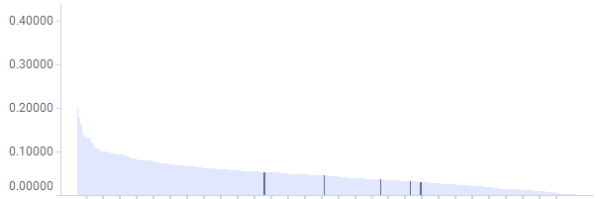


Figure 26: Base Run (2023) Emission Rates ranked for each road, showing Chester Street and Palmerston Place highlighted

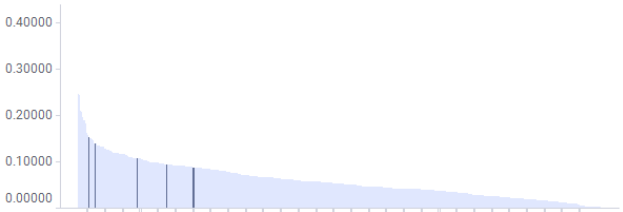


Figure 27: Large LEZ option (2019) Emission Rates ranked for each road, showing Chester Street and Palmerston Place highlighted

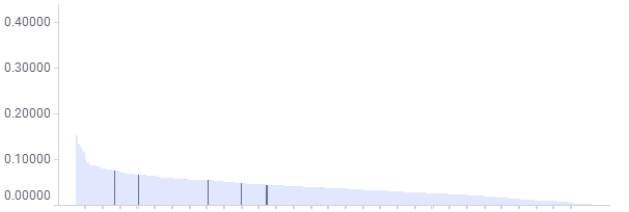


Figure 28: Large LEZ option (2023) Emission Rates ranked for each road, showing Chester Street and Palmerston Place highlighted

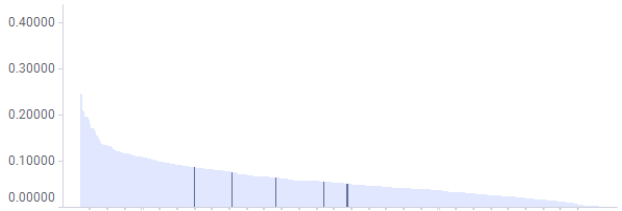


Figure 29: Small LEZ option (2019) Emission Rates ranked for each road, showing Chester Street and Palmerston Place highlighted

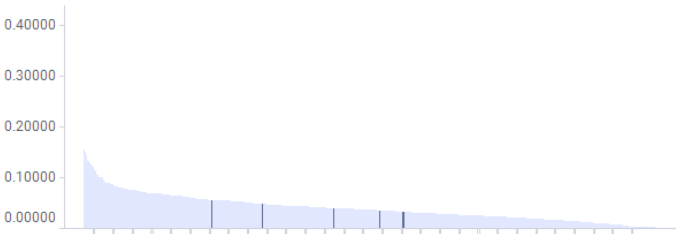


Figure 30: Small LEZ option (2023) Emission Rates ranked for each road, showing Chester Street and Palmerston Place highlighted

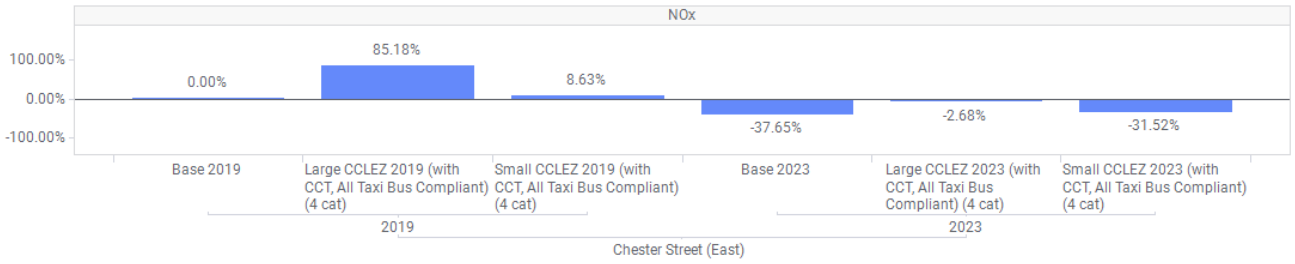


Figure 31: Relative Changes in Emission Rates (Chester Street) compared to Base 2019 Scenario

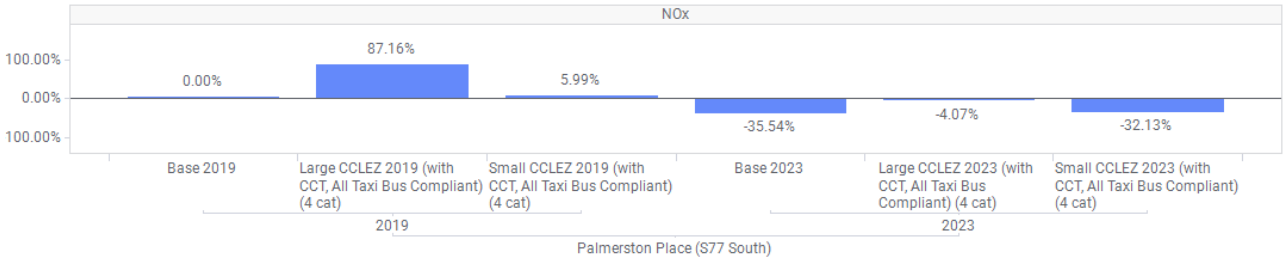


Figure 32: Relative Changes in Emission Rates (Palmerston Place) compared to Base 2019 Scenario.

Grove Street/Gardiner's Crescent

- Grove Street and Gardiner's Crescent are 2 streets where traffic modelling predicts vehicle flows will increase if the Large LEZ is selected, due to non-compliant vehicles re-routing to avoid it.
- 2019 Large LEZ option:
    - NO_x emission rates for the 2019 Large LEZ option are predicted to increase by 99% on Gardiner's Crescent, and 65% on Grove Street (Figure 35).
    - NO_x emission rates are low in the Base (Figure 9, Figure 33) are predicted to remain low if the Large LEZ is selected (Figure 10, Figure 34).
    - Air Quality modelling predicts NO_2 concentrations will increase on both roads, no new model exceedances are predicted (Gardiner's Crescent: From ~32 µg m^{-3} to ~36 µg m-3; Grove Street: From ~31 µg m^{-3} to ~33 µg m^{-3}).

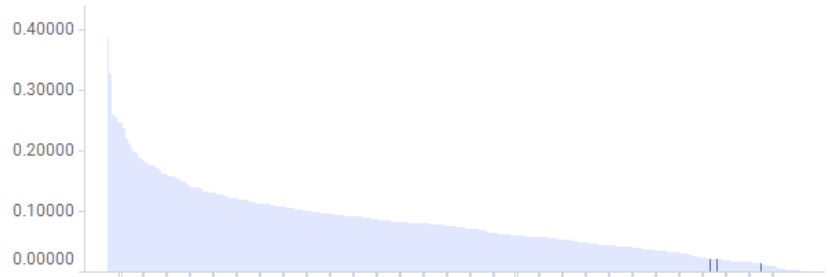


Figure 33: Base (2019) Emission Rates ranked for each road, showing Gardiner's Crescent and Grove Street highlighted

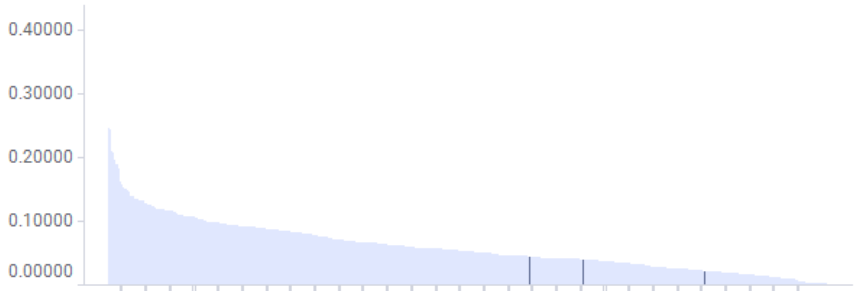


Figure 34: Large LEZ option (2019) Emission Rates ranked for each road, showing Gardiner's Crescent and Grove Street highlighted

- 2019 Small LEZ option:
    - NO_x emission rates for the 2019 Large LEZ option are predicted to increase by 28% on Gardiner's Crescent, and 4% on Grove Street.
    - Air Quality modelling predicts NO_2 concentrations increase will be negligible and no new model exceedances are predicted.
- 2023 'future' LEZ options:
    - NO_x emissions on Grove Street are predicted to decline for the Base and both LEZ options by 15 – 35% when compared to the Base 2019 scenario.
    - NO_x emission rates on Gardiner's Crescent are predicted to increase by 5% for the Small LEZ option when compared to the Base 2019 scenario.
    - Air Quality modelling for both streets predicts NO_2 concentrations of around 27 µg m^{-3} (which is around 4 µg m^{-3} lower than current levels) for both LEZ options.

- For the 2023 ‘future’ scenario, no new model exceedances are expected.

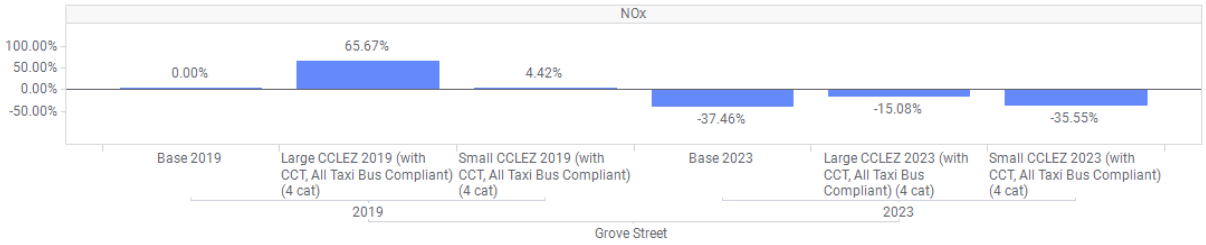


Figure 35: Relative Changes in Emission Rates (Grove Street) compared to Base 2019 Scenario.

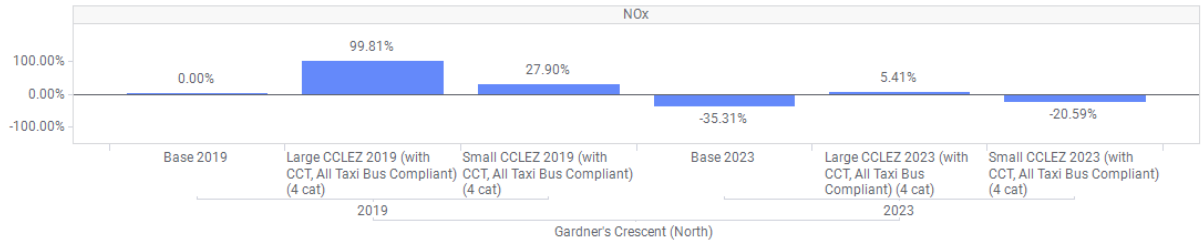


Figure 36: Relative Changes in Emission Rates (Gardiner’s Crescent) compared to Base 2019 Scenario.

Detailed Analysis within the LEZ Boundary

Princes Street

- The introduction of either LEZ option will significantly reduce emission rates on Princes Street compared to the respective Base Scenarios.
- NO_x emission rates are predicted to decrease by 76% if either LEZ option is selected (Figure 37). No difference is expected between 2019 and 2023 scenarios as this street is dominated by buses that will be compliant with LEZ rules.
- Air Quality modelling predicts that NO_2 concentrations are predicted to fall to around 30 µg m^{-3} and therefore model exceedances will be no longer exist.

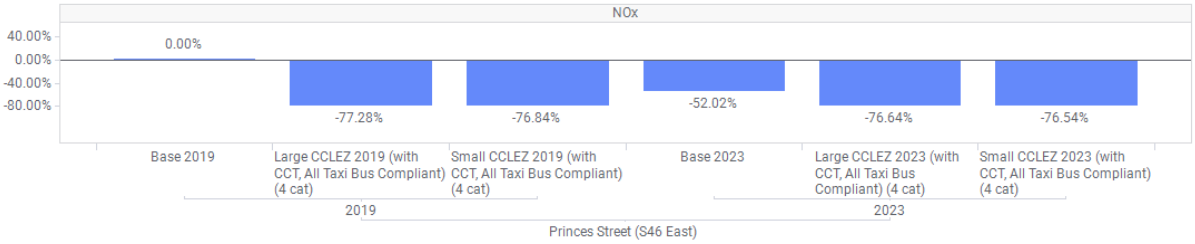


Figure 37: Relative Changes in Emission Rates (Princes Street) compared to Base 2019 Scenario.

South Bridge

- The introduction of either LEZ option will significantly reduce emission rates on South Bridge compared to the respective Base Scenarios.
- 2019 LEZ options:
  - NO_x emission rates are predicted to decrease by 56% if either LEZ option is selected (Figure 38).
  - Air Quality Modelling predicts that NO_2 concentrations will decline by around 16 µg m^{-3} to between 38 and 45 µg m^{-3}. Air quality model exceedances are predicted to remain.
- 2023 'future' LEZ options:
  - NO_x emission rates are predicted to decrease by 64% (when compared to 2019 levels) if the either LEZ option is selected (Figure 38).
  - Air Quality Modelling predicts that NO_2 concentrations will decline by around 21 µg m^{-3} (compared to 2019 levels) to between 36 and 39 µg m^{-3} and therefore model exceedances will be no longer exist.

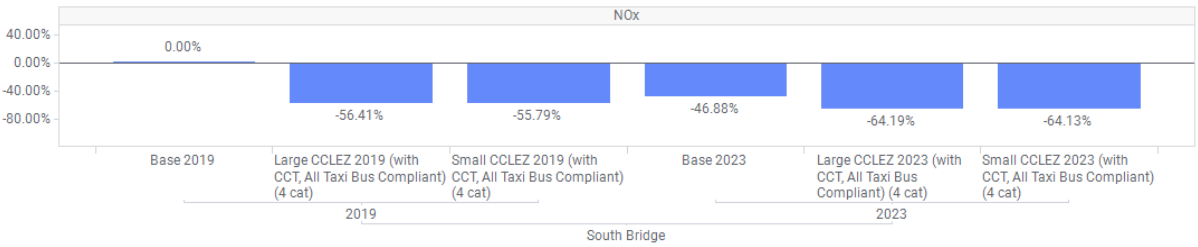


Figure 38: Relative Changes in Emission Rates (South Bridge) compared to Base 2019 Scenario.

Leith Street

- The introduction of either LEZ option will significantly reduce emission rates on Leith Street compared to the respective Base Scenarios.
- 2019 LEZ options:
  - NO_x emission rates are predicted to decrease by 55% if the either LEZ option is selected (Figure 39).
  - Air Quality modelling predicts that NO_2 concentrations would decline by around 12 µg m^{-3} to around 39-41 µg m^{-3}. It is expected that some (though perhaps not all) model exceedances will no longer exist.
- 2023 'future' LEZ options:
  - NO_x emission rates are predicted to decrease by 62% (when compared to 2019 levels) if either LEZ option is selected (Figure 39).
  - Air Quality Modelling predicts that NO_2 concentrations will decline by around 17 µg m^{-3} (compared to 2019 levels) to between 34 and 39 µg m^{-3} and therefore model exceedances will be no longer exist.

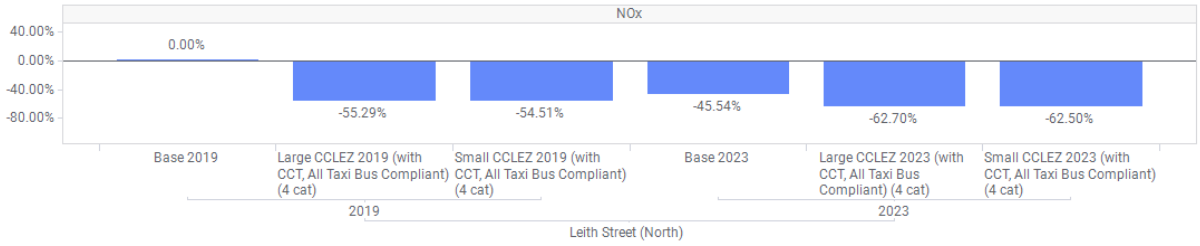


Figure 39: Relative Changes in Emission Rates (Leith Street) compared to Base 2019 Scenario.

West Port/Grassmarket/Cowgate

- The introduction of either LEZ option will reduce emission rates on West Port and Cowgate compared to the respective Base Scenarios. This route has few buses and is dominated by other vehicle types.
- 2019 LEZ options:
  - NO_x emission rates are predicted to decrease by 40% on West Port/Grassmarket and 30% on Cowgate if the either LEZ option is selected (Figure 40, Figure 41).
  - Air Quality modelling predicts that NO_2 concentrations would decline by around 15 µg m^{-3} on West Port and 12 µg m^{-3} on Cowgate. However, due to the deep canyons and poor dispersion on these roads, model exceedances are still predicted (concentrations would be around 45 µg m^{-3}).
- 2023 'future' LEZ options:
  - NO_x emission rates are predicted to decrease by 47% (when compared to 2019 levels) if the either LEZ option is selected (Figure 40, Figure 41).
  - Air Quality modelling predicts that NO_2 concentrations would decline by around 20 µg m^{-3} on West Port and 18 µg m^{-3} on Cowgate. However, due to the deep canyons and poor dispersion on these roads, model exceedances are still predicted on Cowgate (concentrations would be around 41 µg m^{-3}). On West Port, predicted concentrations are around 39.9 µg m^{-3}, so although model exceedances will no longer exist, it is very close to the 40 µg m^{-3} threshold.

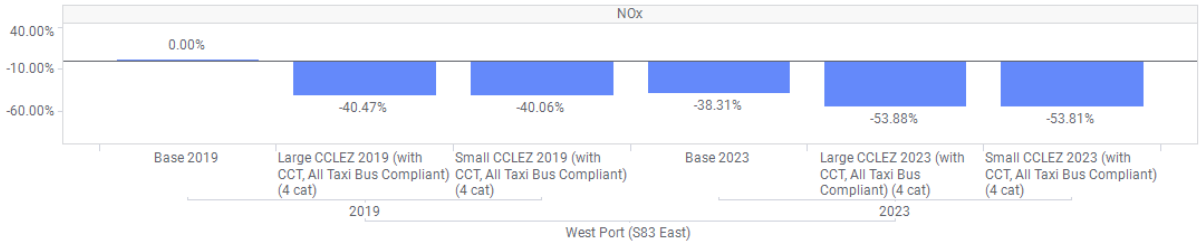


Figure 40: Relative Changes in Emission Rates (West Port) compared to Base 2019 Scenario.

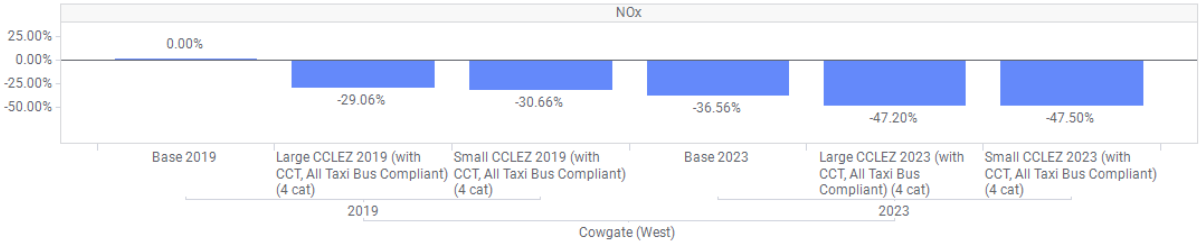


Figure 41: Relative Changes in Emission Rates (Cowgate) compared to Base 2019 Scenario.

Detailed Analysis around the LEZ Boundary

Queen Street (between Frederick Street and Charlotte Square)

- The introduction of either LEZ option will have a small effect on emission rates on Queen Street compared to the respective Base Scenarios.
- 2019 Large LEZ option:
  - NO_x emission rates are predicted to decline by 7% if the Large LEZ is selected (Figure 42).
  - Air Quality modelling predicts NO_2 concentrations are expected to decline by around 3 µg m^{-3}. On the section between Frederick Street and Charlotte Square, NO_2 concentrations are predicted to remain above 40 µg m^{-3} and model exceedances will remain.
- 2019 Small LEZ option:
  - NO_x emission rates are predicted to increase by 7% if the Small LEZ is selected (Figure 42).
  - Air Quality modelling predicts NO_2 concentrations are expected to increase by around 1 µg m^{-3}. On the section between Frederick Street and Charlotte Square, NO_2 concentrations are predicted to remain above 40 µg m^{-3} and model exceedances will remain.
- 2023 'future' LEZ options:
  - NO_x emission rates are expected to decline by around 40% for all scenarios when compared to the Base 2019 scenario, which will be due to fleet turnover.
  - Air Quality Modelling predicts that NO_2 concentrations will decline (Large LEZ option by around 12 µg m^{-3}; Small LEZ option by around 10 µg m^{-3}) when compared to 2019 levels) to between 34 and 39 µg m^{-3}.
  - On Albyn Place, predicted concentrations are likely to remain just above 40 µg m^{-3} for both LEZ options (Large LEZ option: 41 µg m^{-3}; Small LEZ option: 43 µg m^{-3}), therefore model exceedances will remain

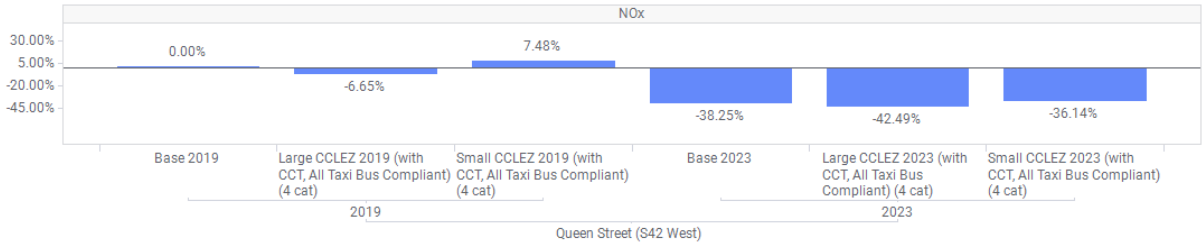


Figure 42: Relative Changes in Emission Rates (Queen Street) compared to Base 2019 Scenario.

Abbeyhill

- The introduction of either LEZ option is predicted to slightly increase emission rates on Abbeyhill compared to the Base Scenario.
- 2019 LEZ options:
  - NO_x emission rates are predicted to increase by 10% if the Large LEZ is selected and increase by 4% of the Small LEZ is selected (Figure 43).
  - Air Quality modelling predicts NO_2 concentrations would increase slightly (~ 1 µg m^{-3}) for both LEZ options. Current air quality modelling predicts concentrations at kerbside points to be around 40 µg m^{-3} threshold. A small increase in emissions may

result in some new model exceedances. Further detailed modelling will be carried out to predict concentrations at building façades.

- 2023 'future' LEZ options:
    - NO_x emission rates are expected to decline by between 33% and 40% for all scenarios when compared to the Base 2019 scenario. The variation suggests that there will still be some traffic displacement if the Large LEZ option is selected as emission rates are not falling as fast as the Base 2023 scenario.
    - Air Quality Modelling predicts that NO_2 concentrations will decline by around 5 µg m^{-3} (compared to 2019 levels) to around 34 µg m^{-3} and therefore model exceedances will be no longer exist.

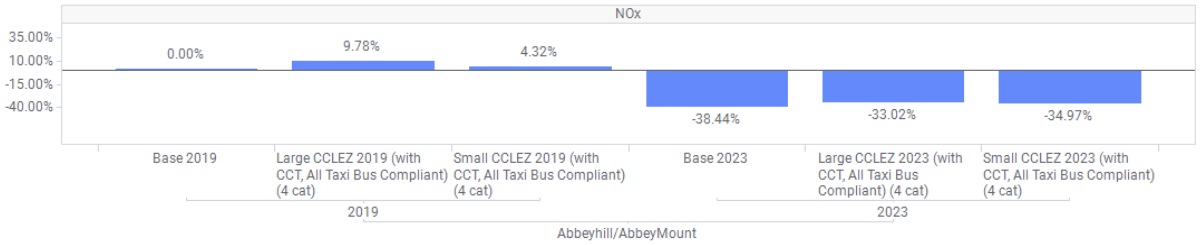


Figure 43: Relative Changes in Emission Rates (Abbeyhill) compared to Base 2019 Scenario.

West Preston Street

- The introduction of either LEZ option will increase emission rates on West Preston Street compared to the 2019 Base scenario.
- 2019 LEZ options:
    - NO_x emission rates are predicted to significantly increase by 37% if the Large LEZ is selected and by 40% of the Small LEZ is selected (Figure 44).
    - The ranking histograms in Figure 45 - Figure 47 show that the emission rates for the LEZ options will remain low.
    - Air Quality modelling predicts NO_2 concentrations are expected to increase from 33 µg m^{-3} to 37 µg m^{-3} for both LEZ options. This is predicted to be below the 40 µg m^{-3} threshold, therefore no new model exceedances are predicted.
- 2023 'future' LEZ options:
    - NO_x emission rates are expected to decline by 26% for either LEZ option and by 35% for the Base 2023 scenario, when compared to the Base 2019 scenario. The variation suggests that there will still be some traffic displacement if the Large LEZ is selected as emissions are not falling as fast as the Base 2023 scenario.
    - Air Quality Modelling predicts that NO_2 concentrations will decline by around 3 µg m^{-3} (compared to 2019 levels) to around 30 µg m^{-3} and therefore model exceedances will be no longer exist.

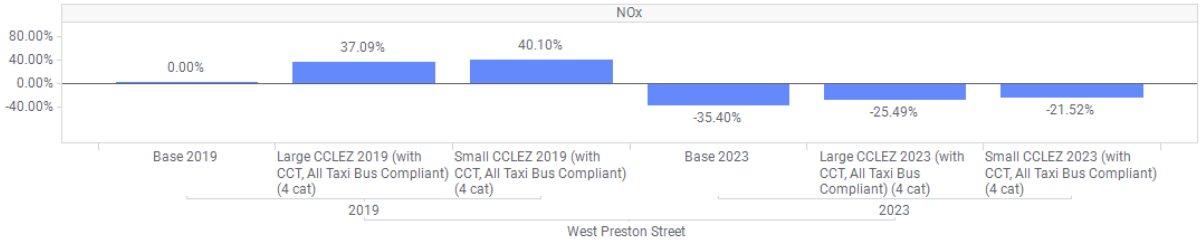


Figure 44: Relative Changes in Emission Rates (West Preston Street) compared to Base 2019 Scenario.

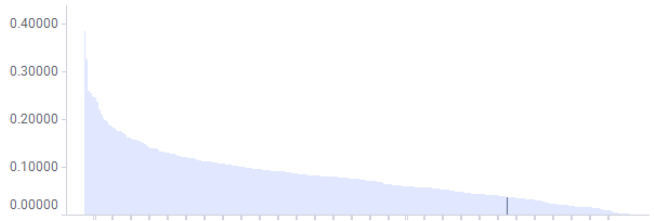


Figure 45: Base Scenario (2019) Emission Rates ranked for each road, showing West Preston Street highlighted

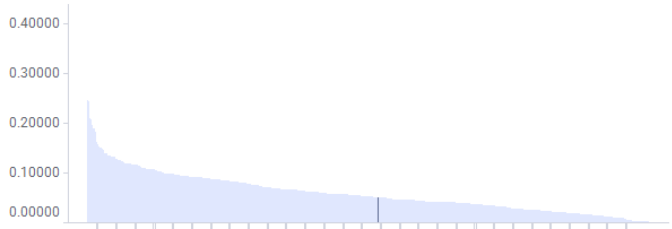


Figure 46: Large LEZ option (2019) Emission Rates ranked for each road, showing West Preston Street highlighted

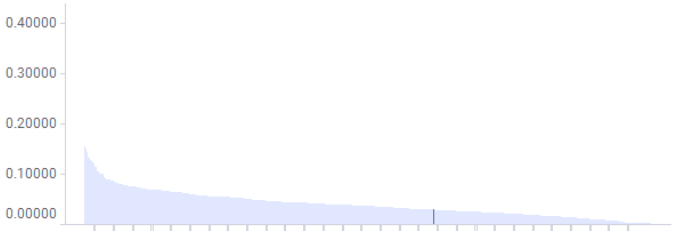


Figure 47: Small LEZ option (2019) Emission Rates ranked for each road, showing West Preston Street highlighted

Melville Drive (Meadows)

- The introduction of either LEZ option will slightly increase emission rates on Melville Drive compared to the 2019 Base scenario.
- 2019 LEZ options:
    - NO_x emission rates are predicted to slightly increase by 0.7% if the Large LEZ is selected and increase by 5.5% of the Small LEZ is selected (Figure 48).
    - Air Quality modelling predicts negligible increases of NO_2 concentrations; they are currently around 33 µg m^{-3} and so no new exceedances are predicted.
- 2023 'future' LEZ options:

- NO_x emission rates are expected to decline by around 35% for all scenarios when compared to the Base 2019 scenario.
- As emission changes between the LEZ options and Base scenario for the relevant year are very small, the effect on air quality due to LEZ traffic displacement is negligible.

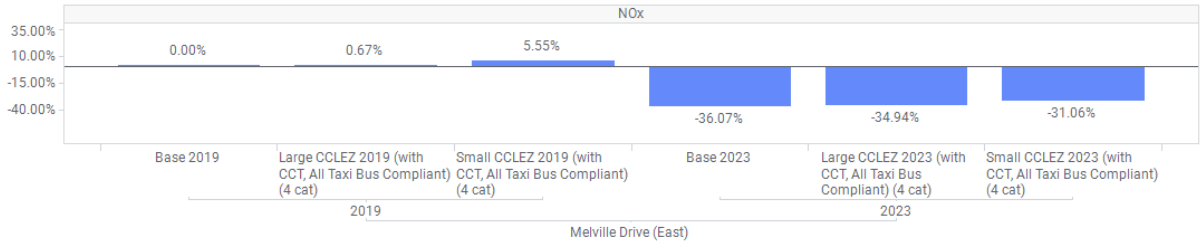


Figure 48: Relative Changes in Emission Rates (Melville Drive) compared to Base 2019 Scenario.

Lothian Road (between West Approach Road and Lothian Road)

- Lothian Road is within the Large LEZ option (all traffic will be compliant), but not in the Small LEZ option (where non-compliant traffic can continue to use this road).
- The introduction of either LEZ option will reduce emissions on Lothian Road compared to the 2019 Base run.
- 2019 LEZ options:
  - NO_x emission rates are predicted to decline by 47% if the Large LEZ is selected and by 28% of the Small LEZ is selected.
  - Although non-compliant traffic being able to use Lothian Road for the Small LEZ option, the large reduction in emissions is due to a large number of buses and taxis on this road which will have become compliant with LEZ rules.
  - Despite large emission reductions, model air quality exceedances are predicted to remain for both LEZ options, though the Large LEZ would have a greater impact on improving air quality. Air Quality modelling predictions for NO_2 concentrations are:
    - Base 2019: 60-70 µg m^{-3}
    - Large LEZ option: 45-55 µg m^{-3}
    - Small LEZ option: 55-65 µg m^{-3}
- 2023 'future' LEZ options
  - NO_x emission rates are expected to decline by (when compared to Base 2019 levels):
    - Base 2023: 44%
    - Large LEZ option: 60%
    - Small LEZ option: 52%
  - Air Quality modelling predictions for NO_2 concentrations are:
    - Large LEZ option: 35-45 µg m^{-3}
    - Small LEZ option: 43-50 µg m^{-3}
  - Model exceedances are still predicted, however concentrations are around 5 µg m^{-3} lower on Lothian Road if the Large LEZ option is selected in preference to the Small LEZ option

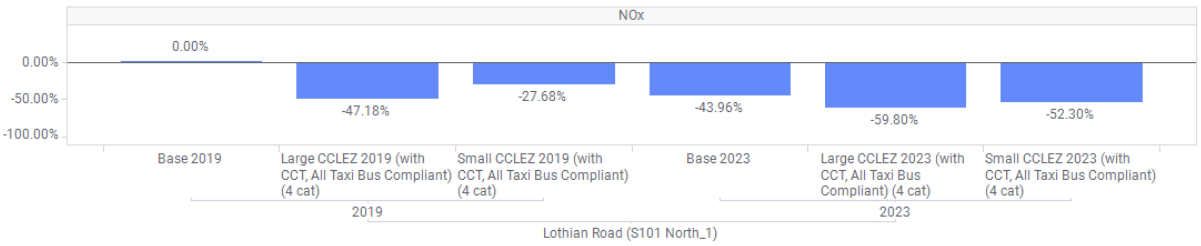


Figure 49: Relative Changes in Emission Rates (Lothian Road) compared to Base 2019 Scenario.

North Charlotte Street

- North Charlotte Street is within the Large LEZ (all traffic will be compliant), but not in the Small LEZ (where non-compliant traffic can continue to use this road).
- 2019 LEZ options:
- If the Large LEZ option is selected, NO_x emission rates are predicted to decline (Figure 50), however if the Small LEZ option is selected, NO_x emissions are predicted to increase.
    - Predicted NO_x emission changes:
        - Large LEZ option: NO_x emission rates decline by 31%
        - Small LEZ option: NO_x emissions rates increase by 14%
    - NO_x emission rates are predicted to increase for the Small LEZ as there are very few buses on this road (all buses becoming compliant accounts for emission reduction on Lothian Road)
    - Air Quality modelling predicts NO_2 concentrations are slightly increase for the Small LEZ option, but decline for the Large LEZ option. Predicted NO_2 concentrations are:
        - Base 2019: 40 µg m^{-3}
        - Large LEZ: 33 µg m^{-3}
        - Small LEZ: 41 µg m^{-3}
- 2023 'future' LEZ options:
    - NO_x emissions are predicted to decline for all options, however the Large LEZ option will still have an impact on reducing emissions on this road in the future.
    - Air Quality Modelling predicts that NO_2 concentrations will decline by around 7-10 µg m^{-3} (compared to 2019 levels) to around 30 µg m^{-3} and therefore model exceedances will be no longer exist.

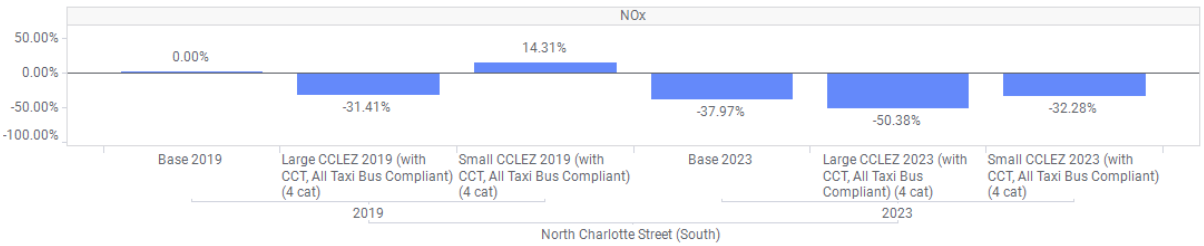


Figure 50: Relative Changes in Emission Rates (North Charlotte Street) compared to Base 2019 Scenario.

Detailed Analysis in other AQMA's

St John's Road

- St John's Road is part of the Corstorphine AQMA.
- 2019 LEZ options:
  - NO_x emission rates are predicted to decline by 24% for both LEZ options (Figure 51). This is likely to be due to buses and taxis moving to full compliance so they can operate within the city centre LEZ regardless of whether this is the Large or Small LEZ.
  - Air Quality modelling predicts NO_2 model concentrations will decline from 53 µg m^{-3} to 48 µg m^{-3}, so model exceedances are expected to remain.
- 2023 'future' LEZ options:
  - NO_x emission rates are predicted to decline by 40% for the Base 2023 scenario and by around 48% for both LEZ options.
  - Air Quality Modelling predicts that NO_2 concentrations will decline by around 10-15 µg m^{-3} (compared to 2019 levels) to around 30 µg m^{-3} on most of St John's Road and therefore, model exceedances at most locations are expected to no longer exist.
  - However, predicted concentrations on the section between Kirk Loan and Clermiston Road are expected to remain just above 40 µg m^{-3} and model exceedances remain there.

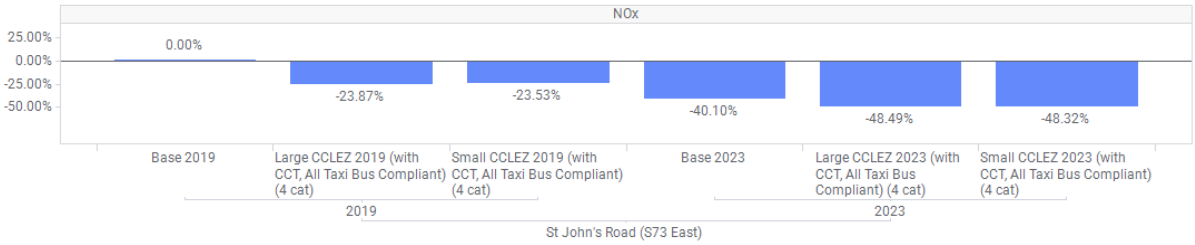


Figure 51: Relative Changes in Emission Rates (St Johns Road) compared to Base 2019 Scenario.

Ferry Road (by Inverleith Row)

- This street is in part of the Inverleith AQMA.
- 2019 LEZ options:
  - NO_x emission rates are predicted to decline by 7-8% for both LEZ options when compared to the Base 2019 scenario (Figure 52). This is likely to be due to buses and taxis moving to full compliance so they can operate within the city centre LEZ, regardless of whether this is the Large or Small LEZ.
  - Air Quality modelling predicts NO_2 concentrations decline slightly (by around 1 µg m^{-3}) for both LEZ options. Current air quality modelling predicts concentrations at kerbside points to be around the 40 µg m^{-3} threshold. A small reduction in emissions may not remove all model exceedances (note that monitored data shows no exceedances since 2018). Further detailed modelling will be carried out to predict concentrations at building façades.
- 2023 'future' LEZ options:
  - NO_x emissions are predicted to decline significantly by 40-43% for the 2023 scenarios.

- Air Quality Modelling predicts that NO_2 concentrations will decline by around 10 µg m^{-3} (compared to 2019 levels) to between 30 and 34 µg m^{-3} and therefore model exceedances will be no longer exist.

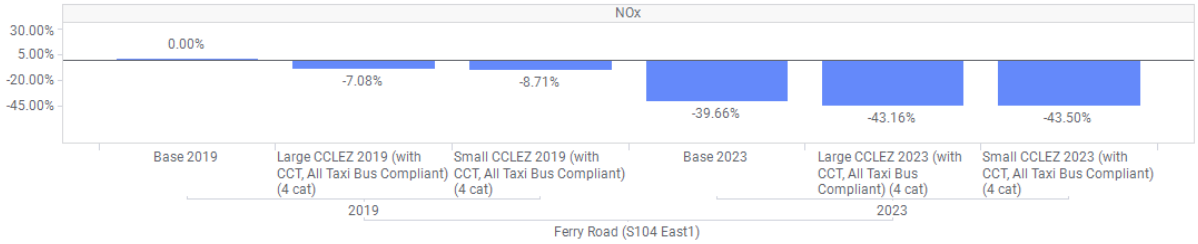


Figure 52: Relative Changes in Emission Rates (Ferry Road, by Inverleith Row) compared to Base 2019 Scenario.

Great Junction Street (by Foot of Leith Walk)

- This street is in part of the Leith AQMA.
- 2019 LEZ options:
  - NO_x emission rates are predicted to decline by 32% for both LEZ options when compared to the Base 2019 scenario (Figure 53). This is likely to be due to buses and taxis moving to full compliance so they can operate within the city centre LEZ, regardless of whether this is the Large or Small LEZ.
  - Air Quality modelling predicts NO_2 concentrations decline slightly (by around 3 µg m^{-3}) for both LEZ options. Current air quality modelling predicts concentrations at kerbside points to be around the 40 µg m^{-3} threshold. A small reduction in emissions may not remove all model exceedances (note that monitored data shows no exceedances since 2017). Further detailed modelling will be carried out to predict concentrations at building façades.
- 2023 'future' LEZ options:
  - NO_x emission rates are predicted to decline significantly by 43-55% for the 2023 scenarios.
  - Air Quality Modelling predicts that NO_2 concentrations will decline by around 12 µg m^{-3} (compared to 2019 levels) to around 32 µg m^{-3} and therefore model exceedances will be no longer exist.

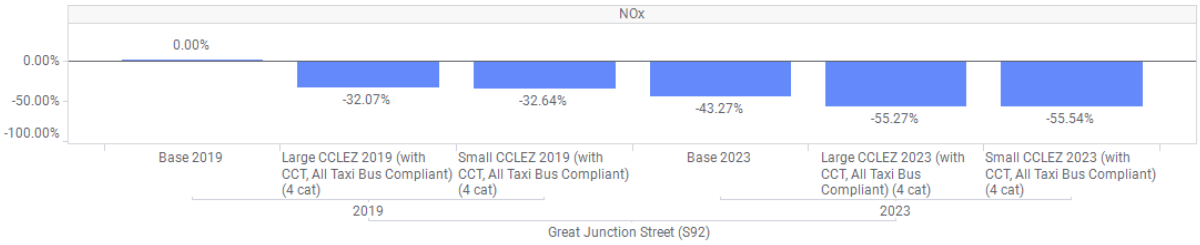


Figure 53: Relative Changes in Emission Rates (Great Junction Street, by the Foot of the Walk) compared to Base 2019 Scenario.

Next Steps

- Complete air quality modelling which has been delayed to due to the cyberattack that reduced SEPA's modelling capabilities.
- Source apportionment to identify the impact of each vehicle class on air quality on different roads.
- Carry out an analysis of Particulate Matter and Carbon Dioxide emissions.
- Further ANPR surveys are required to monitor the changes in the fleet so that the rate of air quality improvements can be monitored.