Cambridge Environmental Research Consultants

Emissions Reduction Scenarios for the City of London Corporation

Final report

Prepared for
City of London Corporation

15th June 2011

CERC

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1. Introduction

Cambridge Environmental Research Consultants was commissioned by the City of London Corporation to carry out air quality modelling, taking into account the latest London Atmospheric Emissions Inventory (LAEI 2008) and Department for Transport (DfT) emission factors. As part of this study, air quality modelling was carried out for various emissions reduction scenarios.

The modelled scenarios were provided by the City of London Corporation to investigate the likely impact of different types of intervention designed to improve local air quality. The results are expected to aid decision making on air quality policy at the City of London.

Air quality modelling for NO_x, PM_{10} and $PM_{2.5}$ was carried out using ADMS-Urban (version 2.3.3.1) air quality modelling software, with projected emissions for the years 2011 and 2015 in the LAEI 2008 for the base case modelling. Model inputs and assumptions used are described in the main CERC modelling report *Air Quality Modelling for the City of London Corporation: Model Verification & Air Quality Maps,* 3rd February 2011. The base case emissions were modified for each scenario to reflect their expected impact.

This report provides a summary of predicted pollutant concentrations at receptor locations across the City of London for the modelled scenarios. Air quality maps of predicted concentrations were also produced for some scenarios.

Section 2 describes the modelled scenarios. Predicted concentrations for the scenarios and a discussion of the results are presented in Sections 3 to 8.

2. Modelled scenarios

Air quality modelling for NO_x, PM_{10} and $PM_{2.5}$ was carried out using ADMS-Urban (version 2.3.3.1) air quality modelling software for various emission reduction scenarios provided by the City of London Corporation. The scenarios will be used to inform policy decisions in relation to air quality management.

The scenarios are compared against base case modelling using projected emissions for the years 2011 and 2015 in the LAEI 2008 base year, with model inputs and assumptions described in the main CERC modelling report *Air Quality Modelling for the City of London Corporation: Model Verification & Air Quality Maps*, 3rd February 2011. The base case emissions were modified for each scenario to reflect their expected impact.

Table 2.1 shows the scenarios where traffic fleet changes or restrictions are applied to a wider area than the City of London. These scenarios are reported in Sections 3 and 4 of the report.

The scenarios represent fleet changes or restrictions applied to roads within two different geographical areas for comparison. The Congestion Charging Zone (CCZ), which covers the City of London and parts of the neighbouring boroughs, not including the Western Extension and the North/South Circular, representing roads bound by the A406 (North Circular) and A205 (South Circular).

For these CCZ and North/South Circular scenarios, emissions were calculated using a conservative assumption that only the traffic fleet within the restriction area will change. In reality, such schemes would also change the traffic fleet outside the area.

PM_{10} and $PM_{2.5}$ emissions were calculated assuming that changes in vehicle technology will affect exhaust emissions only. Non-exhaust emissions, made up of brake wear, tyre wear, road wear and resuspension, were not changed.

For the scenarios which include biomethane vehicles, biomethane emissions were assumed to be equivalent to those from CNG (Compressed Natural Gas) vehicles, emitting 90% less PM_{10} and 60% less NO_x compared to equivalent diesel vehicles.

For Euro Standard compliance, it was assumed that vehicles met the standard by age and not retrofit. This is important as recent research has shown that in urban driving conditions, emissions for diesel vehicles are unlikely to meet the NO_x emission limit specified in progressive Euro Standards.[1] Emissions were therefore assumed to be in line with guidance provided in Defra Frequently Asked Question in September 2010.[2]

[1] *Trends in NO_x and NO_2 emissions and ambient measurements in the UK*, Prepared for Defra, D. Carslaw *et al.*, March 2011

[2] *Measured nitrogen oxides (NOx) and/or nitrogen dioxide (NO2) concentrations in my local authority area do not appear to be declining in line with national forecasts. Should I take this into account in my Review and Assessment work?* http://laqm2.defra.gov.uk/FAQs/General/Measured nitrogen oxides (NOx) and-or nitrogen dioxide (NO_2) concentrations do not appear to be declining in line with national forecasts.pdf

Table 2.1: Summary of CCZ & North/South Circular scenarios

Short name	Year	Area	Description	Pollutants assessed	Report section
Euro 4 CCZ 11	2011	CCZ	Minimum standard of Euro 4 for all diesel vehicles	PM_{10} & $PM_{2.5}$	3
Euro 4 NS 11	2011	North/ South Circular	Minimum standard of Euro 4 for all diesel vehicles	PM_{10} & $PM_{2.5}$	3
Euro 4 plus electric 11	2011	CCZ	Minimum standard of Euro 4 for all diesel vehicles & electric taxis	PM_{10} & $PM_{2.5}$	3
Biomethane	2011	CCZ	Biomethane used by 50% of lorries, large vans & taxis	PM_{10}, $PM_{2.5}$ & NO_x	3
25% electric	2011	CCZ	25% of taxis, vans & cars are electric	PM_{10}, $PM_{2.5}$ & NO_x	3
Euro 5 CCZ	2011	CCZ	Minimum standard of Euro 5 for all diesel vehicles	PM_{10} & $PM_{2.5}$	3
Euro 5 NS	2011	North/ South Circular	Minimum standard of Euro 5 for all diesel vehicles	PM_{10} & $PM_{2.5}$	3
Euro 4 CCZ 15	2015	CCZ	Minimum standard of Euro 4 for all diesel vehicles	NO_x	4
Euro 4 NS 15	2015	North/ South Circular	Minimum standard of Euro 4 for all diesel vehicles	NO_x	4
Euro 4 plus electric 15	2015	CCZ	Minimum standard of Euro 4 for all diesel vehicles & electric taxis	NO_x	4
50% electric	2015	CCZ	50% of taxis vans & cars are electric	PM_{10}, $PM_{2.5}$ & NO_x	4
Euro 4 plus electric & biomethane	2015	CCZ	Minimum standard of Euro 4 for all diesel vehicles, electric taxis & biomethane used by 50% lorries & large vans	NO_x	4
Euro 6	2015	CCZ	Minimum standard of Euro 6 for all diesel vehicles	NO_x	4

Table 2.2 shows the scenarios assumed to have only a local or borough-wide impact on emissions. These scenarios are assumed to affect emissions within the City of London only. They are reported in Sections 5 to 8.

The *50% boiler NO_x* scenario was modelled for the year 2015. The other scenarios were modelled for the year 2011.

The *Low emission buses* scenario is expected to have a small impact on pollutant concentrations across the City of London, therefore only the impact on emissions was assessed.

For the two taxi scenarios, taxi data from the City of London Corporation paper *Taxi Availability Study for the City of London*, June 2007, were used. Further details of the assumptions used for this scenario are described in Section 7.

The proposed removal of the Aldgate Gyratory system and the subsequent changes to the road layout are reported in Section 8. Two options were considered and compared against a base case. Traffic data for the Aldgate Gyratory were provided by the City of London Corporation.

Table 2.2: Summary of borough-wide scenarios

Short name	Year	Area	Description	Pollutants assessed	Report section
50% boiler NO_x	2015	Borough-wide	50% reduction in NO_x emissions from gas-oil boilers, commercial gas & domestic gas use	NO_x	5
Low emission buses	2011	Borough-wide	Low emission buses, with a minimum standard of Euro 5 with particle traps	PM_{10}, $PM_{2.5}$ & NO_x	6
Lights off	2011	Borough-wide	Prevention of taxis plying for hire	PM_{10}, $PM_{2.5}$ & NO_x	7
Euro 4 taxis	2011	Borough-wide	Minimum standard of Euro 4 for taxis	PM_{10}, $PM_{2.5}$ & NO_x	7
-	2011	Scheme	Removal of Aldgate Gyratory system: two options	PM_{10}, $PM_{2.5}$ & NO_x	8

Predicted pollutant concentrations for all modelled scenarios, except the *Low emission buses* scenario and the removal of Aldgate Gyratory system, were predicted at the 16 receptor locations shown in Figure 2.1. In addition, air quality maps of predicted concentrations across the City of London were produced for some scenarios.

Of the receptor locations, four represent monitor locations in the City of London that were used for model verification and in the CERC source apportionment study *Source Apportionment for the City of London Corporation*, 15th June 2011. The remaining 12 receptor locations, provided by the City of London Corporation, are classed as either background (bgd), roadside (rd) or street canyon (canyon) locations. Background locations were defined as being more than 20m from a modelled road. Roadside locations were defined as being 2m from a modelled road. The Fleet Street location is assumed to be in a street canyon, modelled with a road width of 18m and a canyon height of 25m.

For the *Low emission buses* scenario, only the impact on emissions was assessed. For the Aldgate Gyratory scenarios, high resolution air quality maps of predicted concentrations were produced for the area, over which traffic flows are predicted to be affected by the proposed changes in road layout.

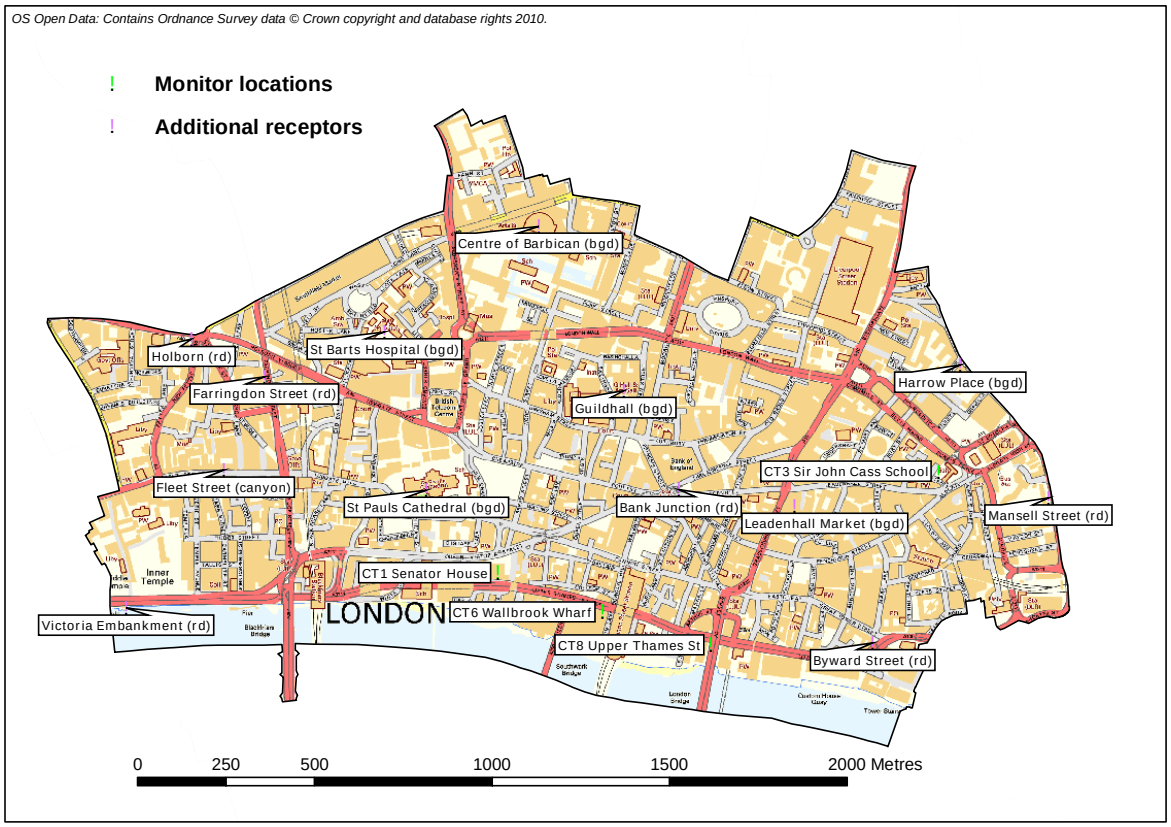


Figure 2.1: Receptor locations

3. CCZ and North / South Circular Scenarios, 2011

The results for the scenarios summarised in Table 3.1 are reported in this section. The scenarios involve vehicle technology restrictions or changes for traffic travelling within the Congestion Charging Zone (CCZ) or North/South Circular for 2011. The predicted concentrations for the scenarios are compared against a *2011 Base* scenario.

Table 3.1: 2011 CCZ and North/South Circular scenarios

Short name	Year	Area	Description	Pollutants assessed
Euro 4 CCZ 11	2011	CCZ	Minimum standard of Euro 4 for all diesel vehicles	PM_{10} & $PM_{2.5}$
Euro 4 NS 11	2011	North/ South Circular	Minimum standard of Euro 4 for all diesel vehicles	PM_{10} & $PM_{2.5}$
Euro 4 plus electric 11	2011	CCZ	Minimum standard of Euro 4 for all diesel vehicles & electric taxis	PM_{10} & $PM_{2.5}$
Biomethane	2011	CCZ	Biomethane used by 50% of lorries, large vans & taxis	PM_{10}, $PM_{2.5}$ & NO_x
25% electric	2011	CCZ	25% of taxis, vans & cars are electric	PM_{10}, $PM_{2.5}$ & NO_x
Euro 5 CCZ	2011	CCZ	Minimum standard of Euro 5 for all diesel vehicles	PM_{10} & $PM_{2.5}$
Euro 5 NS	2011	North/ South Circular	Minimum standard of Euro 5 for all diesel vehicles	PM_{10} & $PM_{2.5}$

Predicted annual average and 90.41st percentile of 24-hour average PM_{10} concentrations at receptor locations are presented in Tables 3.2 and 3.3 respectively, as well as in Figures 3.1 and 3.2. Predicted annual average $PM_{2.5}$ concentrations at the receptor locations are presented in Table 3.4 and Figure 3.3.

The largest reduction in PM_{10} and $PM_{2.5}$ concentrations over the *2011 Base* scenario, is predicted for the two scenarios where a minimum standard of Euro 5 is applied to diesel vehicles. Air quality maps for these Euro 5 scenarios are presented in Figures 3.4 to 3.6.

For the *Biomethane* and *25% electric* scenarios, predicted annual average and 99.79th percentile of hourly average NO_2 concentrations at receptor locations are presented in Table 3.5 and in Figures 3.7 and 3.8. The predicted reductions over the *2011 Base* scenario are similar for both scenarios.

Table 3.2: Annual average PM_{10} concentrations at receptor locations ($\mu g/m^3$), 2011 CCZ & North/South Circular scenarios

Receptor name	*2011 Base*	*Euro 4 CCZ 11*	*Euro 4 NS 11*	*Euro 4 plus electric*	*Biomethane*	*25% electric*	*Euro 5 CCZ 11*	*Euro 5 NS 11*
CT1 Senator House	21.0	20.9	20.8	20.8	20.8	20.9	20.7	20.6
CT6 Walbrook Wharf	27.8	27.3	27.2	26.4	26.4	27.3	25.7	25.6
CT8 Upper Thames Street	31.5	30.7	30.6	29.5	29.6	30.9	28.6	28.5
CT3 Sir John Cass School	21.7	21.6	21.5	21.4	21.5	21.6	21.3	21.2
Mansell Street	23.2	23.2	22.9	23.1	23.1	23.2	23.1	22.4
Centre of Barbican	21.4	21.3	21.3	21.2	21.2	21.4	21.1	21.0
Harrow Place	21.2	21.1	21.1	21.1	21.1	21.1	21.0	20.9
Bank Junction	23.7	23.3	23.3	22.8	23.0	23.4	22.5	22.4
Leadenhall Market	22.1	21.9	21.9	21.7	21.8	22.0	21.6	21.5
Byward Street	23.7	23.3	23.3	23.0	23.1	23.5	22.7	22.6
St Pauls Cathedral	21.9	21.8	21.7	21.6	21.7	21.9	21.5	21.4
St Barts Hospital	21.5	21.3	21.3	21.2	21.3	21.4	21.2	21.1
Farringdon Street	23.4	23.2	23.1	22.8	23.0	23.2	22.6	22.5
Fleet Street	23.5	23.3	23.2	23.0	23.2	23.4	23.0	22.9
Guildhall	21.5	21.4	21.3	21.2	21.3	21.4	21.1	21.0
Holborn	23.4	23.1	23.0	22.7	22.9	23.1	22.5	22.4
Victoria Embankment	24.4	24.1	24.0	23.7	23.8	24.1	23.3	23.2

Table 3.3: 90.41st percentile of 24-hour average PM_{10} concentrations at receptor locations (µg/m^3), 2011 CCZ & North/South Circular scenarios

Receptor name	*2011 Base*	*Euro 4 CCZ 11*	*Euro 4 NS 11*	*Euro 4 plus electric*	*Biomethane*	*25% electric*	*Euro 5 CCZ 11*	*Euro 5 NS 11*
CT1 Senator House	36.2	36.1	36.0	36.0	36.0	36.2	35.9	35.8
CT6 Walbrook Wharf	44.9	44.3	44.2	43.4	43.4	44.4	42.4	42.0
CT8 Upper Thames Street	52.1	51.3	51.3	49.9	49.8	51.6	48.3	48.1
CT3 Sir John Cass School	36.9	36.8	36.8	36.7	36.8	36.8	36.7	36.5
Mansell Street	40.9	40.9	40.5	40.9	40.9	40.9	40.9	39.5
Centre of Barbican	36.5	36.4	36.4	36.4	36.4	36.4	36.4	36.2
Harrow Place	36.1	36.1	36.0	36.1	36.1	36.1	36.1	35.8
Bank Junction	38.5	38.0	37.9	37.3	37.5	38.1	37.1	37.0
Leadenhall Market	36.8	36.6	36.6	36.4	36.4	36.7	36.4	36.3
Byward Street	39.2	38.8	38.7	38.4	38.3	38.9	37.9	37.6
St Pauls Cathedral	36.4	36.4	36.4	36.3	36.4	36.4	36.3	36.3
St Barts Hospital	36.4	36.3	36.3	36.3	36.3	36.3	36.3	36.1
Farringdon Street	40.6	40.3	40.2	39.9	40.1	40.4	39.6	39.5
Fleet Street	39.8	39.6	39.4	39.0	39.3	39.7	39.0	38.7
Guildhall	36.5	36.5	36.4	36.4	36.4	36.5	36.4	36.1
Holborn	40.5	40.2	40.1	39.6	39.8	40.3	39.2	39.0
Victoria Embankment	41.3	41.0	41.0	40.6	40.7	41.1	40.0	40.0

Figure 3.1: Annual average PM_{10} concentrations at receptor locations ($\mu g/m^3$), 2011 CCZ & North/South Circular scenarios

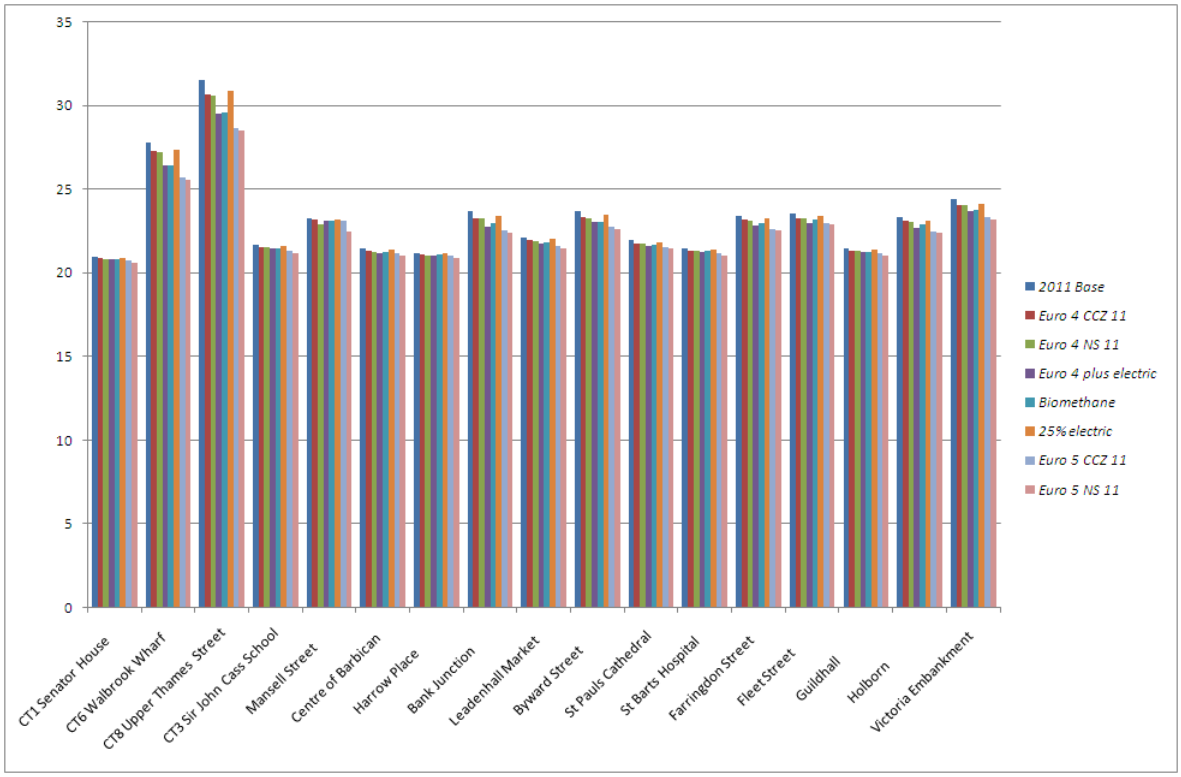


Figure 3.2: 90.41st percentile of 24-hour average PM_{10} concentrations at receptor locations ($\mu g/m^3$), 2011 CCZ & North/South Circular scenarios

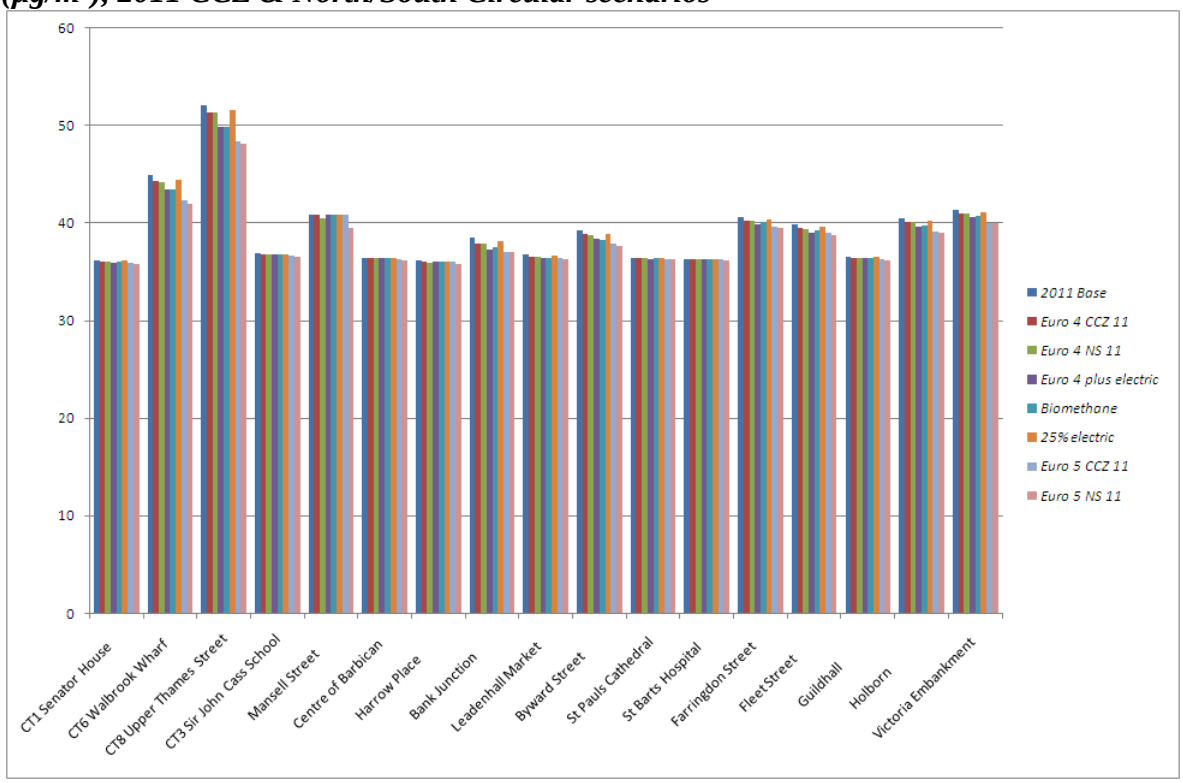


Table 3.4: Annual average $PM_{2.5}$ concentrations at receptor locations (µg/m^3), 2011 CCZ & North/South Circular scenarios

Receptor name	*2011 Base*	*Euro 4 CCZ 11*	*Euro 4 NS 11*	*Euro 4 plus electric*	*Biomethane*	*25% electric*	*Euro 5 CCZ 11*	*Euro 5 NS 11*
CT1 Senator House	10.4	10.3	10.3	10.2	10.3	10.3	10.2	10.1
CT6 Walbrook Wharf	14.6	14.0	13.9	13.2	13.3	14.1	12.5	12.4
CT8 Upper Thames Street	16.5	15.6	15.5	14.5	14.7	15.9	13.6	13.5
CT3 Sir John Cass School	10.9	10.8	10.7	10.6	10.7	10.8	10.6	10.4
Mansell Street	11.7	11.6	11.4	11.6	11.6	11.6	11.5	10.9
Centre of Barbican	10.8	10.7	10.6	10.6	10.6	10.7	10.5	10.4
Harrow Place	10.6	10.5	10.5	10.5	10.5	10.6	10.4	10.3
Bank Junction	12.2	11.8	11.8	11.3	11.5	11.9	11.1	11.0
Leadenhall Market	11.2	11.0	11.0	10.8	10.9	11.1	10.7	10.5
Byward Street	12.0	11.6	11.6	11.4	11.4	11.8	11.1	11.0
St Pauls Cathedral	11.0	10.9	10.8	10.7	10.8	10.9	10.6	10.5
St Barts Hospital	10.8	10.7	10.7	10.6	10.6	10.7	10.5	10.4
Farringdon Street	11.9	11.6	11.6	11.3	11.4	11.7	11.1	11.0
Fleet Street	11.7	11.4	11.4	11.2	11.4	11.6	11.1	11.0
Guildhall	10.8	10.7	10.7	10.6	10.6	10.7	10.5	10.4
Holborn	11.9	11.7	11.7	11.3	11.5	11.7	11.1	11.0
Victoria Embankment	12.5	12.2	12.1	11.8	11.9	12.2	11.4	11.3

Figure 3.3: Annual average $PM_{2.5}$ concentrations at receptor locations ($\mu g/m^3$), 2011 CCZ & North/South Circular scenarios

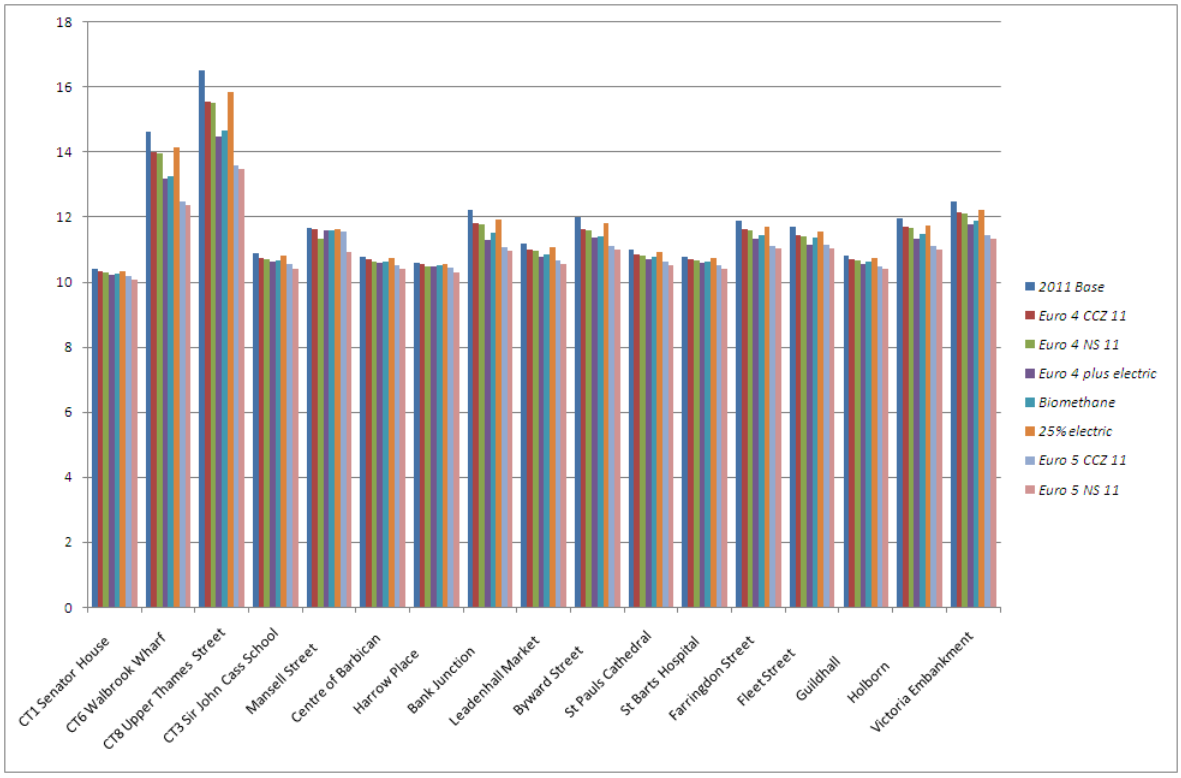
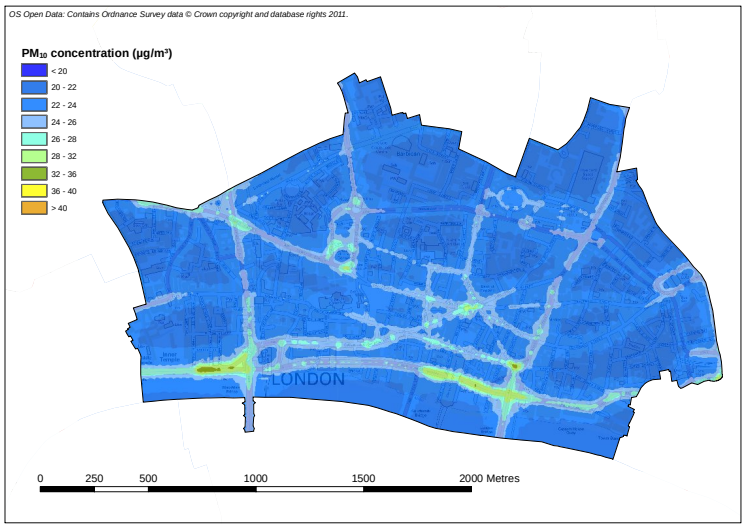


Figure 3.4: Air quality maps of annual average PM_{10} concentrations ($\mu g/m^3$)

a) 2011 Base



b) Minimum standard of Euro 5 for all diesel vehicles within the CCZ

c) Minimum standard of Euro 5 for all diesel vehicles within North/South Circular

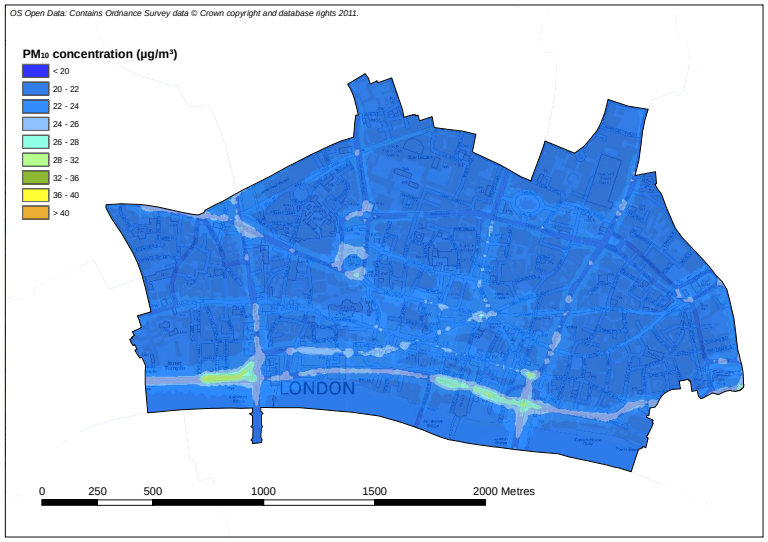
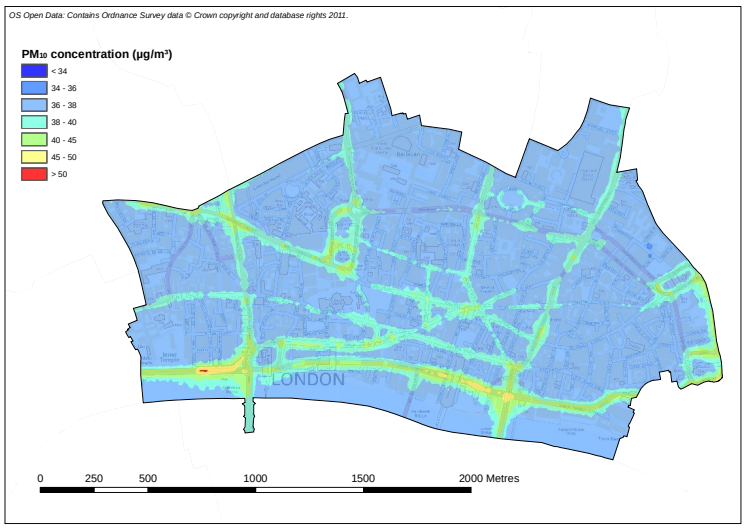


Figure 3.5: Air quality maps of 90.41st percentile of 24-hour average PM_{10} concentrations ($\mu g/m^3$)

a) 2011 Base

b) Minimum standard of Euro 5 for all diesel vehicles within the CCZ



c) Minimum standard of Euro 5 for all diesel vehicles within North/South Circular

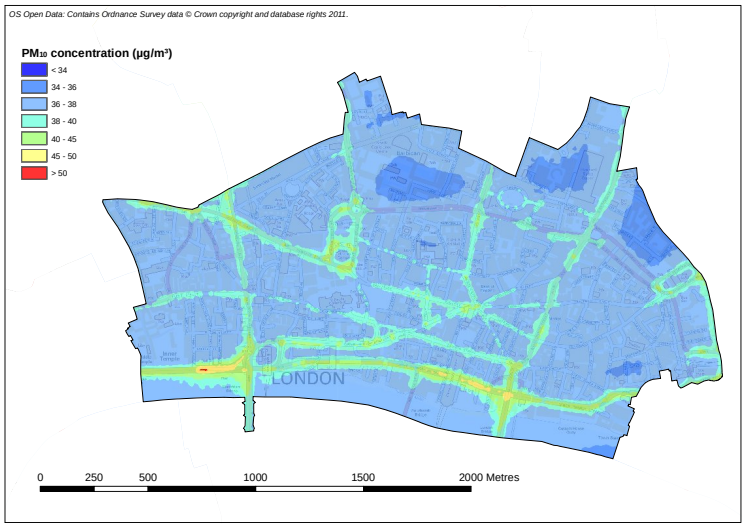
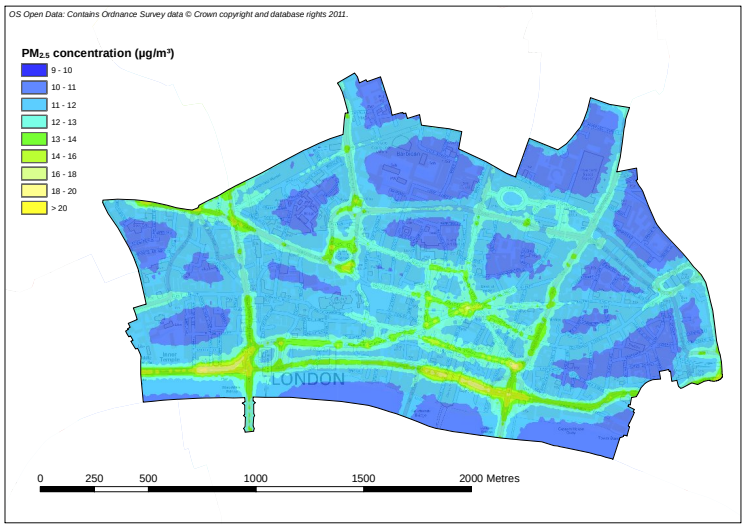
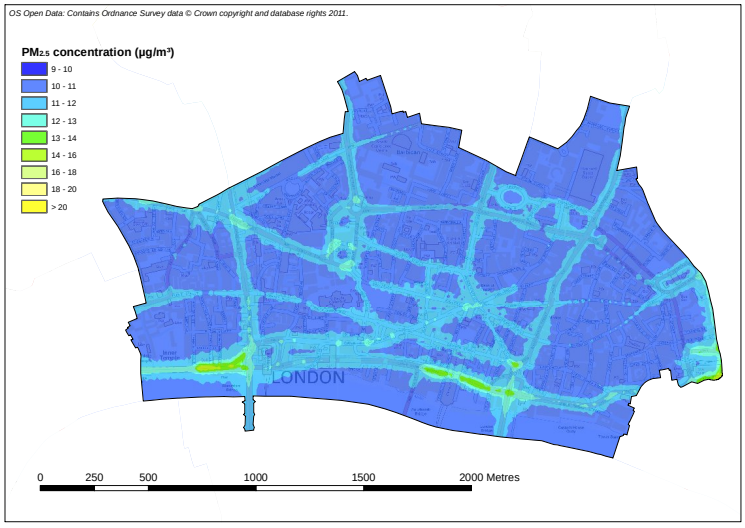


Figure 3.6: Air quality maps of annual average $PM_{2.5}$ concentrations ($\mu g/m^3$)

a) 2011 Base



b) Minimum standard of Euro 5 for all diesel vehicles within the CCZ



c) Minimum standard of Euro 5 for all diesel vehicles within North/South Circular

Table 3.5: Annual average and 99.79th percentile of hourly average NO_2 concentrations at receptor locations (µg/m^3), 2011 CCZ & North/South Circular scenarios

Receptor name	Annual average			99.79th percentile		
	2011 Base	*Biomethane*	*25% electric*	*2011 Base*	*Biomethane*	*25% electric*
CT1 Senator House	42.5	41.1	41.3	162.6	159.3	159.3
CT6 Walbrook Wharf	98.3	88.9	88.9	322.3	296.0	292.8
CT8 Upper Thames Street	123.3	110.9	110.8	423.4	379.8	376.7
CT3 Sir John Cass School	49.3	47.5	47.7	174.9	171.3	171.4
Mansell Street	58.5	57.7	57.8	204.7	204.6	204.6
Centre of Barbican	46.6	44.9	45.2	163.1	158.6	159.3
Harrow Place	44.9	43.9	44.0	165.8	164.9	164.9
Bank Junction	72.9	68.3	68.3	260.5	244.9	244.5
Leadenhall Market	55.0	52.5	52.6	205.6	196.1	195.5
Byward Street	62.3	57.8	58.6	218.4	204.7	205.2
St Pauls Cathedral	53.7	51.6	51.8	183.3	177.5	177.4
St Barts Hospital	47.6	46.0	46.1	164.3	159.3	159.3
Farringdon Street	61.6	57.9	58.0	215.4	205.2	204.3
Fleet Street	74.1	71.5	71.6	237.1	231.5	230.6
Guildhall	48.8	46.9	47.2	165.4	161.4	161.2
Holborn	62.6	58.9	58.6	225.6	212.0	210.1
Victoria Embankment	67.0	62.1	62.0	262.5	240.8	238.0

Figure 3.7: Annual average NO_2 concentrations at receptor locations ($\mu g/m^3$), 2011 CCZ & North/South Circular scenarios

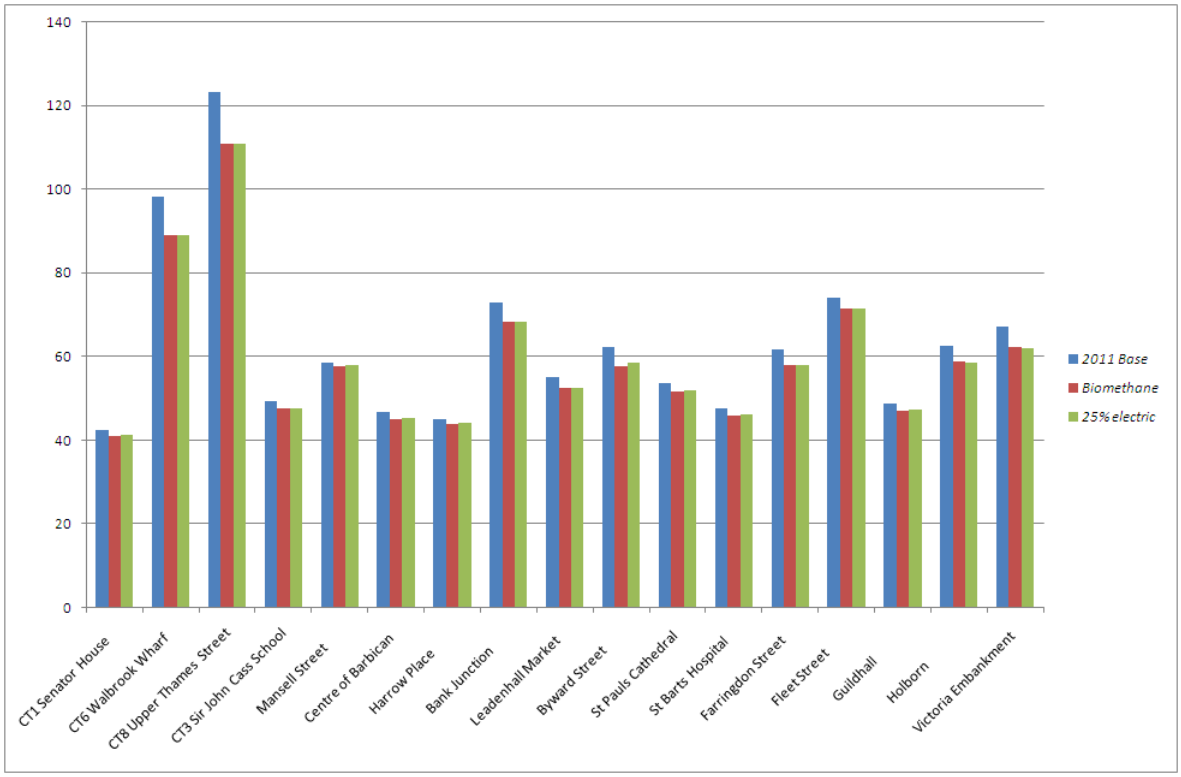
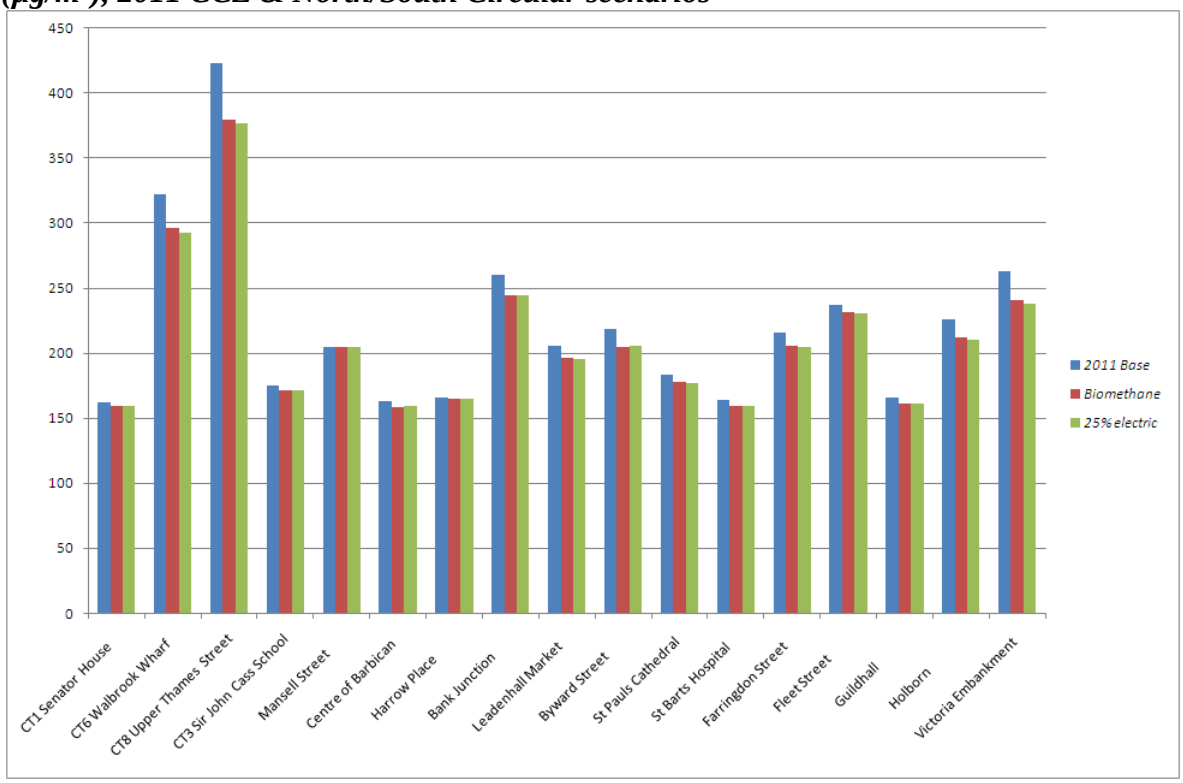


Figure 3.8: 99.79th percentile of hourly average NO_2 concentrations at receptor locations ($\mu g/m^3$), 2011 CCZ & North/South Circular scenarios



4. CCZ and North / South Circular Scenarios, 2015

The results for the scenarios summarised in Table 4.1 are reported in this section. The scenarios involve vehicle technology restrictions or changes for traffic travelling within the Congestion Charging Zone (CCZ) or North/South Circular for 2015. The predicted concentrations for the scenarios are compared against a *2015 Base* scenario.

Table 4.1: 2015 CCZ and North/South Circular scenarios

Short name	Year	Area	Description	Pollutants assessed
Euro 4 CCZ 15	2015	CCZ	Minimum standard of Euro 4 for all diesel vehicles	NO_x
Euro 4 NS 15	2015	North/ South Circular	Minimum standard of Euro 4 for all diesel vehicles	NO_x
Euro 4 plus electric 15	2015	CCZ	Minimum standard of Euro 4 for all diesel vehicles & electric taxis	NO_x
50% electric	2015	CCZ	50% of taxis vans & cars are electric	PM_{10}, $PM_{2.5}$ & NO_x
Euro 4 plus electric & biomethane	2015	CCZ	Minimum standard of Euro 4 for all diesel vehicles, electric taxis & biomethane used by 50% lorries & large vans	NO_x
Euro 6	2015	CCZ	Minimum standard of Euro 6 for all diesel vehicles	NO_x

Predicted annual average and 90.41st percentile of 24-hour average PM_{10} concentrations at receptor locations are presented in Table 4.2, as well as Figures 4.1 and 4.2. Predicted annual average $PM_{2.5}$ concentrations at the receptor locations are also presented in Table 4.2 and in Figure 4.3. Concentrations of PM_{10} and $PM_{2.5}$ are predicted for the *2015 Base* and the *50% electric* scenario only.

Predicted annual average and 99.79th percentile of hourly average NO_2 concentrations at receptor locations are presented in Tables 4.3 and 4.4 respectively, as well as in Figures 4.4 and 4.5.

Concentrations of NO_2 are predicted to increase compared to the *2015 Base*, for *Euro 4 CCZ 15* and *Euro 4 NS 15*, and decrease for all other scenarios. The largest decrease in NO_2 concentrations is for the *Euro 6* scenario.

As described in the main CERC modelling report *Air Quality Modelling for the City of London Corporation: Model Verification & Air Quality Maps*, road transport NO_x emissions have been calculated assuming emissions of Euro 2 to Euro 5 diesel vehicles are the same as equivalent Euro 1 vehicles. This assumption means that NO_x emissions are unchanged, compared to the *2015 Base*, for scenarios where the only fleet change is the Euro standard of diesel vehicles, up to Euro 5. The change in predicted NO_2 concentrations for the *Euro 4 CCZ 15* and *Euro 4 NS 15* scenarios over *2015 Base*, reflects the difference in primary NO_2 emissions between diesel vehicles of different Euro standards.

Figure 4.6 shows air quality maps for annual average NO_2 concentrations for all scenarios predicting reductions in concentrations.

Table 4.2: Annual average PM_{10} , 90.41st percentile of 24-hour average PM_{10} and annual average $PM_{2.5}$ concentrations at receptor locations (µg/m^3), 2015 CCZ & North/South Circular scenarios

Receptor name	Annual average PM_{10}		90.41st percentile PM_{10}		Annual average $PM_{2.5}$	
	2015 Base	*50% electric*	*2015 Base*	*50% electric*	*2015 Base*	*50% electric*
CT1 Senator House	20.2	20.1	34.9	34.9	9.8	9.7
CT6 Walbrook Wharf	26.0	25.4	42.7	41.6	13.0	12.3
CT8 Upper Thames Street	29.3	28.4	49.4	47.9	14.4	13.5
CT3 Sir John Cass School	20.8	20.7	35.7	35.6	10.1	10.0
Mansell Street	22.1	22.1	38.9	38.9	10.7	10.7
Centre of Barbican	20.5	20.5	35.4	35.3	10.1	10.0
Harrow Place	20.4	20.3	34.9	34.9	9.9	9.9
Bank Junction	22.4	22.0	36.7	36.2	11.1	10.7
Leadenhall Market	21.2	21.0	35.4	35.3	10.4	10.2
Byward Street	22.5	22.2	37.3	36.9	11.0	10.7
St Pauls Catherdral	21.0	20.9	35.3	35.3	10.2	10.1
St Barts Hospital	20.6	20.5	35.2	35.1	10.1	10.0
Farringdon Street	22.3	22.1	39.1	38.7	10.9	10.7
Fleet Street	22.5	22.2	38.0	37.6	10.8	10.6
Guildhall	20.6	20.5	35.3	35.2	10.1	10.0
Holborn	22.2	21.9	38.7	38.3	11.0	10.7
Victoria Embankment	23.2	22.8	39.7	39.2	11.4	11.1

Figure 4.1: Annual average PM_{10} concentrations at receptor locations ($\mu g/m^3$), 2015 CCZ & North/South Circular scenarios

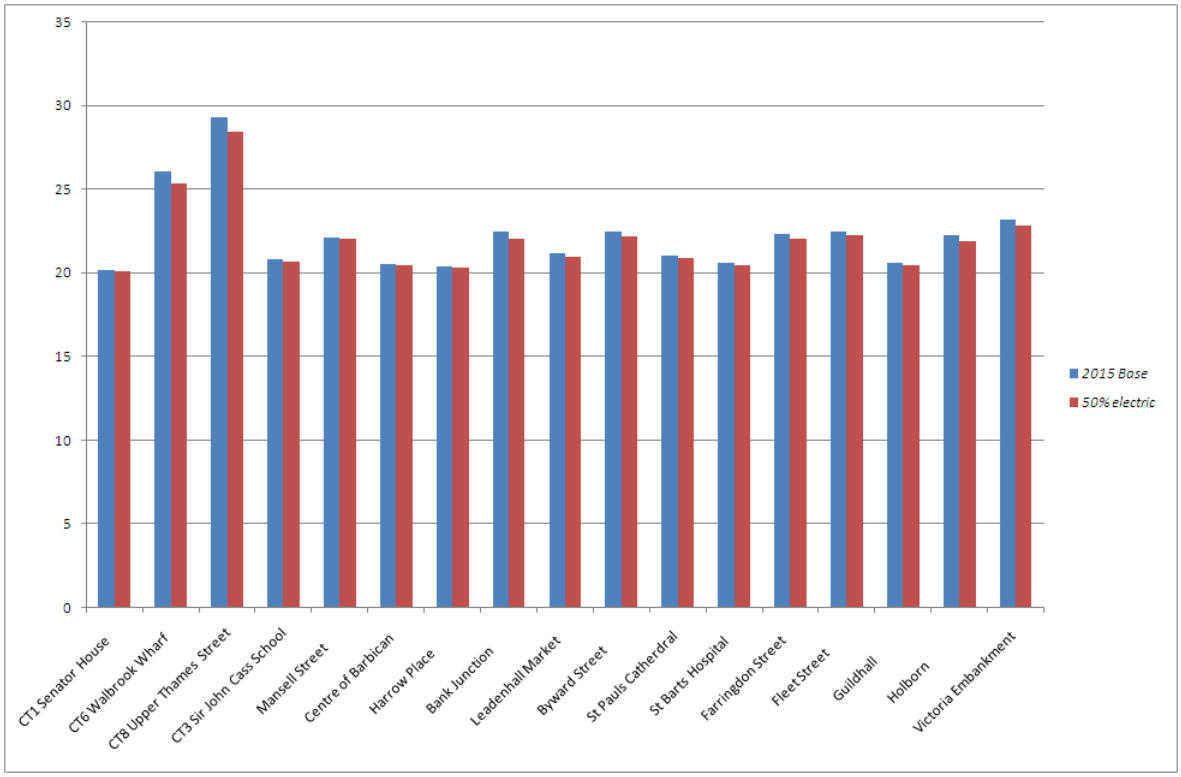


Figure 4.2: 90.41st percentile of 24-hour average PM_{10} concentrations at receptor locations ($\mu g/m^3$), 2015 CCZ & North/South Circular scenarios

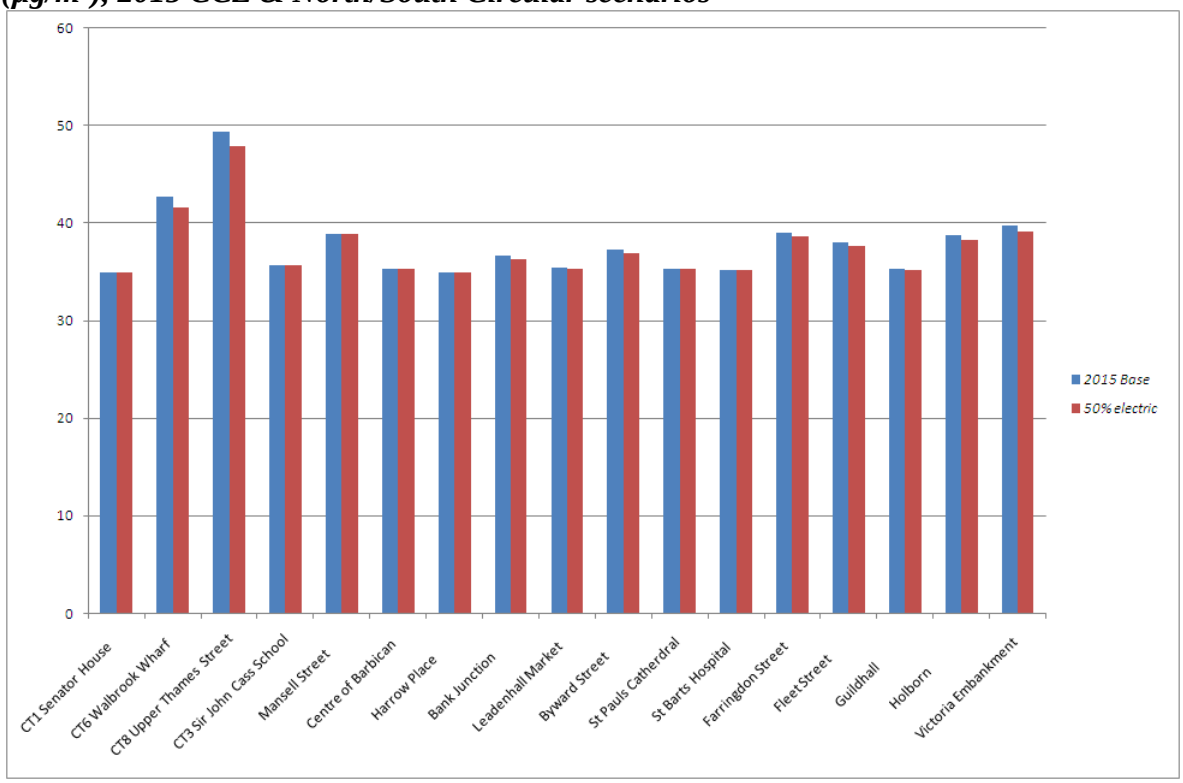


Figure 4.3: Annual average $PM_{2.5}$ concentrations at receptor locations ($\mu g/m^3$), 2015 CCZ & North/South Circular scenarios

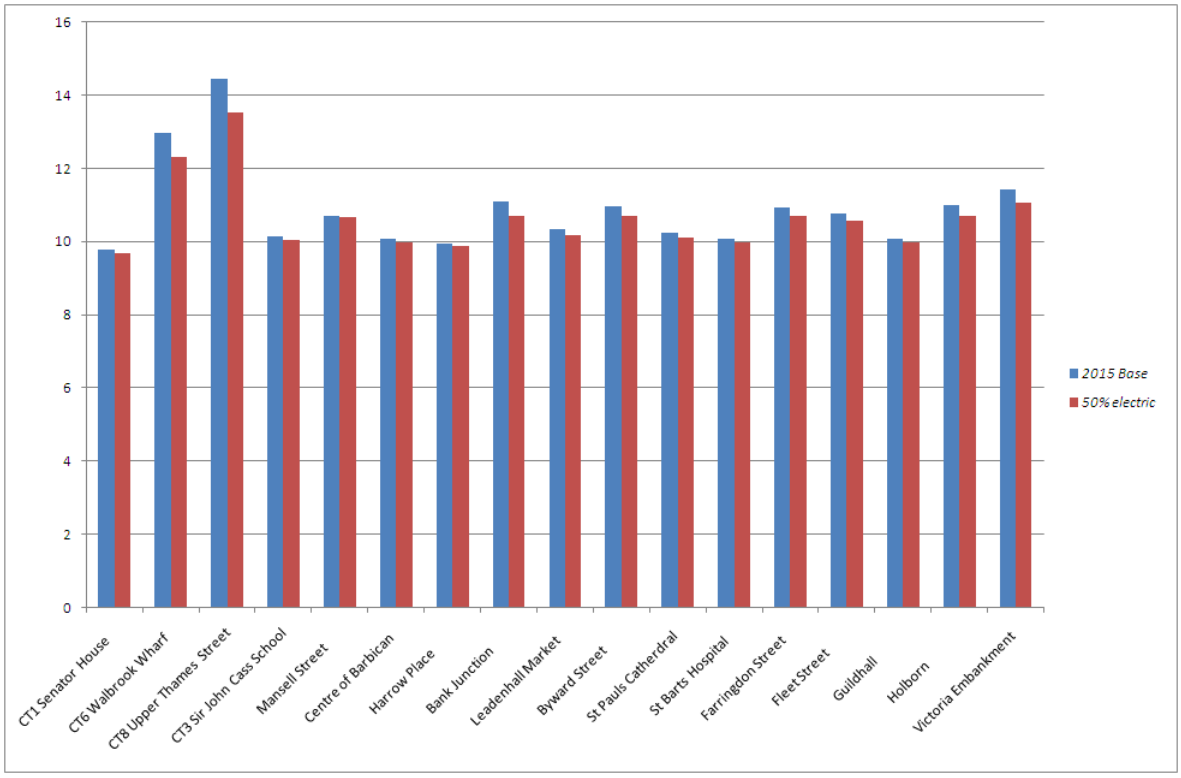


Table 4.3: Annual average NO_2 concentrations at receptor locations (µg/m^3), 2015 CCZ & North/South Circular scenarios

Receptor name	*2015 Base*	*Euro 4 CCZ 15*	*Euro 4 NS 15*	*Euro 4 plus electric 15*	*50% electric*	*Euro 4 plus electric & biomethane*	*Euro 6*
CT1 Senator House	39.5	39.7	39.9	37.2	36.9	36.8	32.9
CT6 Walbrook Wharf	93.4	98.6	98.8	77.6	72.2	74.2	49.6
CT8 Upper Thames Street	115.6	122.0	122.2	93.3	87.5	89.1	54.2
CT3 Sir John Cass School	45.6	46.0	46.2	42.4	42.2	42.0	36.8
Mansell Street	54.0	54.2	54.8	52.6	52.5	52.4	49.9
Centre of Barbican	43.2	43.7	43.9	40.3	40.3	40.1	35.9
Harrow Place	41.5	41.7	41.9	39.8	39.6	39.5	36.2
Bank Junction	66.9	68.3	68.5	56.2	56.7	55.4	39.9
Leadenhall Market	50.9	51.6	51.8	46.2	45.6	45.7	37.4
Byward Street	57.9	59.8	59.9	51.6	49.7	49.9	39.6
St Pauls Catherdral	49.1	49.2	49.4	44.8	45.0	44.3	36.6
St Barts Hospital	44.2	44.6	44.7	41.1	41.0	40.8	36.2
Farringdon Street	57.5	59.3	59.4	49.7	49.4	48.9	38.9
Fleet Street	65.2	63.8	63.9	56.7	59.5	56.1	38.7
Guildhall	45.1	45.5	45.7	41.7	41.7	41.4	36.1
Holborn	58.9	60.7	60.9	51.0	50.0	50.1	39.6
Victoria Embankment	63.6	66.4	66.6	54.6	52.5	53.1	41.2

Table 4.4: 99.79th percentile of hourly average NO_2 concentrations at receptor locations (µg/m^3), 2015 CCZ & North/South Circular scenarios

Receptor name	*2015 Base*	*Euro 4 CCZ 15*	*Euro 4 NS 15*	*Euro 4 plus electric 15*	*50% electric*	*Euro 4 plus electric & biomethane*	*Euro 6*
CT1 Senator House	156.7	159.0	161.2	148.7	147.6	147.4	136.9
CT6 Walbrook Wharf	315.5	339.0	340.5	264.8	244.0	253.3	185.6
CT8 Upper Thames Street	405.6	434.1	436.1	317.4	294.5	300.6	198.4
CT3 Sir John Cass School	165.9	167.4	169.8	155.3	155.0	153.6	140.7
Mansell Street	192.7	192.9	198.6	191.3	191.3	191.2	190.8
Centre of Barbican	156.7	158.7	160.8	148.2	147.5	146.9	140.4
Harrow Place	157.8	158.6	160.1	151.4	151.0	150.8	138.3
Bank Junction	244.8	252.2	254.4	203.4	208.4	199.0	153.8
Leadenhall Market	197.0	202.4	203.9	176.9	173.5	173.7	147.6
Byward Street	210.8	221.3	222.4	186.3	178.5	180.3	151.7
St Pauls Catherdral	173.3	173.9	176.2	156.8	158.6	155.4	143.0
St Barts Hospital	157.7	160.7	162.7	149.7	149.6	149.4	143.2
Farringdon Street	207.5	219.0	221.0	175.8	175.2	173.7	147.0
Fleet Street	215.0	208.4	210.0	182.8	195.9	181.1	148.5
Guildhall	159.9	161.4	162.7	148.8	148.4	147.6	140.4
Holborn	217.4	228.6	230.2	187.2	183.0	182.5	152.0
Victoria Embankment	256.9	275.8	278.3	213.6	202.4	206.3	162.3

Figure 4.4: Annual average NO_2 concentrations at receptor locations ($\mu g/m^3$), 2015 CCZ & North/South Circular scenarios

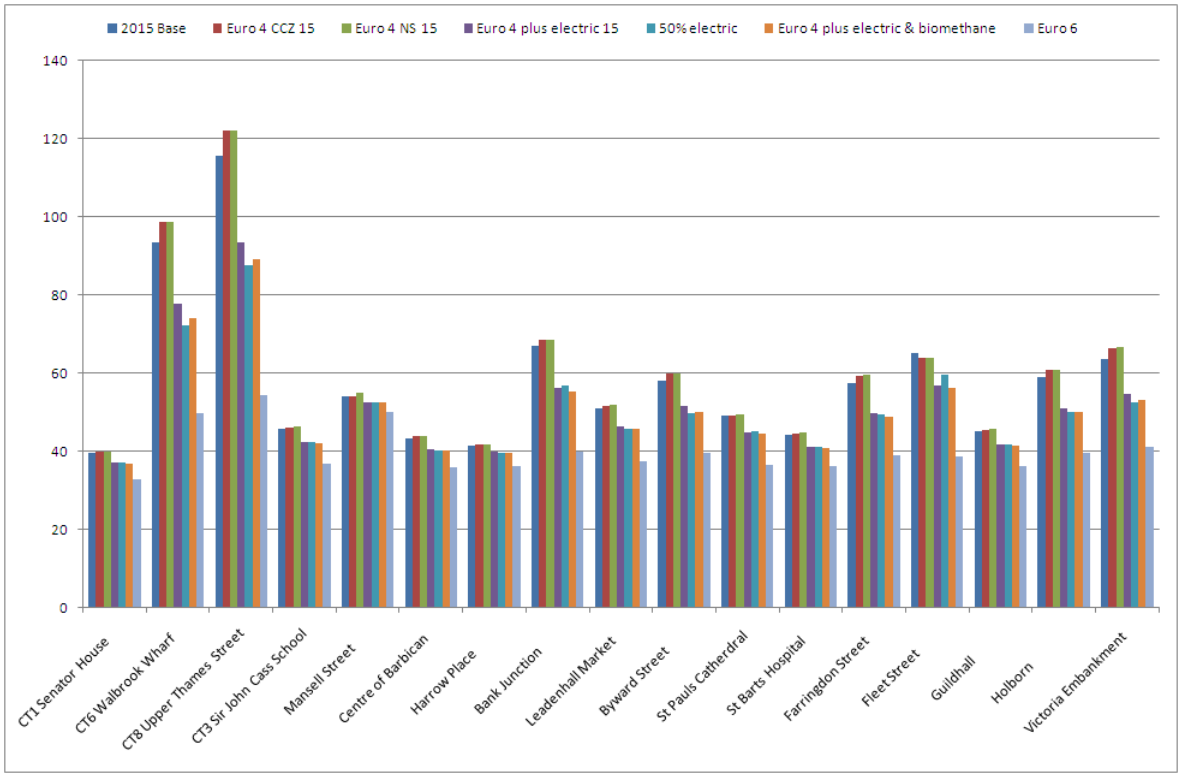


Figure 4.5: 99.79th percentile of hourly average NO_2 concentrations at receptor locations ($\mu g/m^3$), 2015 CCZ & North/South Circular scenarios

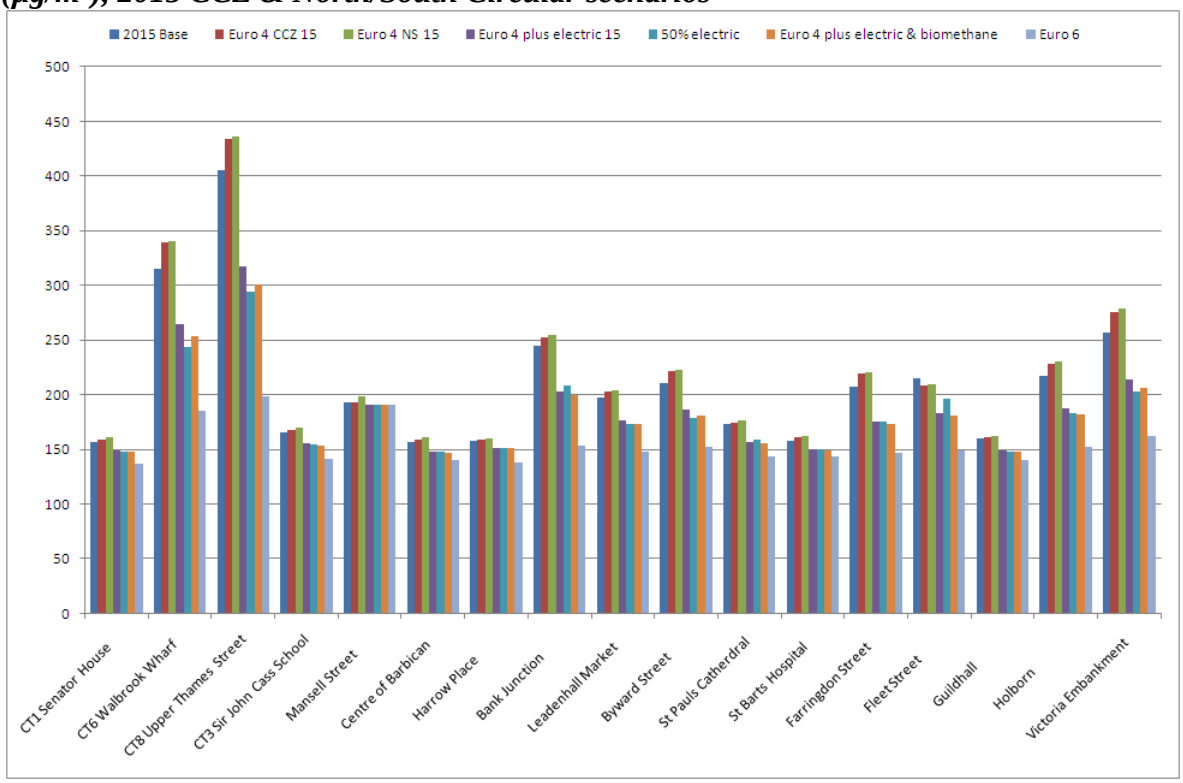
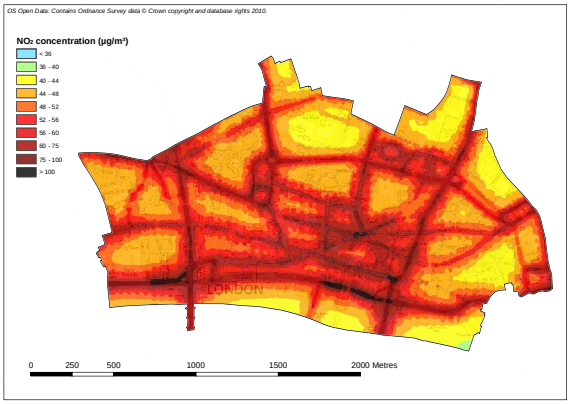
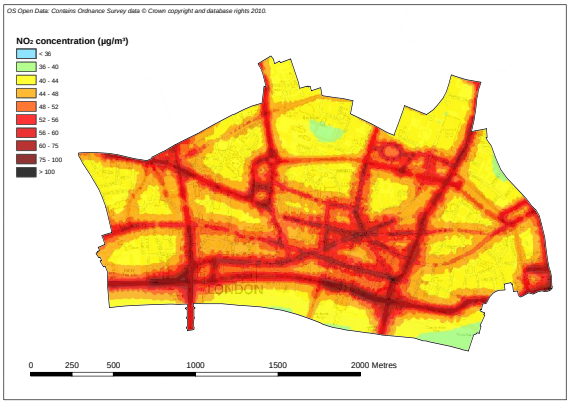


Figure 4.6: Air quality maps of annual average NO_2 concentrations ($\mu g/m^3$)

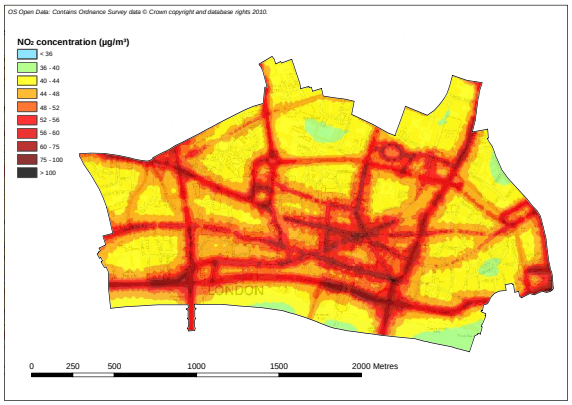
a) 2015 Base



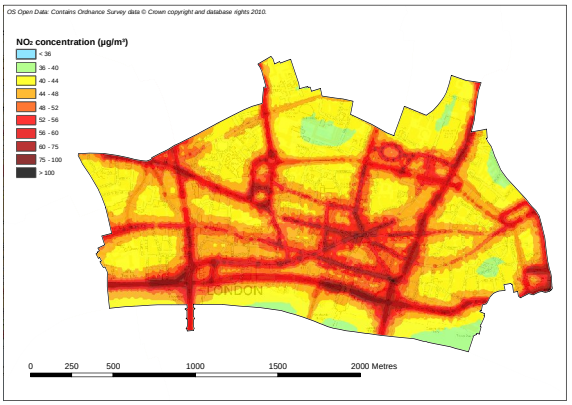
b) Minimum standard of Euro 4 for all diesel vehicles & electric taxis within the CCZ



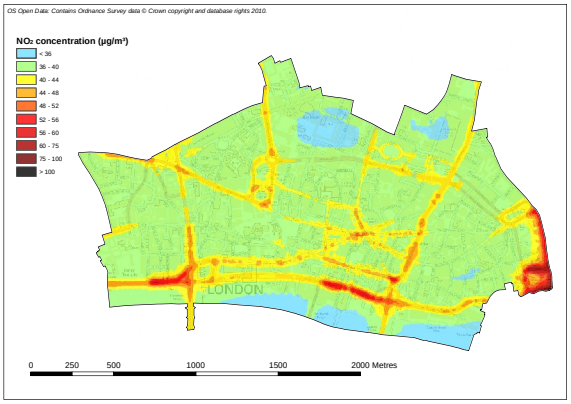
c) 50% taxis, vans & cars are electric within the CCZ



d) Minimum standard of Euro 4 for all diesel vehicles, electric taxis & biomethane used by 50% of lorries & large vans



e) Minimum standard of Euro 6 for all diesel vehicles within the CCZ



5. 50% reduction in boiler NO_x emissions

The effect of a 50% reduction in NO_x emissions from commercial and domestic gas use, as well as commercial gas oil boilers, within the City of London was modelled for the year 2015. Over 99% of these emissions are from commercial and domestic gas use; gas oil boilers within the City of London are standby systems, so their annual emissions are small.

Table 5.1 compares predicted annual average and 99.79th percentile of hourly average NO_2 concentrations at receptor locations for this scenario against the *2015 Base* scenario. These concentrations are also compared in Figures 5.1 and 5.2. The predicted reduction in NO_2 concentrations are consistent with the contribution of commercial and domestic gas to total NO_x concentrations reported in the CERC source apportionment report *Source Apportionment for the City of London Corporation*.

Table 5.1: Annual average and 99.79th percentile of hourly average NO_2 concentrations at receptor locations (µg/m^3), boiler NO_x reduction scenario

Receptor name	Annual average		99.79th percentile	
	Base 2015	*50% boiler NO_x*	*Base 2015*	*50% boiler NO_x*
CT1 Senator House	39.5	38.4	156.7	155.2
CT6 Walbrook Wharf	93.4	92.2	315.5	312.3
CT8 Upper Thames Street	115.6	114.5	405.6	402.7
CT3 Sir John Cass School	45.6	43.9	165.9	162.3
Mansell Street	54.0	52.8	192.7	190.7
Centre of Barbican	43.2	41.8	156.7	154.6
Harrow Place	41.5	39.7	157.8	155.1
Bank Junction	66.9	65.3	244.8	241.5
Leadenhall Market	50.9	49.3	197.0	193.5
Byward Street	57.9	56.6	210.8	208.6
St Pauls Cathedral	49.1	47.4	173.3	170.7
St Barts Hospital	44.2	42.4	157.7	154.8
Farringdon Street	57.5	56.0	207.5	204.5
Fleet Street	65.2	63.9	215.0	212.1
Guildhall	45.1	43.1	159.9	154.8
Holborn	58.9	57.6	217.4	214.9
Victoria Embankment	63.6	62.6	256.9	255.3

Figure 5.1: Annual average NO_2 concentrations at receptor locations ($\mu g/m^3$), boiler NO_x reduction scenario

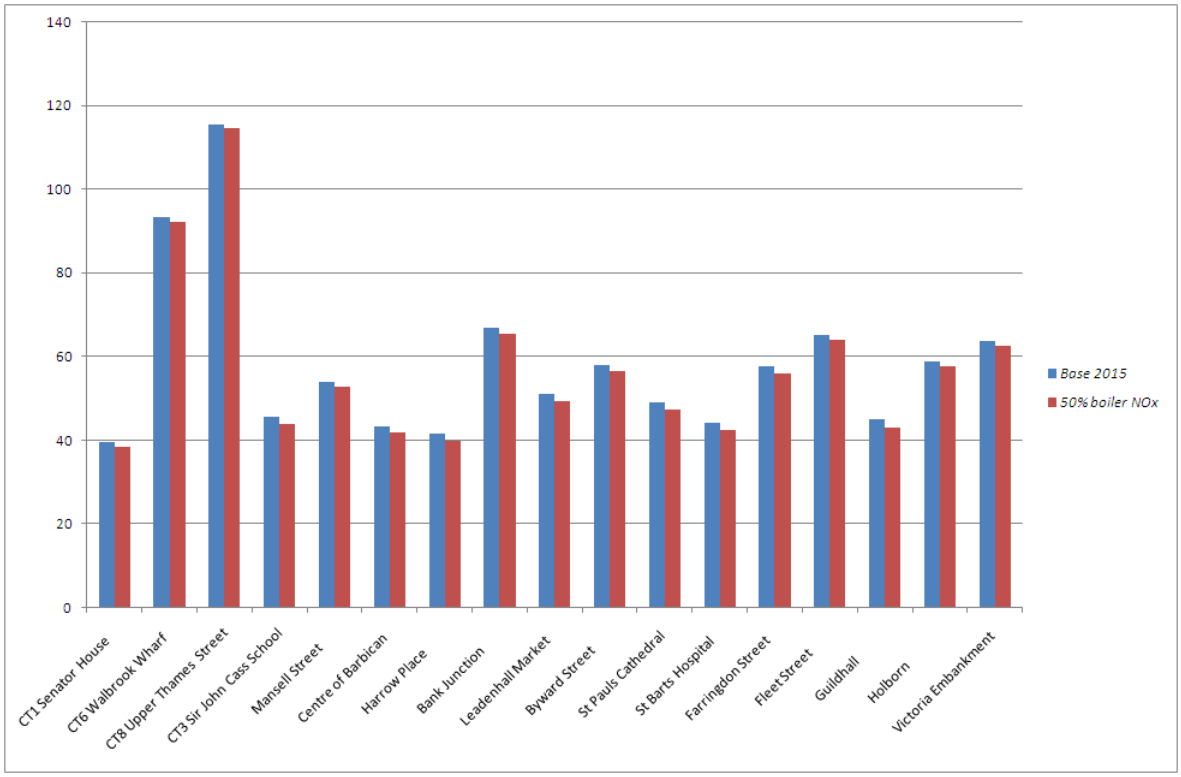
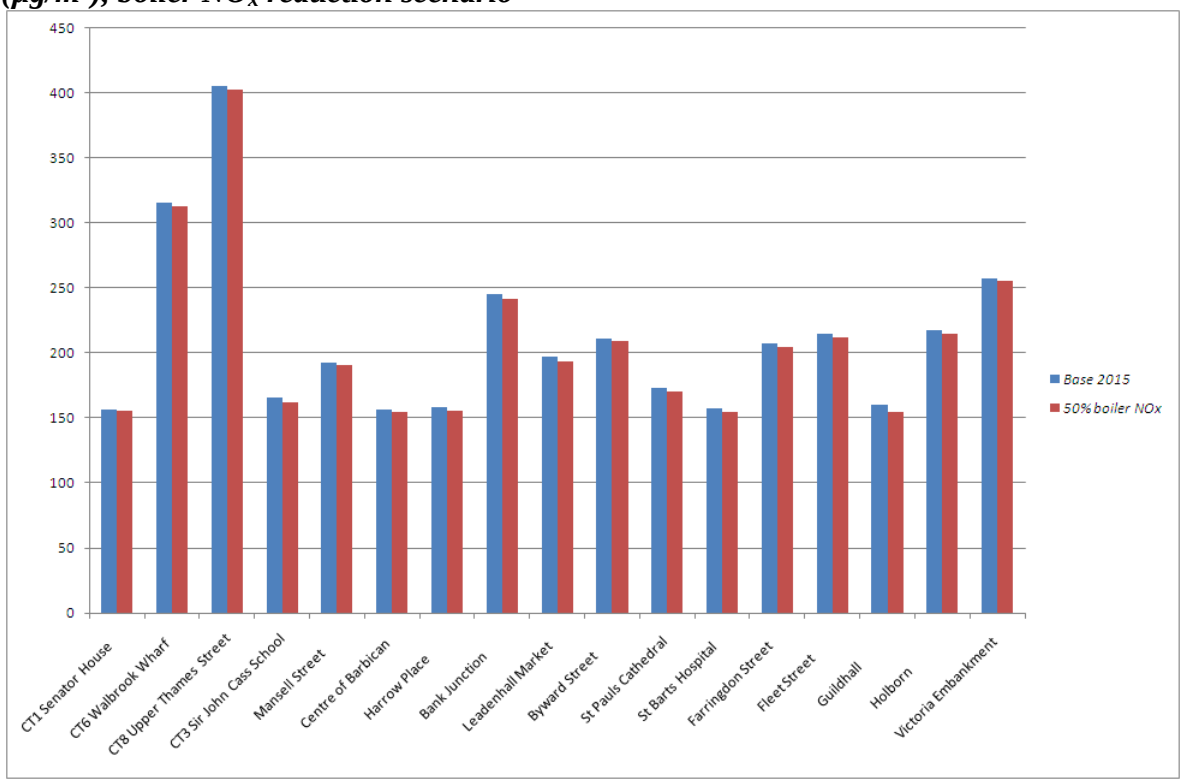


Figure 5.2: 99.79th percentile of hourly average NO_2 concentrations at receptor locations ($\mu g/m^3$), boiler NO_x reduction scenario



6. Low emission buses

The effect of using only Euro 5 buses with particle traps on pollutant emissions within the City of London is shown in Table 6.1, for the year 2011.

As described in the main CERC modelling report *Air Quality Modelling for the City of London Corporation: Model Verification & Air Quality Maps*, road transport NO_x emissions have been calculated assuming emissions of Euro 2 to Euro 5 diesel vehicles are the same as equivalent Euro 1 vehicles, therefore there is no change in NO_x emissions for this scenario compared to the *2011 Base*. For Euro 5 buses, 10% of NO_x emissions are emitted as NO_2, whereas for Euro 1 to Euro 4 buses, 11% to 35% of emissions are emitted as NO_2. This lower primary NO_2 percentage for Euro 5 buses is reflected in the reduction of NO_2 emissions for this scenario compared to the *2011 Base*.

The change in vehicle technology is assumed to affect exhaust PM_{10} and $PM_{2.5}$ only. Non-exhaust emissions, made up of brake wear, tyre wear, road wear and resuspension, were not changed, therefore the reductions in PM_{10} and $PM_{2.5}$ emissions are small.

Table 6.1: Comparison of emissions of NO_x, NO_2, PM_{10} and $PM_{2.5}$ (tonnes/year) for low emission buses scenario against 2011 Base

Sources	Scenario	NO_x	NO_2	PM_{10}	$PM_{2.5}$
All sources	*2011 Base*	726.5	159.1	26.43	17.83
	Low emisson buses	726.5	141.3	26.43	17.82
	as a % of 2011 Base	*100*	*88.83*	*99.98*	*99.97*
Major Roads	*2011 Base*	464.7	130.5	18.83	10.92
	Low emisson buses	464.7	112.8	18.82	10.91
	as a % of 2011 Base	*100*	*86.39*	*99.97*	*99.95*

7. Taxi scenarios

Scenarios were modelled to predict the impact of preventing of taxis plying for hire within the City of London, and the effect of a minimum standard of Euro 4 for taxis within the borough, for the year 2011.

Taxi data from the City of London Corporation paper *Taxi Availability Study for the City of London*, June 2007, were used. The paper surveyed taxis at 11 locations across the City of London, dividing the flows by their availability. The taxi flows are summarised in Table 7.1. The total taxi flows were used to model base case scenario, *Taxi base*, along with traffic flows for other roads and vehicles from the LAEI.

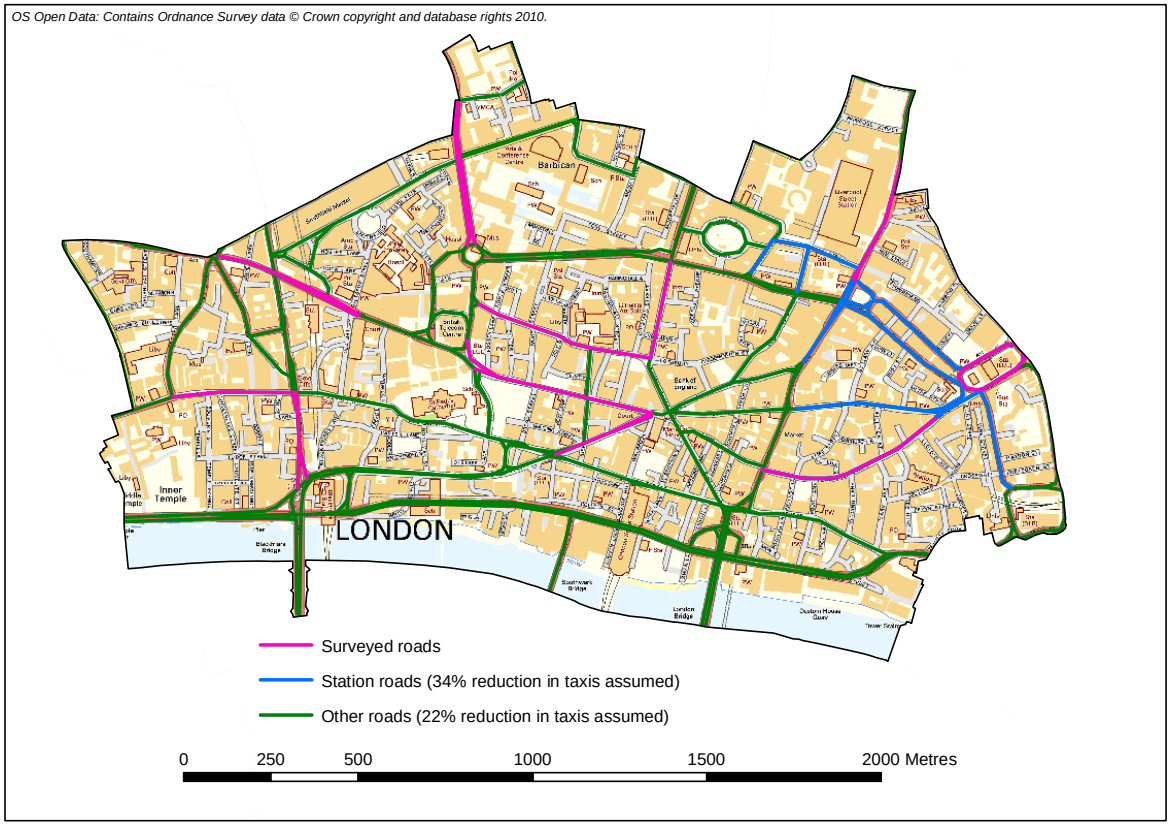
The impact of preventing taxis plying for hire was modelled in the *Lights off* scenario, by only including hired taxis, i.e. by only including taxis with their 'lights off' in the traffic flows. Taxi flows for other roads within the borough were also reduced based on the survey data. It was assumed the scenario would reduce taxi flows by 34% for roads around railway stations, based on the average 'lights on' percentage for Bishopsgate, Aldgate and Fenchurch Street, and by 22% for other roads within the City of London, based on the average 'lights on' percentage for the other surveyed roads. The road classification is summarised in Figure 7.1.

The impact of a minimum standard of Euro 4 for taxis was modelled in the *Euro 4 taxis* scenario, using the same traffic flows as the *Taxi base* scenario with emissions calculated for a modified taxi fleet.

Table 7.1: Modelled taxi flows (vehicles/day)

Surveyed road	All taxis (*Taxi base* & *Euro 4 taxis* scenarios)	Hired taxis (*Lights off* scenario)	% hired ('lights off')	% available ('lights on')
Aldersgate	5750	4435	77	23
Bishopsgate	4475	3025	68	32
Moorgate	3725	3005	81	19
New Bridge St	7800	6170	79	21
Holborn	10995	9250	84	16
Aldgate	5770	3410	59	41
Fleet Street	4590	3160	69	31
Cheapside	3615	2805	78	22
Gresham Street	3565	2850	80	20
Fenchurch Street	3480	2485	71	29
Queen Victoria Street	4785	4070	85	15

Figure 7.1: Modelled roads



Predicted annual average and 90.41st percentile of 24-hour average PM_{10} concentrations at receptor locations are presented in Table 7.2, as well as in Figures 7.2 and 7.3. Predicted annual average $PM_{2.5}$ concentrations at the receptor locations are presented in Table 7.3 and in Figure 7.4.

Concentrations of PM_{10} and $PM_{2.5}$ are predicted to be lower than the base case for both scenarios. Air quality maps of predicted concentrations across the City of London are presented in Figures 7.5 to 7.7.

Predicted annual average and 99.79th percentile of hourly average NO_2 concentrations at receptor locations are presented in Table 7.4, as well as in Figures 7.8 and 7.9. Air quality maps of predicted concentrations across the City of London are presented in Figures 7.10 and 7.11.

For the *Lights off* scenario, NO_2 concentrations are predicted to decrease compared to the *Taxi base* scenario, reflecting the reduction in taxi flows.

For the *Euro 4 taxis* scenario NO_2 concentrations are predicted to increase. As described in the main CERC modelling report *Air Quality Modelling for the City of London Corporation: Model Verification & Air Quality Maps*, road transport NO_x emissions have been calculated assuming emissions of Euro 2 to Euro 5 diesel vehicles are the same as equivalent Euro 1 vehicles. This assumption means that NO_x emissions are unchanged between the *Euro 4 taxis* and *Taxi base* scenarios. Primary NO_2 percentage for Euro 4 taxis is assumed to be 55%, compared with 11% to 35% for Euro 1 to Euro 3 taxis. This change in primary NO_2

emissions for the *Euro 4 taxis* scenario is reflected in the increase in predicted NO_2 concentrations.

Table 7.2: Annual average and 90.41st percentile of 24-hour average PM_{10} concentrations at receptor locations (µg/m^3), taxi scenarios 2011

Receptor name	Annual average			90.41st percentile		
	Taxi base	*Lights off*	*Euro 4 taxis*	*Taxi base*	*Lights off*	*Euro 4 taxis*
CT1 Senator House	21.0	20.9	20.9	36.3	36.2	36.2
CT6 Walbrook Wharf	27.8	27.6	27.4	44.9	44.7	44.5
CT8 Upper Thames Street	31.5	31.2	30.9	52.1	51.9	51.6
CT3 Sir John Cass School	21.7	21.7	21.7	37.0	36.9	36.9
Mansell Street	23.2	23.2	23.2	40.9	40.8	40.8
Centre of Barbican	21.4	21.4	21.4	36.5	36.5	36.4
Harrow Place	21.2	21.2	21.2	36.1	36.1	36.1
Bank Junction	23.8	23.6	23.5	38.6	38.4	38.2
Leadenhall Market	22.2	22.1	22.0	36.8	36.8	36.7
Byward Street	23.7	23.6	23.5	39.2	39.1	39.0
St Pauls Cathedral	22.0	21.9	21.9	36.5	36.4	36.4
St Barts Hospital	21.5	21.5	21.4	36.4	36.4	36.3
Farringdon Street	23.5	23.4	23.3	40.7	40.6	40.5
Fleet Street	24.5	24.2	24.2	40.8	40.4	40.4
Guildhall	21.5	21.5	21.5	36.5	36.5	36.5
Holborn	23.4	23.3	23.2	40.7	40.5	40.4
Victoria Embankment	24.4	24.3	24.2	41.3	41.2	41.1

Figure 7.2: Annual average PM_{10} concentrations at receptor locations ($\mu g/m^3$), taxi scenarios 2011

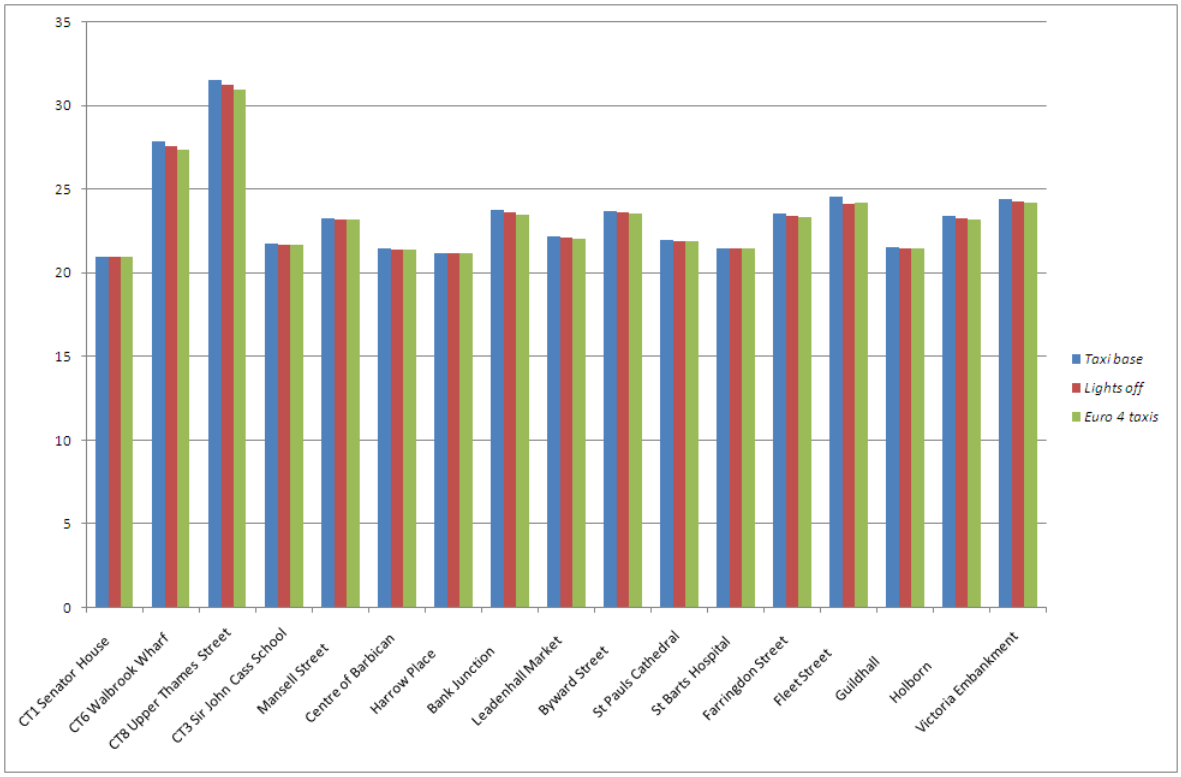


Figure 7.3: 90.41st percentile of 24-hour average PM_{10} concentrations at receptor locations ($\mu g/m^3$), taxi scenarios 2011

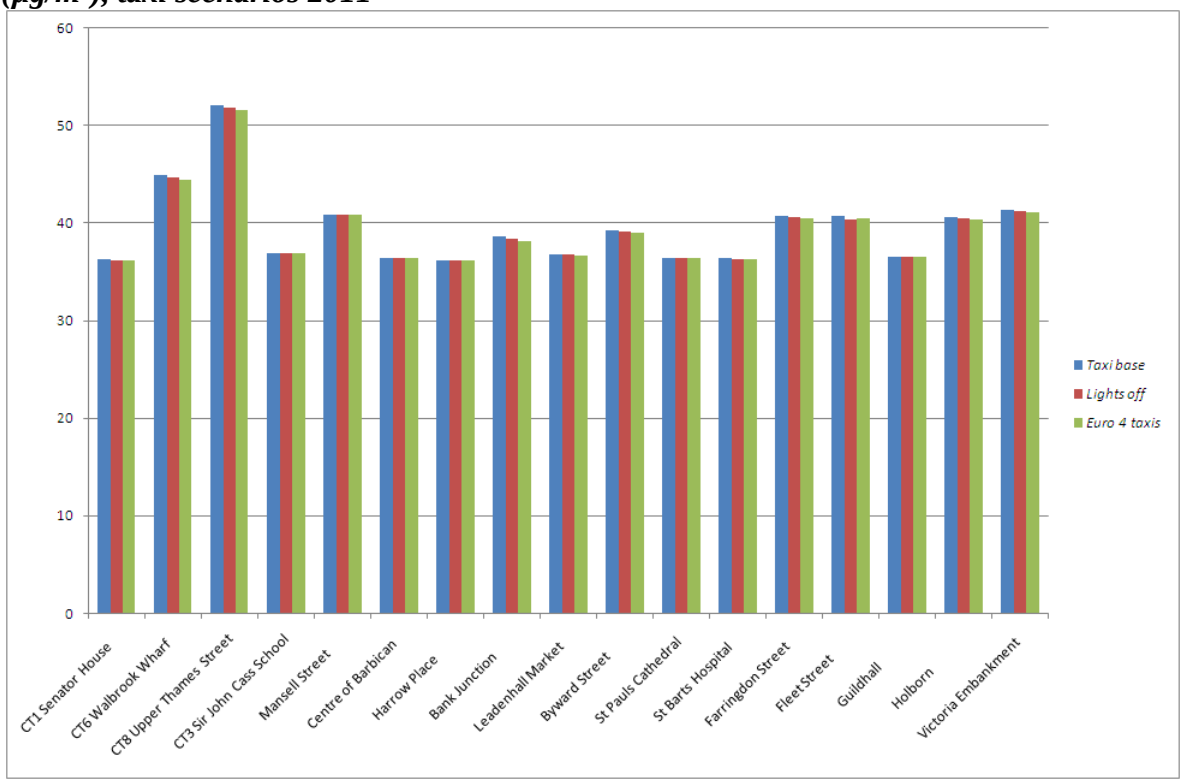


Figure 7.4: Air quality maps of annual average PM_{10} concentrations ($\mu g/m^3$), taxi scenarios 2011

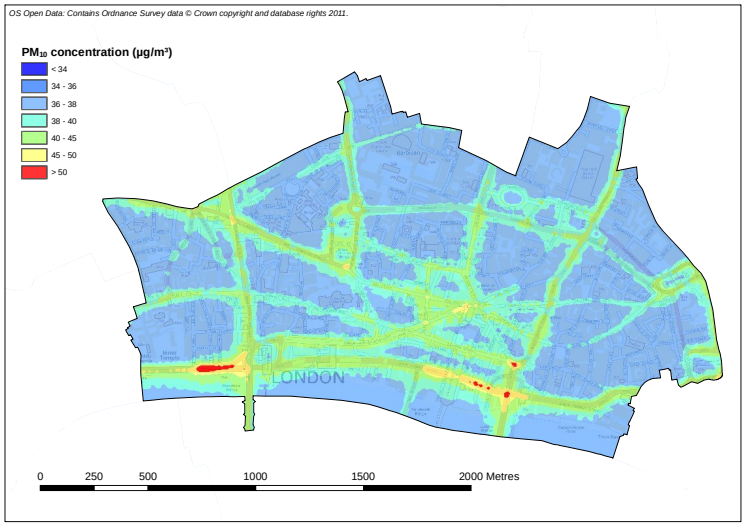
a) Taxi base

b) Lights off

c) Euro 4 taxis

Figure 7.5: Air quality maps of 90.41st percentile of 24-hour average PM_{10} concentrations ($\mu g/m^3$), taxi scenarios 2011

a) Taxi base



b) Lights off

c) Euro 4 taxis

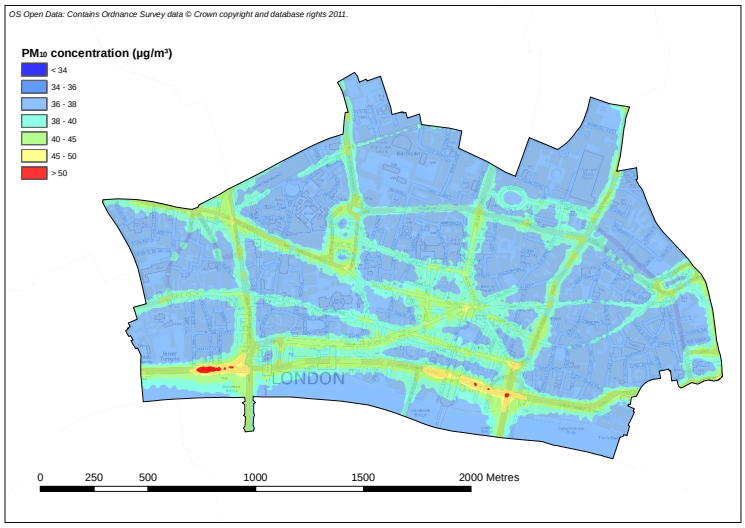


Table 7.3: Annual average $PM_{2.5}$ concentrations at receptor locations (µg/m^3), taxi scenarios 2011

Receptor name	*Taxi base*	*Lights off*	*Euro 4 taxis*
CT1 Senator House	10.4	10.4	10.4
CT6 Walbrook Wharf	14.6	14.4	14.2
CT8 Upper Thames Street	16.5	16.2	15.9
CT3 Sir John Cass School	10.9	10.8	10.8
Mansell Street	11.7	11.7	11.6
Centre of Barbican	10.8	10.8	10.8
Harrow Place	10.6	10.6	10.6
Bank Junction	12.3	12.1	12.0
Leadenhall Market	11.2	11.1	11.1
Byward Street	12.0	11.9	11.8
St Pauls Cathedral	11.0	11.0	11.0
St Barts Hospital	10.8	10.8	10.8
Farringdon Street	12.0	11.9	11.8
Fleet Street	12.7	12.3	12.3
Guildhall	10.9	10.8	10.8
Holborn	12.0	11.9	11.8
Victoria Embankment	12.5	12.4	12.3

Figure 7.6: Annual average $PM_{2.5}$ concentrations at receptor locations (µg/m^3), taxi scenarios 2011

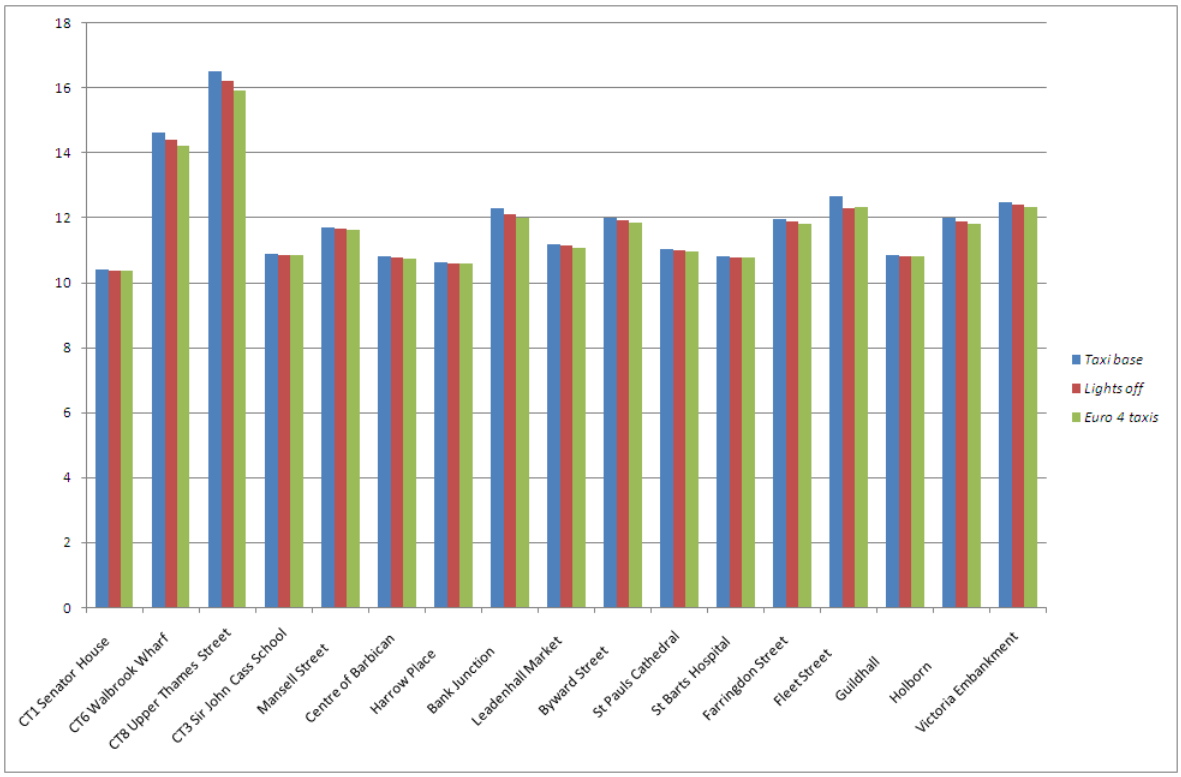
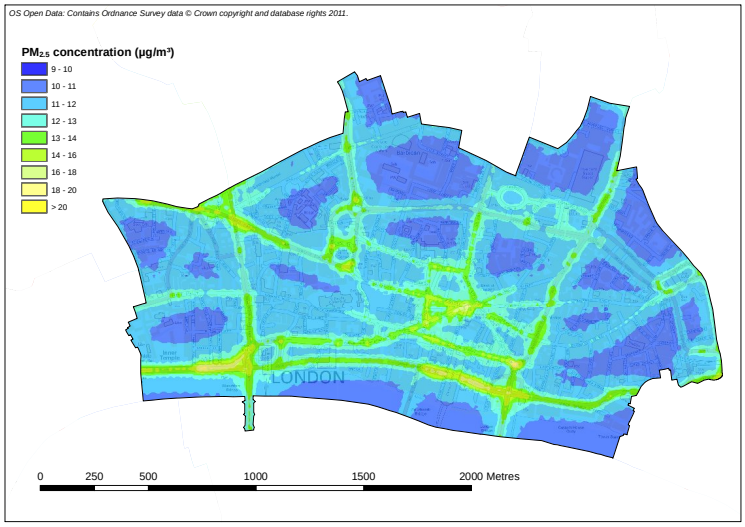
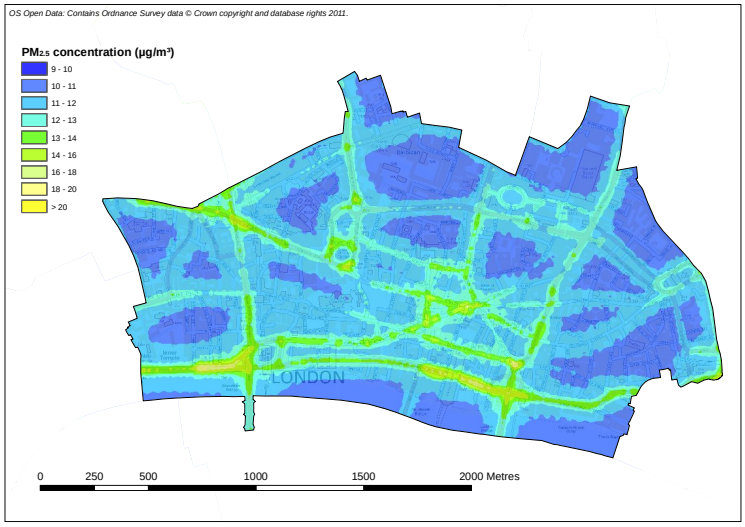


Figure 7.7: Air quality maps of annual average $PM_{2.5}$ concentrations ($\mu g/m^3$), taxi scenarios 2011

a) Taxi base



b) Lights off



c) Euro 4 taxis

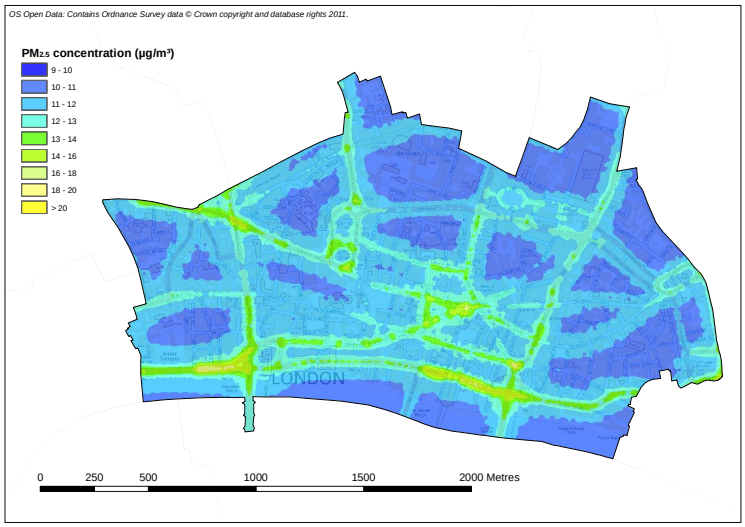


Table 7.4: Annual average and 99.79th percentile of hourly average NO_2 concentrations at receptor locations (µg/m^3), taxi scenarios 2011

Receptor name	Annual average			99.79th percentile		
	Taxi base	*Lights off*	*Euro 4 taxis*	*Taxi base*	*Lights off*	*Euro 4 taxis*
CT1 Senator House	42.6	42.3	42.7	162.8	162.2	163.5
CT6 Walbrook Wharf	98.6	95.6	101.4	322.7	314.7	340.0
CT8 Upper Thames Street	123.4	119.5	127.8	424.1	408.9	448.9
CT3 Sir John Cass School	49.8	48.9	50.2	176.0	174.4	176.8
Mansell Street	58.7	58.2	59.0	204.8	203.6	206.7
Centre of Barbican	46.8	46.4	47.0	163.2	162.5	163.7
Harrow Place	45.2	44.7	45.2	166.0	165.8	166.0
Bank Junction	73.8	71.6	75.7	265.6	256.6	278.1
Leadenhall Market	55.3	54.4	55.7	206.4	203.2	210.4
Byward Street	62.5	61.3	63.3	218.5	214.7	225.3
St Pauls Cathedral	53.9	53.3	54.1	184.0	183.0	184.8
St Barts Hospital	48.1	47.6	48.3	165.1	163.9	166.5
Farringdon Street	63.0	61.5	64.7	223.3	218.2	240.9
Fleet Street	86.0	81.3	93.8	267.9	254.9	303.0
Guildhall	49.5	48.8	49.9	168.1	165.3	170.8
Holborn	63.2	62.0	64.4	227.0	222.0	237.9
Victoria Embankment	67.1	65.9	68.3	262.5	257.0	273.5

Figure 7.8: Annual average NO_2 concentrations at receptor locations ($\mu g/m^3$), taxi scenarios 2011

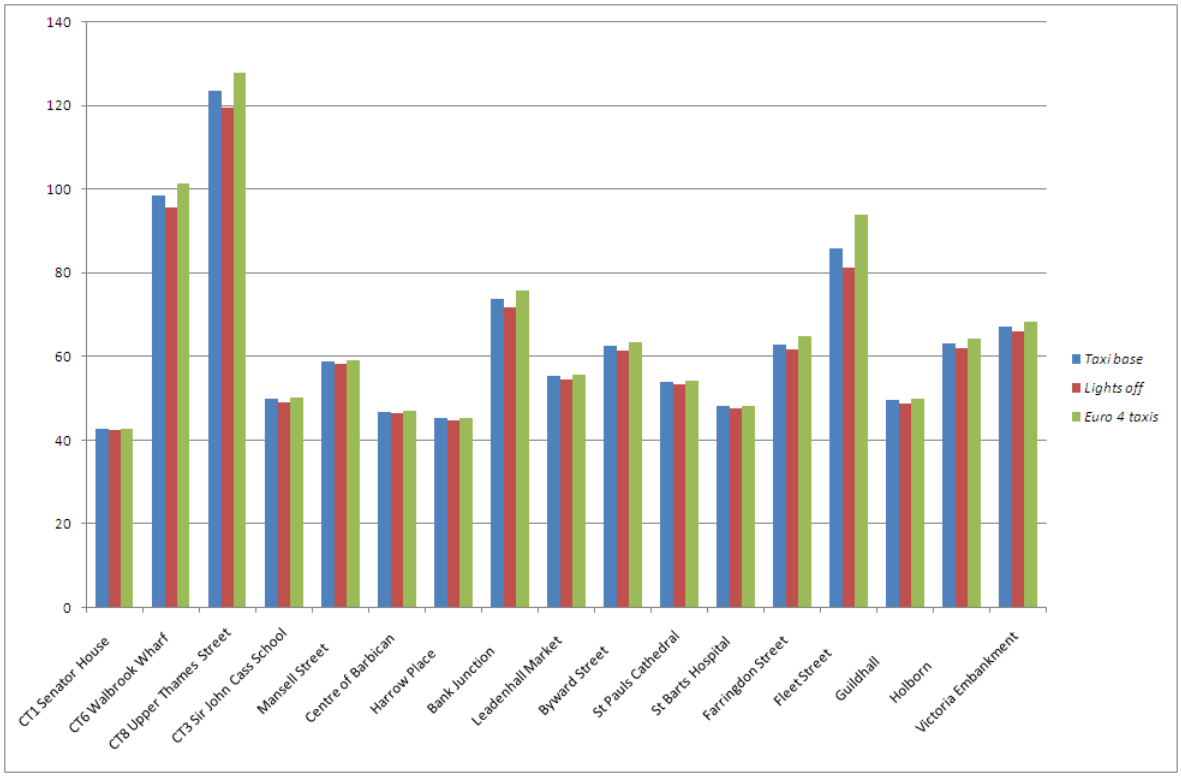


Figure 7.9: 99.79th percentile of hourly average NO_2 concentrations at receptor locations ($\mu g/m^3$), taxi scenarios 2011

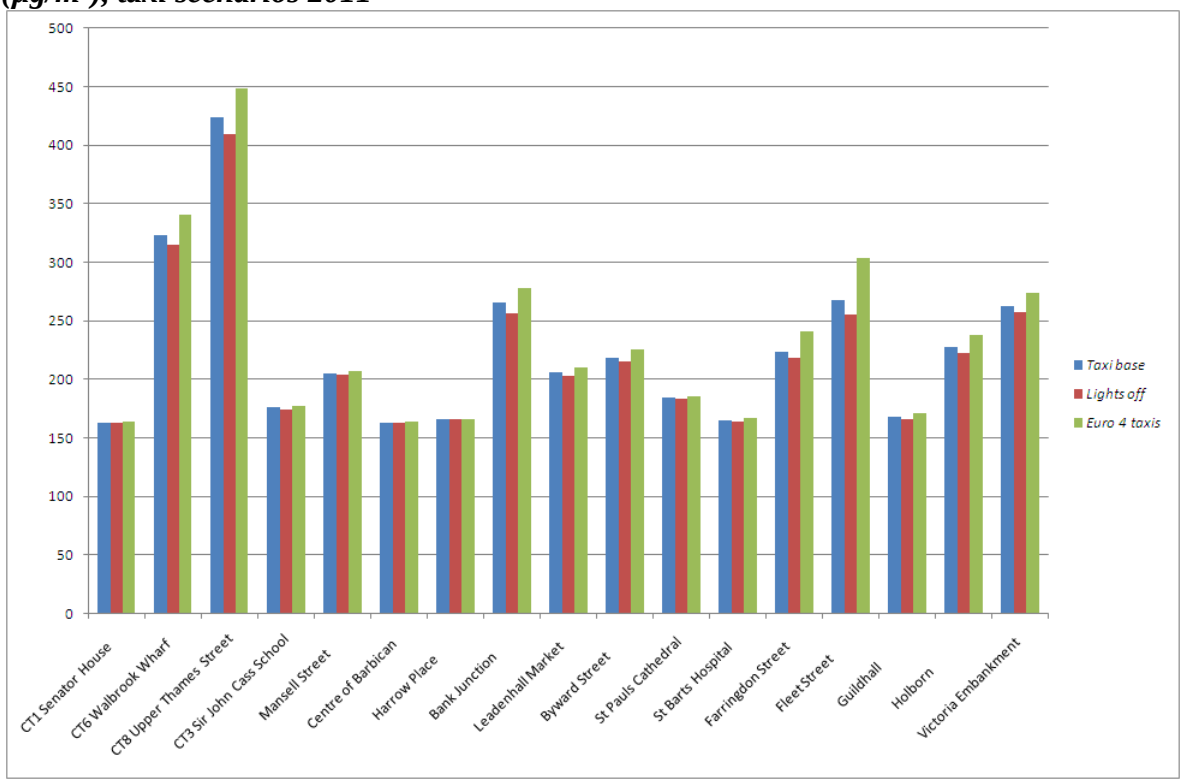
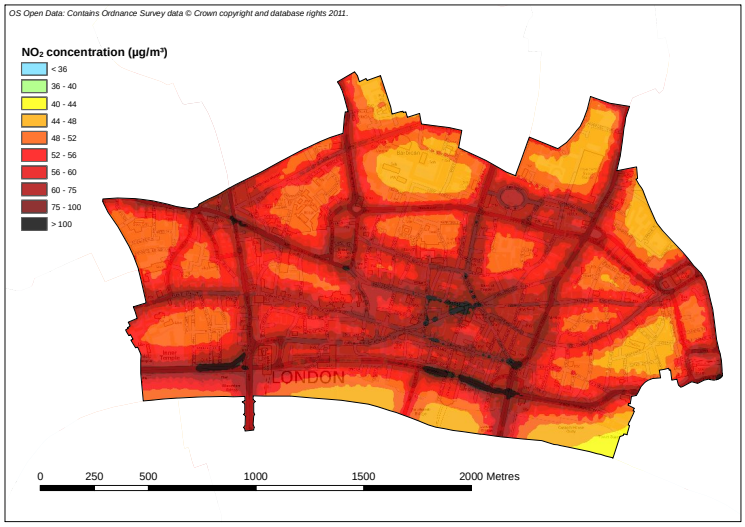
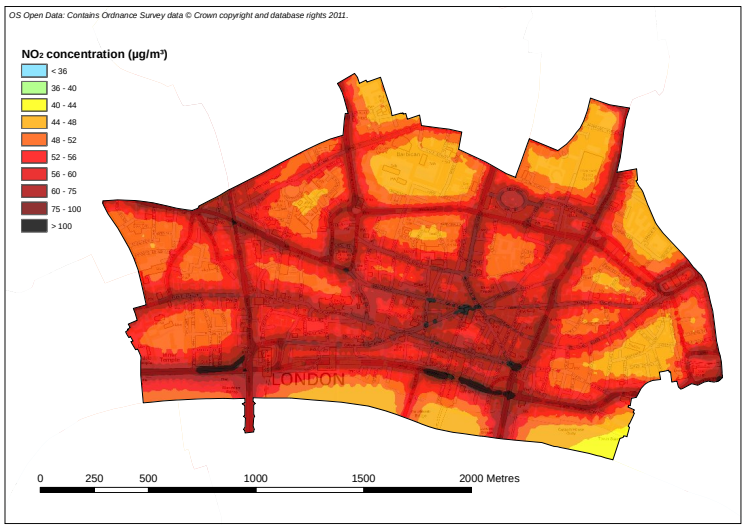


Figure 7.10: Air quality maps of annual average NO_2 concentrations ($\mu g/m^3$), taxi scenarios 2011

a) Taxi base



b) Lights off



c) Euro 4 taxis

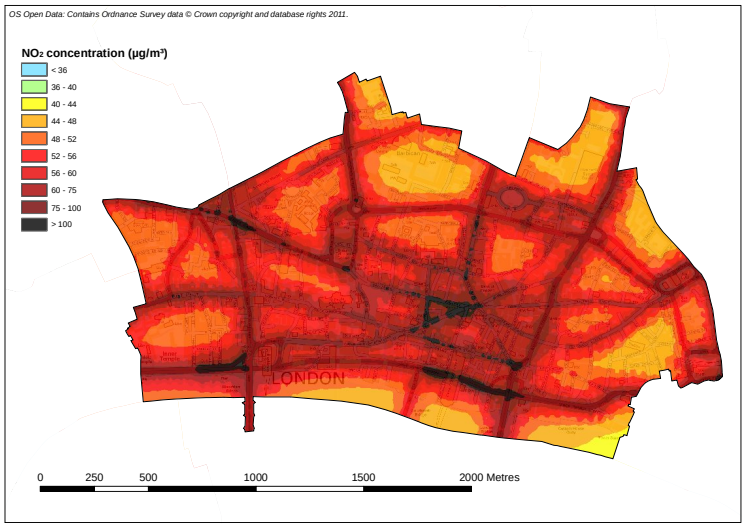
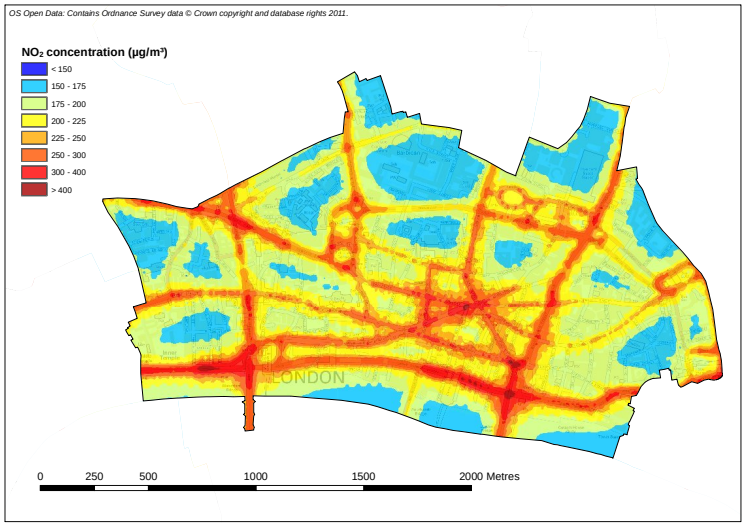
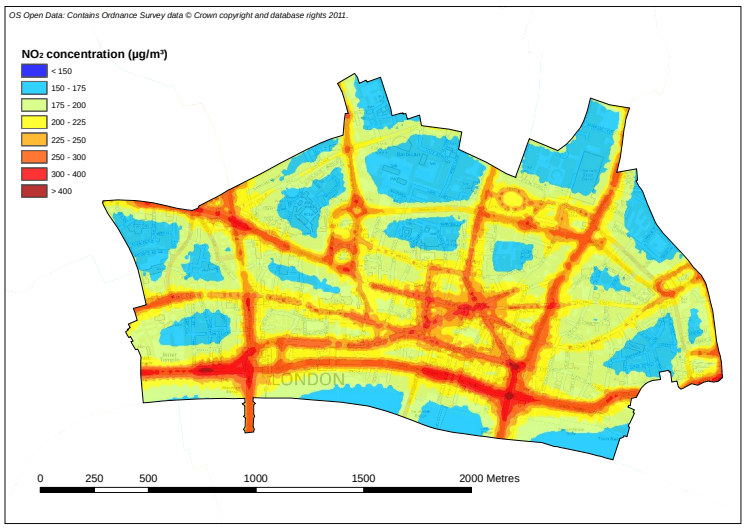


Figure 7.11: Air quality maps of 99.79th percentile of hourly average NO_2 concentrations ($\mu g/m^3$), taxi scenarios 2011

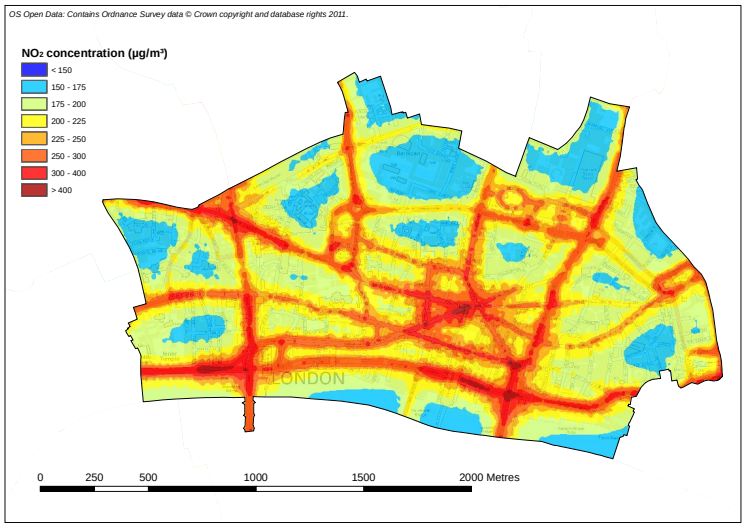
a) Taxi base



b) Lights off



c) Euro 4 taxis



8. Removal of Aldgate Gyratory System

Changes to the road layout are proposed for the gyratory system made up of Aldgate High Street, Houndsditch and St. Botolophs Street. Two layouts are proposed:

- Option 1 proposes the closure of St. Botolophs Street, between Houndsditch and Middlesex Street, to form a park; and
- Option 2 proposes the closure of Houndsditch, between Aldgate High Street and St. Botolophs Street to form a park.

Both options propose the removal of the gyratory system, therefore some one-way roads will become two-way roads.

Air quality modelling was carried out for a base case scenario, representing the existing layout, and the two proposed layouts, for the year 2011. Traffic data were provided by the City of London Corporation for roads around Aldgate Gyratory for each of these scenarios. The modelled traffic flows are summarised in Table 8.1. Emissions for the rest of London were taken from the LAEI.

Air quality maps for the area around the Aldgate Gyratory were produced by calculating concentrations on a grid of receptor points with a resolution of 20m. Extra receptor points were added close to the modelled roads, where concentration gradients are highest.

Predicted annual average and 90.41st percentile of 24-hour average PM_{10} concentrations are presented in Figures 8.1 and 8.2 respectively. Predicted annual average $PM_{2.5}$ concentrations are presented in Figure 8.3. Predicted annual average and 99.79th percentile of hourly average NO_2 concentrations are presented in Figures 8.4 and 8.5 respectively.

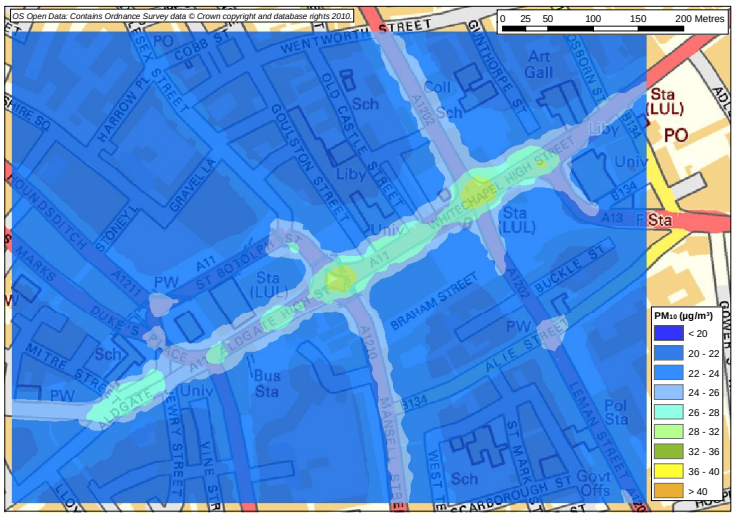
Difference plots for annual average NO_2 concentrations, showing the difference in concentrations between the proposed layout and the existing layout, are presented in Figure 8.6. For both Option 1 and Option 2, annual average NO_2 concentrations are predicted to decrease across most of the modelled area. For Option 1 there are predicted increases in concentrations along Aldgate High Street and Middlesex Street, due to the expected increase in traffic flows along these roads.

Table 8.1: Modelled roads

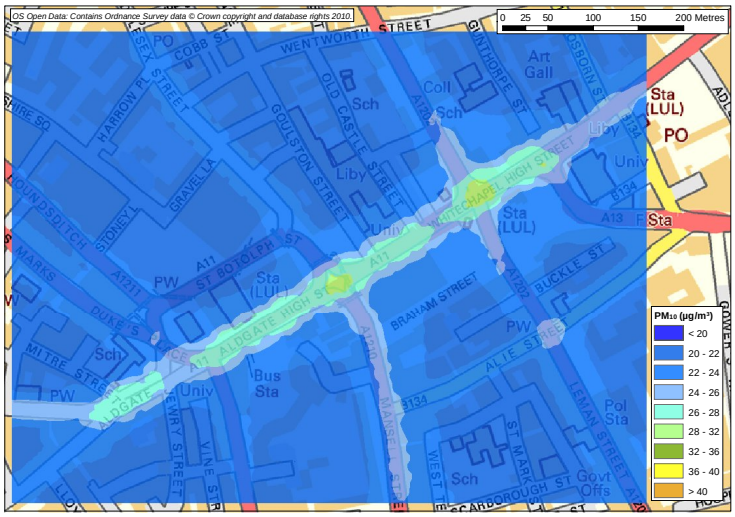
Modelled Road	Base		Option 1		Option 2	
	AADT	% Bus	AADT	% Bus	AADT	% Bus
Aldgate (1)	18,228	2.5	17,156	3.5	15,813	3.8
Aldgate (2)	19,522	2.3	18,268	3.3	16,551	3.7
Aldgate (3)	16,934	2.7	15,665	3.9	13,933	4.3
Aldgate High St (1)	16,934	2.7	24,786	6.6	13,933	4.3
Aldgate High St (2)	22,031	10.4	27,010	6.4	16,767	7.8
Aldgate High St (3)	21,529	8.3	27,286	7.4	16,998	9.0
Alie St (E)	3,877	0	3,513	0	3,513	0
Alie St (W)	1,619	0	1,633	0	1,633	0
Commercial Rd (E)	20,437	3.7	19,999	3.8	19,916	3.8
Commercial Rd (W)	16,182	4.7	13,663	5.5	14,804	5.2
Commercial St	21,879	0.8	17,958	1.0	20,063	0.9
Dukes Place (N)	8,384	6.2	8,457	6.2	6,430	8.1
Dukes Place (S)	8,384	6.2	8,457	6.2	-	-
Fenchurch St	9,736	3.3	9,609	3.3	8,890	3.6
Houndsditch (N)	5,820	8.9	4,571	11.3	5,707	9.1
Houndsditch (S)	8,762	11.6	4,571	11.3	-	-
Jewry Street	2,588	0	2,603	0	2,617	0
Leadenhall St	8,005	1.7	7,547	3.8	6,927	4.1
Lenman St (N)	11,257	0	11,301	0	10,996	0
Lenman St (S)	12,974	0	12,339	0	12,339	0
Mansell St (N)	17,200	3.4	16,659	2.7	16,674	2.7
Mansell St (S)	18,878	3.1	18,292	2.4	18,297	2.4
Middlesex St	4,266	0	5,082	0	3,045	0
Minories	3,473	26.9	3,070	30.4	3,070	30.4
Osbourn St	2,248	0	2,465	0	2,288	0
St Botolph St (W)	-	-	-	-	6,430	8.1
St Botolph St (E)	11,075	10.2	-	-	11,695	8.9
St Botolph St (S)	14,115	8.0	5,082	0	14,745	7.0
Whitechapel High St (1)	28,432	6.3	26,390	6.7	26,371	6.8
Whitechapel High St (2)	26,897	6.6	26,331	6.8	26,341	6.8
Whitechapel High St (3)	32,550	4.9	31,955	5.0	31,930	5.2
Whitechapel High St (4)	17,289	4.8	19,089	4.4	17,958	4.7
Whitechapel Rd	16,629	4.9	16,290	5.2	16,265	5.2
White Church Lane	1,373	0	3,798	0	2,578	0

Figure 8.1: Air quality maps of annual average PM_{10} concentrations ($\mu g/m^3$)

a) Base



b) Option 1



c) Option 2

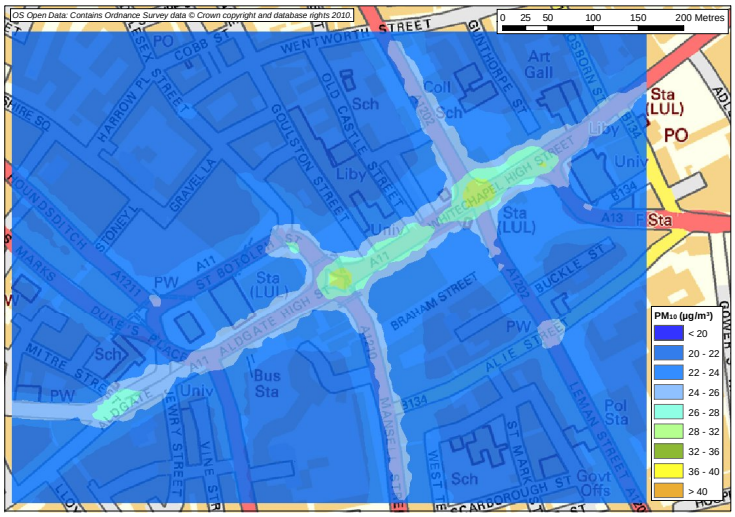


Figure 8.2: Air quality maps of 90.41st percentile of 24-hour average PM_{10} concentrations ($\mu g/m^3$)

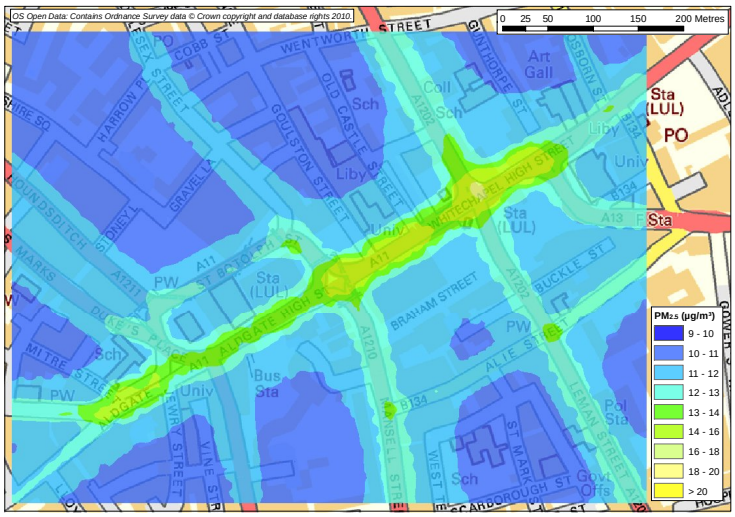
a) Base

b) Option 1

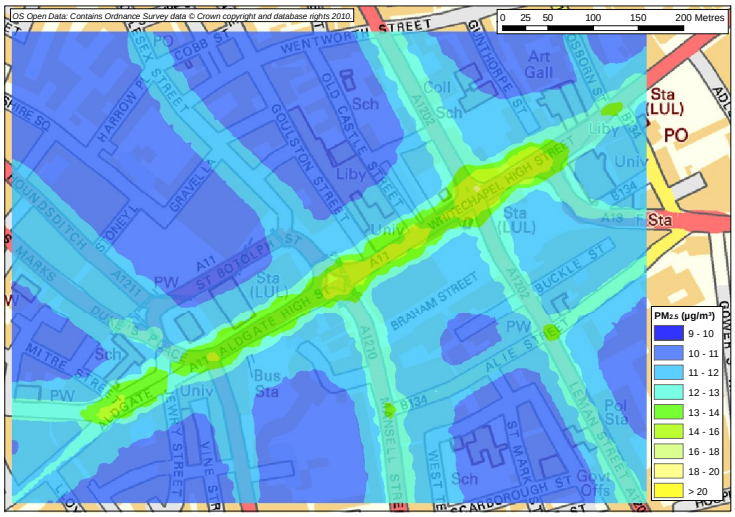
c) Option 2

Figure 8.3: Air quality maps of annual average $PM_{2.5}$ concentrations ($\mu g/m^3$)

a) Base



b) Option 1



c) Option 2

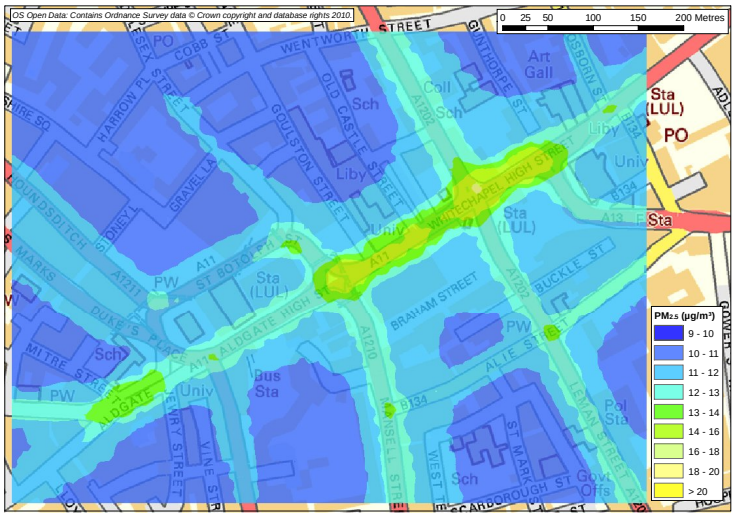
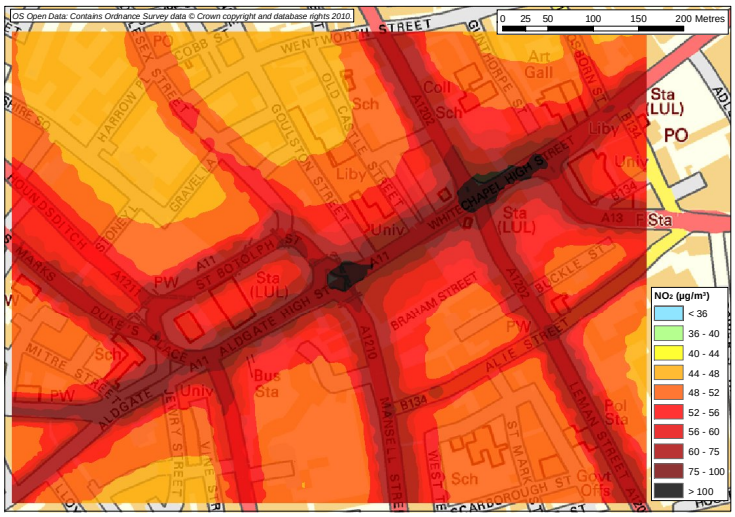
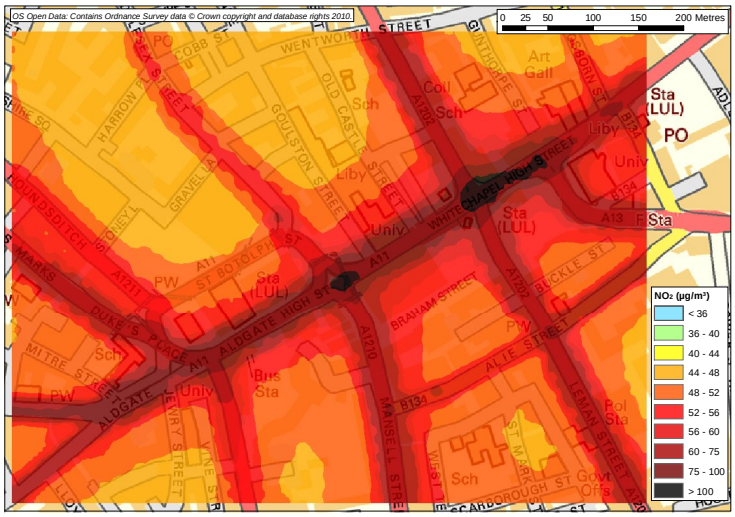


Figure 8.4: Air quality maps of annual average NO_2 concentrations ($\mu g/m^3$)

a) Base



b) Option 1



c) Option 2

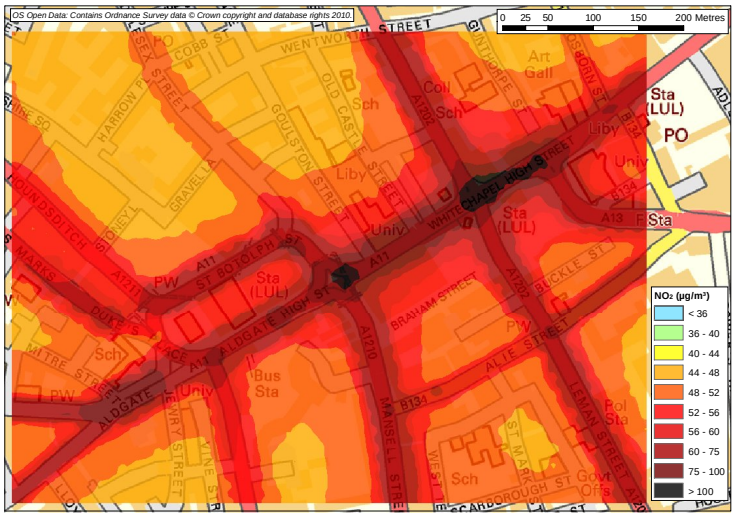
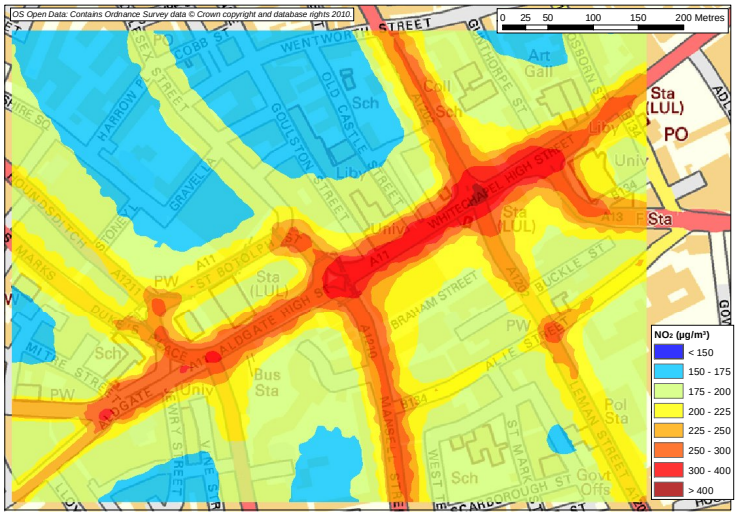
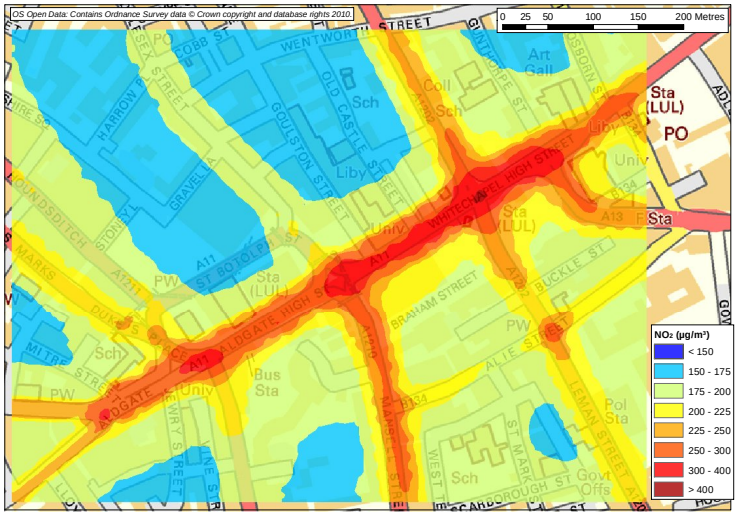


Figure 8.5: Air quality maps of 99.79th percentile of hourly average NO_2 concentrations ($\mu g/m^3$)

a) Base



b) Option 1



c) Option 2

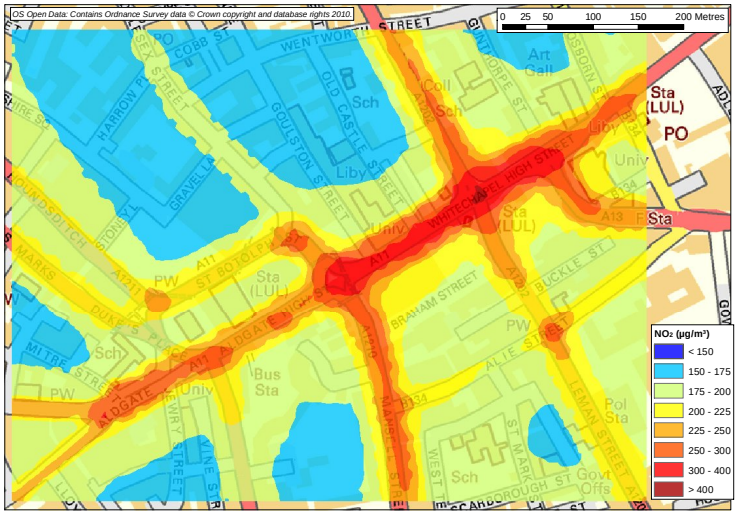
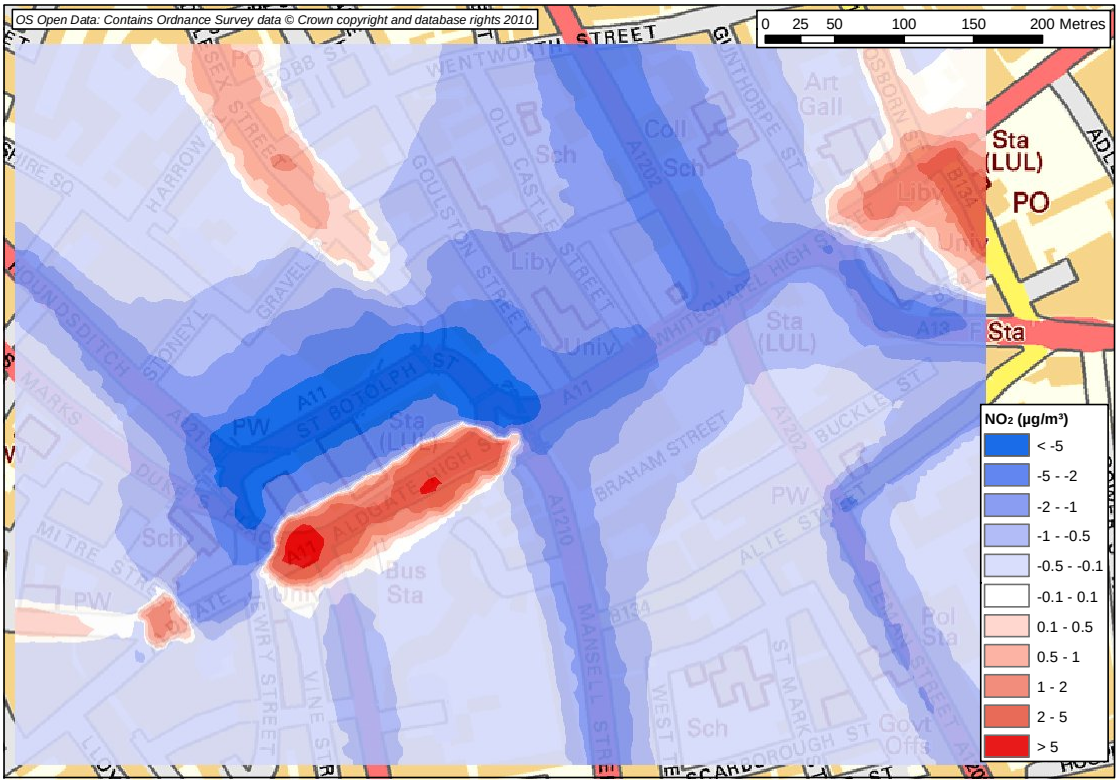


Figure 8.6: Difference plots for annual average NO_2 concentrations ($\mu g/m^3$)

a) Option 1 minus Base



b) Option 2 minus Base