Cambridge Clean Air Zone feasibility study

Final report for the Greater Cambridge Partnership

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Contact:

John Watterson

Ricardo Energy & Environment

Gemini Building, Harwell, Didcot, OX11 0QR, United Kingdom

t: +44 (0) 01235 753595
e: john.watterson@ricardo.com

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Authors:

Mark Attree, David Birchby, Michel Vedrenne, John Watterson, Ancelin Coulon, Beth Conlan

Approved by:

Guy Hitchcock

Date:

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Executive Summary

1. Purpose

1.1 There is clear evidence of the health harm caused by air pollutants. The Government Committee on the Medical Effects of Air Pollutants has highlighted that exposure to air pollution contributes to over 35,000 deaths in the UK from cardiovascular disease, respiratory disease and lung cancer. In Cambridge and South Cambridgeshire 106 deaths each year can be attributed to poor air quality. We know that air pollution disproportionately affects those who live in less affluent areas and broadens health inequalities. There is also emerging evidence that suggests links between air pollution and conditions such as diabetes, lung development and cognitive decline.

1.2 Levels of nitrogen dioxide (NO_2) have been shown to be above legal limits set for the protection of human health within Cambridge city, particularly in Drummer St, Emmanuel Road, Regent St and St Andrew's St. The total predicted area of exceedance in 2017 is 17,600m^2; an additional 48,200m^2 area is within 20% of the limit.

1.3 Without implementation of any emission control measures, Cambridge is not predicted to achieve compliance with the limit value for annual mean NO_2 concentrations in future years, and areas of exceedance along congested roads with bus stops or high bus flows are expected to increase. This study assesses interventions to improve air quality within the Cambridge city area.

2. Context

2.1 The main source of emissions is from road traffic, and the largest contributors are buses which account for 49% of NOx emissions within the city centre. With the planned economic development, it is expected that the number of buses will substantially increase to support the accompanying city access transport plans. The increase in buses from 2017 levels is anticipated to be 15% by 2021, and 100% by 2031. Without intervention, there is a risk that NO_2 levels will remain above the legal limits for the next decade, while other cities see significant reductions.

2.2 Taxis account for 4% of NOx emissions in the city centre although this varies substantially from street to street. The emission improvements from the Cambridge City Council taxi policy, adopted in October 2018 to encourage the uptake of low emission vehicles, have been incorporated into the assessment. However, as the requirement is for all taxis to be ULEV by 2028, there is a long time-lag to reach the desired emission improvement in the fleet.

2.3 Assumptions within this modelling study have been aligned with those of other city access studies being undertaken by the GCP. Analysis of baseline pollutant concentrations demonstrates that 98% of predicted exceedences of the NO_2 AQO, and 75% of predicted concentrations within 20% of the AQO, occur within and around the inner ring road. Therefore, this study focuses on interventions applying within this area, although consideration of impact on the wider Cambridge area has been included.

2.4 A long list of 69 potential interventions were considered by stakeholders in terms of effectiveness, timescales and deliverability. Emission reductions were estimated from seven of these interventions.

3. Findings

3.1 The most effective interventions were those focussed on improving the whole bus fleet to cleaner vehicles through a charging CAZ. A Clean Air Zone Class A (all buses and coaches to be Euro 6, diesel taxis to be Euro 6 and petrol taxis to be Euro 4) would deliver compliance with the limit value for NO_2 across most of the city in 2021, although isolated hotspots may remain along Emmanuel Street and the Inner Ring Road. An alternative scenario of improving all LGV and HGVs and all *new* buses to the cleanest vehicles does reduce NO_2 concentrations, especially along the Inner Ring Road, Regent Street, St Andrews Street and Station Place. However, widespread exceedances of the limit value would remain in 2021.

3.2 A Clean Air Zone Class D (all diesel vehicles to be Euro 6 and all petrol vehicles to be Euro 4) operating around and within the Inner Ring Road is predicted to achieve compliance with the NO_2 limit value in 2021. This intervention would bring a 43% reduction in NOx emissions in the city centre. This intervention would require the use of ANPR cameras to enforce a charge. This could be aligned to that being considered in other cities e.g. £12.50 for non-compliant passenger cars and LGVs and £100 for buses and HGVs. Such an intervention could be implemented using the Council's powers in the Transport Act (2000) where a road-use based charging scheme can have variable charges related to the environmental performance of the vehicle.

3.3 By 2031, assuming that the increase in buses to service the transport needs would be mainly Euro V buses (2008-2013), compliance with the NO_2 limit value is not achieved and emissions remain at 2017 levels. While emissions reduce from private cars, HGVs and LGVs, emissions from buses increase. With many other cities considering the introduction of Clean Air Zones which would restrict access to buses to Euro VI (those manufactured from 2014 onwards), there is likely to be a high supply of older buses to cities with no similar access restrictions.

3.4 Assuming that the bus fleet turnover in Cambridge is reflective of the national average then by 2031 it is likely that compliance with the NO_2 limit value is achieved in some parts of the city but that exceedances will persist in areas where pedestrians and cyclists are exposed. The number of cyclists has increased by 10% over the past year and by 74% since 2004 in Cambridge, and with further encouragement of active travel over the next decade intervention is required to reduce the detrimental health impact of poor air quality for this mode of transport.

3.5 An economic assessment of the potential interventions included upfront and operational costs and installation of an Electric Vehicle charging infrastructure to support the intervention. Initial costs are mainly due to ANPR cameras on the 27 roads that join the Inner Ring Road, signs and road markings. Operational costs include data collection, vehicle registration assessment, compliance checking and processing of payments and disputes/appeals. Public health benefits due to improved air quality were monetised. In 2031, the Net Present Value of improving LGVs and buses was strongly positive at £44m.

4. Recommendations

4.1. Without intervention and with the expected doubling of the bus fleet, there is a risk that the air quality in Cambridge will not improve over the next decade. Air pollution accounts for 106 deaths each year in Cambridge and South Cambridgeshire.

4.2. The most effective intervention to improve air quality and protect public health is a charging `Class D' Clean Air Zone which includes all vehicles[1]. Improvement in the bus fleet should be a priority due to their large contribution to emissions. It is recommended that focus is given to improvement in the vehicle fleet within the city centre area by 2021. It is expected that the implementation of a Clean Air Zone would take approximately 18 months.

4.3. By 2031, reductions in concentrations across the whole of Cambridge will bring further public health benefits. Introducing a more ambitious charging CAZ (including LGVs, buses and coaches to be ZEV or ULEV) is predicted to reduce NO_2 levels to below 80% of the AQO across Cambridge; it is recommended that this option is pursued.

[111] Exemptions can apply e.g. to emergency services, disabled access, residents within the zone etc

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1 Introduction

Cambridge, like many cities across the UK, is suffering from poor air quality and has failed to meet National Air Quality Objectives (AQOs) in relation to nitrogen dioxide (NO_2). While recent trends show concentrations of air pollutants decreasing, substantial infrastructure development is planned in Cambridge over the next decade, bringing many thousands of new employment opportunities, and increasing traffic and pollution levels. To support this development, the City Council and the Greater Cambridgeshire Partnership have developed a City Access Strategy to manage the associated increase in traffic flows and pollution. As part of this City Access Strategy, this study was undertaken to investigate options to improve air quality in terms of their effectiveness, deliverability and timescales.

1.1 Health impacts of air quality

There is clear evidence of the health harm caused by air pollutants. The Committee on the Medical Effects of Air Pollutants (COMEAP) has highlighted that exposure to air pollution contributes to many thousands of deaths in the UK from cardiovascular disease, respiratory disease and lung cancer. In Cambridge and south Cambridgeshire, there are 106 deaths each year that can be attributed to air pollution. We know that air pollution disproportionately affects those who live in less affluent areas and deepens health inequalities. There is also emerging evidence that suggests links between air pollution and conditions such as diabetes, lung development and cognitive decline.

The links between exposure to poor air quality and adverse health outcomes are well established, underscored by an evidence base which is both mature and extensive. The role which exposure to poor air quality plays in health inequalities is less well understood, although there is a developing literature on the issue. Highly vulnerable groups include those in poor health, the very old and the very young. It has also been shown that individuals in more deprived areas are more likely to suffer from poor health. Therefore, given that those in a more deprived situation, or those in populations where the proportion of very old or young people are higher than average, are also exposed to relatively higher levels of air pollution, it could be argued that poor air quality is exacerbating health inequalities.

1.2 National Air Quality Objectives (AQOs)

The EU ambient air quality directive (2008/50/EC) sets binding limits for concentrations of air pollutants, which take into account the health impacts of the pollutant in question. The directive has been transposed into English legislation as the *Air Quality Standards Regulations 2016*. This document includes National Air Quality Objectives, which provide limit values for air pollutants based on their health impacts. Table 1 presents the relevant National Air Quality Objectives for NO_2, PM_{10} and $PM_{2.5}$ concentrations.

Table 1: UK National Air Quality Objectives (AQOs) for the protection of human health

Pollutant	Objective	Concentration measured as	Date to be achieved and maintained thereafter	New or existing
Particulate matter (PM_{10})	50 µg.m^{-3} not to be exceeded more than 35 times a year	24 hour mean	1 January 2005	Retain existing
	40 µg.m^{-3}	Annual mean	1 January 2005	Retain existing
Particulate matter ($PM_{2.5}$)	25 µg.m^{-3}	Annual mean	2010	Retain existing
	Target of 15% reduction in concentrations at urban background	Annual mean	Between 2010 and 2020	New (European obligations still under negotiation)
Nitrogen dioxide (NO_2)	200 µg.m^{-3} not to be exceeded more than 18 times a year	1 hour mean	1 January 2010	Retain existing
	40 µg.m^{-3}	Annual mean	1 January 2010	Retain existing

1.3 World Health Organisation guidelines

The World Health Organisation (WHO) publishes air quality guidelines, which are intended for worldwide use for the protection of public health. National standards will vary according to the approach adopted for balancing health risks, technological feasibility, economic considerations and various other political and social factors. Therefore, these may be different to the WHO guidelines. The guideline values for NO_2 concentrations are the same as the equivalent UK AQOs. However, the guideline values for particulate matter are lower than the equivalent AQOs. The WHO also state that there is no safe level for particulate matter and consequently interventions to reduce emissions will bring health benefits. Since the publication of the guidelines in 2006, the evidence base for adverse health effects related to short- and long-term exposure to these pollutants has become much larger and broader. Work is underway to revise the guidelines, and it is possible that the guidelines for NO_2 will reduce.

1.4 Government Policy on Air Quality

At the national level, the EU has commenced infraction proceedings against the UK Government and Devolved Administrations for their failure to meet the EU Limit Value for NO_2. In 2015, the Supreme Court ordered the Government to consult on new air pollution plans that had to be submitted to the European Commission no later than 31 December 2015. As such, DEFRA released plans[2] to improve air quality, specifically tackling NO_2, in December 2015. These plans were successfully challenged in the High Court by Client Earth in 2016, and a subsequent set of plans were published in July 2017. The plans identified many Local Authorities where the EU Limit Values for NO_2 are not expected to be met by 2021. These authorities have been undertaking feasibility studies to investigate interventions to bring forward compliance, including the implementation of a charging clean air zone.

A Clean Air Zone (CAZ) as defined by Government is an *area where targeted action is taken to improve air quality and resources are prioritised and coordinated in order to shape the urban environment in a way that delivers improved health benefits and supports economic growth.* Clean Air Zones should be designed to deliver the cleanest possible fleet. To ensure that only the cleanest vehicles are encouraged to enter or operate in a charging Clean Air Zone, common standards need to be set for their entry. The minimum emission standards required for entry into a charging zone

[2] https://www.gov.uk/government/publications/air-quality-in-the-uk-plan-to-reduce-nitrogen-dioxide-emissions

without paying a charge are given in Table 2. Vehicles that conform to more recent euro standards should emit less pollution than older vehicles and will be allowed free entry into the zone. Other vehicles should be subject to a charge unless they are covered by an exemption, a discount on the charge, or other acceptable vehicle requirements set out in the Government's Clean Air Zone policy framework, such as meeting retrofitting or ultra low emission requirements.

Table 2: Minimum emission standards for entry into a Clean Air Zone without paying a charge by class

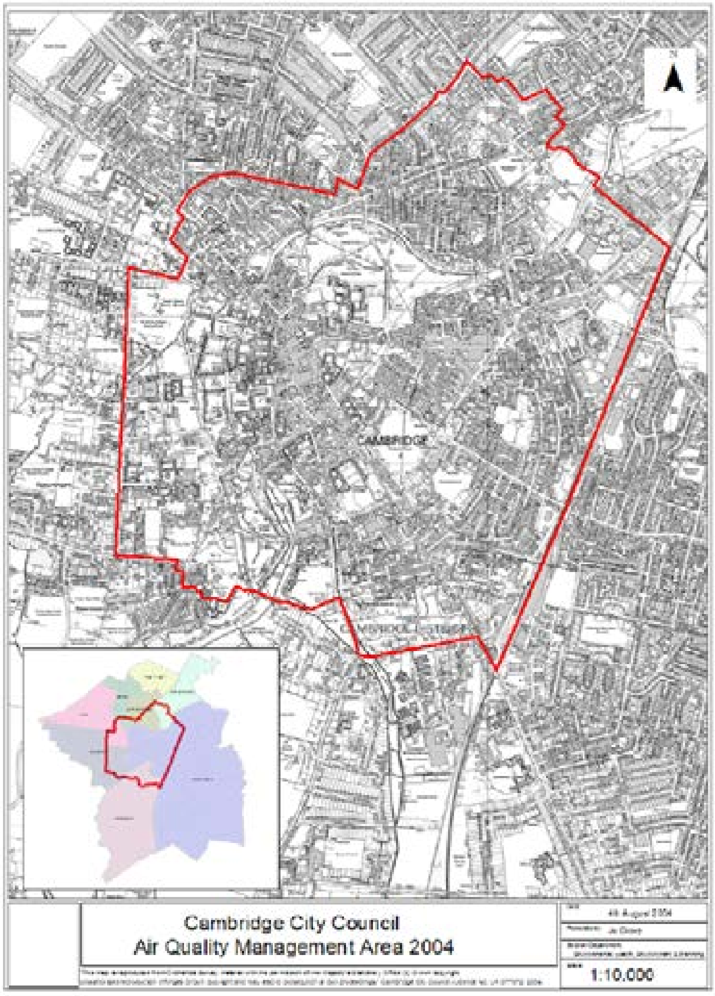
Class	Bus	Coach	Taxi and private hire	HGV	Large van/ minibus/small van	Cars
A	Euro VI	Euro VI	Euro 6 (diesel) Euro 4 (petrol)	No restriction	No restriction	No restriction
B	Euro VI	Euro VI	Euro 6 (diesel) Euro 4 (petrol)	Euro VI	No restriction	No restriction
C	Euro VI	Euro VI	Euro 6 (diesel) Euro 4 (petrol)	Euro VI	Euro 6 (diesel) Euro 4 (petrol)	No restriction
D	Euro VI	Euro VI	Euro 6 (diesel) Euro 4 (petrol)	Euro VI	Euro 6 (diesel) Euro 4 (petrol)	Euro 6 (diesel) Euro 4 (petrol)

2 Study scope and local context

Cambridge, like many cities across the UK, is suffering from poor air quality and has failed to meet National Air Quality Objectives (AQOs) in relation to nitrogen dioxide (NO_2). The worst affected areas are around busy and congested roads, with transport being the main source of the nitrogen oxide (NOx) emissions that are responsible for NO_2 pollution. In response to these challenges, Cambridge City Council (referred to from here as 'the City Council') declared an Air Quality Management Area (AQMA) in 2004 and drew up an Air Quality Action Plan (AQAP) to address the problem.

The AQMA of Cambridge is an area encompassing the inner ring road[3] and all the land within it (including a buffer zone around the ring road and its junctions with main feeder roads); the area is shown in Figure 1. Historically, high concentrations have been measured at monitoring sites in this area; when the AQMA was declared in 2004, the annual mean NO_2 concentration was 49 μg m^{-3} at a continuous monitor in Parker Street and 59 μg m^{-3} at a diffusion tube in Emmanuel Street. In recent years, a series of initiatives undertaken by the City Council have led to a reduction in concentrations. In 2016, Parker Street exceeded the annual mean objective; the recorded NO_2 was 41 μg m^{-3}. In 2017, there were no exceedances of the annual mean NO_2 concentrations.

Figure 1: Cambridge Air Quality Management Area (reproduced from Figure Three in the AQAP)



[3] Queen's Road, the Fen Causeway, Lensfield Road, Gonville Place, East Road, Elizabeth Road, Chesterton Way, and Northampton Street

Around 206,000 vehicles travel in and out of Cambridge every day, with 50,000 workers travelling in alone. Nearly 10.5 million rail passengers travel to/from Cambridge each year. The Greater Cambridge area of Cambridge and South Cambridgeshire is expected to grow by up to 30% over the next 15 years – with the population rising by 65,000 to 338,000 by 2031 (from 273,000 in 2011). Population growth will lead to an increase in trips on the transport network of 25,000 by 2031 (from 101,000 in 2011 to 126,000). Without intervention, this will lead to:

- An increase in traffic in Cambridge of over 30% in the morning peak;
- An increase in traffic in South Cambridgeshire of almost 40% in the morning peak;
- A doubling of congestion time.

As such, the air quality situation in Cambridge is delicately balanced; the increases in traffic flows and congestion may lead to non-compliance with the AQOs in future years and erase recent improvements to air quality and health outcomes in spite of improvements in vehicle emission standards over time.

The Greater Cambridge Partnership City Access Strategy is a package of 8 measures to tackle congestion in Cambridge. This package of measures plans to achieve a reduction in peak-time traffic levels in Cambridge of 10-15% by 2031. The measures comprise:

1. pedestrian and cycling infrastructure;
2. public space and air quality;
3. better bus services;
4. travel planning;
5. smart technology;
6. traffic management;
7. workplace parking levy;
8. on-street parking management (including Controlled Parking Zones).

In recognition of the strong public support for addressing air quality, as part of measure 2, the GCP commissioned Ricardo E&E to carry out a feasibility study to investigate options to improve air quality in Cambridge. Cambridge City is not a directed city and therefore has flexibility to investigate the implementation of a charging Clean Air Zone alongside other Low Emission Strategy options. As such, there are a large number of possible options covering different CAZ classes (A/B/C/D)[4], geographic areas, and emission reduction measures.

A longlist of intervention options was developed, taking into account existing policies and key sources of pollution, including permutations of location, charging, and vehicle classes. A consultation, via stakeholder engagement, was completed to select a shortlist of options to be implemented from this longlist. Baseline emissions modelling for 2017 was used to choose the most effective geography.

An emissions analysis of the impacts of these options was carried out. Following the emissions analysis, detailed dispersion modelling and economic analysis was carried out for selected intervention packages.

The study was subject to a number of key constraints:

- Measure 3 includes the provision of additional bus services, which will be expected to further impact air quality. For the purposes of this study, GCP decided that the effects of this policy would be a 15% increase in bus flows in 2021 (relative to 2017 levels), and a 100% increase in bus flows in 2031.
- Only one boundary was chosen for this study in order to ensure consistency and fairness in comparing different vehicle type interventions. This geography includes the inner ring road; the rationale for choosing this geography is provided in Section 5.

[4] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/612592/clean-air-zone-framework.pdf

3 Modelling methodology

Emissions analysis, dispersion modelling analysis, and economic analysis was carried out for 3 years:

1. 2017, the existing baseline;
2. 2021, the nearest feasible year of implementation of any interventions;
3. 2031, representing longer-term ambitions.

The air quality modelling was carried out using the latest version of the RapidAir dispersion model, following LAQM.TG(16) guidance published by the Department for Environment, Food and Rural Affairs (Defra)[5]. NOx to NO_2 chemistry was modelled using the NOx:NO_2 calculator published by Defra[6]. Modelling was conducted using meteorological data for 2017 from Cambridge Airport, supplemented by the Bedford and Andrewsfield sites. Speed-dependent vehicle emission factors for NOx, primary NO_2, and particulates were taken from the latest version of the Emission Factor Toolkit (EFT), version 8.0.1[7].

The emission factors were combined with traffic flow and speed data to calculate emissions for each modelled scenario. Trafficmaster speed data was used in the modelling for all years. Annual average daily traffic flows (AADTs) were derived from the Cambridge Sub-Regional Traffic Model 2 (CSRM2), augmented by additional timetable and split data provided by the City Council.

Vehicle fleet data was sourced from an automatic number plate recognition (ANPR) campaign carried out by Greater Cambridge Partnership (GCP) in 2017, combined with detailed local taxi and bus fleet data provided by Cambridge City Council. The local bus fleet was assumed to stay constant between 2017 and 2031; this is a conservative assumption, which ignores turnover and replacement by newer vehicles. This represents a plausible worst-case scenario, as availability of new buses may be limited in the immediate future by high demand resulting from the proposed implementation of CAZs across a number of cities in the UK. In the event that Cambridge does not implement restrictions on bus emissions, it is likely that operators will move older buses from cities with restrictions to areas such as Cambridge. For all other vehicle types, fleet composition was projected for future years using national fleet projections published by the DfT[8].

Taxis account for 4% of NOx emissions in the city centre, although this varies substantially from street to street. The Cambridge City Council Hackney Carriage and Private Hire Licensing Policy, adopted in October 2018, identifies a number of incentives and regulatory policies which are designed to encourage and reward the uptake of ultra low emission vehicles and electric vehicles within the taxi fleet. This policy is separate to any interventions in this study, and its effects are included in the baseline for this assessment. However, as the requirement is for all taxis to be ULEV by 2028, there is a long time-lag to reach the desired emission improvement in the fleet. Following advice from Cambridge City Council, the effects of this policy were assumed to be:

- In 2021, 50% of Cambridge City Council taxis (Hackney carriages and Private Hire Vehicles) were assumed to be ULEVs, with the remaining taxis following the 2017 fleet.
- In 2031, 100% of Cambridge City Council licensed taxis were assumed to be ULEVs.

As part of the City Access Strategy, the GCP has made a commitment to reduce traffic flows in Cambridge by 10-15% relative to 2011 levels by 2031. No traffic modelling data is currently available

[5] https://laqm.defra.gov.uk/documents/LAQM-TG16-February-18-v1.pdf
[6] https://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html
[7] https://laqm.defra.gov.uk/review-and-assessment/tools/emissions-factors-toolkit.html
[8] http://naei.beis.gov.uk/data/ef-transport

for the expected effects of this policy. Instead, the GCP advised that traffic flows for private cars and HGVs should be reduced by 2031 by 10-15% relative to 2011 levels, as per GCP stated targets. The upper range of that target, 15%, would represents a 30.0% decrease in traffic flows relative to the 2031 case without the implementation of a Demand Management area.

Further details on the emissions inventory compilation are presented in Appendix C; details of the dispersion modelling are presented in Appendix B.

4 Baseline air quality in Cambridge

Emissions inventories were compiled and dispersion modelling carried out to quantify the air quality situation in Cambridge without any intervention, following the methodology described in Section 3.

4.1 Emissions analysis

Table 3 presents the total NOx emissions in Cambridge apportioned by traffic type, vehicle type, and area for 2017. A full source apportionment analysis is presented in Appendix E.

Table 3: Source apportionment of road NO_x emissions, tonnes per year, 2017 baseline inventory

Vehicle type	Total emissions inside inner ring road (tonnes/year)			Total emissions outside inner ring road (tonnes/year)		
	Flowing	Idling	Total	Flowing	Idling	Total
Petrol car	2.0	0.3	2.2	50.5	0.6	51.2
Diesel car	14.7	2.3	17	277	4.5	281.5
LGV	4.5	0.8	5.3	110	1.7	111.7
HGV	2.6	0.7	0	202.5	1.3	203.8
Non-local bus & coach	6	2.8	8.8	17.5	1.7	19.2
Local bus	7.6	13.1	20.7	36	11.8	47.7
Motorcycle	0.1	0	0.1	2	0	2.04
Taxi & private hire	2.1	0.5	2.6	21.6	0.3	21.9
Total	39.6	20.6	60.1	717.1	21.9	738.9

a) b)

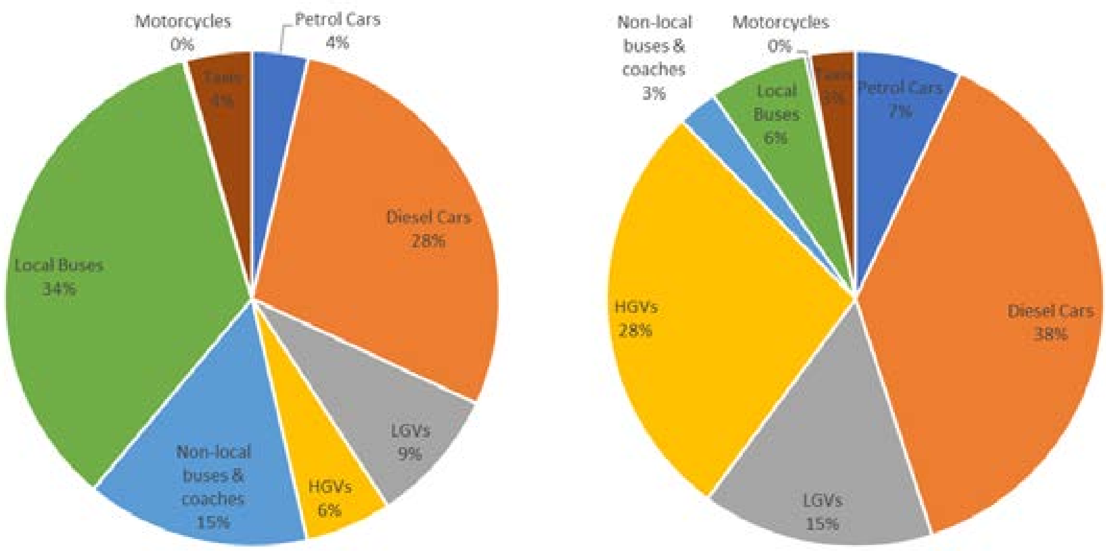


Figure 2: Source apportionment of road traffic NOx emissions in 2017 a) inside the inner ring road, and b) outside the inner ring road

Inside the inner ring road, diesel cars (28%) and local buses (34%) are the main contributors to NOx emissions from road traffic. The majority of emissions from diesel cars occur during free-flowing traffic, whereas the majority of emissions from buses occur during congestion, reflecting the relatively high emission factors for buses travelling at low speeds. Petrol cars, while accounting for a significant proportion of total vehicle movements, are a relatively small contributor to total NOx emissions in the city centre, contributing only 2.2 tonnes per year, or 3.7% of the total.

Congestion accounts for 27% of road traffic NOx emissions in the city centre, reflecting the oversaturation of flows along the narrow roads during peak hours. Local buses account for over half of congestion emissions; congestion along busy bus routes therefore contributes significantly to the air quality problem in Cambridge.

Outside the city centre, local buses are not a significant contributor to NOx or PM_{10} emissions except along radial routes out of the city centre. The largest sources of road traffic NOx emissions outside the inner ring road are diesel cars (281 tonnes/year) and rigid HGVs. The majority of HGV emissions occur along the M11 and A14; these vehicles are not expected to travel into the city.

Table 4 presents the total calculated road traffic emissions across the model domain in the 2017, 2021 and 2031 baseline scenarios. In future years, the natural evolution of the fleet over time has three effects:

1. A shift to newer engine technologies, particularly Euro 6/VI and related standards associated with improved vehicle testing regimes;
2. A significant fuel use shift from diesel to petrol, particularly for private cars;
3. A smaller shift towards the use of electric vehicles.

These three changes lead to substantial decreases in expected emissions of NOx and primary NO_2 in future years relative to 2017, and smaller decreases in emissions of PM_{10} and $PM_{2.5}$.

Table 4: Total emissions across Cambridge, baseline, tonnes per year

Year	Emissions inside inner ring road		Emissions outside inner ring road		Total emissions			
	NOx	PM_{10}	NOx	PM_{10}	NOx	Primary NO_2	PM_{10}	$PM_{2.5}$
2017	60.1	375.5	738.9	375.5	799.0	185.3	375.5	224.3
2021	54.5	373.3	598.6	373.3	652.5	152.2	373.3	213.3
2031	58.4	294.2	347.5	294.2	405.9	67.2	294.2	161.8

Table 5 presents total NOx emissions across Cambridge without intervention for each modelled year, apportioned by vehicle type.

Table 5: Total NOx emissions across Cambridge apportioned by vehicle type, baseline, tonnes per year

Vehicle type	Total emissions inside inner ring road (tonnes/year)			Total emissions outside inner ring road (tonnes/year)		
	2017	2021	2031	2017	2021	2031
Petrol car	2.2	1.6	1.4	51.2	32.8	25.0
Diesel car	17.0	15.0	4.2	281.5	247.0	66.5
LGV	5.3	4.8	3.9	111.7	103.5	77.6
HGV	3.4	2.5	0.6	203.8	129.2	15.0
Non-local bus & coach	8.8	6.5	1.3	19.2	13.3	3.5
Local bus	20.7	22.2	46.1	47.7	54.6	151.3
Motorcycle	0.1	0.0	0.0	2.0	1.6	1.0
Taxi & private hire	2.6	1.9	1.0	21.9	16.6	7.7
Total	60.1	54.6	58.5	739.0	598.6	347.5

Emissions from all vehicle types except for local buses decrease over time due to the evolution of the fleet. However, as the local bus fleet is not predicted to evolve to newer technologies in future years without intervention, NOx emissions from local buses are predicted to increase in future years due to the GCP City Access Strategy.

As a result, total NOx emissions outside the inner ring road, where local bus emissions constitute a relatively small proportion of the total, decrease over time, while emissions inside the inner ring road, where local bus emissions are significant, remain constant. In 2031, without intervention local buses account for 79% of total NOx emissions inside the inner ring road, eclipsing the contribution from other sources.

The proportional contribution of each vehicle type to total NOx emissions inside and outside the inner ring road in 2021 and 2031 is presented in Figure 3 and Figure 4 respectively.

a) b)

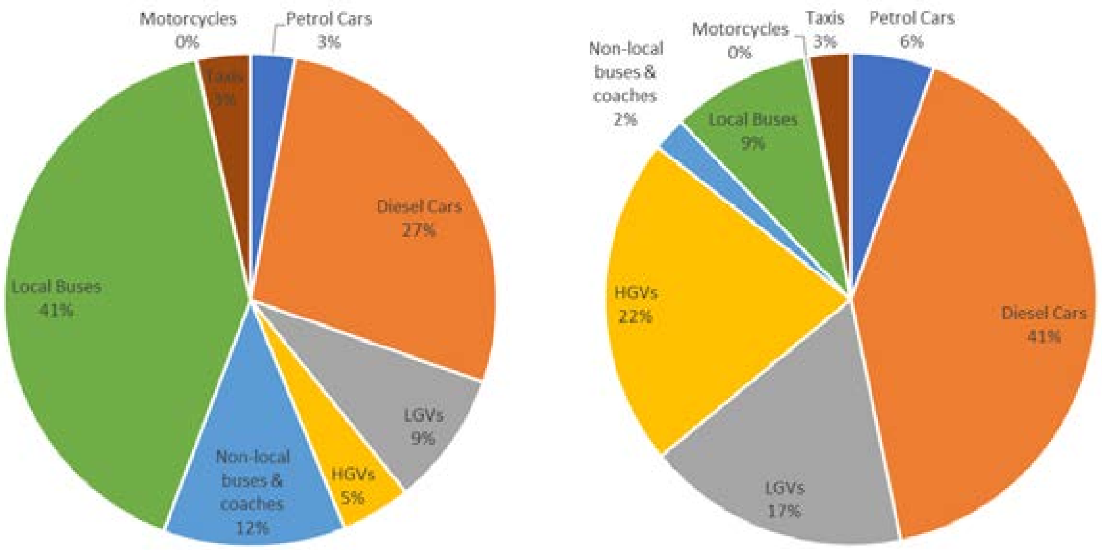


Figure 3: Source apportionment of road traffic NOx emissions in 2021 a) inside the inner ring road, and b) outside the inner ring road

a) b)

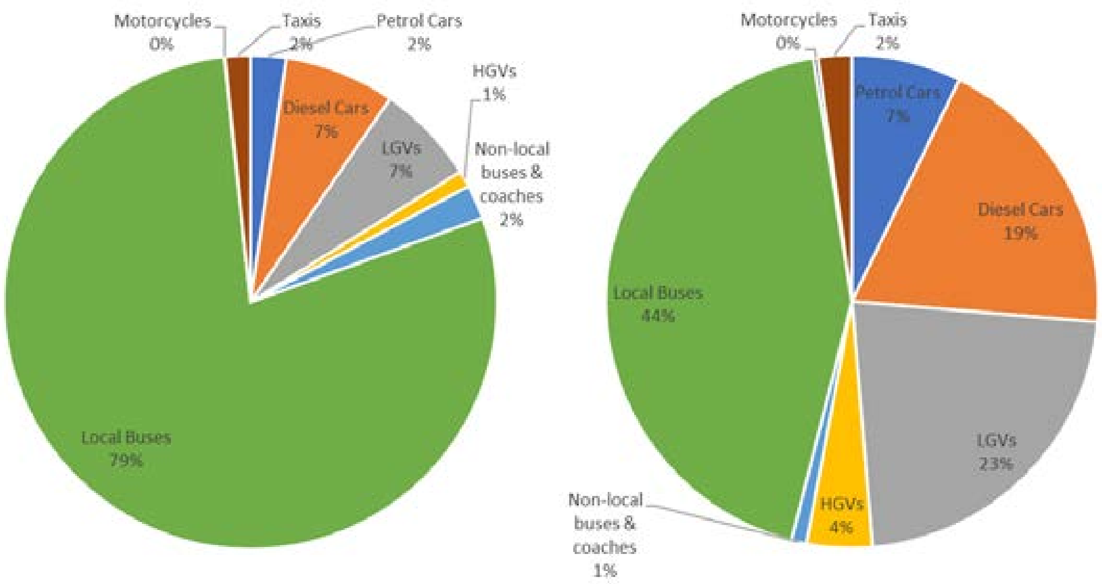


Figure 4: Source apportionment of road traffic NOx emissions in 2031 a) inside the inner ring road, and b) outside the inner ring road

4.2 Predicted concentrations

Figures 6 to 8 present predicted annual mean NO_2 concentrations for 2017, 2021, and 2031 in and around the Cambridge city centre AQMA.

In 2017, elevated NO_2 concentrations are predicted along the inner ring road where traffic flows are relatively high, and on roads in the city centre with significant congestion and high bus flows.

Exceedances of the AQO of 40 µg.m^{-3} for annual average NO_2 concentrations are seen at building façades along the following roads:

- The area around the Drummer Street bus stop, including along Emmanuel Street, sections of Drummer Street, and Emmanuel Road. The maximum predicted NO_2 concentrations across Cambridge occur in the road on Emmanuel Street, where a concentration of 70 µg/m³ is predicted.
- Long sections of Regent Street and St. Andrew's Street. These roads are associated with heavy congestion and bus flows, as the majority of buses entering the city centre from the south use this route. The high emissions along this route are compounded by street canyon effects caused by the narrow road widths and surrounding buildings, trapping pollutants.
- The Gonville Place-Hills Road junction. This junction is highly congested.
- Victoria Avenue (at the Chesterton Road junction).
- Fen Causeway, associated with high traffic flows.
- Lensfield Road, also associated with high traffic flows.

In addition, concentrations within 10% of the AQO are seen at building façades at the following locations:

- The section of Newmarket Road between East Lane and Coldhams Lane;
- East Road;
- street canyons on Hills Road;
- sections of Station Road and Tennison Road.

These exceedances and at-risk areas are concentrated at locations where pedestrians and cyclists may be exposed. The number of cyclists has increased by 10% over the past year and by 74% since 2004 in Cambridge, and with further encouragement of active travel over the next decade, intervention is required to reduce the detrimental health impact of poor air quality for this mode of transport. These results show that a combination of measures targeting traffic volumes along the inner ring road, and measures targeting congestion and bus flows in the city centre, would be required in order to achieve compliance with the AQO for annual mean NO_2 concentrations.

Table 6 presents the total area of exceedance and at-risk area for the annual mean AQO for NO_2 (defined as areas within 20% of the AQO) for 2017, 2021, and 2031. No exceedances of the AQO for annual average PM_{10} concentrations are predicted.

Table 6: Area of exceedance and at-risk area for annual mean NO_2 AQO without intervention, 2017 to 2031

Area	Area of exceedance of the AQO for annual mean NO_2 (m²)			Area within 20% of the AQO for annual mean NO_2 (m²)		
	2017	2021	2031	2017	2021	2031
Central Cambridge without Inner Ring Road	11400	8200	13000	32300	24100	35300
Around Inner Ring Road	5800	2000	1300	33000	18000	4700
Outside Inner Ring Road	400	600	4100	21300	12300	16300
Total	17600	10800	18400	86600	54400	56300

Figure 5 presents the evolution in the total area of exceedance, apportioned by region, over time. Without implementation of any emission control measures, Cambridge is not predicted to achieve compliance with the AQO for annual mean NO_2 concentrations; there is no year of compliance within the temporal scope of the study, even if emissions improvements occur along projected lines for non-bus vehicles.

Improvements in vehicle emissions technology are nevertheless predicted to substantially reduce the area of exceedance of the AQO around the inner road, as exceedances in this area are primarily associated with high traffic volumes rather than congestion or bus flows.

However, in areas with high bus flows, bus stops or congestion, areas of exceedance are predicted to increase in future years. New areas of exceedance are predicted around Cambridge bus station and around the CB1 development, and as a result, without intervention, the total predicted area of exceedance of the AQO is slightly larger in 2031 than in 2017.

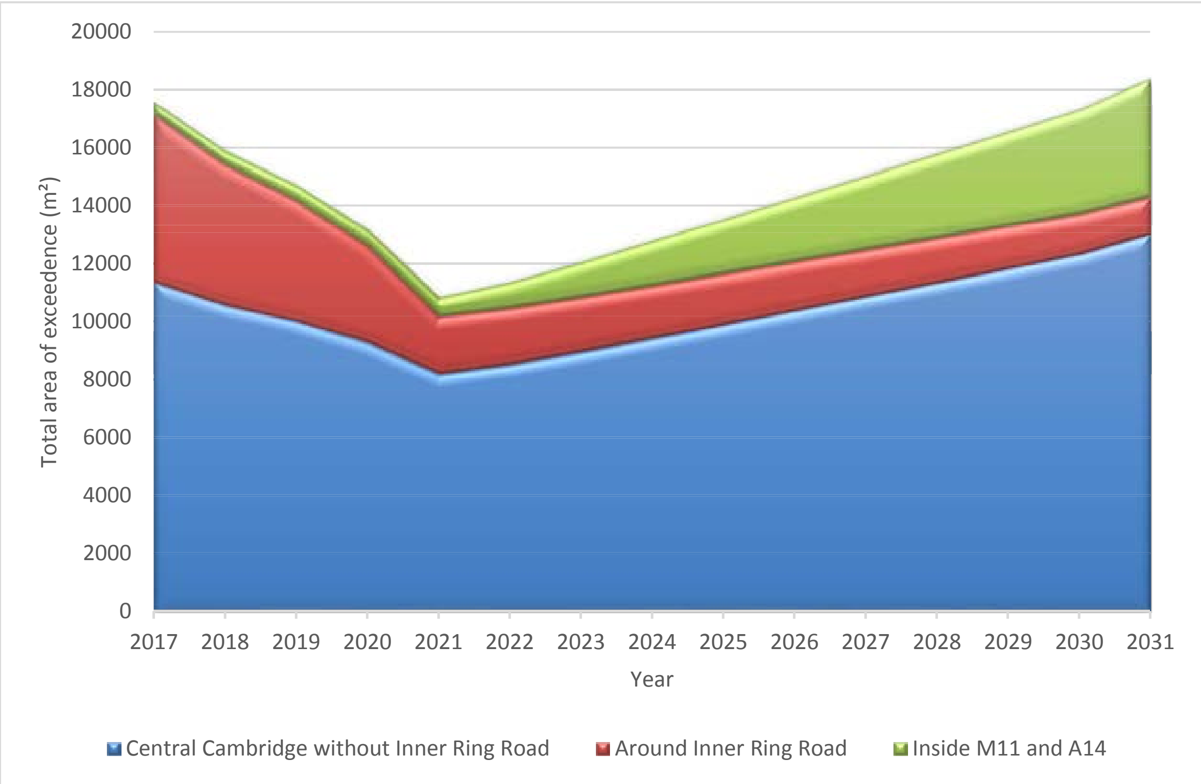


Figure 5: Area of exceedance of the annual mean NO_2 AQO without intervention, 2017 to 2031

Figure 6: Annual average NO_2 concentrations, central Cambridge, 2017, µg.m^{-3}

Figure 7: Annual average NO_2 concentrations, central Cambridge, 2021, μg.m^{-3}

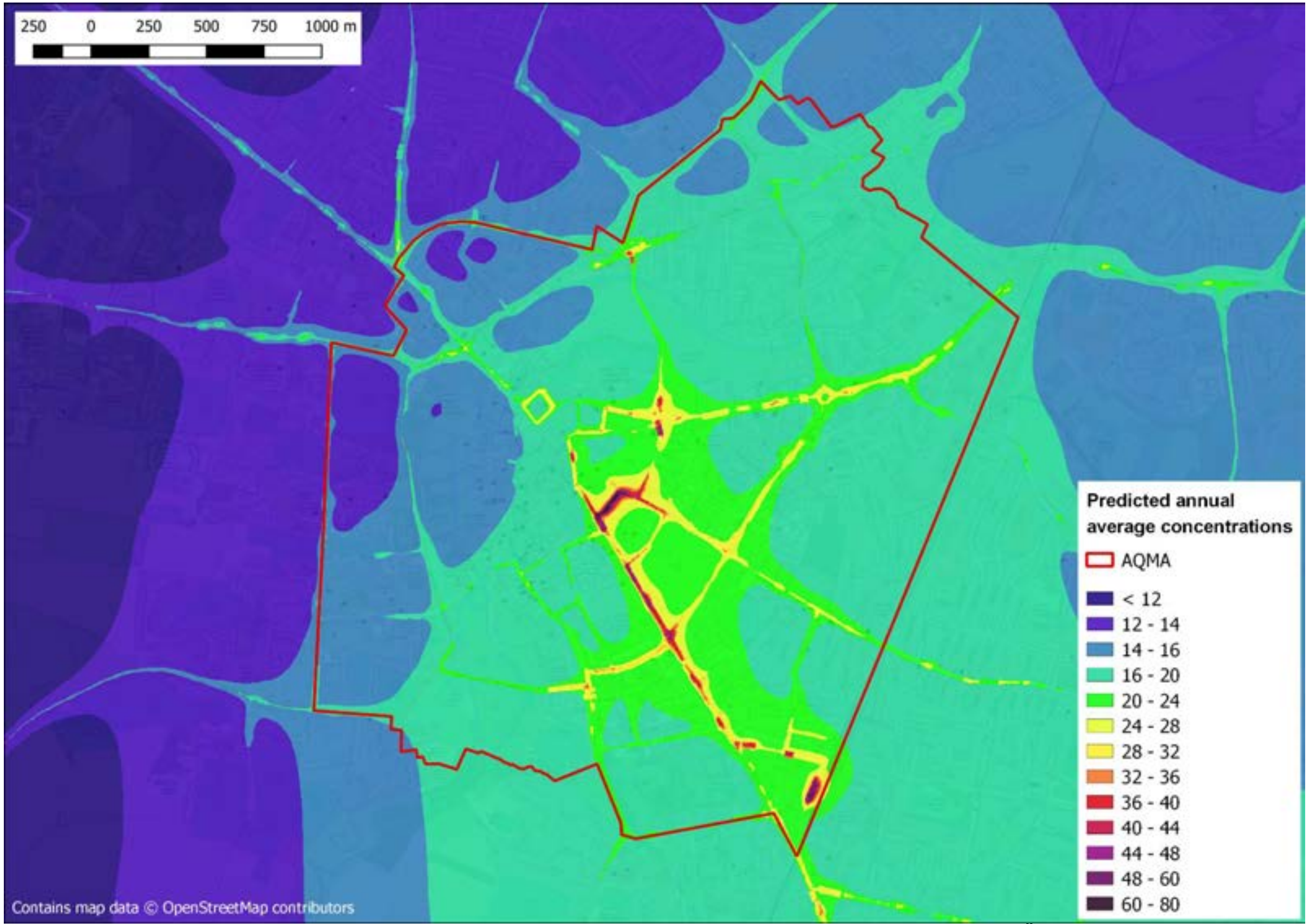


Figure 8: Annual average NO_2 concentrations, central Cambridge, 2031, $\mu g.m^{-3}$

5 Developing air quality mitigation options

There are a large number of air quality mitigation options that could be implemented in Cambridge covering different CAZ classes (A/B/C/D)[9], boundaries, and wider emission reduction measures. To develop a shortlist of options for the modelling, a structured sifting approach was carried out in collaboration with the Greater Cambridge Partnership, the City Council and the County Council.

5.1 Defining the geographic scope

Three potential scheme boundaries were considered, representing the most sensible potential constraints based on the road layout of Cambridge:

1. The area bounded by (but not including) the inner ring road. This 2.5km^2 area covers the central Cambridge locations where maximum recorded air pollutant concentrations occur, including the area surrounding the Drummer Street bus station.
2. The area bounded by, and including, the inner ring road. This includes congested areas along Gonville Place, Lensfield Road, and Fen Causeway.
3. A proposed cordon inside the M11 and A14.

The proposed boundaries, and AQMAs in the model domain, are presented in Figure 9.

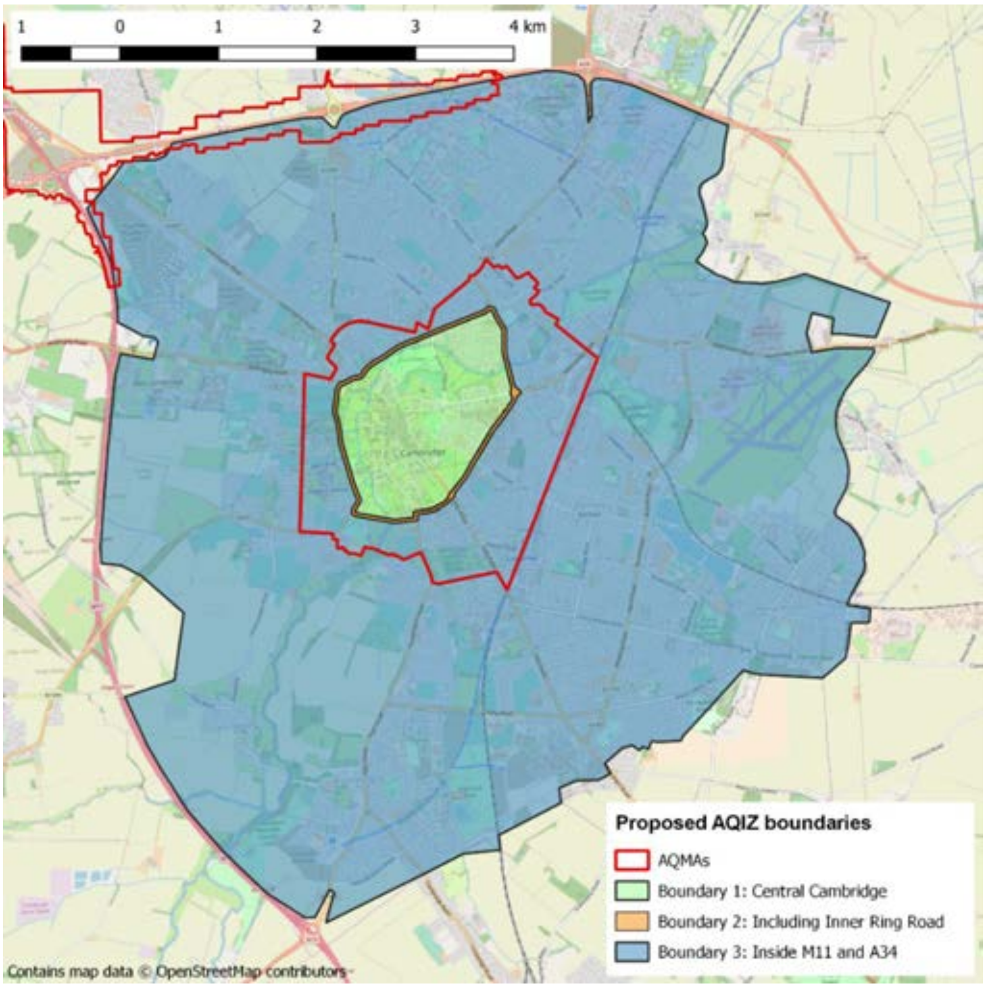


Figure 9: Proposed Air Quality Intervention Zone boundaries

[9] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/612592/clean-air-zone-framework.pdf

An analysis of 2017 annual average NO_2 concentrations and initial costs for charging infrastructure was carried out to determine which boundary would provide the best balance between delivering concentration reductions in areas where NO_2 concentrations exceed the AQO or are at risk of exceeding the AQO, without incurring disproportionate implementation costs or causing disproportionate disruption to travel and local businesses.

A summary of the calculated implementation costs for a charging CAZ in each proposed boundary is provided in Table 7. A detailed description of the calculation methodology is provided in Appendix H.

Table 7: Implementation and ongoing maintenance costs associated with each proposed boundary

Boundary	Area (km²)	Entry roads	Upfront costs	Ongoing maintenance (per year)
1: Central Cambridge without Inner Ring Road	2.5	15	£707,000	£90,000
2: Central Cambridge including Inner Ring Road	2.7	27	£1,273,000	£162,000
3: Inside M11 and A14	49.2	14	£660,000	£84,000

Options 1 and 3 incur lower overall upfront and maintenance costs due to the smaller number of entryways requiring CAZ infrastructure, while Option 2 (including the inner ring road in the CAZ) is more expensive to implement, as there are a large number of small entryways onto the inner ring road which would need to be covered in order to prevent vehicles avoiding the scheme. Minimum disruption will be caused by restricting access to the smallest possible area. Table 8 presents the area of exceedance and near-exceedance inside each proposed boundary.

Table 8: Predicted areas of exceedance of the AQO for annual mean NO_2 in 2017

Boundary	Area (km²)	Area of exceedance of the AQO for annual mean NO_2, 2017					
		m^2			% of total		
		32	36	40	32	36	40
1: Central Cambridge without Inner Ring Road	2.5	32300	17500	11400	37%	45%	65%
2: Central Cambridge including Inner Ring Road	2.7	65400	32900	17200	75%	85%	98%
3: Inside M11 and A14	49.2	86700	38700	17600	100%	100%	100%

A boundary covering Central Cambridge without including the inner ring road has the potential for significant positive impacts on exposure; 65% of exceedances of the AQO for annual mean NO_2 occur in this area, together with 45% of concentrations within 10% of the AQO. However, this option is likely to move older vehicles onto the inner ring road, leading to an increase in the area of exceedance around this road which may counterbalance any positive impacts from the implementation of any measures.

Extending the boundary to include the inner ring road has the potential to deliver more comprehensive benefits; 98% of the area of exceedance across Cambridge occurs within this expanded area.

There is relatively little benefit to extending the CAZ beyond the inner ring road (boundary 3), as only 2% of the total area of exceedance of the Air Quality Objective in 2017 is outside this region.

On the basis of this evidence, boundary 2 (including the inner ring road) was selected for detailed analysis in the study in consultation with the GCP and the City Council, in spite of the implementation costs associated with the large number of entryways. Both Options 1 and 3 have significant drawbacks: Option 3 will cause increased disruption to traffic due to the larger area covered, while Option 1 will lead to increases in pollution levels around the inner ring road as older vehicles are pushed out onto it. Including the inner ring road in the area (Option 2) allows exceedances of the AQO around this road to be targeted, while minimising disruption to households and businesses.

5.2 Defining the vehicle types and classes

The baseline emissions and concentration analysis described in Section 4 demonstrates the following principles which informed the development of a longlist of intervention options:

- Exceedences of the AQO for annual mean NO_2 concentrations occur across a variety of roads in Cambridge in 2017;
- Further NOx emission reductions are required in addition to existing taxi policy in order to achieve compliance with the AQO for annual mean NO_2 concentrations in 2021 and 2031;
- PM_{10} concentrations are predicted to be substantially below the AQO of 40 $\mu g.m^{-3}$;
- Natural fleet turnover should deliver decreases in $PM_{2.5}$ concentrations below the AQO of a 15% reduction in urban background $PM_{2.5}$ levels;
- The majority of predicted exceedances of the AQO in 2017, 2021, and 2031 occur in Cambridge city centre, along roads with high levels of congestion or bus traffic.

As such, the emphasis of any CAZ should be on reducing NOx and primary NO_2 emissions. The short-term focus of any intervention should therefore be in reducing emissions in the city centre, while in the longer term, it is important to deliver continued reductions in concentrations of all pollutants, including particulates, across Cambridge, as continued reductions in concentrations deliver additional health benefits.

A longlist of 69 intervention options was developed, taking into account existing policies and key sources of pollution, including reasonable permutations based on charging and vehicle classes, along with possible implementation barriers (described in Section 6). A consultation, via stakeholder engagement, was completed to select a shortlist of prioritised options. The consultation was held on Tuesday, 29th May 2018 in Cambridge, and a summary of the meeting is presented in Appendix A.

A simplified approach was taken to focus the discussions and options were considered with regards to 4 main themes:

1. *Impact on emissions*
2. *Potential for wider environmental benefits*
3. *Implementation costs*
4. *Implementation risk*

The decision was made to align interventions as closely as possible with those described in the Clean Air Zone framework. The charge for assessment purposes has been set at the same level as the London ULEZ; £100/day for HGVs and buses, and £12.50 per day for taxis. This charging scheme has been adopted because the modelling uses vehicle upgrade assumptions provided by JAQU which are based on the evidence from the London ULEZ. This has been chosen as it firstly offers an established evidence base for potential behavioural response. There is also an anticipation that there will be consistency nationally in approach to charging, in particular consistency with London.

The shortlisted options selected were configurations of a charging CAZ, corresponding to the different classes in the Clean Air Zone framework published by Defra[10]. The options for 2021 were chosen to replicate the minimum emission standards for each class of CAZ outlined in the framework, while for 2031, two options were considered:

[10] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/612592/clean-air-zone-framework.pdf

- A Class A charging CAZ following the minimum emission standards outlined in the framework. This option would enforce bus turnover to Euro VI buses in line with national projections, and reinforce the existing Taxi and Private Hire Vehicle licensing policy, providing an additional lever to ensure the success of these policies.

- A Class C or D CAZ with more ambitious emissions requirements, with the aim of delivering widespread health benefits across Cambridge.

For 2021, it was suggested that the short time scale would lead to difficulties in implementing a Class A Charging CAZ due to challenges in bus procurement. It was therefore decided that in addition to the conventional charging CAZ options, an intervention package would be modelled, whereby incentives to procurement would ensure that all new buses (i.e. those buses providing the 15% increase in bus services provided as part of the Greater Cambridge Partnership City Access Strategy) complied with the Euro VI emission standard, without requiring upgrades to the rest of the fleet. This restriction was combined with a charging CAZ for HGVs and LGVs, in order to determine the maximum possible benefits achievable without substantially upgrading the existing bus fleet.

Table 9 presents the shortlist of CAZ intervention options. An emissions analysis was carried out for each of the shortlisted options to quantify potential air quality impacts across Cambridge. The emissions inventory compilation and analysis for these intervention options are described in Section 3 and Appendix C and Appendix E.

Table 9: Shortlisted interventions included in emissions analysis

<table>
<tr><th>Year</th><th>CAZ Class</th><th>Local bus</th><th>Non-local bus/coach</th><th>Taxi/ private hire</th><th>HGV</th><th>LGV</th><th>Private car</th></tr>
<tr><td rowspan="5">2021</td><td>Non-CAZ intervention package 1</td><td>All new buses (15% of fleet) Euro VI</td><td>No restriction</td><td>No restriction</td><td>Euro VI</td><td>Euro 6 (diesel)
Euro 4 (petrol)</td><td>No restriction</td></tr>
<tr><td>A</td><td rowspan="4">Euro VI*</td><td rowspan="4">Euro VI</td><td rowspan="4">Euro 6 (diesel)
Euro 4 (petrol)</td><td>No restriction</td><td rowspan="2">No restriction</td><td rowspan="3">No restriction</td></tr>
<tr><td>B</td><td rowspan="3">Euro VI</td></tr>
<tr><td>C</td><td rowspan="2">Euro 6 (diesel)
Euro 4 (petrol)</td></tr>
<tr><td>D</td><td>Euro 6 (diesel)
Euro 4 (petrol)</td></tr>
<tr><td rowspan="3">2031</td><td>A</td><td>Euro VI*</td><td>Euro VI</td><td>ZEV or ULEZ, in line with existing policy</td><td>No restriction</td><td>No restriction</td><td>No restriction</td></tr>
<tr><td>C**</td><td rowspan="2">ZEV or ULEZ</td><td rowspan="2">ZEV or ULEZ</td><td rowspan="2">ZEV or ULEZ, in line with existing policy</td><td rowspan="2">Euro VI</td><td rowspan="2">ZEV or ULEV: 100% inside boundary, 50% outside</td><td>No restriction</td></tr>
<tr><td>D</td><td>ZEV</td></tr>
</table>

* The impacts on the local bus fleet were assumed to apply to all local buses in Cambridge; all other changes were restricted to within the boundary.

** Note the reference to CAZ Class C in this study for 2031 is not exactly aligned to that referred to in Defra's CAZ framework, as buses, taxis and LGV in this study have more stringent emissions controls of ULEZ or ZEZ.

6 Implementation

6.1 Economic assessment

6.1.1 Methodology and assumptions

An economic assessment of the implementation of a Class C charging CAZ in Cambridge has been undertaken and follows a Cost-Benefit methodology. The policy is analysed by determining the monetary value of the costs and benefits associated with the policy and weighing them against each other; a detailed methodology is provided in Appendix H.

The Defra and DfT Joint Air Quality Unit (JAQU) have provided detailed guidance regarding the economic appraisal of air quality improvement intervention options. This provides a steer for many of the key data inputs and assumptions (in particular around behavioural responses, and how these will be incentivised) that have framed the analysis undertaken. We base our analysis on this guidance, but it has been necessary to construct additional assumptions and approaches specifically for Cambridge's purposes. A lifetime approach has been adopted and all impacts that are assessed at the two points in time (2021 and 2031) are appraised over a subsequent 10-year period.

The costs and benefits are broken down into 8 key areas, each covering an essential aspect of the policy. Table 10 gives an overview of these different core areas.

Table 10: Key costs and benefits considered

Option	Description
Air quality impact	Monetary benefit of reducing the levels of NOx and $PM_{2.5}$ in Cambridge
Upgrade costs	Costs incurred from individuals having to purchase a compliant vehicle
Implementation costs	Costs incurred by the council in implementing the CAZ
Operational costs	Costs/benefits from having a younger fleet on the road
Fuel costs	Benefit from having more efficient vehicles on the road
CO_2 costs	Monetary cost of the CO_2 not emitted from the implementation of the CAZ
Welfare effect	Monetary representation of the lost benefits received by individuals entering the city centre.
Congestion effect	Monetary representation of the change in congestion in Cambridge resulting from the creation of a CAZ

There are several key cost assumptions that are being applied to the assessment of the interventions. The key assumptions are:

1. Revenue generated from Clean Air Zone implementation is used to cover the running costs of the scheme, and surpluses will be reinvested in air quality initiatives by the local authority.
2. CAZ charges are considered to be a non-business activity for the purposes of VAT.
3. The charges applied for CAZ are in line with the London Low Emissions Zone (LEZ).
4. Enforcement of violations will take place, with fines in line with LEZ.
5. Volumes of chargeable journeys, and the associated vehicle types, are based on available traffic data. An assumption has been made on the reduction of non-compliant vehicles over the life of the scheme.

6.1.2 Upgrade costs comparison

An additional cost of the implementation of the CAZ is the cost of upgrading vehicles. The requirements to enter the Clean Air Zone change in 2021 and 2031 hence the type of upgrades that take place in the two scenarios will change. In 2021 it is assumed that individuals will either pay the charge or upgrade the vehicle. In 2031, it is assumed that all individuals will upgrade their vehicles, leading to a significantly increased number of vehicle upgrades.

Upgrade costs for the implementation of a class C charging CAZ in 2021 and 2031, together with costs for smaller interventions in 2021, are presented in in Table 11. The cost of the non-CAZ intervention (where only new buses are required to meet the Euro VI emission standard, but LGVs and HGVs are subject to the minimum emission restrictions for a Class C charging CAZ) is greater than that for the Class A charging CAZ, as more non-bus vehicles are affected. Similar costs are accrued by each successive upgrade in the class of charging CAZ in 2021, suggesting that no particular vehicle type leads to a disproportionate increase in upgrade costs.

The total upgrade cost for the Class C charging CAZ is significantly higher in 2031, as the more stringent entry requirements render the majority of the baseline fleet non-compliant, requiring far more vehicles to upgrade.

Table 11: Upgrade costs for modelled interventions, £millions

Year	Intervention	Upgrade cost (millions)	Vehicle upgrades
2021	non-CAZ intervention	-£13.36	17325
	Class A CAZ	-£8.07	753
	Class B CAZ	-£15.88	4845
	Class C CAZ	-£20.97	18049
2031	Class C CAZ*	-£140.72	32196

* Note the reference to CAZ Class C in this study for 2031 is not exactly aligned to that referred to in Defra's CAZ framework, as buses, taxis and LGV in this study have more stringent emissions controls of ULEZ or ZEZ.

6.1.3 Detailed cost-benefit analysis

A full cost-benefit analysis was carried out for the following ambition steps:

1. The Class C charging CAZ (meeting minimum emission requirements) in 2021;
2. The Class C charging CAZ (meeting more ambitious emission requirements) in 2031.

The cost-benefit analysis results are presented in Appendix H. The Net Present Values of the two ambition steps, and the combined assessment, are as follows:

- 2021: The NPV of the 2021 ambition is slightly positive at +£13.3m
- 2031: The NPV of the 2031 ambition is strongly positive at +£47.5m
- Combined, the NPV of the scenario is positive at +£60.8m.

In summary, the benefits felt by residents and the environment from upgrading vehicles, in the form of reduced levels of NOx, CO_2 and particulate matter, in addition to the financial benefits through reduced fuel costs, outweigh the costs of upgrading, implementation and operating the CAZ.

However, several additional impacts may have a bearing on the balance of costs and benefits: in particular a) the additional benefit of air pollutant emission reductions outside the city and b) the additional costs of vehicles avoiding the city intervention area or cancelling journeys.

Overall, several conclusions can be drawn from the analysis, which are:

1. The interventions as proposed would achieve large reductions in air pollutant emissions in Cambridge, and with resulting improvements in health;
2. Whilst the NPV for the staggered implementation of a Clean Air Zone is positive overall, there is significant uncertainty around this assessment;
3. Consideration should be given to increasing ambition on the same mode between 2021 and 2031 to avoid placing two waves of costs on vehicle owners.
4. Early sight of ambition (in particular upgrading to ULEV) will generally help vehicle owners plan their purchases to minimise costs.
5. Upgrading to newer vehicles leads to efficiency savings. However, upgrading to ULEVs leads to even greater operating, fuel and GHG emission savings than upgrading to conventional fuelled alternatives.
6. Upfront implementation costs are constant, regardless of the options implemented, if the boundary is kept constant.

6.1.4 Delivery Risk

This CBA was facilitated through the use of several simplifying assumptions. When viewing this analysis, it is important to recognise the uncertainty and caveats around these results, and that risks exist which may impact on the ability of the interventions to achieve these anticipated effects in practice. Risks exist around whether or not charging is deployed as a mechanism to encourage desired vehicle fleet improvement:

1. **CAZ charging:** The analysis assumes the charge levels and behavioural response recommended nationally by JAQU and does not account for local characteristics which may influence these responses. Furthermore, the response assumed is immediate on the date the CAZ comes into force and the analysis does not recognise the potential implementation issue of identifying taxis in the absence of a national database.
2. **Non-charging measures:** The impact of these measures also critically relies on behavioural change from vehicle owners, but in this case on voluntary responses to incentives rather than a CAZ charge. There are several issues which may affect the response in practice:
    a) vehicle owners do not hold complete information on trade-offs between strategies
    b) vehicle owners may still not act rationally – e.g. agents are more averse to loss than attracted to benefits of equal amount
    c) other barriers exist which may prevent take up of non-charging measures, in particular in the short term, e.g. contractual arrangements.

It could be considered that there is greater uncertainty and risk around the ability of non-charging measures to deliver anticipated air pollution emissions reductions than around the CAZ charging options.

Additionally, there is significant uncertainty in fleet assumptions and vehicle emission factors for future years; historically vehicle emissions have underperformed substantially compared with early emission factor estimates in real-world driving conditions, and as a result real-world reductions in total emissions in future years may be smaller than those predicted.

6.1.5 Distributional Impact

The likely impacts on business can be summarised as follows:

- All business located in and around the CAZ will be impacted to some extent, determined by factors including but not limited to, proximity of business to CAZ and type of business.
- Impact greatest on business who own and operate non-compliant vehicles.
- Direct impacts on HGV operators, coach operators and taxi drivers.
- Smaller operators are likely to face greater costs in terms of both direct and knock-on effects.

- If a business cannot 'afford' the costs of a Clean Air Zone, a business may cancel a trip, go out of business or shift location outside of the zone. All have potential consequences for local jobs and the local economy.
- HGVs operate in highly competitive market, limiting ability to pass through or internalise costs. Smaller, localised coach services may struggle to pass on costs to a smaller cohort of frequent travellers. Taxi drivers will directly hit the take-home income of a cohort who tend to be on the lower income distribution. Therefore, affordability risk is highest for smaller operators impacted by a Clean Air Zone.

Although the key impacts are anticipated to be negative, there will be some mitigating factors:

- The baseline is anticipated to 'catch-up' with the CAZ at some point, increasing the potential that more firms can internalise costs for a short period.
- Larger firms can redistribute fleets between different geographical areas.
- Longer-term balancing forces in the economy will limit the knock-on effects and potentially mitigate some of the short-term impacts.

The likely impact on households can be summarised as follows:

Affordability

- Not expected to be any significant impacts on household affordability.
- Taxis may pass on costs to consumers which may be a disproportionate impact on poorer households.

Traffic Impacts

- Traffic modelling should be undertaken to assess if there are road links with significant changes in traffic measured as changes in the number of journeys. Assumption for this study was that there would be no traffic route displacement.

Accessibility

- Traffic modelling should be undertaken to assess any changes in accessibility measured as changes in travel time, and assess those who may choose to cancel/avoid the zone.

A summary of the distributional impacts is provided in Table 122.

Table 12 Summary of Possible Distributional Analysis for Preferred Option (CAZ Class D city wide)

Group Impacted	How are they impacted?
Bus & Coach	• A citywide Class D CAZ will charge non-CAZ compliant buses to enter the CAZ. • Smaller, local bus/coach operators likely to face higher costs and be subject to greater knock-on local impacts
HGV	• A citywide Class D CAZ will charge non-CAZ compliant HGVs to enter the CAZ. • Strong competition in sector severely limits ability to pass through costs. • Low profit margins significantly reduce ability to internalise • Smaller, local HGV operators likely to face higher costs and be subject to greater knock-on local impacts. • Operating vehicles that are highly specialised and have both a significant lead-in time on production (6-18 months), and additional expense due to specificity. • Other challenges for smaller operators including: retirement more viable option, retrofit not currently available and finance attached to vehicles.
Taxi	• A citywide Class D CAZ will charge non-compliant taxi and private hire vehicles to enter the CAZ. • Predominantly sole traders and less able to internalise cost or spread cost across multiple operations and will more likely impact directly on household income. • Likely to face greatest upfront cost without capacity to internalise and are generally lower income • Customer base and lack of alternatives may allow some pass through but could affect regular customers, e.g. elderly and disabled
Business / Other	• Small business with LGVs impacted in Clean Air Zone. Relocation could impact on local jobs.
Households	• A citywide Class D CAZ will charge non-compliant passenger cars to enter the CAZ. • Vehicle owners can pay to enter, upgrade to a compliant vehicle or find an alternative route/mode of transport. This will directly impact on household income • Indirect impacts associated with costs passed through by taxi operators or bus companies

6.2 Legal basis and enforcement

There are two main approaches to the legal basis for a Clean Air or Zero Emission Zone:

- An access restricted zone based on vehicle standards using a traffic regulation order (TRO);
- An environmental charging scheme using road user charging powers.

In addition, there are powers that can be used to regulate buses (road traffic conditions) and taxis (taxi licencing) specifically.

6.2.1 Traffic regulations orders (TRO)

Road traffic regulation orders are typically used to regulate parking and general vehicle access restrictions such as lorry weight bans or pedestrian zones. They are the powers used to establish the current access restrictions in Cambridge City Centre. The legal basis is the Road Traffic Regulations Act 1984 and this was broadened under the 1995 Environment Act to allow for access restrictions in respect to the management of air quality. The responsible transport authority is Cambridgeshire County Council.

A TRO is a direct access restriction that could be used to ban vehicles not meeting specific criteria (in this case zero emission) from given streets. They can be set up like any other access restrictions to apply either 24 hours a day or at certain times of the day.

In most cases TROs are enforced as stationary vehicle offences (e.g. contraventions of parking restrictions) by the local authority.

For a small CAZ TROs would represent a simplified approach to enforcement which would take place only with respect to stationary vehicles, such as those which are parked, loading/unloading or waiting. However, as the zone boundary expands this strategy is likely to be less effective and enforcement against moving vehicles using ANPR is likely to be needed.

Current enforcement of TROs as a moving vehicle offence is only permissible by the police. However, there is provision in the Traffic Management Act 2004 (Part 6) for civil enforcement of traffic contraventions including moving vehicle offences. That said, it is not clear from initial investigation if these powers have been fully enacted allowing local authorities to enforce using ANPR. Therefore, further discussions with the DfT would be needed to clarify the powers available to enforce a TRO based CAZ.

6.2.2 Road use based (environmental) charging

Local authorities have the power in the Transport Act 2000 to introduce road use based charging schemes. Such schemes can have variable charges related to the environmental performance of the vehicle. This is the current approach being used for the London LEZ and proposed Ultra-Low Emission Zone. Furthermore, this is what is set out in the Government's framework for Clean Air Zones as the basis of for a CAZ charging scheme.

In this case the legislation provides for the charging to be carried out via ANPR, and so the moving vehicle enforcement issue does not arise. The operation of the charging would be expected to be carried out with ANPR to identify and charge vehicles as appropriate. In respect to a charging scheme, enforcement is related to non-payment of charges rather than access to the zone itself, and the local authority has the powers to issue fixed penalty notices in this case. This removes the issue of moving vehicle enforcement which potentially arises with the use of a TRO.

If this approach is taken, the scheme is not a strict access restriction rather a charge for vehicles that do not comply with the standard set. In this regard, there could be some political sensitivities in relation to the scheme being a charging scheme. However, the GCP is looking at other charging schemes such as the Workplace Parking Levy and congestion charging under which the charging principle is already being considered.

6.2.3 Recommendations

Further discussion with the DfT would realistically be needed to clarify some of the issues above. However, a potential route to establishing the CAZ is to implement using road use based charging powers. Again, any CAZ scheme should be considered in relation to wider ongoing discussions on charging schemes (such as the Workplace Parking Levy) to ensure consistency and compatibility.

6.2.4 Timeline for Preferred Option Implementation

Implementing the preferred option for 2021 is estimated to take 18 months.

6.3 Monitoring and Evaluation

Evaluation is an objective process of understanding how a policy or other intervention was implemented, what effects it had, for whom, how and why.[11] The aim of a monitoring and evaluation plan is to produce results that provide accountability and defence, allow adaptive policy-making and identify where future interventions are required.

Any monitoring plan will seek to check progress against planned targets and can be defined as the formal reporting and evidencing that spend and outputs are successfully delivered, and milestones met. Implementation of the interventions and supporting measures will produce a range of data throughout the life of the project. A monitoring plan should therefore measure data on areas such as:

1. Air quality improvements; a detailed discussion of monitoring air quality is provided below.
2. Baseline behaviour and behaviour change; ANPR data can be used to monitor the effect of the interventions on traffic flows and the vehicle fleet entering the intervention area, evaluating whether behavioural responses match assumptions.
3. Roadside emissions testing; testing can be carried out to measure the effectiveness of newer technologies in reducing emissions in the congested conditions in central Cambridge.
4. Assessment of other impacts (including noise, accidents).
5. Monitoring economic impact.
6. Buses – Current Fleet and yearly fleet reports can be used to assess effectiveness in encouraging fleet replacement.
7. Taxis – Locally licensed vehicles emissions report.
8. HGVs – use of consolidation centre/logistics options and ANPR enforcement data.
9. Cycling – km of infrastructure installed, cycle counters, annual survey.
10. Public perception – People's panel questionnaires, public engagement.

The evaluation of the Clean Air Zone will assess the policy effectiveness and efficiency during and after implementation. It will seek to measure outcomes and impacts in order to assess whether the anticipated benefits have been realised.

The primary objective of the proposed interventions will be to reduce pollution concentrations at areas of exposure in Cambridge; as such, the primary form of evaluation will be in monitoring changes in pollutant concentrations, both in areas where improvements in air quality are predicted, and along roads where traffic may increase as the result of the interventions. As of 2017, Cambridge City Council operates 5 continuous monitors and approximately 70 diffusion tubes across the City. The density of monitoring is sufficient to provide assess broader changes in concentrations across the city as part of this policy evaluation. However, there are a number of limitations to the current monitoring network:

- The majority of monitoring sites are diffusion tubes, and therefore do not allow analysis of diurnal trends, for instance identifying areas where changes to congestion patterns are significantly impacting pollutant concentrations.
- The monitoring sites do not capture the maximum predicted concentrations across the area; modelling shows that NO_2 concentrations vary dramatically over short distances, and no exceedences of the AQO for NO_2 were recorded at monitoring sites in 2017 even though a 11400m² area is predicted to have exceeded the AQO in the baseline modelling.

The use of a network of mobile smart monitors to augment current monitoring in Cambridge would allow the City Council greater flexibility in evaluating and monitoring the impacts of the proposed interventions, including analysis of short-term trends and peak hour concentrations. The flexibility provided by mobile monitors would allow the Council to directly monitor areas of concern as they develop, and help to diagnose any issues which occur, such as unexpected traffic changes.

[11] The Magenta Book, published by HM Treasury: https://www.gov.uk/government/publications/the-magenta-book

7 Emissions analysis of shortlisted interventions

An emissions analysis was carried out for each scenario identified in Table 9 in order to quantify and compare the predicted impacts on NOx inside and outside the proposed boundary; these impacts are presented in Figure 10 and Figure 11 respectively. Details of the emissions inventory composition for the modelled scenarios are provided in Appendix C.

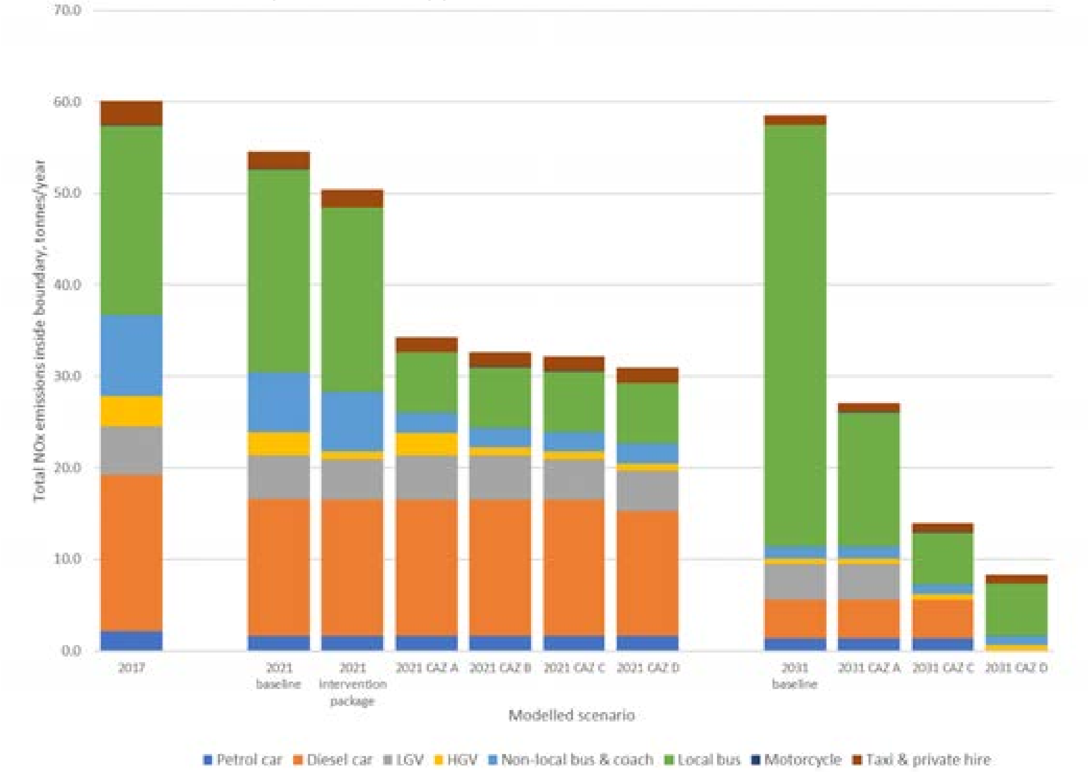


Figure 10: Total calculated NOx emissions inside the boundary for each scenario, tonnes/year

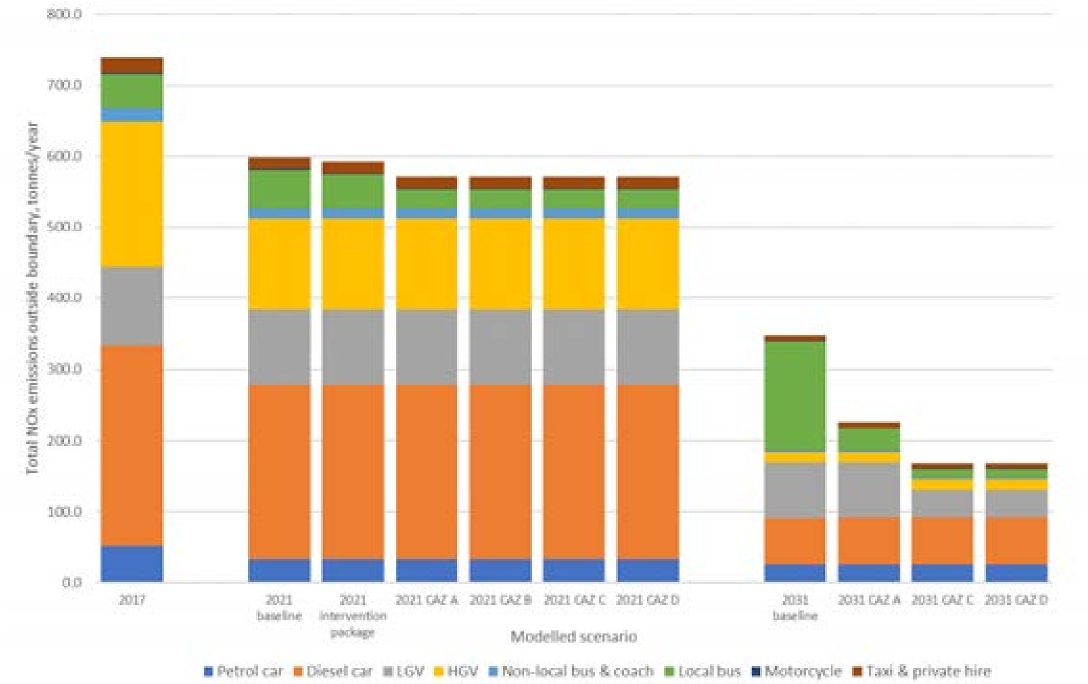


Figure 11: Total calculated NOx emissions outside the boundary for each scenario, tonnes/year

7.1 2021

Table 133 presents the total NOx emissions inside the boundary for 2021 in the different intervention scenarios, apportioned by vehicle type; Table 144 presents the total NOx emissions outside the boundary.

Table 13: Total NOx emissions inside the boundary for 2021 for each modelled intervention scenarios, apportioned by vehicle type, tonnes/year

Vehicle	2017	2021 baseline	2021 package 1	2021 CAZ A	2021 CAZ B	2021 CAZ C	2021 CAZ D
Petrol car	2.2	1.6	1.6	1.6	1.6	1.6	1.6
Diesel car	17.0	15.0	15.0	15.0	15.0	15.0	13.7
LGV	5.3	4.8	4.4	4.8	4.8	4.4	4.4
HGV	3.4	2.5	0.9	2.5	0.9	0.9	0.9
Non-local bus & coach	8.8	6.5	6.5	2.2	2.2	2.2	2.2
Local bus	20.7	22.2	20.1	6.6	6.6	6.6	6.6
Motorcycle	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Taxi & private hire	2.6	1.9	1.9	1.6	1.6	1.6	1.6
Total	60.1	54.6	50.4	34.3	32.7	32.2	31.0
% reduction	-	-	-7.7%	-37.2%	-40.2%	-41.0%	-43.3%

Table 14: Total NOx emissions outside the boundary for 2021 for each modelled intervention scenarios, apportioned by vehicle type, tonnes/year

Vehicle	2017	2021 baseline	2021 package 1	2021 CAZ A	2021 CAZ B	2021 CAZ C	2021 CAZ D
Petrol car	51.2	32.8	32.8	32.8	32.8	32.8	32.8
Diesel car	281.5	247.0	247.0	247.0	247.0	247.0	247.0
LGV	111.7	103.5	103.5	103.5	103.5	103.5	103.5
HGV	203.8	129.2	129.1	129.1	129.1	129.1	129.1
Non-local bus & coach	19.2	13.3	13.3	13.3	13.3	13.3	13.3
Local bus	47.7	54.6	48.7	26.7	26.7	26.7	26.7
Motorcycle	2.0	1.6	1.6	1.6	1.6	1.6	1.6
Taxi & private hire	21.9	16.6	16.6	16.6	16.6	16.6	16.6
Total	739.0	598.6	592.7	570.7	570.7	570.7	570.7
% reduction	-	-	-1.0%	-4.7%	-4.7%	-4.7%	-4.7%

The emissions analysis carried out for 2021 demonstrates that the most effective way to reduce NOx emissions is to introduce a charging CAZ for buses. As a result, for the non-CAZ Class intervention package (where only new buses are restricted to Euro VI), the predicted total reduction in NOx emissions inside the CAZ is small compared with the conventional charging CAZ options, which affect the entire bus fleet.

The implementation of a Class A charging CAZ leads to a large reduction in NOx emissions inside the boundary (20.3 tonnes per year, corresponding to 37.2% of the total baseline emissions). This intervention also achieves a small reduction in NOx emissions outside the boundary, as changes to the local bus fleet affect emissions along all local bus routes.

Restricting the bus fleet is also the most cost-effective option, as the local bus fleet is small relative to the much larger fleets of other vehicle types, therefore requiring a relatively small upgrade cost; economic analysis suggests that the cost of requiring new buses to comply with the Euro VI emission standard would be £340,000, leading to a decrease in total NOx emissions across Cambridge of 4.7%.

While interventions affecting other vehicles have a smaller effect on emissions totals, the spatial distribution of emissions reduction varies by vehicle type; as such, emission reductions can be delivered across more areas of central Cambridge by including additional requirements, without incurring an additional implementation cost. However, as restrictions on other vehicle types have not been assumed to affect the vehicle fleet outside the boundary, no additional improvements are achieved outside the boundary by implementing additional restrictions.

Upgrading the charging CAZ from Class A to Class B (restricting HGVs) is predicted to lead to a 3% decrease in NOx emissions inside the boundary, and would represent a sensible addition to the CAZ, with an associated upgrade cost of £5.2 million.

Upgrading the CAZ from a Class B CAZ to a Class C CAZ (including LGVs) has smaller upgrade costs (£2.5 million), but the associated emissions reductions are negligible.

Upgrading the CAZ from a Class C CAZ to a Class D CAZ (including private cars) leads to a further 2.3% reduction in NOx emissions inside the proposed boundary. This reduction is relatively small, as the private car fleet in Cambridge is already relatively new compared with the national average; as a result, a relatively small proportion of the fleet would be affected. However, these improvements would be focussed on the inner ring road, where exceedances of the objective are predicted.

7.2 2031

Table 155 presents the total NOx emissions inside the boundary for 2031 in the different intervention scenarios, apportioned by vehicle type; Table 166 presents the total NOx emissions outside the boundary.

Table 15: Total NOx emissions inside the boundary for 2031 for each modelled intervention scenarios, apportioned by vehicle type, tonnes/year

Vehicle	2017	2031 baseline	2031 CAZ A	2031 CAZ C	2031 CAZ D
Petrol car	2.2	1.4	1.4	1.4	0.0
Diesel car	17.0	4.2	4.2	4.2	0.0
LGV	5.3	3.9	3.8	0.0	0.0
HGV	3.4	0.6	0.6	0.6	0.6
Non-local bus/coach	8.8	1.3	1.3	1.0	1.0
Local bus	20.7	46.1	14.7	5.7	5.7
Motorcycle	0.1	< 0.1	< 0.1	< 0.1	< 0.1
Taxi & private hire	2.6	1.0	0.9	0.9	0.9
Total	60.1	58.5	27.1	13.9	8.4
% reduction	-	-	-53.7%	-76.2%	-85.7%

Table 16: Total NOx emissions outside the boundary for 2031 for each modelled intervention scenarios, apportioned by vehicle type, tonnes/year

Vehicle	2017	2031 baseline	2031 CAZ A	2031 CAZ C	2031 CAZ D
Petrol car	51.2	25.0	25.1	25.1	25.1
Diesel car	281.5	66.5	66.5	66.5	66.5
LGV	111.7	77.6	77.6	38.8	38.8
HGV	203.8	15.0	15.0	15.0	15.0
Non-local bus/coach	19.2	3.5	3.4	2.8	2.8
Local bus	47.7	151.3	30.0	11.7	11.7
Motorcycle	2.0	1.0	1.0	1.0	1.0
Taxi & private hire	21.9	7.7	7.7	7.7	7.7
Total	739.0	347.5	226.3	168.5	168.5
% reduction	-	-	-34.9%	-51.5%	-51.5%

In 2031, upgrading the local and non-local bus fleet has the single largest effect on total NOx emissions inside and outside the proposed boundary: NOx emissions inside the boundary are reduced by 38.4%, and emissions outside the boundary are reduced by 27.5%.

This reflects the high contribution of local buses to emissions in the 2031 baseline under the assumption that no further improvements are made to the bus fleet. These reductions are concentrated inside the CAZ, where the majority of exceedances of the AQO for annual mean NO_2 concentrations are predicted to occur.

Implementing the ambitious CAZ Class C leads to a 76.2% reduction in NOx emissions inside the boundary relative to the baseline, primary due to reductions in emissions from the local bus fleet (9.0 tonnes/year). This intervention also delivers 51.5% reduction in NOx emissions outside the boundary, primarily due to the modelled impacts of the restriction on the LGV fleet outside the boundary (38.8 tonnes/year). As the effects of restrictions on LGVs and buses have strikingly different spatial distribution patterns, it is recommended that restrictions on LGVs be included in addition to any restrictions on the local bus fleet in order to achieve significant health benefits both inside and outside the proposed boundary.

Upgrading the CAZ to a Class D (including private cars) leads to a further 9.5% reduction in NOx emissions inside the boundary. This reduction follows approximately the same spatial distribution as changes to the bus fleet.

8 Dispersion modelling analysis of packages of measures

Detailed dispersion modelling of the most effective interventions identified in Section 7 was carried out to quantify air quality impacts. Table 16 lists the modelled interventions.

Table 17: Modelled interventions

Year	CAZ Class	Local bus	Non-local bus/coach	Taxi/ private hire	Private car	LGV	HGV
2021	Non-CAZ intervention package	All new buses (15% of fleet) Euro VI	Euro VI	No restriction	No restriction	Euro 6 (diesel) Euro 4 (petrol)	Euro VI
	A	Euro VI*	Euro VI	Euro 6 (diesel) Euro 4 (petrol)	No restriction	No restriction	No restriction
	D	Euro VI*	Euro VI	Euro 6 (diesel) Euro 4 (petrol)	Euro 6 (diesel) Euro 4 (petrol)	Euro 6 (diesel) Euro 4 (petrol)	Euro VI
2031	A	Euro VI*	Euro VI	ZEV or ULEZ, in line with existing policy	No restriction	No restriction	No restriction
	C**	ZEV or ULEZ	ZEV or ULEZ	ZEV or ULEZ, in line with existing policy	No restriction	ZEV or ULEV: 100% inside, 50% outside	Euro VI

* The impacts on the local bus fleet were assumed to apply to all local buses in Cambridge; all other changes were restricted to within the boundary.

** Note the reference to CAZ Class C in this study for 2031 is not exactly aligned to that referred to in Defra's CAZ framework, as buses, taxis and LGV in this study have more stringent emissions controls of ULEZ or ZEZ.

This section presents annual mean NO_2 concentration results in the city centre; maps of PM_{10} concentrations and other areas in Cambridge are presented in Appendix F.

8.1 2021

Figures 123 to 176 present annual mean NO_2 concentrations in the AQMA for the modelled intervention scenarios, and the differences between these scenarios and the 2021 baseline described in Section 4. Table 188 presents the modelled area of exceedance and 'at-risk' area for each modelled intervention.

Table 18: Predicted area of exceedance and area at risk of exceeding the AQO with each modelled intervention, 2021, m²

Area	Area of exceedance of the AQO				Area within 20% of the AQO			
	Baseline	Non-CAZ	CAZ Class A	CAZ Class D	Baseline	Non-CAZ	CAZ Class A	CAZ Class D
Central Cambridge	8208	6093	9	9	24084	19458	792	702
Around Inner Ring Road	2007	1512	171	27	18009	13347	4815	1908
Inside M11 and A14	639	333	0	0	12348	9900	144	126
Total	10854	7938	180	36	54441	42705	5751	2736

The dispersion modelling shows that the implementation of the non-CAZ class intervention package is not predicted to lead to compliance with the AQO for annual average NO_2 concentrations in Cambridge in 2021. While predicted NO_2 concentrations decrease by up to 2μg.m^{-3} in areas of exceedance, these reductions are not sufficient to reduce concentrations below the AQO. As such, stronger measures are required in order to achieve compliance.

Implementing a charging CAZ Class A leads to compliance at almost all locations across Cambridge, with small exceedances occurring along the road centreline along Fen Causeway and Gonville Place. This represents compliance at all locations of relevant exposure for the annual mean AQO for NO_2, although cyclists and pedestrians may still be exposed in these areas. This intervention also achieves an 89% reduction in the at-risk area, in particular reducing the at-risk area near the Drummer Street bus station.

Implementing a charging CAZ Class D at the proposed boundary is predicted to result in compliance with the AQO at almost all locations except for locations in the centre of junctions, representing compliance at all locations of relevant exposure. Furthermore, the substantial emission reductions resulting from this measure reduce the total at-risk area to 2736 m², 5% of the baseline.

Figure 12: Annual average NO_2 concentrations, central Cambridge, 2021, non-CAZ intervention package, µg.m^{-3}

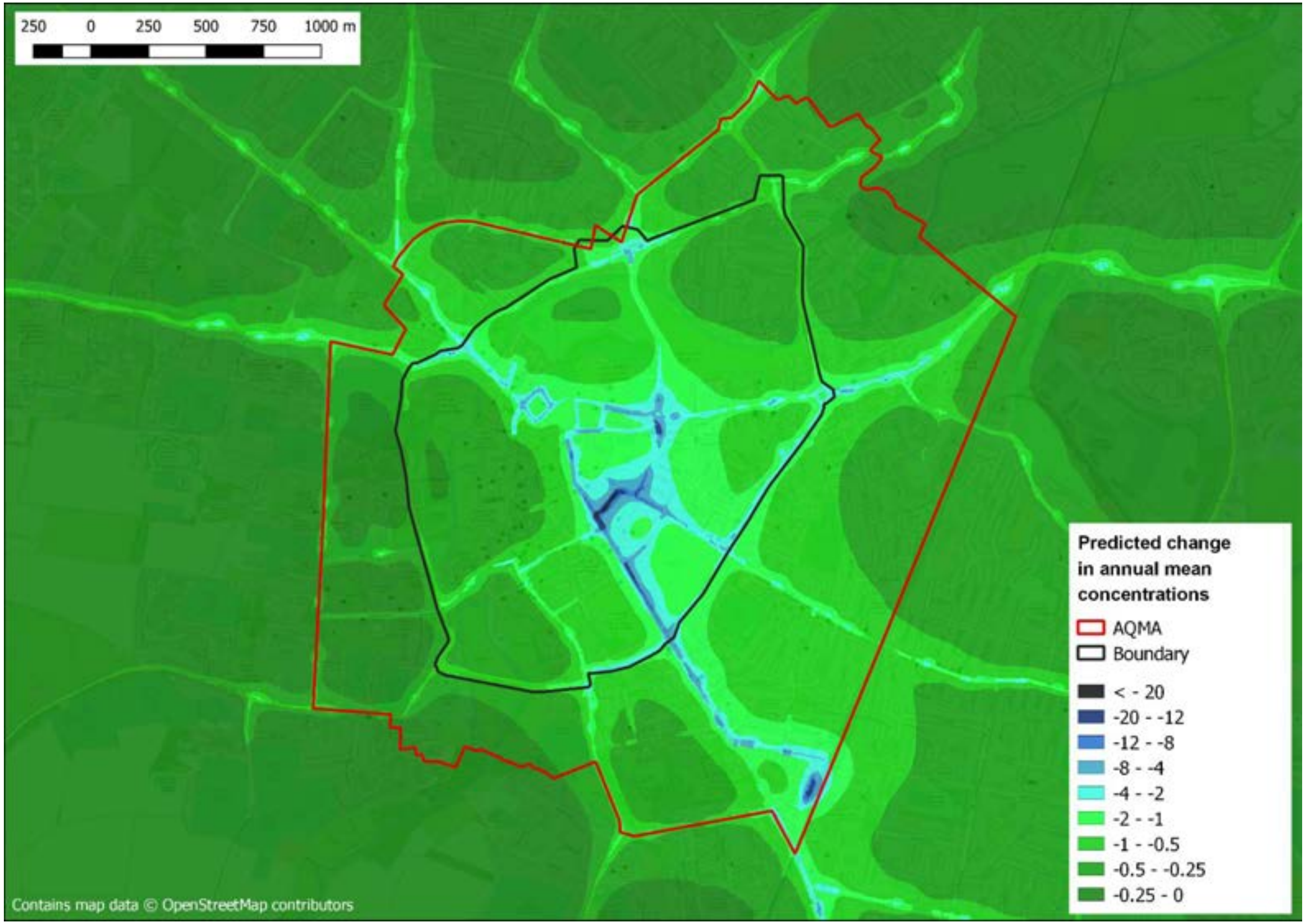


Figure 13: Predicted change in annual average NO_2 concentrations with the implementation of the non-CAZ intervention package, central Cambridge, 2021, $\mu g.m^{-3}$

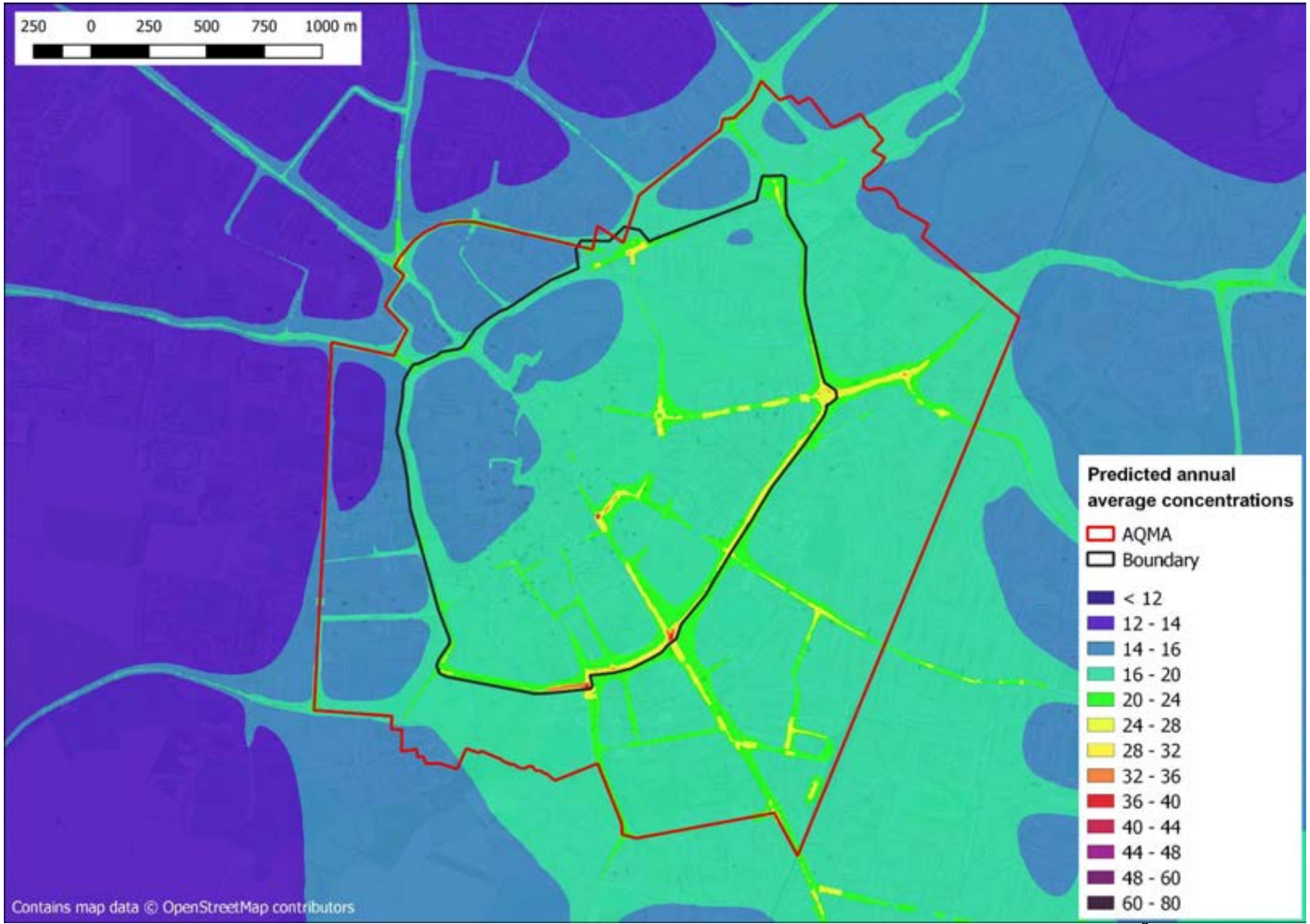


Figure 14: Annual average NO_2 concentrations, central Cambridge, 2021, Class A charging CAZ, µg.m^{-3}

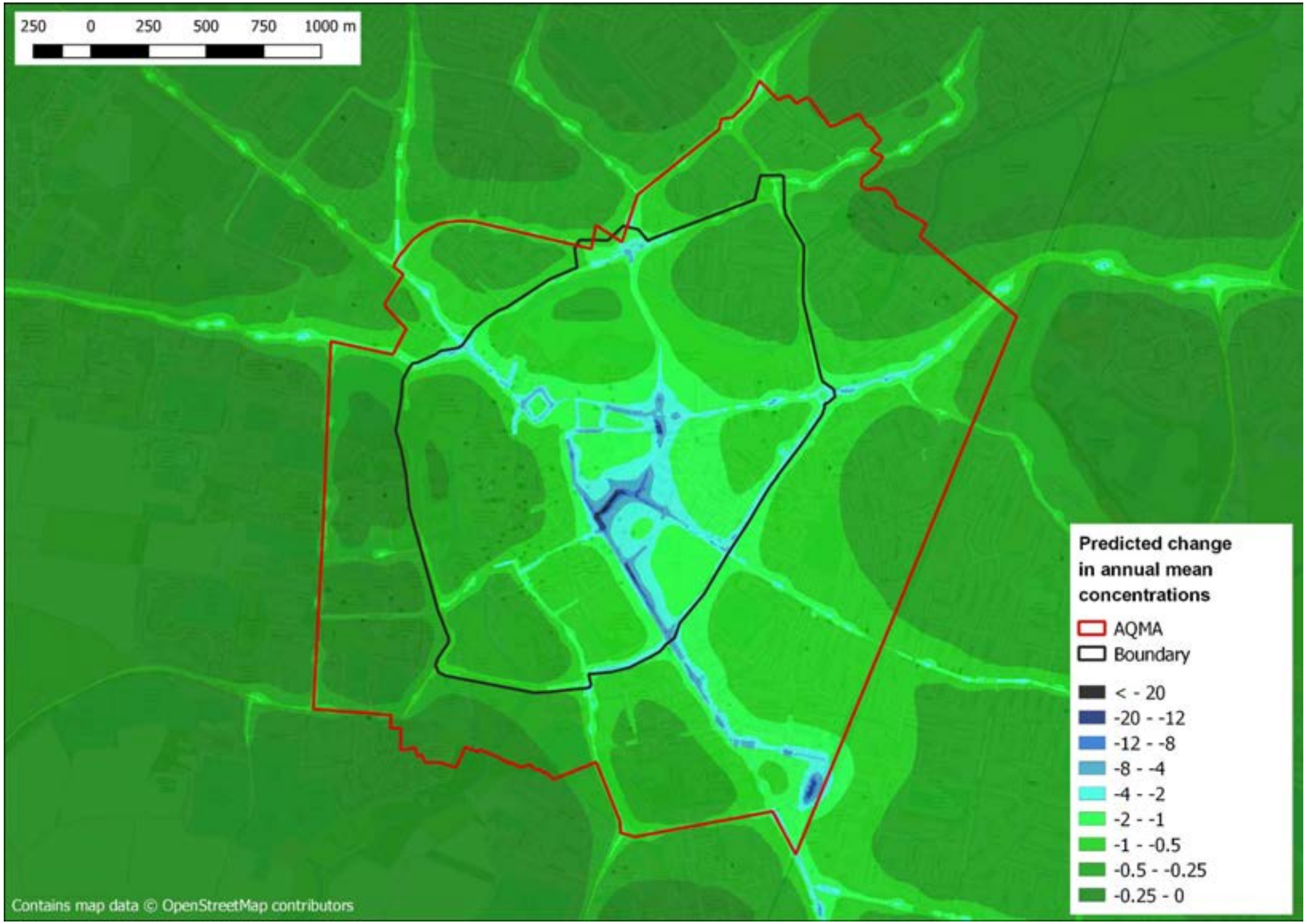


Figure 15: Predicted change in annual average NO_2 concentrations with the implementation of a Class A charging CAZ, central Cambridge, 2021, µg.m^{-3}

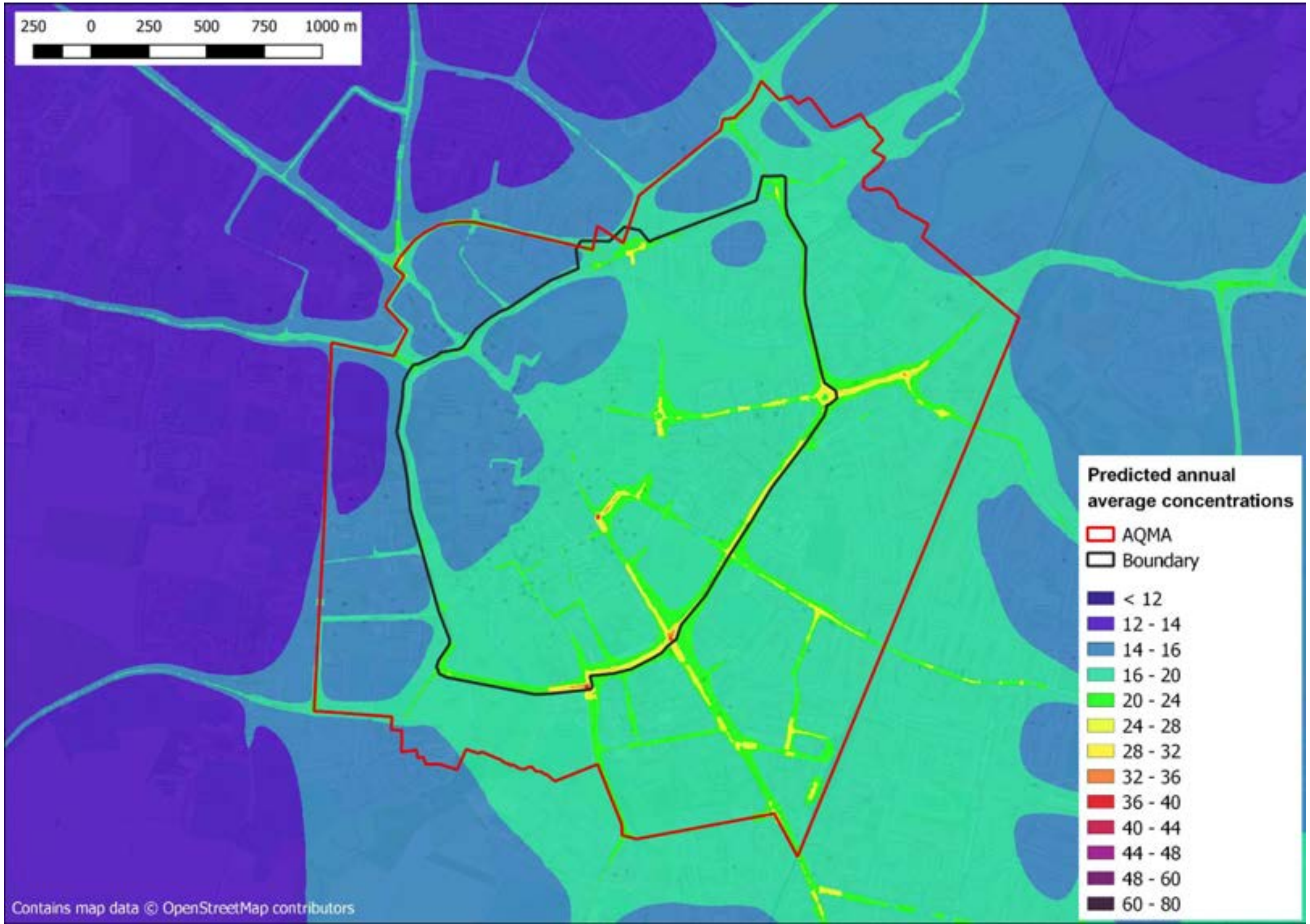


Figure 16: Annual average NO_2 concentrations, central Cambridge, 2021, Class D charging CAZ, $\mu g.m^{-3}$

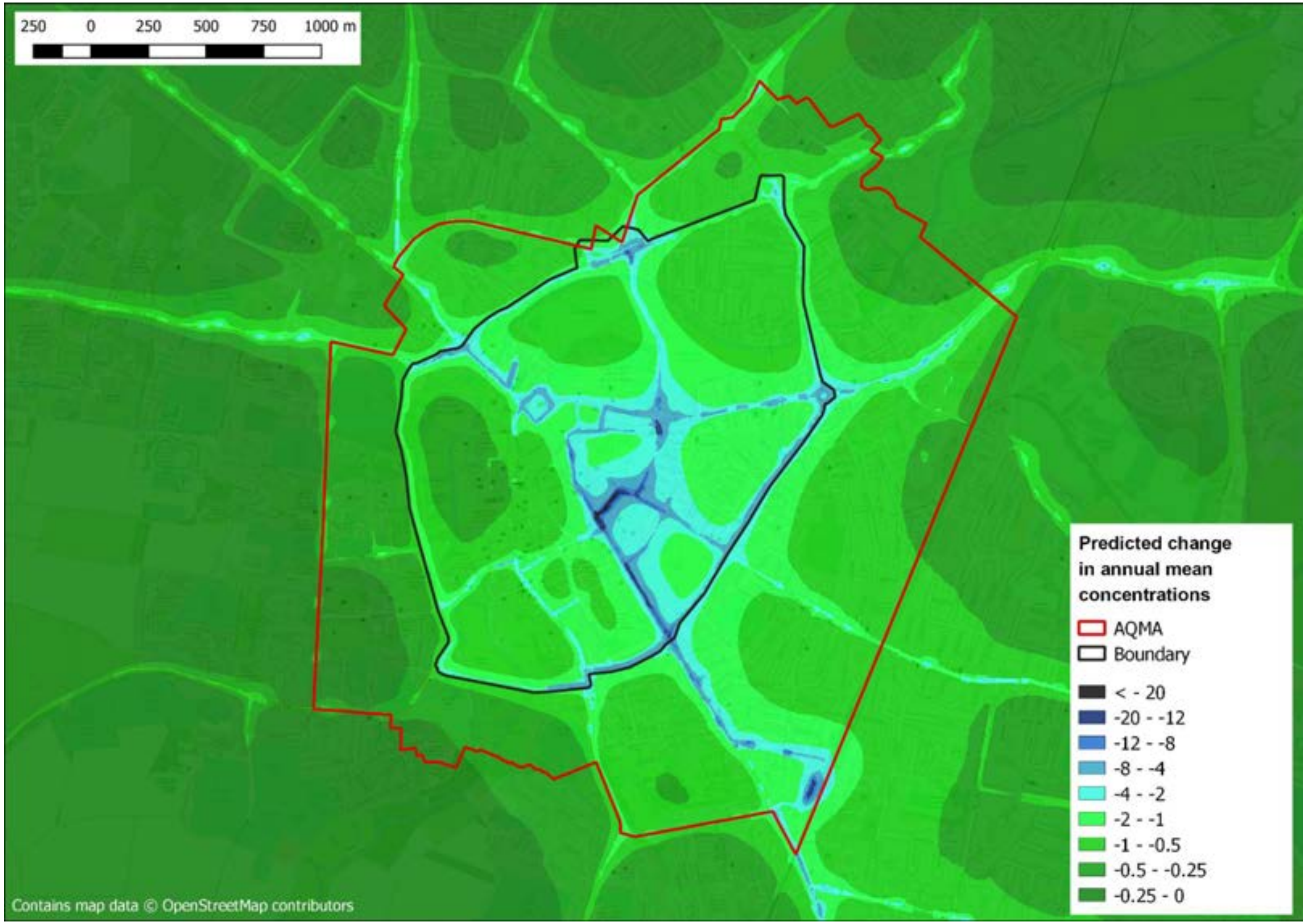


Figure 17: Predicted change in annual average NO_2 concentrations with the implementation of a Class D charging CAZ, central Cambridge, 2021, $\mu g.m^{-3}$

8.2 2031

Figures 18 to 21 present annual mean NO_2 concentrations in the AQMA for the modelled intervention scenarios, and the differences between these scenarios and the 2031 baseline. Table 19 presents the modelled area of exceedance and risk of exceedance for each modelled intervention.

Table 19: Predicted area of exceedance and area at risk of exceeding the AQO with each modelled intervention, 2031, m²

Area	Area of exceedance of the AQO			Area within 20% of the AQO		
	Baseline	CAZ Class A	CAZ Class C	Baseline	CAZ Class A	CAZ Class C
Central Cambridge	13032	1611	0	35289	9567	54
Around Inner Ring Road	1305	603	0	4689	3258	0
Inside M11 and A14	4077	0	0	16344	4383	72
Total	18414	2214	0	56322	17208	126

The implementation of the Class A charging CAZ meeting the minimum emission requirements identified in the Clean Air Zone framework, consistent with the CAZ Class A option for 2021, does not lead to compliance across Cambridge, but does significantly reduce the area of exceedance of the AQO; the area of exceedance inside the boundary is reduced by 85%, and the area of exceedance outside the boundary is brought into compliance. Predicted NO_2 concentrations reduce by up to 3µg.m^{-3} along the inner ring road, and by up to 12µg.m^{-3} around the Drummer Street bus station.

Areas of exceedance of the objective remain along the following roads:

- Emmanuel Street, including the junction with St. Andrew's Street;
- The Gonville Place – Regent Street junction.

While compliance is achieved over the majority of the area in this scenario, a large number of roads in central Cambridge remain at risk of exceedance if predicted improvements in vehicle emissions in future years are not met:

- Regent Street;
- An extended area around the Drummer Street bus station, including St. Andrew's Street, Parker Street, and the junctions of Emmanuel Road;
- Sections of Hill Road, Station Road, and the area surrounding the Station Place bus station;
- The Victoria Avenue – Mitcham's Corner junction.

The implementation of the ambitious Class C charging CAZ for 2031 leads to annual average NO_2 concentrations complying with the Air Quality Objective of 40µg.m^{-3} at all locations in Cambridge, primarily due to the improvement in emissions from local buses and LGVs. On roads which exceed the AQO in the baseline, the following concentration reductions are seen:

- Along Emmanuel Street, concentrations reduce by up to 20 µg.m^{-3}. This is the largest reduction in modelled concentrations across the model domain, and is driven by the significant reduction in emissions from idling buses along the link;
- Along Parker Street, concentrations reduce by approximately 12 µg.m^{-3}; this is again driven by reductions in bus emissions;
- Along Emmanuel Road and Short Street, concentrations reduce by up to 20 µg.m^{-3};
- Along Regent Street, concentrations reduce by approximately 16 µg.m^{-3};
- At Station Place, concentrations reduce by 16 µg.m^{-3} at building façades next to bus stops;
- Decreases in concentration of up to 4 µg.m^{-3} are also seen along most links in central Cambridge as the result of the implementation of the Class C charging CAZ.

The result of these decreases in concentration is that almost all of Cambridge falls below 80% of the AQO, and as such is not classified as being at risk of exceedance; only 126 m² remains at risk, and these areas lie within road centrelines.

These results demonstrate that the ambitious CAZ Class C package represents the most effective option for improving air quality in Cambridge by 2031, and will deliver significant health benefits across Cambridge. However, large improvements can also be achieved through the implementation of a Class A CAZ following the minimum emissions requirements set out in the Clean Air Zone framework.

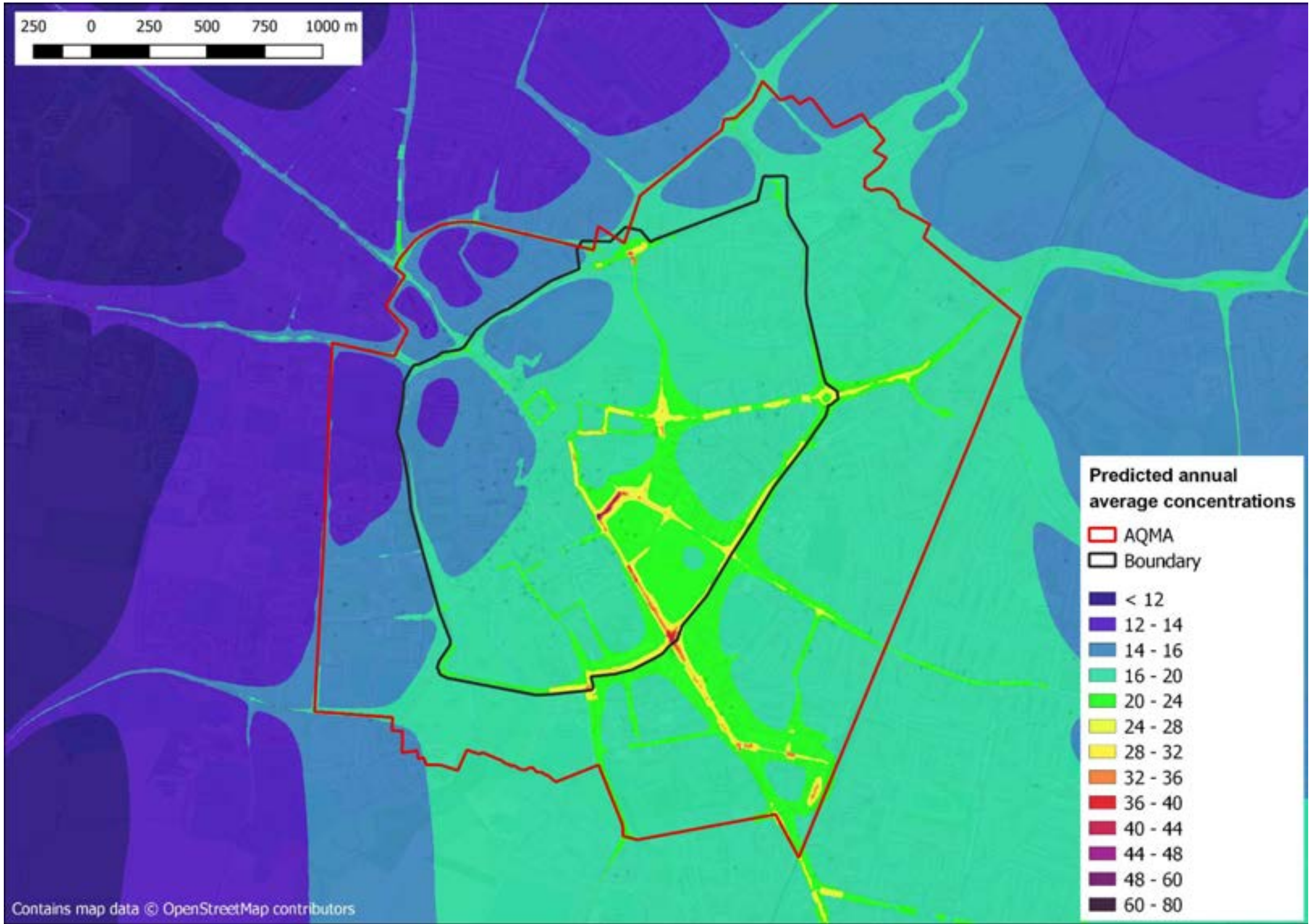


Figure 18: Annual average NO_2 concentrations, central Cambridge, 2031, Class A charging CAZ, $\mu g.m^{-3}$

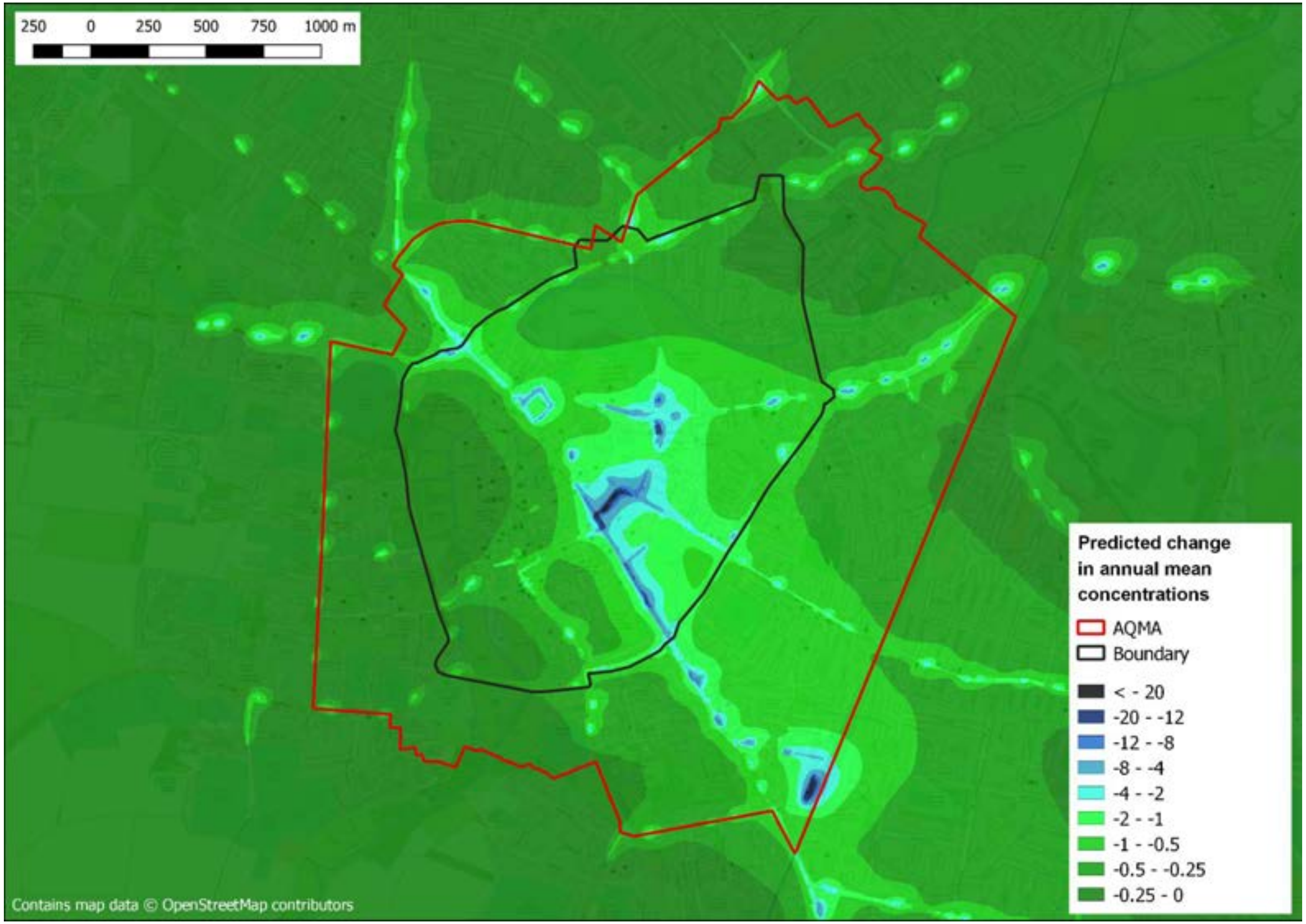


Figure 19: Predicted change in annual average NO_2 concentrations with the implementation of a Class A charging CAZ, central Cambridge, 2031, $\mu g.m^{-3}$

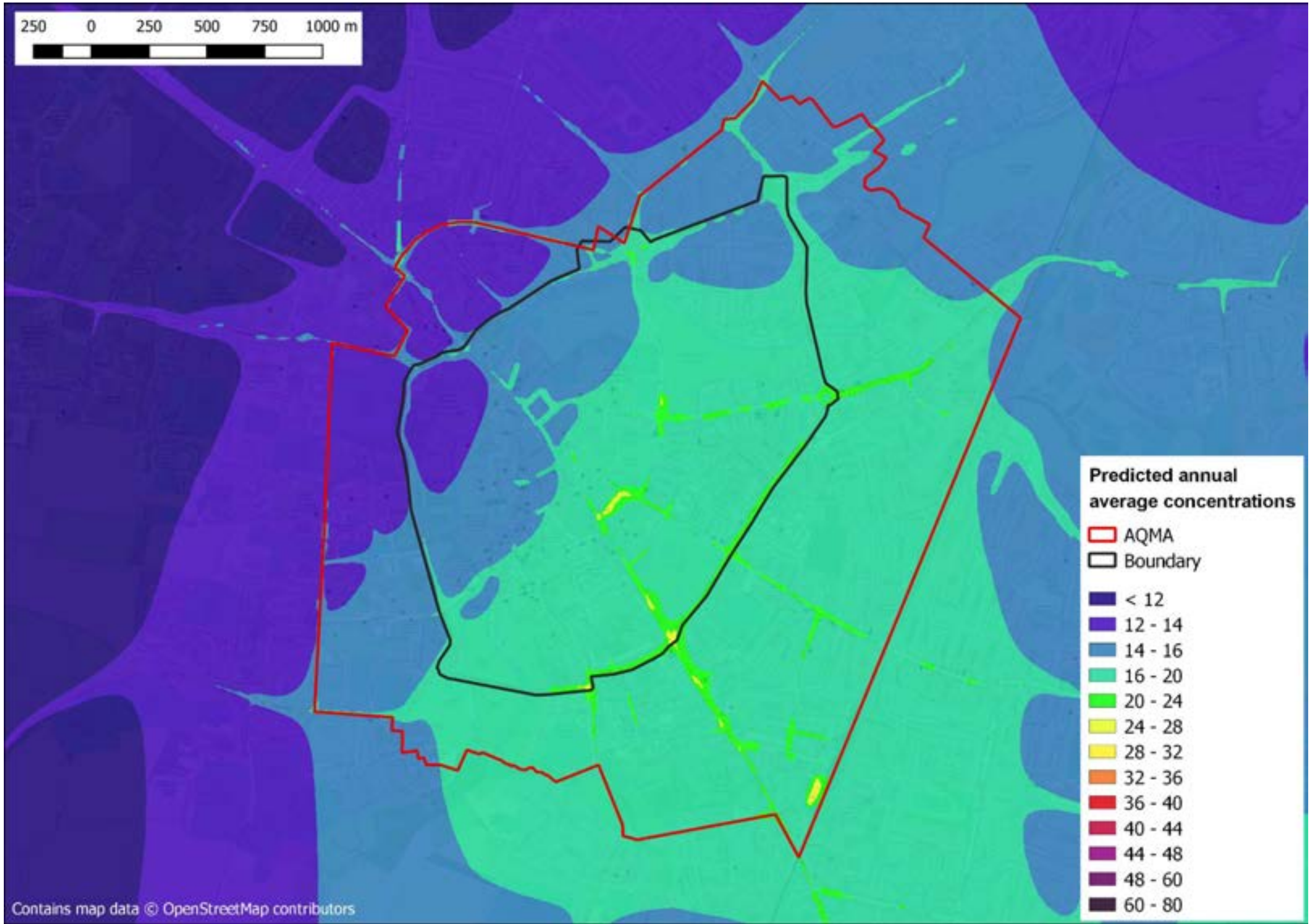


Figure 20: Annual average NO_2 concentrations, central Cambridge, 2031, Class C charging CAZ, $\mu g.m^{-3}$

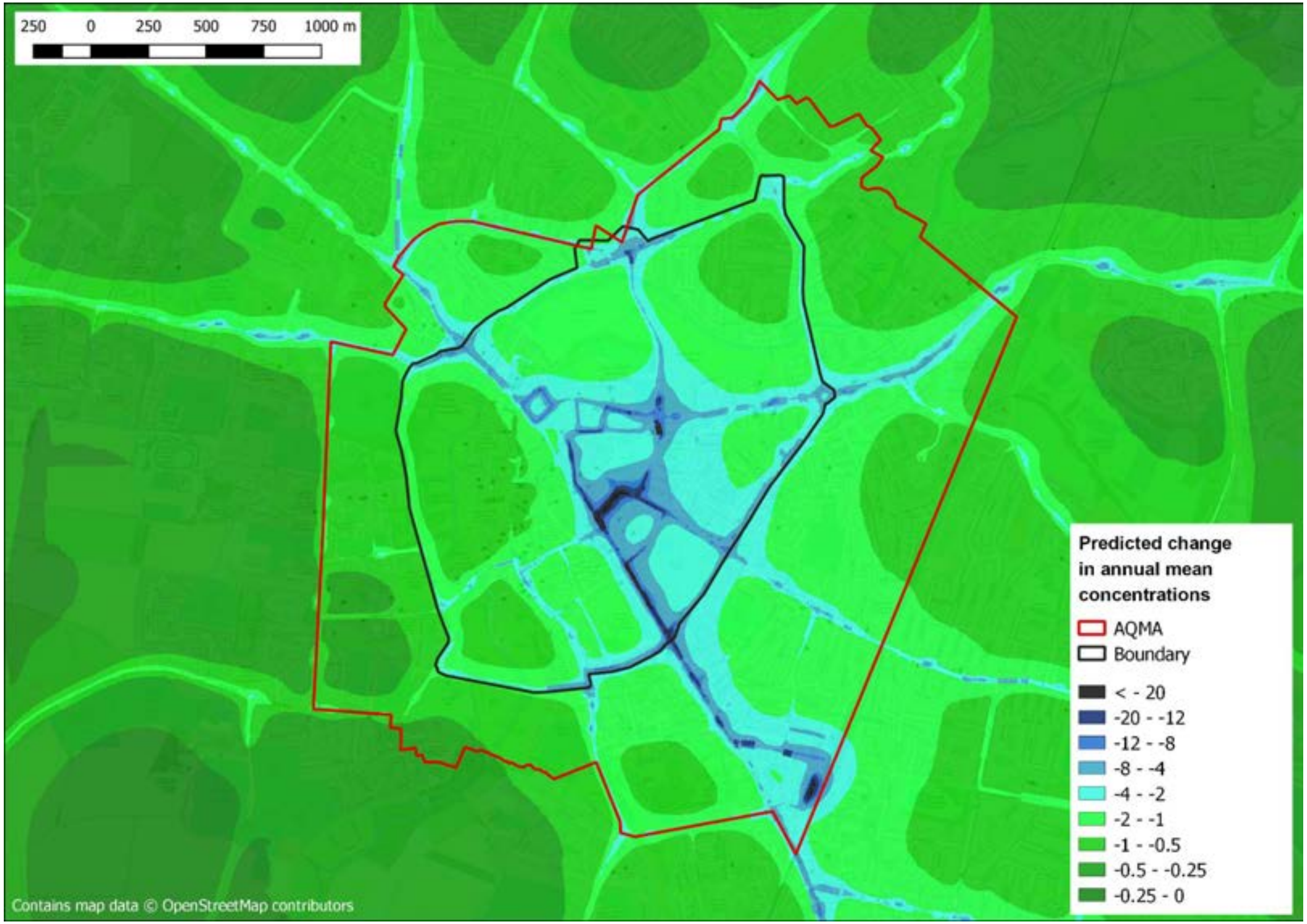


Figure 21: Predicted change in annual average NO_2 concentrations with the implementation of a Class C charging CAZ, central Cambridge, 2031, $\mu g.m^{-3}$

9 Recommendations

1. Air pollution accounts for 106 deaths each year in Cambridge and South Cambridgeshire. The baseline emissions and concentration analysis described in Section 4 shows that exceedances of the AQO for annual average NO_2 currently occur in Cambridge along a number of roads at locations of relevant exposure.

2. Without intervention, it is likely that these exceedances will remain beyond 2031. In a worst-case scenario, the total area of exceedance of the annual mean NO_2 AQO is predicted to increase in 2031 due to the additional provision of bus services to the city centre proposed as part of the Greater Cambridge Partnership City Access Strategy. As a result, mortality levels are predicted to maintain at 2017 levels, or increase.

3. Further NOx emission reductions are therefore required in addition to existing taxi policy in order to achieve compliance with the AQO for annual mean NO_2 concentrations in 2021 and 2031 and reduce mortality due to air pollution. As such, the emphasis of any CAZ should be on reducing NOx and primary NO_2 emissions. The majority of predicted exceedances of the AQO for 2017, 2021 and 2031 occur in the city centre, along roads with high levels of congestion or bus traffic. As such, the focus of the intervention in 2021 should be on reducing emissions in the centre of Cambridge. However, by 2031 it is important to deliver reductions in concentrations across Cambridge, and as such further reaching measures should be adopted.

4. The recommended intervention to improve air quality and protect public health in 2021 is a charging \`Class D' Clean Air Zone which includes all vehicles[12]. Analysis shows that implementation of this scheme would lead to compliance with the AQO for annual mean NO_2 concentrations at all locations of relevant exposure. It is expected that the implementation of a Clean Air Zone would take approximately 18 months, and improvement in the bus fleet should be a priority due to their large contribution to total NOx emissions.

5. By 2031, reductions in concentrations across the whole of Cambridge will bring further public health benefits. Introducing a more ambitious Class C charging CAZ (including LGVs, buses and coaches to be ZEV or ULEV) is predicted to reduce NO_2 levels to below 80% of the AQO across Cambridge; it is recommended that this option is pursued. The NPV for this bundle of measures is predicted to be strongly net positive at +£44.44 million, although there is some uncertainty as to the proposed approach. As such, both the economic and air dispersion modelling analysis supports the adoption of a Class C charging CAZ by 2031.

6. In order to monitor the effectiveness of any recommendations, it is recommended that a monitoring plan be put into place. As the primary objective of the interventions recommended above are to improve air quality in Cambridge, it is recommended that additional monitoring is put in place to allow the City Council to monitor trends in areas where maximum concentrations are predicted. Use of a network of mobile smart monitors to augment the existing monitors would allow the council greater temporal and spatial flexibility in monitoring trends, providing the capability to directly monitor areas of interest or concern as they develop, and help to diagnose any issues which may occur.

[121212] Exemptions can apply e.g. to emergency services, disabled access, residents within the zone etc

Ricardo Energy & Environment

The Gemini Building
Fermi Avenue
Harwell
Didcot
Oxfordshire
OX11 0QR
United Kingdom

t: +44 (0)1235 753000
e: enquiry@ricardo.com

ee.ricardo.com