MAYOR OF LONDON

EXPANDED ULTRA LOW EMISSION ZONE – SIX MONTH REPORT

INCLUDING LOW EMISSION ZONE – ONE YEAR REPORT

July 2022

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Key Findings

On 8 April 2019 the Mayor of London launched the world's first 24-hour Ultra Low Emission Zone (ULEZ) in central London. On 25 October 2021 the zone was expanded up to, but not including, the North and South Circular Roads. The ULEZ is now 18 times the size of the original area and covers 4 million people – over a third of London's population.

The ULEZ does not operate in isolation. It operates in conjunction with the London-wide Low Emission Zone (LEZ). This was originally launched in 2008. It is the oldest of the capital's emission control schemes and applies to large and heavy vehicles. In March 2021 enforcement of tougher emission standards for the LEZ began. Prior to this, the standards hadn't changed since 2012. The LEZ standards are now the same as the ULEZ standards for most large and heavy vehicles.

Six months on from the ULEZ expansion and over a year on from the enforcement of tighter LEZ standards the data indicate that these schemes are having a significant impact on the number of older, more polluting vehicles seen driving in London and the levels of harmful pollution Londoners are exposed to.

- **A bigger share of vehicles in London are cleaner.** Six months after the launch of the ULEZ expansion nearly 94 per cent of vehicles seen driving in the whole zone meet the strict ULEZ standards on an average day, up from 87 per cent in the weeks before the zone expanded and up from 39 per cent in 2017 when impacts associated with the ULEZ began. The compliance rate on boundary roads is 90 per cent and the compliance rate in outer London is 85 per cent.

- **There are fewer older, more polluting vehicles in the zone.** There were 67,000 fewer non-compliant vehicles in the zone on an average day compared with the period right before the ULEZ expanded, down from an average of 124,000 daily vehicles. This is a reduction of 54 per cent.

- **The Low Emission Zone continues to have an impact.** Large and heavy vehicles, which fall under the London-wide LEZ, have a compliance rate of 96 per cent, up from an estimated 48 per cent in February 2017.

- **There has been an overall reduction in vehicles and traffic flows in the zone.** Overall, there were 21,000 fewer vehicles seen in the zone on an average day (a reduction of 2 per cent) and early estimates suggest traffic flows are around 2 per cent lower than the weeks before the expansion launched. However, many factors are currently affecting traffic trends in London and we will continue to review the data to better understand the impact of ULEZ expansion in the longer term.

- **Drivers are ditching diesel cars.** On average there were 44,000 fewer diesel cars driving in the zone each day – a 20 per cent decrease since the weeks before the ULEZ expanded.

- **This means people in the zone are breathing cleaner air.** The amount of pollution in the air, the concentration, is what ultimately impacts people's health. Harmful NO_2 concentrations alongside roads in inner London are estimated to be 20 per cent lower than they would have been without the ULEZ and its expansion. In central London, NO_2 concentrations are estimated to be 44 per cent lower than they would have been. This decrease in concentrations close to roads would have also led to reduced air pollution in locations away from traffic.

- **The air is also cleaner on the boundary.** All monitoring sites on the boundary of the expanded zone have seen reductions in NO_2 concentrations, with an estimated 17-24 per cent reduction in pollution on the boundary compared to a scenario without the ULEZ.

Introduction

We would all be healthier if we breathed cleaner air. Research has shown that exposure to air pollution – even at low levels – has a big impact on health at all life stages, from development in the womb to the end of life.

Long standing structural inequalities in our society mean that the health impacts of pollution fall disproportionally on certain communities, affecting the poorest, the youngest, the oldest, those with pre-existing health conditions and those from Black, Asian and minority ethnic groups.

A study by Imperial College London found that in 2019 toxic air contributed to the premature deaths of more than 4,000 Londoners[1], with the greatest number of deaths attributable to air pollution in outer London boroughs, mainly due to the higher proportion of elderly people in these areas. Over 600,000 Londoners live with a lung condition and are more vulnerable to the impacts of air pollution, with more than half of these people living in outer London.

To reduce the health burden of air pollution in London, on 8 April 2019 the Mayor of London launched the world's first 24-hour Ultra Low Emission Zone (ULEZ) in central London. On 25 October 2021 the Mayor expanded the ULEZ up to, but not including, the North and South Circular Roads, making it 18 times larger than the central London zone.

To complement this change, the standards for the existing London-wide Low Emission Zone (LEZ) for buses, HGVs and coaches were tightened on 21 March 2021, the first time the standards have changed since 2012. These standards are now the same as the ULEZ standards meaning there is only one charge for most large and heavy vehicles operating in London.

By reducing pollution and protecting the health of the poorest and most marginalised, the expansion of ULEZ and tightening the LEZ standards are important steps towards a fairer and healthier society.

What is the ULEZ?

The aim of the ULEZ is to reduce harmful emissions from road transport by disincentivising the use of older, more polluting vehicles. The ULEZ specifically targets the air pollutants that are most harmful to human health: nitrogen dioxide (NO_2) and particulate matter (PM). NO_2 is an invisible gas that comes mostly from burning fuels and other materials. PM is categorised by its size and is made up of little bits of material that are invisible to the naked eye. Fine particulate matter ($PM_{2.5}$) is the air pollutant considered by scientists to be the most harmful to health.

1 https://www.london.gov.uk/sites/default/files/london_health_burden_of_current_air_pollution_and_future_health_benefits_of_mayoral_air_quality_policies_january2020.pdf

The emissions of these pollutants from road vehicles are regulated by the Euro standards. It is a legal requirement for vehicles to meet the Euro standard emission limits to be sold in the European Union and United Kingdom.

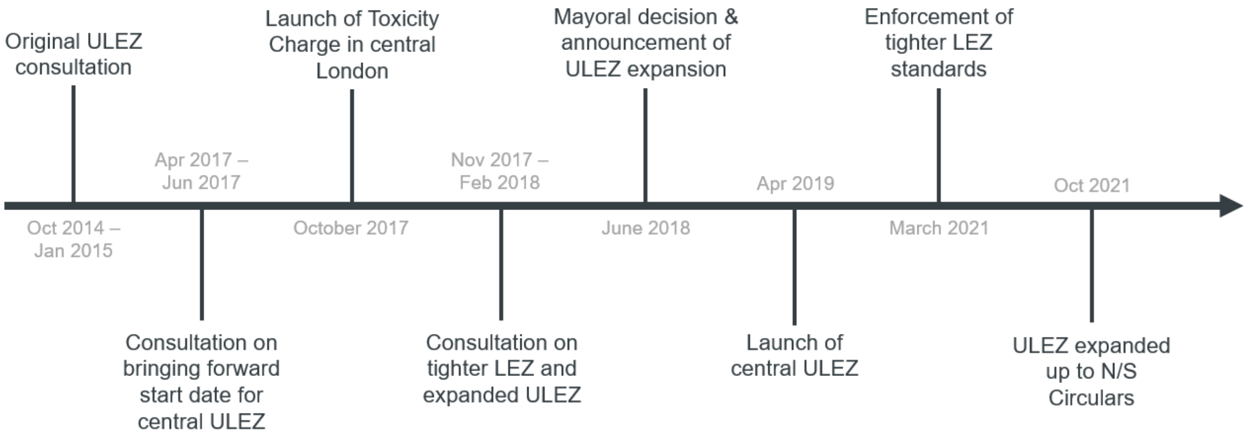

Figure 1: Timeline of successive emission-based charging schemes in London

Figure 1 above shows the timeline of the development and implementation of the various stages of the ULEZ, including the Toxicity Charge (the precursor to the ULEZ). Figure 2 below is a detailed map of the areas covered by the original central London ULEZ and the existing, recently expanded ULEZ. For the purposes of this report, the term ULEZ is used to describe the existing ULEZ covering the whole of the recently expanded zone (up to, but not including, the North and South Circular Roads). The original ULEZ in central London will be referred to as the central ULEZ.

The ULEZ operates 24 hours a day, every day of the year except Christmas Day (25 December). Vehicles must meet strict emission standards to drive in the ULEZ area:

- Euro 4 for petrol cars and small vans (registered new from January 2006)
- Euro 6 for diesel cars and small vans (registered new from September 2015)
- Euro 3 for motorcycles and other L-category vehicles (registered new from July 2007)

Vehicles that do not meet these standards must pay a charge of £12.50 per day to travel in the zone.

To help improve air quality and public health, tackle the climate emergency and reduce traffic congestion across Greater London, on 20 May 2022 Transport for London (TfL) launched a consultation to expand the ULEZ London-wide, to the same boundary as the LEZ. A decision on this policy is expected in late 2022.

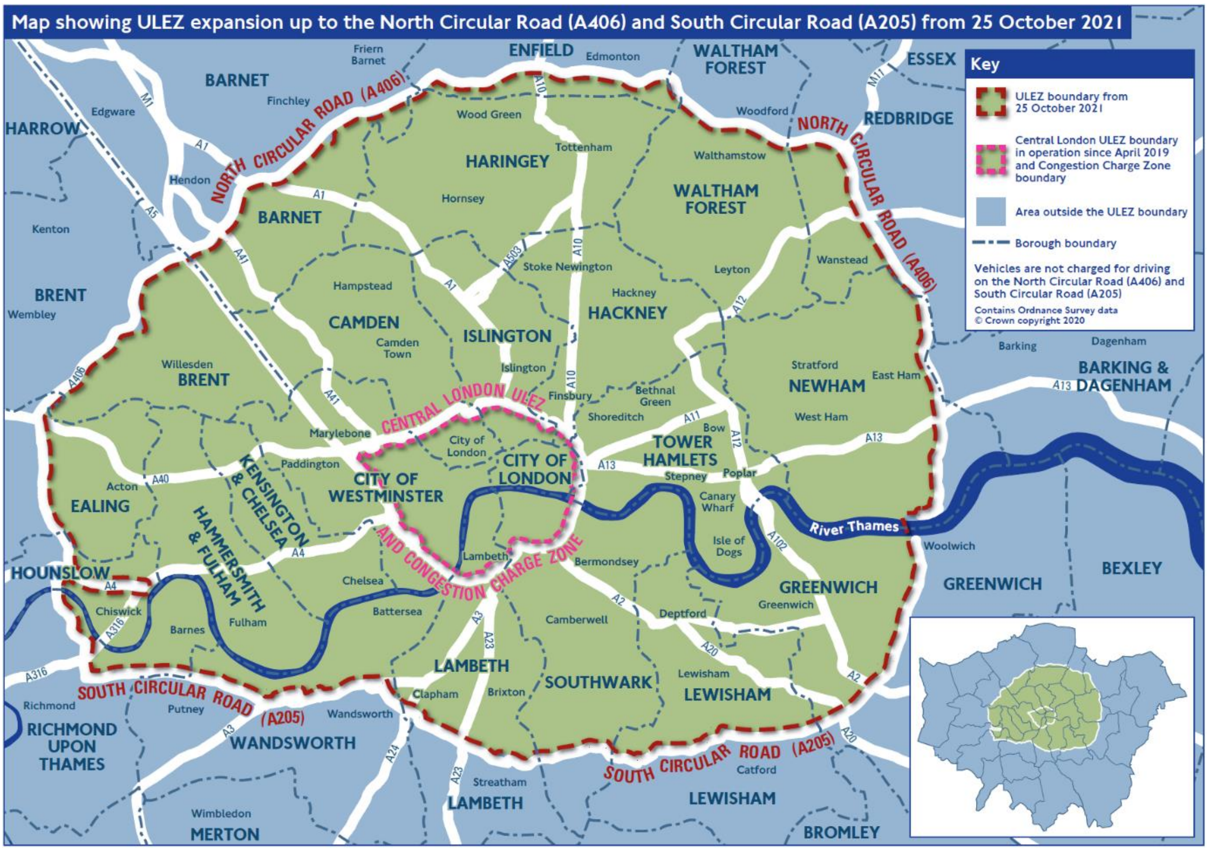

Figure 2: Map of the ULEZ

What is the London-wide Low Emission Zone (LEZ)?

The London-wide Low Emission Zone was introduced in 2008 and operates 24 hours a day, every day of the year. On 1 March 2021 the emission standards for the LEZ were strengthened for heavy vehicles, the new standards are:

- Euro VI for buses coaches and HGVs/vans over 3.5T (vehicles registered new from September 2016),
- Euro 3 for particulate matter only for vans between 1.2T and 3.5T and minibuses under 5T (vehicles registered new from January 2001).

Vehicles that do not meet these standards must pay a charge of £100 per day. Heavy vehicles that do not meet the lower Euro IV standard must pay a higher charge of £300 per day.

For the majority of vehicles, the strengthening of the LEZ standards means that they are not separately subject to LEZ and ULEZ standards. The exception is for vans between 1.2T and 3.5T and minibuses under 5T where the LEZ and ULEZ standards are different. These vehicles need to comply with both schemes if they drive within the ULEZ area or pay both sets of charges.

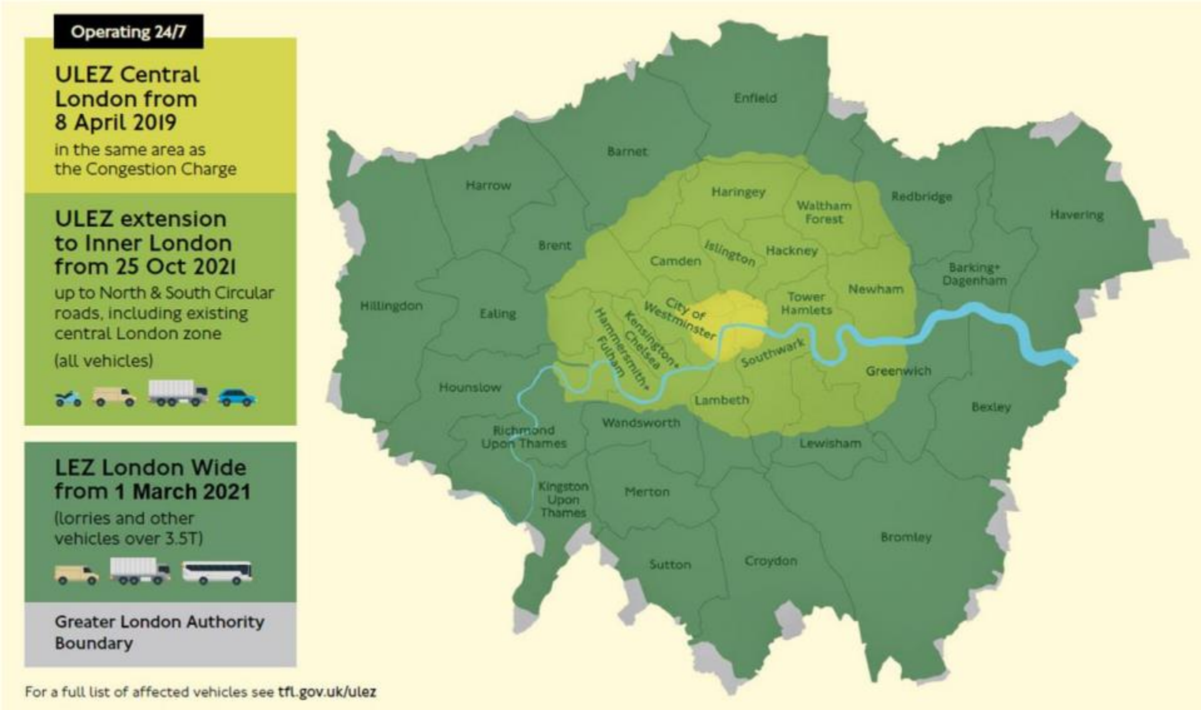

Figure 3: Map of the Low Emission Zone (LEZ) and ULEZ boundaries

What to expect in this report

Tougher LEZ standards were enforced from March 2021 and the expansion of the ULEZ took place on the 25 October 2021. This report covers the first year of the stronger LEZ and the first 6 months of operation of the expanded ULEZ. It provides the first analysis of the impact of expanding the ULEZ on air pollution concentrations in inner London, as well as compliance rates, traffic and fleet composition.

Vehicles that are subject solely to the LEZ are excluded from the ULEZ compliance rates but are reported separately, later in the report.

This is the latest in a series of reports evaluating the impact of the ULEZ and London-wide LEZ for heavy vehicles. Previous reports include:

- Central London Ultra Low Emission Zone – First Month Report
- Central London Ultra Low Emission Zone – Four Month Report
- Central London Ultra Low Emission Zone – Six Month Report
- Central London Ultra Low Emission Zone – Ten Month Report
- Central London Ultra Low Emission Zone 2020 Report
- London Low Emission Zone: Six Month Report
- Expanded Ultra Low Emission Zone – First Month Report

An updated evaluation will be published once 12 months of data on the ULEZ expansion is available.

Assessing the impacts of the expanded ULEZ and the LEZ

The purpose of the ULEZ and LEZ is to improve air quality in and around London by reducing the number of older and more polluting vehicles that drive in the city. The impact of the ULEZ and LEZ can be assessed using a number of different metrics including:

- Number of vehicles and compliance rates
- Modelling of vehicle emissions (which will be covered in the next evaluation report)
- Changes in fleet composition
- Air quality monitoring
- Traffic flow data

Compliance, emissions and concentrations

Vehicle compliance refers to the number of vehicles that meet the ULEZ emission standards. Vehicles that do not comply and are not exempt must pay the daily charge or be liable for enforcement action.

To comply with the ULEZ, a vehicle must meet the relevant standards (Euro 4 for petrol, Euro 6 for diesel and Euro 3 for motorbikes). Schemes such as the ULEZ not only incentivise people to drive cleaner vehicles, but also reduce the number of vehicles that are on the road and reduce pollution and carbon emissions in this way.

As the vehicle fleet in London becomes cleaner because of the Mayor's policies, we expect to see a reduction in emissions from vehicles operating in London. Policies like the ULEZ and LEZ are effective at reducing emissions because they incentivise the uptake of cleaner vehicles above and beyond the natural turnover of vehicles that would be expected.

Estimating emissions reductions requires detailed traffic data by vehicle type across London and this data has not been available at the required level of detail for the time periods covered in this report. Further analysis will be undertaken for the future One Year Report, following publication of the Department for Transport fleet composition data.

Ultimately it is the amount of pollution in the air, the concentration, that matters for people's health. While reducing emissions is the vital step in reducing concentrations there are other important factors that affect concentrations, particularly the impact of weather, natural seasonal variations and, for NO_2, significant atmospheric chemistry processes involving other pollutants and sunlight. The evidence indicates that long term exposure is the key driver of health impacts from air pollution. It is for these reasons that the focus for measuring air pollution concentrations has traditionally focused on long-term measurements, usually annual means. This report includes a preliminary assessment of measured pollutant concentrations, but a fuller picture will properly emerge in the One Year Report.

Limitations of this analysis

The impact of the COVID-19 pandemic (“the pandemic”) and individual, regional and national responses to address it, mean that 2020 and 2021 have been different from previous years. This is particularly so for travel and transport as people reacted to lockdown measures and wider concerns about the pandemic by changing their work and travel habits.

The pandemic impacted traffic volumes in London in 2020 and 2021, with central London being especially affected. This will in turn have impacted pollution levels across the city. In July 2021 most lockdown restrictions were formally lifted, and much of the economy has now returned to near normal levels of activity. However, central London traffic levels are still not back to pre-pandemic levels.

The fuel shortage in late September and early October 2021 was another factor impacting travel habits and the cost-of-living crisis emerging in early 2022 is also affecting traffic patterns. These factors mean that traffic patterns for the period 2020 to present are not as usual or comparable to previous years, which consequently affects emissions data and hence pollution concentrations. This makes it difficult to definitively attribute changes in emissions and concentrations to the impacts of the ULEZ, its expansion and changes to the LEZ. However, compliance rates remain a robust indicator of the impact of the scheme.

Air pollution concentrations are affected by many different factors including the weather and regional contributions from outside London, as well as impacts from other local schemes. Therefore, analysis of air quality monitoring data will need to continue over time. At present reductions in air pollution concentrations are reported for locations that have reference air quality monitoring stations[2].

[2] Air quality data used in this analysis is from the reference monitors in the London Air Quality Network and Air Quality England Network. This is because both provide data going back many years and provide the highest accuracy data. Data from the Breathe London Network of low-cost sensors is not included in this report as it uses different measurement techniques.

Number of vehicles and compliance rates

Vehicle compliance refers to the number of vehicles that meet the ULEZ/LEZ emission standards. Vehicles that do not comply and are not exempt must pay the daily charge or be liable for enforcement action. The higher the compliance rate the more successful the scheme has been in terms of accelerating the transition to lower pollution vehicles. This means compliance rates are a key metric in determining the success of the expanded ULEZ and the strengthened LEZ. Vehicles which do not meet the ULEZ/LEZ standards are described in this report as "non-compliant".

Non-compliant vehicles do not meet the strict ULEZ emission standards and their drivers have either:

- Paid the daily charge
- Incurred a penalty charge

Not been required to pay the daily ULEZ charge as they are eligible for a 100% discount or exemption**Error! Reference source not found.**
Table 1 below details the emission standards for each vehicle type and which of the two schemes, ULEZ or LEZ, they fall under.

Table 1: Vehicle types, emission limits and relevant scheme for compliance figures

Vehicle type	Included in ULEZ compliance?	Emissions limits	Relevant scheme
Cars	Yes	Euro 4 (Petrol) Euro 6 (Diesel)	ULEZ
Motorbikes	Yes	Euro 3	ULEZ
Smaller vans	Yes	Euro 4 (Petrol) Euro 6 (Diesel)	ULEZ
Larger vans and minibuses (vans up to and including 3.5 t, minibuses up to and including 5t)	Yes	Euro 4 (Petrol) Euro 6 (Diesel)	ULEZ Diesel vehicles are additionally subject to a LEZ standard (Euro 3 for particulates) London-wide
Heavy diesel vehicles (incl. buses and coaches over 5t and	No	Euro VI	LEZ (London-wide)

HGVs and other heavy vehicles over 3.5t)			
Taxis (Black cabs)	No	All new taxis required to be "Zero Emission Capable" since 2018 and are subject to age limits and other restrictions to reduce emissions.	Taxi licensing

ULEZ compliance

Table 2 below shows the growth in compliance rates for different vehicle types after the first six months of the expanded ULEZ, compared to indicative figures prior to the launch and from 2017 when the Mayor announced plans for expansion and confirmed the T-Charge, the predecessor to the ULEZ and its expansion.

Table 2 : Daily average and proportion of compliant vehicles detected in the ULEZ

Vehicle type	Feb-17*	Oct – 21 (prior to launch) §	May-22
All ULEZ vehicles	39%	86.9%	93.8%
Cars (incl. PHV, excl taxi)	44%	89.0%	95.4%
Vans (up to and incl. 3.5 tonnes)	12%	71.0%	82.6%
Motorcycles	50%	95.7%	96.7%

*****_February 2017 based on data from the London Atmospheric Emissions Inventory, except for Motorcycles which is based on Defra fleet composition data._

§ _Based on indicative data gathered from 12 to the 20 October_

Table 3 below shows the compliance rates and vehicle numbers for the first six months of operation of the expanded ULEZ, compared to figures from the month immediately prior to the launch of the expansion (October 2021).

Table 3: Daily average number and proportion of compliant vehicles detected in the zone per month

Date	Number of vehicles driving in the charging zone			Proportions of vehicles driving in the charging zone	
	Unique vehicles detected in zone*	Non-compliant vehicles	Compliant vehicles	Non-compliant vehicles	Compliant vehicles
Oct – 21 (prior to launch) §	950,000	124,000	826,000	13.1%	86.9%
Nov-21	941,000	75,000	866,000	8.0%	92.0%
Dec-21	886,000	66,000	820,000	7.4%	92.6%
Jan-22	862,000	57,000	806,000	6.6%	93.4%
Feb-22	909,000	61,000	848,000	6.7%	93.3%
Mar-22	931,000	61,000	869,000	6.6%	93.4%
Apr-22	894,000	57,000	837,000	6.4%	93.6%
May-22	929,000	57,000	871,000	6.2%	93.8%
Change Oct – May 22	- 21,000	- 67,000	45,000	-6.9ppt	6.9ppt
% Change	-2.2%	-54.0%	5.4%		

§ *Based on indicative data gathered from 12 to the 20 October*

Table 3 shows that compliance within the expanded ULEZ is extremely high reaching 93.8 per cent in May 2022. The daily average number of older, more polluting vehicles detected in the zone has been steadily reducing from 124,000 prior to launch to 57,000 in May 2022. There has been a 54 per cent reduction in the number of non-compliant vehicles entering the zone from October 21 to May 2022.

The overall number of vehicles detected in the zone has reduced further since the expansion of the scheme, with a two per cent reduction compared to the month before launch. External factors including the continued rise in fuel prices and the return to office-based work following partial lockdowns in the winter and early spring are also likely influencing this data, however, the relative contribution of these competing factors is not known.

More detail on the changes in vehicle numbers by vehicle type is shown in Tables 4, 5, 6 and 7 below.

Table 4: Changes in the daily average number and proportion of cars (M1 and PHV, excl. Taxis) detected in the zone

Date	Number of vehicles driving in the charging zone			Proportions of vehicles driving in the charging zone	
	Unique vehicles detected in zone*	Non-compliant vehicles	Compliant vehicles	Non-compliant vehicles	Compliant vehicles
Oct – 21 (prior to launch) §	792,000	87,000	706,000	11.0%	89.0%
Nov-21	784,000	47,000	737,000	6.0%	94.0%
Dec-21	756,000	44,000	712,000	5.8%	94.2%
Jan-22	730,000	36,000	694,000	4.9%	95.1%
Feb-22	762,000	38,000	724,000	5.0%	95.0%
Mar-22	775,000	37,000	738,000	4.8%	95.2%
Apr-22	751,000	35,000	715,000	4.7%	95.3%
May-22	778,000	35,000	742,000	4.6%	95.4%
Change Oct – May 22	-14,000	-52,000	36,000	-6.5ppt	6.5ppt
% Change	-1.8%	-59.8%	5.1%		

§ *Based on indicative data gathered from 12 to the 20 October*

Table 5: Changes in the daily average number and proportion of diesel cars (M1 and PHV, excl. Taxis) detected in the zone

Date	Number of vehicles driving in the charging zone			Proportions of vehicles driving in the charging zone	
	Unique vehicles detected in zone*	Non-compliant vehicles	Compliant vehicles	Non-compliant vehicles	Compliant vehicles
Oct – 21 (prior to launch) §	216,000	79,000	138,000	36.4%	63.6%
Nov-21	186,000	43,000	143,000	23.0%	77.0%
Dec-21	177,000	40,000	137,000	22.5%	77.5%
Jan-22	164,000	32,000	131,000	19.8%	80.2%
Feb-22	173,000	34,000	139,000	19.9%	80.1%
Mar-22	175,000	34,000	141,000	19.4%	80.6%
Apr-22	167,000	32,000	135,000	19.2%	80.8%
May-22	172,000	32,000	140,000	18.6%	81.4%
Change Oct – May 22	- 44,000	- 47,000	2,000	-17.8ppt	17.8ppt
% Change	-20.4%	-59.5%	1.4%		

§ *Based on indicative data gathered from 12 to the 20 October*

Table 6: Changes in the daily average number and proportion of vans (N1) detected in the zone

Date	Number of vehicles driving in the charging zone			Proportions of vehicles driving in the charging zone	
	Unique vehicles detected in zone*	Non-compliant vehicles	Compliant vehicles	Non-compliant vehicles	Compliant vehicles
Oct – 21 (prior to launch) §	128,000	35,000	93,000	29.0%	71.0%
Nov-21	127,000	27,000	100,000	21.4%	78.6%
Dec-21	105,000	21,000	84,000	20.0%	80.0%
Jan-22	107,000	20,000	88,000	18.3%	81.7%
Feb-22	120,000	22,000	98,000	18.3%	81.7%
Mar-22	125,000	23,000	102,000	18.2%	81.8%
Apr-22	113,000	20,000	93,000	17.9%	82.1%
May-22	119,000	21,000	98,000	17.4%	82.6%
Change Oct – May 22	- 9,000	- 14,000	5,000	-11.6ppt	11.6ppt
% Change	-7.0%	-40.0%	5.4%		

§ *Based on indicative data gathered from 12 to the 20 October*

Table 7: Changes in the daily average number and proportion of motorcycles (L) detected in the zone

Date	Number of vehicles driving in the charging zone			Proportions of vehicles driving in the charging zone	
	Unique vehicles detected in zone*	Non-compliant vehicles	Compliant vehicles	Non-compliant vehicles	Compliant vehicles
Oct – 21 (prior to launch) §	27,700	1,200	26,600	4.3%	95.7%
Nov-21	28,500	1,000	27,500	3.4%	96.6%
Dec-21	23,100	800	22,300	3.4%	96.6%
Jan-22	23,600	800	22,900	3.3%	96.7%
Feb-22	25,900	900	25,100	3.3%	96.7%
Mar-22	28,900	1,000	28,000	3.3%	96.7%
Apr-22	28,800	900	27,800	3.3%	96.7%
May-22	30,500	1,000	29,500	3.3%	96.7%
Change Oct – May 22	2,800	- 200	2,900	-1.0ppt	1.0ppt
% Change	10.1%	-16.7%	10.9%		

§ *Based on indicative data gathered from 12 to the 20 October*

Diesel vehicles produce emissions which are particularly harmful to human health. Diesel exhaust is a known carcinogen, and diesel cars generally emit more NOx and $PM_{2.5}$ than petrol cars, especially in dense urban environments like London. This is why the ULEZ standard is higher for diesel cars (Euro 6) than for petrol cars (Euro 4).

As shown in Table 4 above, the ULEZ expansion has been particularly successful in helping reduce the number of non-compliant diesel cars driving in the zone. Prior to the ULEZ expansion, 64 per cent of diesel cars met the ULEZ standard. This has increased to 81 per cent, a jump of nearly 18 percentage points. This means there are currently around 60 per cent fewer polluting diesel cars in the zone each day.

It is important to note that overall numbers of compliant cars detected in the zone has gone up by 36,000 as some drivers are now using compliant vehicles. However, the data suggests that people are not just replacing one diesel car with another diesel car, as overall there were 44,000 fewer diesel vehicles in the zone, a reduction of 20 per cent.

LEZ compliance

Table 8 shows the steady growth in compliance rates for large and heavy vehicles which fall under the London-wide LEZ. Over 96 per cent of large and heavy vehicles now meet the strict standards, which are the same as the ULEZ standards. TfL buses are included in these figures. From April 2019 all buses operating in central London met or exceeded the ULEZ standards and since January 2021, all TfL buses meet or exceed the new tougher LEZ standards.

More detailed information on the progression of emission standards under the LEZ is available in the previous London Low Emission Zone 6 Month Report.

Table 8: LEZ compliance rates

Month	LEZ Compliance Rate (new standards)
Feb – 2017 baseline[§]	48%
May-19[*]	71.0%
Sep-19[*]	73.7%
Jan-20[*]	78.5%
May-20[†]	83.2%
Jun-20[†]	83.4%
Jul-20[†]	83.8%
Aug-20[†]	85.0%
Sep-20[†]	85.0%
Oct-20[†]	85.8%
Nov-20[†]	87.9%
Dec-20[†]	88.7%
Jan-21[†]	89.9%
Feb-21[†]	90.4%
March-21	93.5%
Apr-21	94.3%
May-21	94.5%
June-21	94.9%
July-21	95.3%
August-21	95.5%
Sep-21	95.4%
Oct-21	95.7%
Nov-21	95.8%
Dec-21	95.9%

Month	LEZ Compliance Rate (new standards)
Jan-22	96.1%
Feb-22	96.2%
Mar-22	96.1%
Apr-22	96.2%
May-22	96.2%
Overall change in compliance February 17 to present	**Increase of 48.2 percentage points**
Change in compliance since the scheme was launched	**Increase of 5.8 percentage points**

Table notes:
§ February 2017 based on data from the London Atmospheric Emissions Inventory
** Analysis based on sampled days within these months, using historical data*
† Compliance rates estimated using information from ANPR camera data and associated vehicle information such as age and type of vehicle

Compliance rates across London

The ULEZ operates for light vehicles up to, but not including the North and South Circular roads, whilst the LEZ for large and heavy vehicles operates London-wide. The phased introduction and expansion of these policies mean that impacts can be seen in different locations and at different times.

Compliance within the expanded ULEZ area has overtaken compliance in central London. This is due to the differences in fleet composition in the two areas, with a higher proportion of vans (which generally have a lower compliance rate than cars) operating in central London, and the fact that activity levels in central London are still well below pre-pandemic levels. Importantly, however, compliance levels continue to increase in in this area.

Figure 4 shows how the proportion of compliant and non-compliant cars has changed since June 2020 (when monthly figures began) across central, inner and outer London, on the North and South Circular boundary roads, and for London as a whole. This shows that compliance outside of the original central London ULEZ increased sharply alongside the expansion of the ULEZ to inner London.
Whilst compliance is highest in the ULEZ itself, the boundary roads have also seen a large jump in compliance. Despite improvements, compliance in outer London has not grown at the same rate or to the same level as compliance within the zone and has a much lower compliance rate than the boundary, which has seen compliance rise sharply following the ULEZ expansion.

Compliance within the expanded ULEZ area has overtaken compliance in central London. This is due to the differences in fleet composition in the two areas, with a higher proportion of vans (which generally have a lower compliance rate than cars) operating in central London, and the fact that activity levels in central London are still well below pre-pandemic levels. Importantly, however, compliance levels continue to increase in in this area.

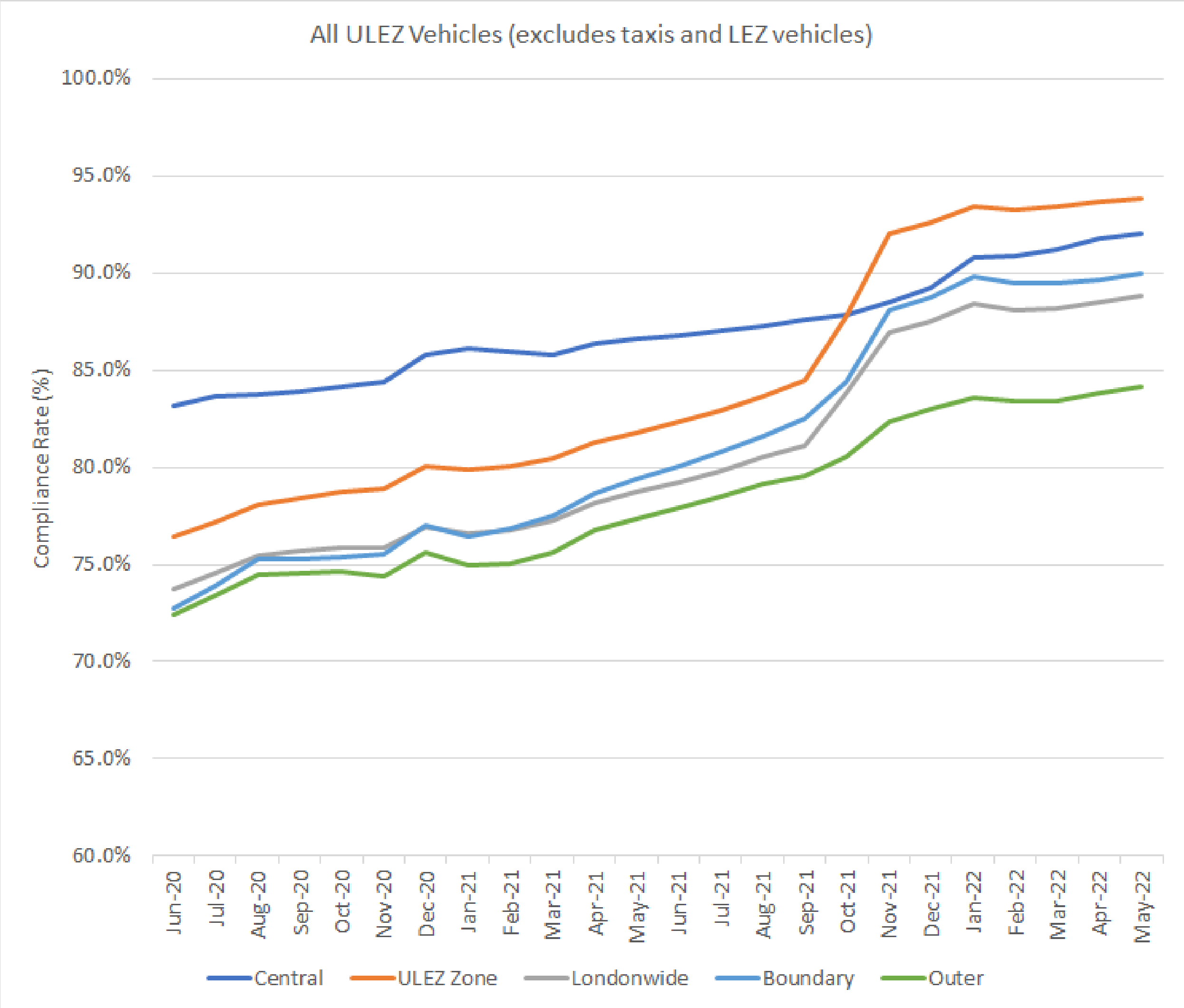

Figure 4: ULEZ average compliance rates for all vehicles detected, split by area

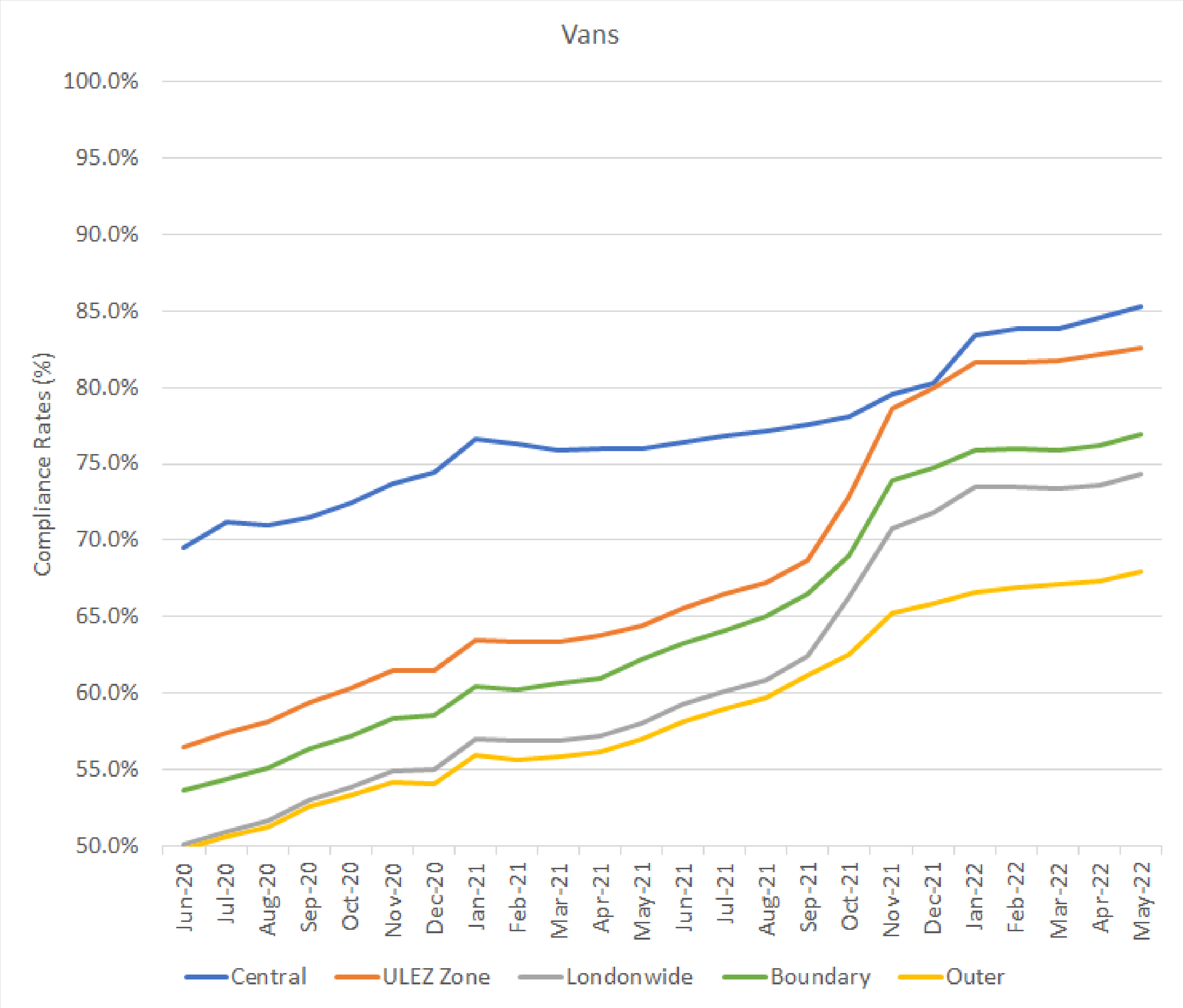

Figure 5: ULEZ average compliance rates for vans detected, split by zone

A similar pattern in compliance rate improvements across all zones can be seen in vans in Figure 5 above, with a marked increase in compliance within the new larger ULEZ between September and October 2021 when the scheme went live.

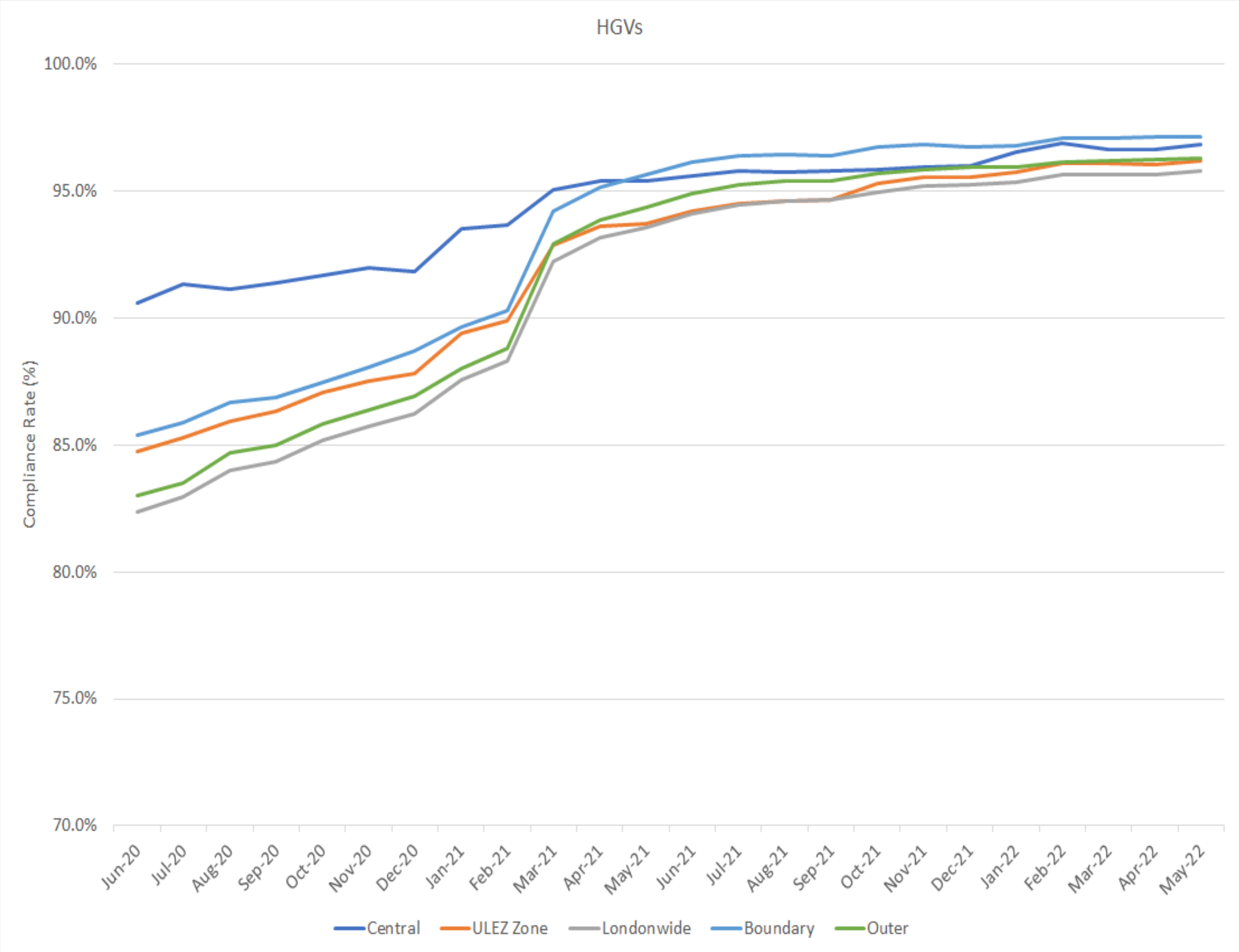

Figure 6: LEZ compliance rates for HGVs detected, split by zone

Compliance rates for HGVs have also increased across all zones in London, with a marked increase when tighter LEZ standards were enforced from March 2021, bringing them in line with the ULEZ standards. As a London-wide scheme, the LEZ has led to a convergence in compliance rates across the city, as shown in Figure 6.

Air pollution concentrations

In 2019, 44 per cent of London's nitrogen oxides (NO_x) emissions were from road transport.[3] By disincentivising the use of older, more polluting vehicles in inner London, the ULEZ expansion is designed to reduce the amount of NO_x emitted by vehicles, leading to lower nitrogen dioxide (NO_2) concentrations in the zone. This will reduce the health impacts associated with high levels of NO_2, which is a key aim of expanding the zone. Positive impacts will also be seen outside the zone, including on the boundary, as many vehicles often do not drive solely within the zone.

Air pollution concentrations are affected by a number of factors and follow patterns of seasonal variation, it is therefore preferable to have at least a full year of data to fully understand the impacts of a scheme on air quality. This section presents an initial analysis of air pollution data from London's automatic monitoring network, looking at how pollution levels have changed over time. Further analysis will be carried out once one year of data is available.

Data sources

The data used is publicly available from the London Air Quality Network and Air Quality England websites. Full details of the methodology for this section can be found in the Appendix.

For this analysis, air quality monitoring stations are grouped by site type. This analysis focuses on the two most common types of monitoring site in London: roadside and urban background.

Roadside sites are within 1 – 5m of a busy road and usually located close to adult breathing height. Roadside sites enable us to track and understand changes in air pollution concentrations from traffic. These sites give the best estimate of public exposure on busy roads. Roadside sites are useful for identifying air quality hotspots caused by traffic that may have potential health impacts - especially those areas frequented by large numbers of people travelling on the road or pavement or where homes are close to the kerb.

Urban background sites are located further away from the main sources of emissions and are not influenced by one single nearby pollution source. In London, traffic is the main source for background sites to avoid and there are guidelines about how close background sites can be to roads. The benefit of urban background sites is they are usually representative of air pollution exposure for the wider area.

Trend analysis

Air pollution concentrations are highly sensitive to the prevailing meteorology, such as wind speed, wind direction, precipitation, and temperature, as well as the associated long-range transport of pollutants from outside London. Many pollutants also have a seasonal cycle. This seasonal cycle may be caused by seasonally

[3] London Atmospheric Emissions Inventory 2019 (LAEI 2019)

varying emissions, such as heating in wintertime or agricultural emissions during the spring. Seasonal cycles can also be caused by other factors, including sunlight, that can induce chemical reactions between air pollutants and meteorological conditions hindering dispersal. These seasonal and day-to-day variations can make it difficult to assess short term trends and the impact of interventions such as the ULEZ. One approach to minimise the impact of these variations is to consider a sufficiently long time period. Another is to use statistics to smooth out short-term variability, this reduces the impact of weather and seasonal factors.

In this section monthly average concentrations were used to calculate trends in the period from 2010 to the end of June 2022. It should be noted that measurement data from 2022 have not yet been ratified. As a result, these may be subject to change following equipment tests undertaken as part of the routine audit and servicing of air quality monitoring sites.[4]

Context

The ULEZ is one of many policies to reduce air pollution from road transport in London. Other local policies include the London-wide LEZ (for heavy vehicles) and investment in cleaner buses and taxis, alongside wider policies such as progressively tighter EU-wide exhaust controls for new vehicles. As a result, it is not straightforward to isolate the impact of the ULEZ and its expansion.

For this analysis the trends in outer London (largely away from the influence of the earlier central ULEZ and recently expanded zone) were used as a predictor of the change in central and inner London that would have happened without the ULEZ was not in place. Comparing the measured trends in central and inner London with those in outer London reveals the additional changes within the central and inner zones, which provides an estimate for the impact of the ULEZ.

Detecting the additional change within the ULEZ area by comparing trends in the zone to those in outer London has both strengths and weaknesses. Key amongst the strengths is the ease of analysis, allowing data to be analysed as it is produced, and the large number of measurement sites involved. Another strength is the use of outer London data that also acts, to some extent, as a control for the weather and seasonal factors that can confound this type of analysis. The key weakness stems from differences in the vehicle fleets in the ULEZ area compared with outer London. Traffic in central and inner London has a greater proportion of certain vehicle types, such as taxis and PHVs, and proportionally fewer private cars than outer London[5]. Interventions from other Mayoral policies targeting these vehicle types would have a different impact in the ULEZ area than outside it, even in the absence of the ULEZ.

Changes to transport habits due to the pandemic may also affect the attribution of change to the ULEZ scheme. However, the use of outer London measurements in the analysis will partially control for pandemic changes, at least those that affected all of London equally.

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[4] Monitoring data for a specific year is usually finalised by April the following year and usually only shows small variations from the initial readings.
[5] London Atmospheric Emission Inventory (LAEI) 2019, Greater London Authority 2022

Another potential limitation to the analysis presented in this chapter is changes in the number and location of monitoring sites across London over the 12-year period. More detail on this can be found in the Appendix.

Trends in Nitrogen Dioxide (NO_2)

The method used in this report is based on that used in the first central ULEZ reports. The method has been revised to ensure that the central London concentration trend captures both pandemic and post-pandemic changes in concentrations.

In line with previous reports, statistical smoothing was used to reduce the impacts of weather and seasonal changes in the long-term trend data. However, this smoothing process means that the trend analysis becomes less responsive to short-term variations from other factors including pandemic and post-pandemic traffic changes. The method was therefore revised to reduce the degree of smoothing and allow the trend data to be more responsive to change.

This was necessary to reduce the risk of misattributing the pandemic induced change of these impacts to the ULEZ. The on-going impact of pandemic changes to traffic, and therefore pollution concentrations in 2022 will be picked up in the trends analysis when more data is available and presented in the future One Year Report. Further detail on the methodology is contained in the Appendix.

Figure 7 shows the trends in nitrogen dioxide (NO_2) at monitoring sites in London from 2010 to May 2022. The graph shows monthly average NO_2 concentrations grouped by site type and location, statistically smoothed to reduce the impact of weather and seasonality.

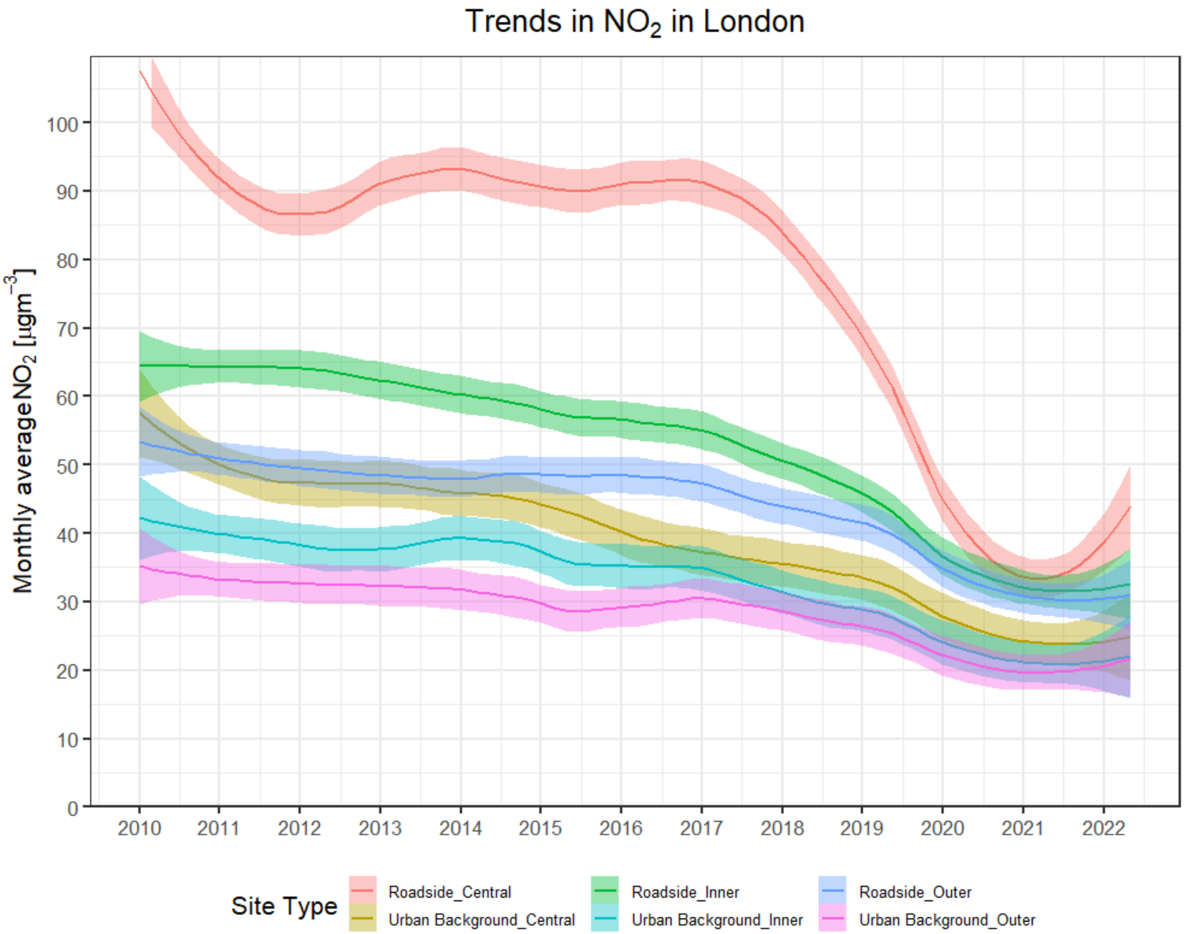

Figure 7: Trends in monthly average NO_2 concentrations in London from 2010 to 2022

Figure 7 shows that there was a slow decrease in NO_2 concentrations across London from 2010 to 2017 at both background and roadside sites. From 2017, when the Mayor introduced the Toxicity Charge and people began preparing for the introduction of the original central ULEZ, the central London roadside sites saw significant reductions in concentrations. From 2019 an increased downward trend was also seen at inner London sites, though these did not reduce as rapidly as the central London sites.

The impacts of the pandemic on air quality in London have been extreme and variable with much deeper and sustained impacts in central London compared with inner and outer London.[6] This can be seen in Figure 7 where the red line representing central London roadside shows concentrations were similar to those in inner London (the green line). At their lowest point central London roadside concentrations were 6 per cent greater than inner London, down from 16 per cent immediately before the pandemic.

[6] Further analysis on the initial impact of the pandemic on air quality in London is available here: https://www.london.gov.uk/sites/default/files/london_response_to_aqeg_call_for_evidence_april_2020.pdf

The pandemic had huge impacts on traffic volumes in London in 2020 and in 2021, with central London being especially heavily affected. This in turn has had impacts on pollution levels across the city and will have contributed to reductions, particularly in central London, as seen in Figure 7. Further analysis of traffic impacts is provided later in the report.

From late 2021 and into 2022, roadside concentrations in central London have increased. This was likely due to a return to economic activity following the impacts of the pandemic. In April – June 2022, NO_2 concentrations are at their greatest levels since the start of the pandemic but still remain below pre-pandemic levels despite the return to economic activity, highlighting the positive impact of the ULEZ scheme.

Table 9 lists the quarterly average concentrations of NO_2 in London from January 2017 to June 2022, averaged by site type and location. Substantial reductions have been seen across all site types and locations. The greatest reduction in average NO_2 concentrations was seen at central London roadside sites, which had reduced by 49µgm^{-3} or 54 per cent from January – March in 2017 to April – June in 2022. Overall, concentrations at inner London roadside sites reduced by 43 per cent and outer London roadside sites by 36 per cent over the same time period.

Unlike central London roadside sites, average roadside trends in inner and outer London remained relatively constant in 2022.

Table 9: Quarterly average NO_2 at roadside sites by zone based on the trends analysis in Figure 7

Period	Average NO_2 [µgm^{-3}]					
	Roadside Central	Background Central	Roadside Inner	Background Inner	Roadside Outer	Background Outer
Jan - March 17	91	37	55	35	47	30
April - June 17	90	37	54	34	46	30
July - Sept 17	88	36	52	33	45	30
Oct - Dec 17	86	36	51	32	45	29
Jan - March 18	83	36	50	31	44	29
April - June 18	80	35	49	31	43	28
July - Sept 18	76	35	48	30	43	27
Oct - Dec 18	72	34	47	29	42	27
Jan - March 19	67	33	45	28	41	26
April - June 19	62	32	43	28	40	25
July - Sept 19	56	31	41	26	38	24
Oct - Dec19	49	29	38	25	36	23
Jan - March 20 *	43	27	36	24	34	22
April - June 20	39	26	35	23	33	21
July - Sept 20	36	25	34	22	32	20
Oct - Dec 20	34	25	33	22	31	20
Jan - March 21	33	24	32	21	31	20
April - June 21	33	24	31	21	30	20

Period	Average NO_2 [μgm^{-3}]					
	Roadside Central	Background Central	Roadside Inner	Background Inner	Roadside Outer	Background Outer
July - Sept 21	34	23	31	21	30	20
Oct - Dec 21	36	23	31	21	30	20
Jan - March 22	38	23	31	21	30	20
April – June 22	42	23	31	21	30	20
Reduction Q1 2017-Q2 2022 [µgm-3]	49	14	24	14	17	10
Reduction Q1 2017-Q2 2022 [per cent]	54%	37%	43%	40%	36%	33%

**Pandemic starts*

ULEZ impact analysis

The previous section highlights the overall NO_2 concentration trends in London. Additional analysis has been carried out to assess the extent of the impact of the central London ULEZ and its expansion. This is important to ensure the recent trends in decreasing NO_2 seen above are not just a product of weather, seasonal factors, the pandemic or due to the natural reduction in emissions that would be expected with the general vehicle fleet turnover.

Method

A technique often used to isolate the proportion of pollution related to traffic sources is to subtract the background concentration from the roadside concentration. This is referred to as the “roadside increment”[7]. Changes in the roadside increment, or traffic contribution, in outer London, have been used to represent the changes that would have occurred in a “no ULEZ” scenario for roadside sites in central and inner London and at the boundary sites in the later section. However, policies including the LEZ and other transport schemes have also been implemented in outer London meaning pollution changes here are not solely due to natural turnover over the fleet.

As time progresses and NO_2 concentrations continue to decline due to Mayoral policies, it is becoming increasingly complex to disentangle the impacts of each separate policy on air pollution concentrations in the different areas of London. In addition to the ULEZ and LEZ, many of the Mayor’s other policies, such as the growth of the zero-emission bus and taxi fleets, will have had positive impacts on concentrations, particularly in central and inner London. Therefore, the analysis below can be seen to show the impacts of not just the central London ULEZ and its expansion, but of all the Mayor’s policies to reduce emissions from transport.

[7] Font, A. & Fuller, G. (2016) Did policies to abate atmospheric emissions from traffic have a positive effect in London? Environmental Pollution, Volume 218, November 2016, Pages 463-474

The full methodology for calculating the "no ULEZ" trend can be found in the Appendix.

Results

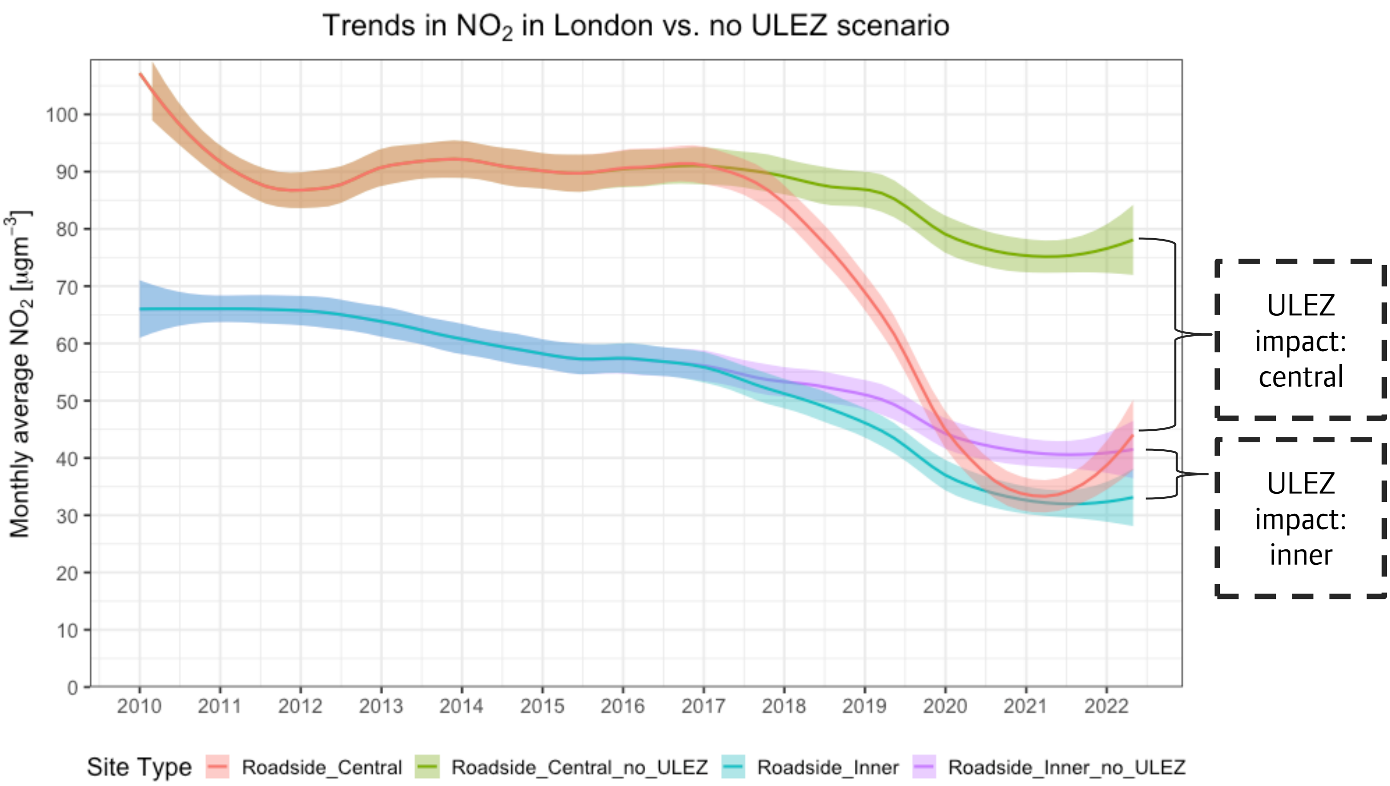

Figure 8: Trends in monthly average NO_2 concentrations in London with and without ULEZ

Figure 8 shows the trends in monthly average NO_2 concentrations at central and inner London roadside sites compared with the estimated path they would have followed had they reduced at the same rate as outer London roadside sites since 2017 (the 'no ULEZ' scenarios on the graph). The graph shows that both central and inner London roadside sites have seen concentrations reduce much quicker and further than would be expected without the ULEZ and its expansion.

Table 10 quantifies the difference between the analysed trends for central and inner London roadside and the estimated 'no ULEZ' scenarios averaged over 3-month periods since 2019. This can be understood as the reduction at central and inner London roadside concentrations that is in addition to the changes measured at outer London roadside sites.

Table 10: Estimated reduction in NO_2 concentrations due to ULEZ policies

Period	Reduction in central London roadside compared with no ULEZ		Reduction in inner roadside London compared with no ULEZ	
	[μgm^{-3}]	[per cent]	[μgm^{-3}]	[per cent]
Jan – March 19	19	22%	5	10%
April – June 19	23	27%	6	12%
July – Sept 19	27	33%	6	13%
Oct – Dec19	32	39%	7	15%
Jan – March 20	35	45%	7	17%
April – June 20	38	49%	8	18%
July – Sept 20	40	52%	8	19%
Oct – Dec 20	41	55%	8	20%
Jan – March 21	42	56%	8	21%
April – June 21	42	55%	9	21%
July – Sept 21	41	54%	9	21%
Oct – Dec 21	39	52%	9	21%
Jan – March 22	37	48%	9	21%
April- June 22	35	44%	8	20%

The difference between the measured trend and the ‘no ULEZ scenario’ in central London is substantial and demonstrates that the ULEZ, LEZ and other policies have had a transformative impact on reducing NO_2 levels in this area. In April – June 2022, the most recent data available, the mean roadside NO_2 concentrations measured in central London were 35μgm^{-3} lower than the estimated ‘no ULEZ’ scenario, a difference of 44 per cent. In inner London, roadside NO_2 concentrations were 8 μgm^{-3} lower than the estimated ‘no ULEZ’ scenario, a difference of 20 per cent.

Crucially, the air quality improvements in inner London are being seen over an area that is 18 times the size of the original central zone, improving air quality directly for the 4 million people living in this area and those who come into the area for work, study or leisure

Figure 8 and Table 10 also clearly highlight the importance of “pre-compliance” – improvements in air quality as vehicle owners prepared for the introduction of the ULEZ in 2019 and its expansion in 2021.

As mentioned previously, the pandemic had large impacts on traffic volumes that continued over a longer period in central London. Therefore, it is not possible to attribute the recent reductions in concentrations solely to the ULEZ policies. However, it is clear that fleet compositions in London have been affected by the ULEZ policies, as described earlier. These changes are attributed to the ULEZ because they clearly align with the implementation dates of both the enforcement of tougher LEZ standards and the ULEZ expansion.

While traffic volumes have started to return to pre-pandemic levels in inner and outer London, this analysis shows that the ULEZ has helped to prevent the return to previous pollution levels even as traffic volumes start to return to pre-pandemic levels. Further analysis of traffic data can be found later in the report.

Because the rate of reduction for the no ULEZ scenario has been derived from outer London monitoring trends, some benefits of the expanded ULEZ and tighter LEZ standards that may have occurred in outer London are incorporated into the analysis. This may affect the magnitude of change attributable to the ULEZ.

Trends in nitrogen dioxide on ULEZ boundary roads

When charging schemes, such as the ULEZ and its expansion, are introduced in part of a city it is always important to measure the impact of the scheme not only in the zone itself, but also in the surrounding area.

There are six established air quality monitoring stations on the North and South Circular boundary roads for the ULEZ. Figure 9 shows that, similar to monitoring sites within the ULEZ, there has been a decreasing trend in NO_2 concentrations at all the expanded ULEZ boundary sites and that generally this trend has accelerated since 2019. All monitoring sites on the boundary roads have seen reductions in NO_2 concentrations.

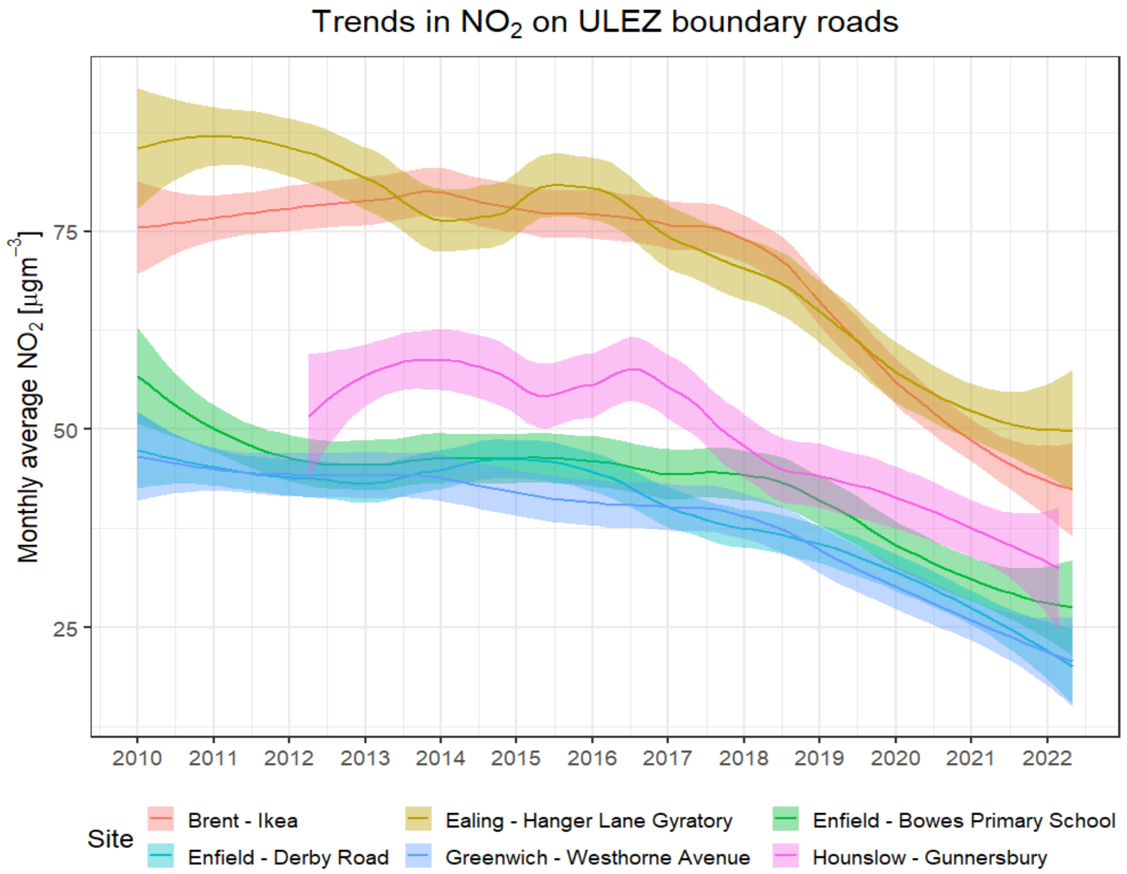

Figure 9: Trends in monthly average NO_2 concentrations at sites on ULEZ boundary roads

Further analysis will be carried out on the impacts on boundary roads once a full year of monitoring data is available, but this analysis provides an initial indication that the ULEZ expansion has had a positive impact on air pollution concentrations on the boundary of the expanded zone.

We have also analysed the impact of the ULEZ and its expansion on the boundary roads using the same method as presented in Figure 8 above. For the purposes of this analysis, Brent and Hanger Lane have been grouped because of the greater concentrations that prevail on these sections of the North Circular Road. Figure 10 below shows the average monthly NO_2 concentrations for both groups of boundary sites, along with the trend they would have followed if they had reduced at the same rate as outer London monitoring sites (the “no ULEZ scenario”).

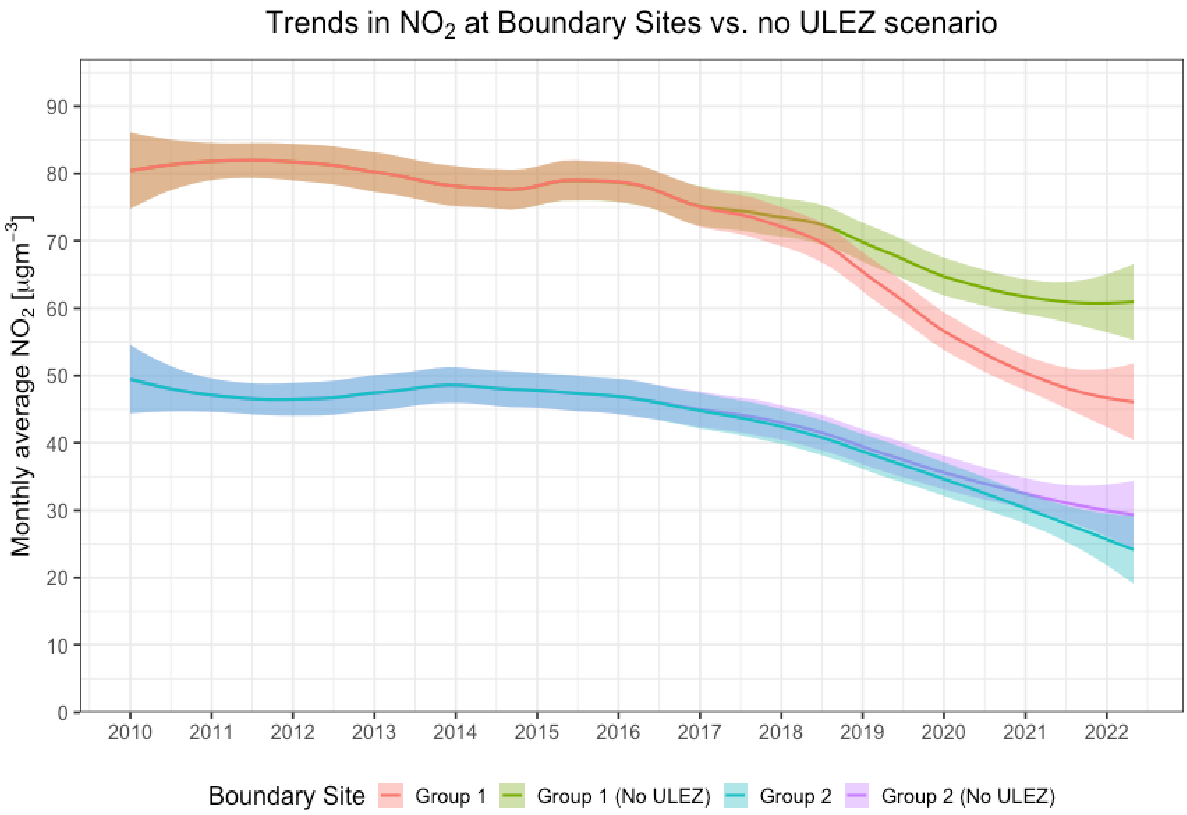

Figure 10: Trends in monthly average NO2 concentrations at ULEZ boundary roads, with and without ULEZ. Group 1 is Brent Ikea and Hanger Lane. Group 2 includes the other boundary sites.

The analysis indicates that for Brent Ikea and Hanger Lane monitoring sites (Group 1) there has been an estimated reduction of 15 μgm^{-3} (24 per cent) compared with the estimated no ULEZ trend. For the other boundary monitoring sites (Group 2), the estimated reduction is 5 μgm^{-3} (17 per cent). Further detail is shown in Table 11 below.

Table 11: Estimated reduction in NO_2 concentrations at boundary sites, as a result of ULEZ policies

Period	Reduction in Group 1 boundary sites compared to no ULEZ		Reduction in Group 2 boundary sites compared to no ULEZ	
	[μgm^{-3}]	[per cent]	[μgm^{-3}]	[per cent]
Jan - March 19	5	7%	1	2%
April - June 19	6	8%	1	2%
July - Sept 19	7	10%	1	2%
Oct - Dec19	8	11%	1	2%
Jan - March 20	8	13%	1	3%
April - June 20	9	14%	1	4%
July - Sept 20	10	16%	2	5%
Oct - Dec 20	11	17%	2	6%
Jan - March 21	12	19%	2	7%
April - June 21	12	20%	3	9%
July - Sept 21	13	21%	3	11%
Oct - Dec 21	14	22%	4	13%
Jan - March 22	14	23%	5	15%
April- June 22	15	24%	5	17%

Fine particulate matter ($PM_{2.5}$)

Road transport is the largest single source of fine particulate matter in London, accounting for around 30 per cent of emissions[8]. However, unlike NO_2, over half of London's concentrations of $PM_{2.5}$ come from regional, and often transboundary (non-UK) sources outside of London. $PM_{2.5}$ concentrations from these sources are also heavily influenced by meteorological conditions, causing more variation between different years.

There is also a large proportion of $PM_{2.5}$ emitted within London that the Mayor does not currently have the powers to control, for example wood burning, which accounts for 17 per cent of $PM_{2.5}$ emissions[9] and would not be affected by the ULEZ. Additionally, a growing proportion of road transport $PM_{2.5}$ emissions are now non-exhaust emissions including road wear and tyre and brake wear, as well as resuspension of road dust which would not be affected by the tightening of tailpipe emission standards for traffic in the ULEZ area.

For these reasons, the reduction in $PM_{2.5}$ emissions that would occur due to a cleaner fleet will have a less pronounced impact on concentrations than seen for NO_2, which is dominated by London-based traffic sources.

[8] London Atmospheric Emissions Inventory 2019 (LAEI 2019)
[9] London Atmospheric Emissions Inventory 2019 (LAEI 2019)

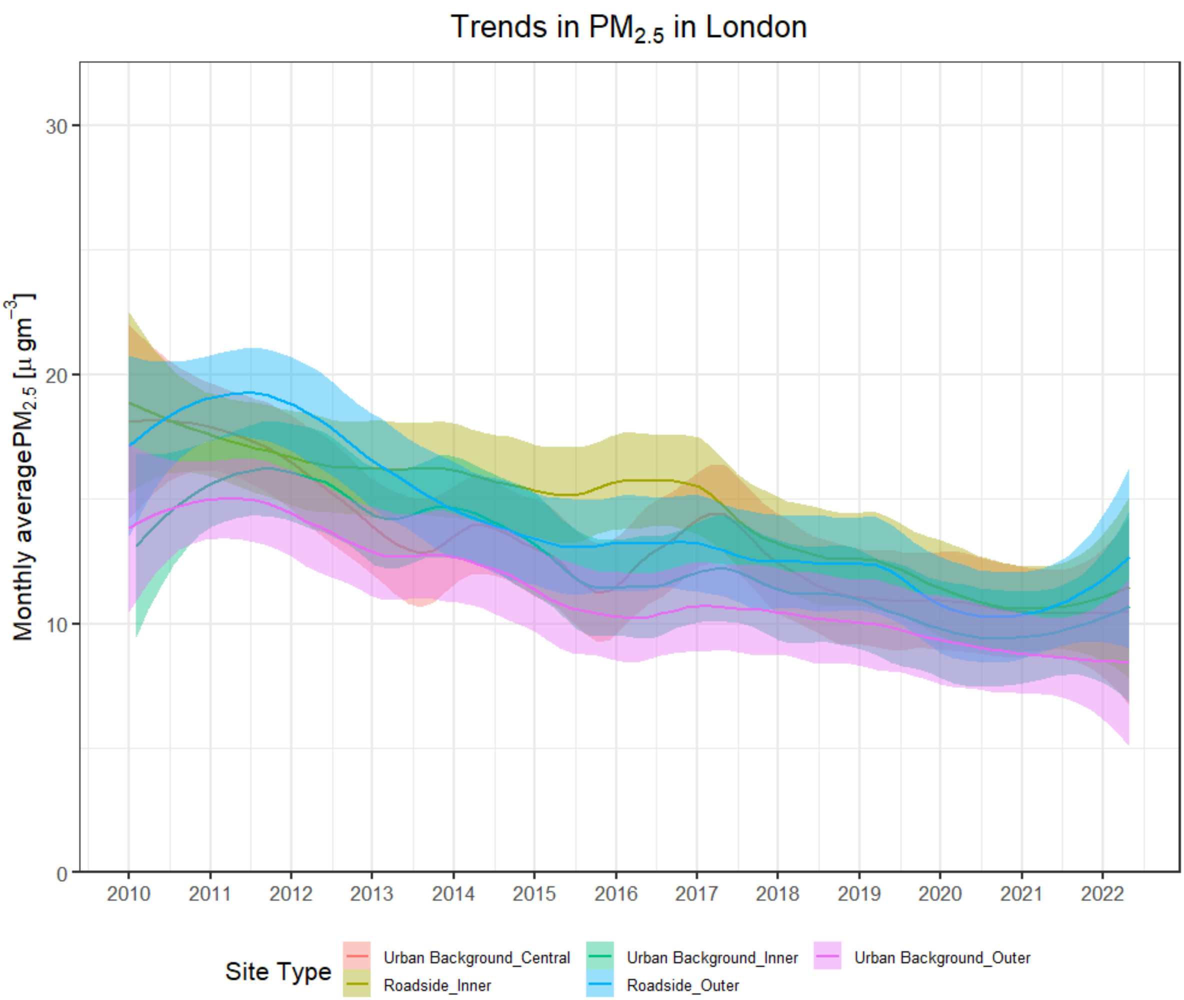

Figure 11: Monthly average $PM_{2.5}$ concentrations in London

Figure 11 shows that there has been a gradual and continuous reduction in $PM_{2.5}$ concentrations since 2010, at all site types and locations. This trend has continued through the introduction of the ULEZ and its expansion. However, recent data indicates some increases in $PM_{2.5}$ at roadside sites in outer London, which may be a reflection of both the influence of wider background $PM_{2.5}$ concentations which are highly variable, alongside increased traffic and other activity.

The difference in concentrations between site types and locations is much smaller than that for NO_2 and, for inner London, gradually narrows from 2017 to 2022 as levels at roadside sites become close to those at background sites.

At outer London sites, roadside concentrations have increased from spring 2021 and are now slightly higher than those seen at inner London roadside sites. As background concentrations haven't increased to the same extent this may be reflecting greater economic activity and a corresponding increase in traffic. We will continue to monitor these trends and including further reporting in the One Year

Report. Roadside central is not included in this analysis due to the lack of monitoring sites available.

Table 12: Quarterly average $PM_{2.5}$ at roadside sites by zone, based on trends analysis in in Figure 14

Period	Average $PM_{2.5}$ [μgm^{-3}]				
	Background Central	**Roadside Inner**	**Background Inner**	**Roadside Outer**	**Background Outer**
Jan - March 17	14	15	12	13	11
April - June 17	14	15	12	13	11
July - Sept 17	14	14	12	13	11
Oct - Dec 17	13	13	12	12	11
Jan - March 18	12	13	11	12	10
April - June 18	12	13	11	12	10
July - Sept 18	11	13	11	12	10
Oct - Dec 18	11	13	11	12	10
Jan - March 19	11	13	11	12	10
April - June 19	11	12	11	12	10
July - Sept 19	11	12	10	12	10
Oct - Dec19	11	12	10	11	9
Jan - March 20	11	11	10	11	9
April - June 20	11	11	10	10	9
July - Sept 20	11	11	9	10	9
Oct - Dec 20	11	11	9	10	9
Jan - March 21	10	11	9	10	9
April - June 21	10	11	10	11	9
July - Sept 21	10	11	10	11	9
Oct - Dec 21	10	11	10	11	8
Jan - March 22	10	11	10	12	8
April- Jun 22	10	11	10	12	8
Reduction Q1 2017-Q1 2022 [µgm-3]	4	4	2	1	3
Reduction Q1 2017-Q1 2022 [per cent]	29%	29%	16%	6%	24%

Traffic flows

The reduction of traffic or congestion is not the primary aim of the ULEZ. However, introducing an emissions requirement for vehicles has been shown to deter a small proportion of vehicle trips and lead to a change in how some people travel.

Many factors are currently affecting traffic trends in London. The pandemic has significantly impacted traffic patterns, with traffic demand changing due to a combination of newer and more flexible ways of working, and different pandemic responses including work from home orders throughout 2021 and early 2022. The fuel shortage in late September 2021 and the escalated higher fuel prices in 2022 has also impacted travel demand. Therefore, it has not been fully possible to isolate the impact of the ULEZ expansion on traffic flows. We will continue to review the data to better understand the impact of ULEZ expansion in the longer term.

Data sources and analysis method

The data presented in this section of the report are based on vehicle kilometres that have been estimated from Automatic Traffic Count (ATC) sites in and around London as provided by TfL Network Management. The vehicle kilometres data are used as an indicator of traffic levels.

The following periods apply:

- Post-ULEZ expansion – based on data collected from date of the ULEZ launch (25 October 2021) to May 2022
- Pre-ULEZ expansion baseline – 13 September to 24 October 2021 (excluding 25 September – 3 October 2021 due to the petrol shortage)
- 2019 baseline – pre-COVID baseline using 2019 traffic data

The pre-ULEZ expansion baseline uses traffic data collected during September and October, which are considered to be ‘neutral’ months in terms of traffic patterns, away from school holidays and inclement weather conditions. This baseline has been adjusted to vary throughout the months to incorporate seasonal variations in traffic. Whilst every effort has been taken to exclude the dates during the petrol shortage, there is no certainty that the lingering effects of the shortage is not reflected in the data.

Results

Table 13 below quantifies the monthly average percentage differences between the post-ULEZ expansion and pre-ULEZ expansion traffic data and between the post-ULEZ expansion and 2019 baseline (pre-central London ULEZ) traffic data. The rows shaded yellow in the chart show quarterly data, including the most recent incomplete quarter and the most recent six-month outlook.

The data show that following the ULEZ expansion, there have been reductions in traffic levels both inside the zone and outside the zone and also on the boundary roads compared to the pre-ULEZ expansion period. The reductions are even greater when comparing against the 2019 baseline data, however that is more likely to be influenced by the pandemic.

During January to March 2022, traffic levels fell by 4 per cent inside the zone and 4 per cent outside the zone compared to the pre-ULEZ expansion baseline.

April to May 2022 is the most recent period available and reflects the return to work and increased economic and traffic activity as well as higher fuel prices. During this period traffic flows stabilised at 2 per cent below the pre-ULEZ expansion baseline in the zone and 1.7 per cent below the baseline outside the zone.

This is in line with our initial modelled estimates of a one to three per cent fall in traffic within the zone. However, it is not possible to isolate the impact of the continued rise in fuel prices and the longer-term pandemic effects on travel including return to work from mid-March 2022.

Table 13: Change in vehicle kilometres post-ULEZ expansion vs 2019 baseline and pre-ULEZ expansion baseline

	Inside expanded ULEZ		Outside expanded ULEZ		Boundary roads	
Time period	**Change vs 2019 baseline**	**Change vs pre-expansion baseline**	**Change vs 2019 baseline**	**Change vs pre-expansion baseline**	**Change vs 2019 baseline**	**Change vs pre-expansion baseline**
Sep-21	-7.1%	0.6%	-3.8%	0.4%	-2.9%	0.4%
Oct-21	-7.6%	-1.4%	-4.1%	-1.5%	-2.1%	-1.2%
Nov-21	-7.2%	-0.7%	-4.3%	-1.6%	-1.9%	-2.5%
Dec-21	-9.3%	-5.9%	-8.2%	-8.3%	-5.2%	-7.1%
Jan-22	-9.7%	-8.0%	-6.3%	-7.6%	-3.8%	-7.0%
Feb-22	-6.7%	-2.8%	-4.0%	-3.0%	-2.4%	-3.2%
Mar-22	-10.2%	-1.3%	-6.3%	-1.6%	-4.4%	-1.7%
Apr-22	-10.4%	-3.5%	-6.6%	-2.9%	-5.9%	-2.3%
May-22	-8.8%	-0.5%	-5.2%	-0.5%	-3.0%	-0.1%
Oct to Dec-21	-8.1%	-2.7%	-5.5%	-3.8%	-3.0%	-3.6%
Jan to Mar-22	-8.9%	-4.0%	-5.5%	-4.1%	-3.5%	-4.0%
Apr to May-22 (incomplete Q2)	-9.6%	-2.0%	-5.9%	-1.7%	-4.4%	-1.2%
Dec-21 to May-22 (most recent 6 months)	-9.2%	-3.7%	-6.1%	-4.0%	-4.1%	-3.6%

The reductions in traffic are somewhat variable throughout the period and the impacts of seasonal variations are evident in the data. Traffic from October to December and January to March includes the impacts of Christmas and New Year. As the ULEZ expansion went live on 25 October 2021, data for this quarter is also not fully representative of the traffic impacts of the scheme. The work from home government directive introduced around the second week of December 2021 (following the rise in Omicron cases) may have suppressed traffic levels further. This alongside the fuel price increases may contribute to the continued reduction in traffic compared to the 2019 baseline.

When comparing against the pre-ULEZ expansion data the traffic levels appear to have recovered in recent months with only a 0.5 per cent reduction in May 2022 compared to the pre-ULEZ expansion period, both inside and outside the zone. We will continue to monitor traffic levels and will provide further analysis in the One Year Report.

Appendix 1: Methodology

We are grateful to Dr Gary Fuller of Imperial College London who kindly provided peer review support and comments on this methodology.

Air quality concentrations

All air quality data analysis was performed using the open source statistical software R.[10] Air pollutant concentration monitoring data across London is publicly available from the London Air Quality Network and Air Quality England websites. Only data from reference analysers has been used in this analysis. In order to present the full context for any changes in air pollutant concentrations, the period from 1 January 2010 to 31 May 2022 has been analysed.

Air quality monitoring stations are funded and maintained by the London boroughs, Defra, Transport for London and Business Improvement Districts. Over the period 2010 to 2022 many monitoring stations have opened, moved or closed. Figure 9 shows how the number of sites in each zone has changed over this period.

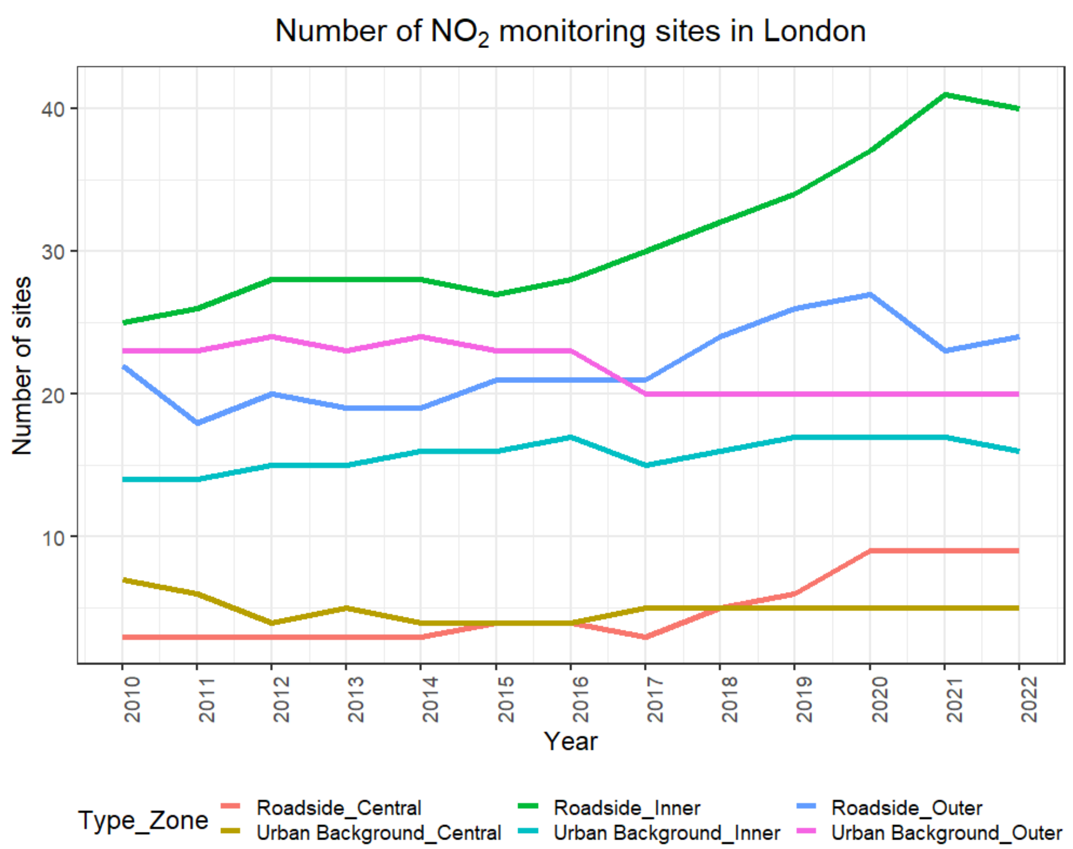

Figure 12: Number of NO_2 monitoring sites in London by zone and site type

Monthly average concentration trends for NO_2 and $PM_{2.5}$

[10] https://www.r-project.org/

The trends analysis includes all historic monitoring sites in London categorised as "Roadside" or "Urban Background". For this analysis "Suburban" and "Urban Centre" sites have been treated as "Urban Background". "Industrial", "Airport" and "Kerbside" sites have not been included as they are fewer in number and not typical of population exposure. The table below includes a list of all 158 sites that measured NO_2 concentrations in London between 2010 and 2022 and were included in the NO_2 trend analysis presented in this report. Sites were only included if they have one year or more of data.

Table 14: Sites included in NO_2 trend analysis

Site Code	Name	Site Type	Data Owner	Site Manager	ULEZ Location
BG1	Barking and Dagenham - Rush Green	Urban Background	Barking and Dagenham	Imperial College London	Outer
BG2	Barking and Dagenham - Scrattons Farm	Urban Background	Barking and Dagenham	Imperial College London	Outer
BL0	Camden - Bloomsbury	Urban Background	Camden	Imperial College London	Central
BN2	Barnet - Chalgrove School	Urban Background	Barnet	Ricardo-AEA	Outer
BQ7	Bexley - Belvedere West	Urban Background	Bexley	Imperial College London	Outer
BT1	Brent - Kingsbury	Urban Background	Brent	Imperial College London	Outer
BT4	Brent - Ikea	Roadside	Brent	Imperial College London	Outer
BT6	Brent - John Keble Primary School	Roadside	Brent	Imperial College London	Inner
BT7	Brent - St Marys Primary School	Urban Background	Brent	Imperial College London	Inner
BT8	Brent - ARK Franklin Primary Academy	Roadside	Brent	Imperial College London	Inner
BX1	Bexley - Slade Green	Urban Background	Bexley	Imperial College London	Outer
BX2	Bexley - Belvedere	Urban Background	Bexley	Imperial College London	Outer
BX7	Bexley - Thames Road North	Roadside	Bexley	Imperial College London	Outer
BX8	Bexley - Thames Road South	Roadside	Bexley	Imperial College London	Outer
BY7	Bromley - Harwood Avenue	Roadside	Bromley	Imperial College London	Outer
CD009	Camden - Euston Road	Roadside	Camden	Ricardo-AEA	Inner
CD010	Camden - High Street	Roadside	Camden	Ricardo-AEA	Inner
CD3	Camden - Shaftesbury Avenue	Roadside	Camden	Imperial College London	Central
CD4	Camden - St Martins College (NOX 1)	Urban Background	Camden	Imperial College London	Central
CD5	Camden - St Martins College (NOX 2)	Urban Background	Camden	Imperial College London	Central

Site Code	Name	Site Type	Data Owner	Site Manager	ULEZ Location
CE1	Westminster - Regent St (Crown Estate)	Roadside	Westminster	Imperial College London	Central
CE2	Westminster - Waterloo Pl (Crown Estate)	Roadside	Westminster	Imperial College London	Central
CR2	Croydon - Purley Way	Roadside	Croydon	Imperial College London	Outer
CR4	Croydon - George Street	Roadside	Croydon	Imperial College London	Outer
CR7	Croydon - Purley Way A23	Roadside	Croydon	Imperial College London	Outer
CR9	Croydon - Park Lane	Roadside	Croydon	Imperial College London	Outer
CT1	City of London - Senator House	Urban Background	City of London	Imperial College London	Central
CT3	City of London - Sir John Cass School	Urban Background	City of London	Imperial College London	Central
CT4	City of London - Beech Street	Roadside	City of London	Imperial College London	Central
CT6	City of London - Walbrook Wharf	Roadside	City of London	Imperial College London	Central
CW3	Tower Hamlets - Jubilee Park	Urban Background	Tower Hamlets	Imperial College London	Inner
CY1	Croydon - Crystal Palace Parade	Roadside	Croydon	Imperial College London	Outer
EA010	Ealing - Green Quarter	Urban Background	Ealing	Ricardo-AEA	Outer
EA1	Ealing - Ealing Town Hall	Urban Background	Ealing	Imperial College London	Outer
EA2	Ealing - Acton Town Hall	Roadside	Ealing	Imperial College London	Inner
EA6	Ealing - Hanger Lane Gyratory	Roadside	Ealing	Imperial College London	Outer
EA7	Ealing - Southall	Urban Background	Ealing	Imperial College London	Outer
EI1	Ealing - Western Avenue	Roadside	Ealing	Imperial College London	Inner
EI2	Ealing - Southall Railway	Roadside	Ealing	Imperial College London	Outer
EI3	Ealing - Acton Vale	Urban Background	Ealing	Imperial College London	Inner
EN1	Enfield - Bush Hill Park	Urban Background	Enfield	Imperial College London	Outer
EN4	Enfield - Derby Road	Roadside	Enfield	Imperial College London	Outer
EN5	Enfield - Bowes Primary School	Roadside	Enfield	Imperial College London	Inner
EN7	Enfield - Prince of Wales School	Urban Background	Enfield	Imperial College London	Outer
GB6	Greenwich - Falconwood	Roadside	Greenwich	Imperial College London	Outer
GN0	Greenwich - A206 Burrage Grove	Roadside	Greenwich	Imperial College London	Outer

Site Code	Name	Site Type	Data Owner	Site Manager	ULEZ Location
GN3	Greenwich - Plumstead High Street	Roadside	Greenwich	Imperial College London	Outer
GN4	Greenwich - Fiveways Sidcup Rd A20	Roadside	Greenwich	Imperial College London	Outer
GN5	Greenwich - Trafalgar Road (Hoskins St)	Roadside	Greenwich	Imperial College London	Inner
GN6	Greenwich - John Harrison Way	Roadside	Greenwich	Imperial College London	Inner
GR4	Greenwich - Eltham	Urban Background	Greenwich	Imperial College London	Outer
GR5	Greenwich - Trafalgar Road	Roadside	Greenwich	Imperial College London	Inner
GR7	Greenwich - Blackheath	Roadside	Greenwich	Imperial College London	Inner
GR8	Greenwich - Woolwich Flyover	Roadside	Greenwich	Imperial College London	Inner
GR9	Greenwich - Westhorne Avenue	Roadside	Greenwich	Imperial College London	Inner
GV1	Westminster - Ebury Street (Grosvenor)	Roadside	Westminster	Imperial College London	Inner
GV2	Westminster - Duke Street (Grosvenor)	Roadside	Westminster	Imperial College London	Central
HF4	Hammersmith and Fulham - Shepherd's Bush	Roadside	Hammersmith and Fulham	Ricardo-AEA	Inner
HF5	Hammersmith and Fulham - Hammersmith Town Centre	Roadside	Hammersmith and Fulham	Ricardo-AEA	Inner
HG1	Haringey - Haringey Town Hall	Roadside	Haringey	Imperial College London	Inner
HG2	Haringey - Priory Park	Urban Background	Haringey	Imperial College London	Inner
HG4	Haringey - Priory Park South	Urban Background	Haringey	Imperial College London	Inner
HI0	Hillingdon - Keats Way	Urban Background	Hillingdon	Imperial College London	Outer
HI1	Hillingdon - South Ruislip	Roadside	Hillingdon	Ricardo-AEA	Outer
HI2	Hillingdon - Hillingdon Hospital	Roadside	Hillingdon	Imperial College London	Outer
HI3	Hillingdon - Oxford Avenue	Urban Background	Hillingdon	Ricardo-AEA	Outer
HIL1	Hillingdon - Harmondsworth	Urban Background	Hillingdon	Ricardo-AEA	Outer
HIL5	Hillingdon - Hayes	Roadside	Hillingdon	Ricardo-AEA	Outer
HK4	Hackney - Clapton	Urban Background	Hackney	Imperial College London	Inner
HK6	Hackney - Old Street	Roadside	Hackney	Imperial College London	Inner
HN1	Hackney - Hommerton Library	Roadside	Hackney	Imperial College London	Inner

Site Code	Name	Site Type	Data Owner	Site Manager	ULEZ Location
HN0	Hackney - Amhurst Road	Roadside	Hackney	Imperial College London	Inner
HP1	Lewisham - Honor Oak Park	Urban Background	Lewisham	Imperial College London	Inner
HR1	Harrow - Stanmore	Urban Background	Harrow	Imperial College London	Outer
HR2	Harrow - Pinner Road	Roadside	Harrow	v College London	Outer
HS010	Hounslow - Boston Manor Park	Roadside	Hounslow	Ricardo-AEA	Outer
HS2	Hounslow - Cranford	Urban Background	Hounslow	Ricardo-AEA	Outer
HS4	Hounslow - Chiswick	Urban Background	Hounslow	Ricardo-AEA	Inner
HS5	Hounslow - Brentford	Roadside	Hounslow	Ricardo-AEA	Outer
HS6	Hounslow - Heston	Roadside	Hounslow	Ricardo-AEA	Outer
HS7	Hounslow - Hatton Cross	Urban Background	Hounslow	Ricardo-AEA	Outer
HS8	Hounslow - Gunnersbury	Roadside	Hounslow	Ricardo-AEA	Outer
HS9	Hounslow - Feltham	Urban Background	Hounslow	Ricardo-AEA	Outer
HV1	Havering - Rainham	Roadside	Havering	Imperial College London	Outer
HV3	Havering - Romford	Roadside	Havering	Imperial College London	Outer
IS2	Islington - Holloway Road	Roadside	Islington	Imperial College London	Inner
IS6	Islington - Arsenal	Urban Background	Islington	Imperial College London	Inner
KC1	Kensington and Chelsea - North Ken	Urban Background	Kensington and Chelsea	Imperial College London	Inner
KC2	Kensington and Chelsea - Cromwell Road	Roadside	Kensington and Chelsea	Ricardo-AEA	Inner
KC3	Kensington and Chelsea - Knightsbridge	Roadside	Kensington and Chelsea	Ricardo-AEA	Inner
KC4	Kensington and Chelsea - Chelsea	Roadside	Kensington and Chelsea	Ricardo-AEA	Inner
KC5	Kensington and Chelsea - Earls Court Road	Roadside	Kensington and Chelsea	Ricardo-AEA	Inner
KG1	Kensington and Chelsea - Green Screen RS	Roadside	Kensington and Chelsea	Imperial College London	Inner
KG2	Kensington and Chelsea - Green Screen BG	Urban Background	Kensington and Chelsea	Imperial College London	Inner
KT3	Kingston - Sopwith Way	Roadside	Kingston	Imperial College London	Outer
KT4	Kingston - Tolworth Broadway	Roadside	Kingston	Imperial College London	Outer
KT5	Kingston - Cromwell Road	Roadside	Kingston	Imperial College London	Outer
KT6	Kingston - Kingston Vale	Roadside	Kingston	Imperial College London	Outer

Site Code	Name	Site Type	Data Owner	Site Manager	ULEZ Location
LB1	Lambeth - Christchurch Road	Roadside	Lambeth	Imperial College London	Inner
LB3	Lambeth - Loughborough Junct	Urban Background	Lambeth	Imperial College London	Inner
LB6	Lambeth - Streatham Green	Urban Background	Lambeth	Imperial College London	Outer
LH0	Hillingdon - Harlington	Urban Background	Hillingdon	Imperial College London	Outer
LHRBR	Hillingdon - Heathrow Bath Road	Roadside	Hillingdon	Ricardo-AEA	Outer
LW1	Lewisham - Catford	Urban Background	Lewisham	Imperial College London	Inner
LW2	Lewisham - New Cross	Roadside	Lewisham	Imperial College London	Inner
LW4	Lewisham - Loampit Vale	Roadside	Lewisham	Imperial College London	Inner
LW5	Lewisham - Deptford	Urban Background	Lewisham	Imperial College London	Inner
LW6	Lewisham - Laurence House Catford	Roadside	Lewisham	Imperial College London	Inner
ME1	Merton - Morden Civic Centre	Roadside	Merton	Imperial College London	Outer
ME9	Merton - Morden Civic Centre 2	Roadside	Merton	Imperial College London	Outer
NB1	Westminster - Strand (Northbank BID)	Roadside	Westminster	Imperial College London	Central
NM2	Newham - Cam Road	Roadside	Newham	Imperial College London	Inner
NM3	Newham - Wren Close	Urban Background	Newham	Imperial College London	Inner
RB1	Redbridge - Perth Terrace	Urban Background	Redbridge	Imperial College London	Outer
RB4	Redbridge - Gardner Close	Roadside	Redbridge	Imperial College London	Inner
RB5	Redbridge - South Woodford	Roadside	Redbridge	Imperial College London	Outer
RB7	Redbridge - Ley Street	Urban Background	Redbridge	Imperial College London	Outer
RHG	Richmond - Chertsey Road	Roadside	Richmond	Imperial College London	Outer
RI1	Richmond - Castelnau	Roadside	Richmond	Imperial College London	Inner
RI2	Richmond - Barnes Wetlands	Urban Background	Richmond	Imperial College London	Inner
SIPS	Hillingdon - Sipson	Urban Background	Hillingdon	Ricardo-AEA	Outer
SK5	Southwark - A2 Old Kent Road	Roadside	Southwark	Imperial College London	Inner
SK6	Southwark - Elephant and Castle	Urban Background	Southwark	v College London	Central
SK7	Southwark - Heygate	Urban Background	Southwark	Imperial College London	Inner

Site Code	Name	Site Type	Data Owner	Site Manager	ULEZ Location
SK8	Southwark - Tower Bridge Road	Roadside	Southwark	Imperial College London	Inner
SKA	Southwark - Lower Road	Roadside	Southwark	Imperial College London	Inner
SKB	Southwark - Vicarage Grove	Roadside	Southwark	Imperial College London	Inner
SKC	Southwark - South Circular Road	Roadside	Southwark	Imperial College London	Inner
ST3	Sutton - Carshalton	Urban Background	Sutton	Imperial College London	Outer
ST9	Sutton - Beddington Village	Roadside	Sutton	Imperial College London	Outer
TD0	Richmond - National Physical Laboratory	Urban Background	Richmond	Imperial College London	Outer
TH001	Tower Hamlets - Millwall Park	Urban Background	Tower Hamlets	Ricardo-AEA	Inner
TH002	Tower Hamlets - Victoria Park	Urban Background	Tower Hamlets	Ricardo-AEA	Inner
TH1	Tower Hamlets - Poplar	Urban Background	Tower Hamlets	Imperial College London	Inner
TH2	Tower Hamlets - Mile End Road	Roadside	Tower Hamlets	Imperial College London	Inner
TH4	Tower Hamlets - Blackwall	Roadside	Tower Hamlets	Imperial College London	Inner
TH5	Tower Hamlets - Victoria Park	Urban Background	Tower Hamlets	Imperial College London	Inner
TH6	Tower Hamlets - Millwall Park	Urban Background	Tower Hamlets	Imperial College London	Inner
TL4	Greenwich - Tunnel Avenue TFL	Roadside	Greenwich	Imperial College London	Inner
TL5	Newham - Hoola Tower TFL	Roadside	Newham	Imperial College London	Inner
TL6	Newham - Britannia Gate TFL	Roadside	Newham	Imperial College London	Inner
WA2	Wandsworth - Wandsworth Town Hall	Urban Background	Wandsworth	Imperial College London	Inner
WA8	Wandsworth - Putney High Street Facade	Roadside	Wandsworth	Imperial College London	Inner
WA9	Wandsworth - Putney	Urban Background	Wandsworth	Imperial College London	Inner
WAA	Wandsworth - Battersea	Roadside	Wandsworth	Imperial College London	Inner
WAB	Wandsworth - Tooting High Street	Roadside	Wandsworth	Imperial College London	Outer
WAC	Wandsworth - Lavender Hill (Clapham Jct)	Roadside	Wandsworth	Imperial College London	Inner
WL1	Waltham Forest - Dawlish Road	Urban Background	Waltham Forest	Ricardo-AEA	Inner
WL5	Waltham Forest - Leyton	Urban Background	Waltham Forest	Ricardo-AEA	Inner
WM0	Westminster - Horseferry Road	Urban Background	Westminster	Imperial College London	Central

Site Code	Name	Site Type	Data Owner	Site Manager	ULEZ Location
WM4	Westminster - Charing Cross Library	Roadside	Westminster	Imperial College London	Central
WM5	Westminster - Covent Garden	Urban Background	Westminster	Imperial College London	Central
WM8	Westminster - Victoria	Urban Background	Westminster	Imperial College London	Inner
WM9	Westminster - Victoria (Victoria BID)	Roadside	Westminster	Imperial College London	Inner
WMA	Westminster - Buckingham Palace Road	Roadside	Westminster	Imperial College London	Inner
WMB	Westminster - Oxford Street East	Roadside	Westminster	Imperial College London	Central
WMC	Westminster - Cavendish Square	Roadside	Westminster	Imperial College London	Central
WMD	Westminster - Elizabeth Bridge	Roadside	Westminster	Imperial College London	Central

In order to assess long term trends, monthly average concentrations grouped by site type and London zone (central / inner / outer) were calculated for NO_2 and $PM_{2.5}$. This is an update to the trend analysis carried out by King's College London for the London Environment Strategy[11] and that used in the previous ULEZ impact reports.

Sites with less than 75% data capture in a given month were excluded for that month and missing monthly data was interpolated. This data capture threshold is consistent with that used for EU reporting when calculating daily mean concentrations. This was calculated using Openair — an R package for air quality data analysis. Trends were then created using the LOESS smoothing function which "de-seasonalized" the data.[12] The span argument for the LOESS function was set to 0.375 to avoid over smoothing the recent impacts of the pandemic in central London, which occurred when using the span setting of 0.75, as used in previous analysis including the central London ULEZ analysis reports. This has resulted in the historical data on the trends analysis charts looking different to the analysis presented in previous central London ULEZ reports.

For the boundary roads analysis, a higher span of 0.5 has been used as it was only the need to reflect the pandemic changes in central London that required us to use a lower span for the impacts within the zone. The pandemic impacts seen in central are not as apparent on the boundary roads.

Reductions in NO_2 concentrations, from early February 2017 (when changes associated with the ULEZ began) to March 2022 (the most recent period for which data is available), have then be calculated by three-month averages (referred to as quarters) and are presented in Table 9.

[11] London Environment Strategy (pg 46), Greater London Authority, 2018
[12] Cleveland et al, STL: a seasonal-trend decomposition procedure based on loess, 1990

NO_2 roadside increment (R_{inc})

To analyse the changes in pollution concentrations from local road traffic emissions (i.e. changes attributable to the ULEZ and other policies), trends in NO_2 roadside increments were assessed. The roadside increment isolates the changes in concentration at the roadside from changes in background concentrations, using the equation below:

$$R_{inc} = roadside\ concentration - urban\ background\ concentration$$

This removes the impact of changes over time due to processes at the regional scale (such as meteorological conditions, boundary layer dynamics, policies outside the city, etc.) as described in more detail by Lenschow et al[13] and Font and Fuller[14] in a London context.

For this analysis a R_{inc} was derived from hourly data. A single hourly roadside increment was calculated per site by averaging concentrations across all outer London urban background sites. This approach was adopted for three reasons (following similar methodology to Font and Fuller 2016):

- The use of a single background hourly value allows R_{inc} to be directly compared between different roadside locations
- Averaging across outer urban background sites creates a complete time series for the period being assessed (2010 – 2022) without interpolation
- Averaging across outer urban background sites ensures R_{inc} follows general trends across a number of sites, although bias can be induced from changes to site availability

In addition, the outer London R_{inc} has been used as a predictor for "business as usual" or in other words the change in R_{inc} that would have happened irrespective of the Ultra Low Emission Zone, its expansion and other policies.

There are a number of outer urban background air quality monitoring sites in the near vicinity of Heathrow airport. These sites have been excluded from the background sites used to calculate the road increments due to the reduction in activity around the airport caused by the pandemic which is yet to return. The effect of these changes due to the airport activity were not seen over most of outer London. Inclusion of these sites in the outer London background would have induced a bias in the estimate of the impacts of ULEZ and its expansion.

[13] Lenschow et al, Some ideas about the sources of PM10, 2001

[14] Font and Fuller, Did policies to abate atmospheric emissions from traffic have a positive effect in London? 2016

Table 15: Heathrow sites excluded from this analysis

Site Code	Name	Site Type	Data Owner	Site Manager	ULEZ Location
HI0	Hillingdon - Keats Way	Urban Background	Hillingdon	Imperial College London	Outer
HI3	Hillingdon - Oxford Avenue	Urban Background	Hillingdon	Ricardo-AEA	Outer
HIL1	Hillingdon - Harmondsworth	Urban Background	Hillingdon	Ricardo-AEA	Outer
HS2	Hounslow - Cranford	Urban Background	Hounslow	Ricardo-AEA	Outer
HS7	Hounslow - Hatton Cross	Urban Background	Hounslow	Ricardo-AEA	Outer
LH0	Hillingdon - Harlington	Urban Background	Hillingdon	Imperial College London	Outer
SIPS	Hillingdon - Sipson	Urban Background	Hillingdon	Ricardo-AEA	Outer

In order not to skew the impact analysis at the latter end of the trends for the ULEZ expansion in 2021, any sites that were opened in 2021 or later were excluded from this analysis. For the same reason any sites that closed in 2021 were also excluded from the impact analysis.

The sites that either opened in or after 2021 or closed in 2021 and hence excluded from the analysis are listed below.

Table 16: Further sites excluded due to opening/closing in 2021

Site Code	Name	Site Type	Data Owner	Site Manager	ULEZ Location	Reason for exclusion
CD010	Camden - High Street	Roadside	Camden	Ricardo-AEA	Inner	Closed 24.05.2021
EA010	Ealing - Green Quarter	Urban Background	Ealing	Ricardo-AEA	Outer	Opened 03.11.2021
LW1	Lewisham - Catford	Urban Background	Lewisham	Imperial College London	Inner	Closed 03.11.2021
LW6	Lewisham - Laurence House Catford	Roadside	Lewisham	Imperial College London	Inner	Opened 17.11.2021
SKC	Southwark - South Circular Road	Roadside	Southwark	Imperial College London	Inner	Opened 24.07.2021
TL5	Newham - Hoola Tower TFL	Roadside	Newham	Imperial College London	Inner	Opened 08.03.2021

The average concentration across the outer London urban background sites was subtracted from the average central roadside, inner roadside and outer roadside concentrations. This was done on an hourly basis. Monthly averages were calculated excluding sites with less than 75 per cent data capture, values were then linearly interpolating for missing months. This was then aggregated by zone (Central / Inner / Outer London).

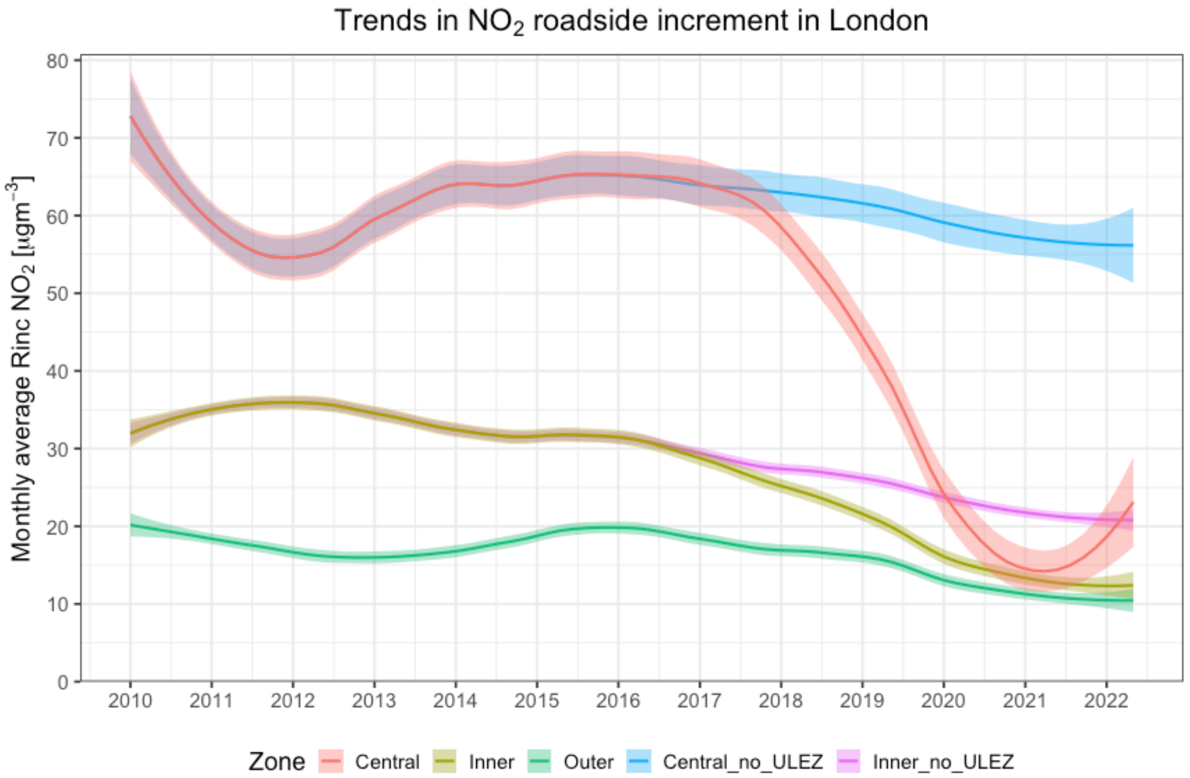

Figure 13: Trends in monthly average NO_2 roadside increment by zone

Figure 13 shows the LOESS trends of monthly average NO_2 roadside increment in central, inner and outer London as well as the central and inner "no ULEZ" scenario roadside increments. As with the previous trend analysis, the LOESS smoothing function "de-seasonalized" the data.[15]

Changes associated with the ULEZ were expected to begin in central London at the beginning of 2017. However, there is also some reduction in the NO_2 roadside increment concentrations in outer London. Independent of schemes such as the ULEZ, a certain proportion of older vehicles are replaced each month. As newer vehicles produce less NO_x emissions, fleet turnover will slowly clean up the vehicle fleet. This means that, in general, if traffic volumes were to remain constant, the roadside increment concentration R_{inc} would be expected to gradually decrease as newer vehicles enter the fleet.

The reductions in outer London R_{inc} reflect turnover of the fleet as well as changes at a regional level. This can be seen as the reduction that would have occurred London-wide, regardless of the introduction of the ULEZ, its expansion and other policies. The implementation of the LEZ for heavy vehicles would also have affected

[15] Cleveland et al, STL: a seasonal-trend decomposition procedure based on loess, 1990

vehicle turnover in outer London therefore the estimate of the trend in roadside increment may be slightly underestimated because it is not possible to remove the effect of the LEZ on monitoring data in outer London.

The blue and purple “no ULEZ” curves in Figure 13 are a prediction of central and inner London roadside increments if there was no ULEZ (assuming reductions at central and inner London roadside sites would follow the trend measured at outer London sites). The difference between the red curve and blue curve in Figure 13 represents the reduction in traffic contribution to NO_2 above that is expected from “no ULEZ” scenario. This is an estimate for the impact in central London of the preparation for, the introduction of and the expansion of the ULEZ and other policies including upgrading the bus fleet and the increase in zero emissions taxis.

The no ULEZ scenario was calculated by subtracting the reduction in R_{inc} in outer London compared to January 2017 from the R_{inc} in central/ inner London in January 2017.

$$R_{inc}^{cenral\ no\ ulez}{}_{i} = R_{inc}^{central}{}_{Jan17} - \left(R_{inc}^{outer}{}_{Jan17} - R_{inc}^{outer}{}_{i} \right)$$

It is therefore important to remove these “no ULEZ” concentrations to isolate the NO_2 reduction in central and inner London that can be attributed to the ULEZ. This has been done using the equation below:

$$ULEZ\ impact = R_{inc}^{no\ ULEZ} - R_{inc}^{central}$$

Impact of ULEZ on monthly average NO_2

The equation above produces an estimate of the impact (in ug m^{-3}) of the ULEZ, ULEX and other policies at central and inner London roadside locations. This has been used to estimate “no ULEZ” monthly average NO_2 concentrations, as in Figure 8 in the report. This was done by adding the estimated ULEZ impact concentration (in µg m^{-3}) to the actual monthly average measurements.