Appendix 2 – Modelling Results

Contents

1 Introduction and summary of main results

This annex provides the evidence collected as the basis for developing the LES, in terms of assessing the impact of transport on local air quality (i.e. nitrogen dioxide- NO_2 and fine particulate – PM_{10} pollutants), noise and carbon dioxide emissions. The first step in this process was to develop three types of emission inventories, for a base year of 2013 and future base year of 2018 (producing six in total). The impacts of the LES could then be compared with the future baseline information.

The modelling has been used to estimate the impacts different levels of LES, terms LES 'light' and LES full options.

TABLE 1.1: SUMMARY OF EMISSION BENEFITS

Test	**Annual emissions (t/y) and change from 2018 baseline (%)**		
	NO_x	**PM_{10}**	**CO_2**
2013 Baseline	*409.2*	*27.8*	*155,751*
2018 Baseline	330.9	26.9	173,546
2018 LES Lite option	306.1 (-7%)	24.5 (-9%)	156,275 (-10%)
2018 LES Full option	200.5 (-39%)	15.45 (-45%)	127560 (-26%)

The LES lite option is estimated to deliver emission reductions in the range of 7 to 10% over the 2018 predicted baseline.

The LES full option is estimated to result in a much more significant change, with:

- A reduction in road traffic NOx emissions by 39% and PM10 emissions by 45%.

The significant reductions from the LES full option is estimated to produce:

- A reduction in annual mean NO2 concentrations at selected receptors along a corridor by an average of 24%;
- A reduction in the area of exceedence above the annual mean NO2 objective which results in improvements to public exposure. For example, concentrations between 40-50 µg/m3 in the baseline are likely to be reduced to levels below the objective of 40µg/m3;
- A reduction in road traffic related noise levels by up to 0.6dB on many roads;
- A reduction in road traffic CO2 emissions by 26%.

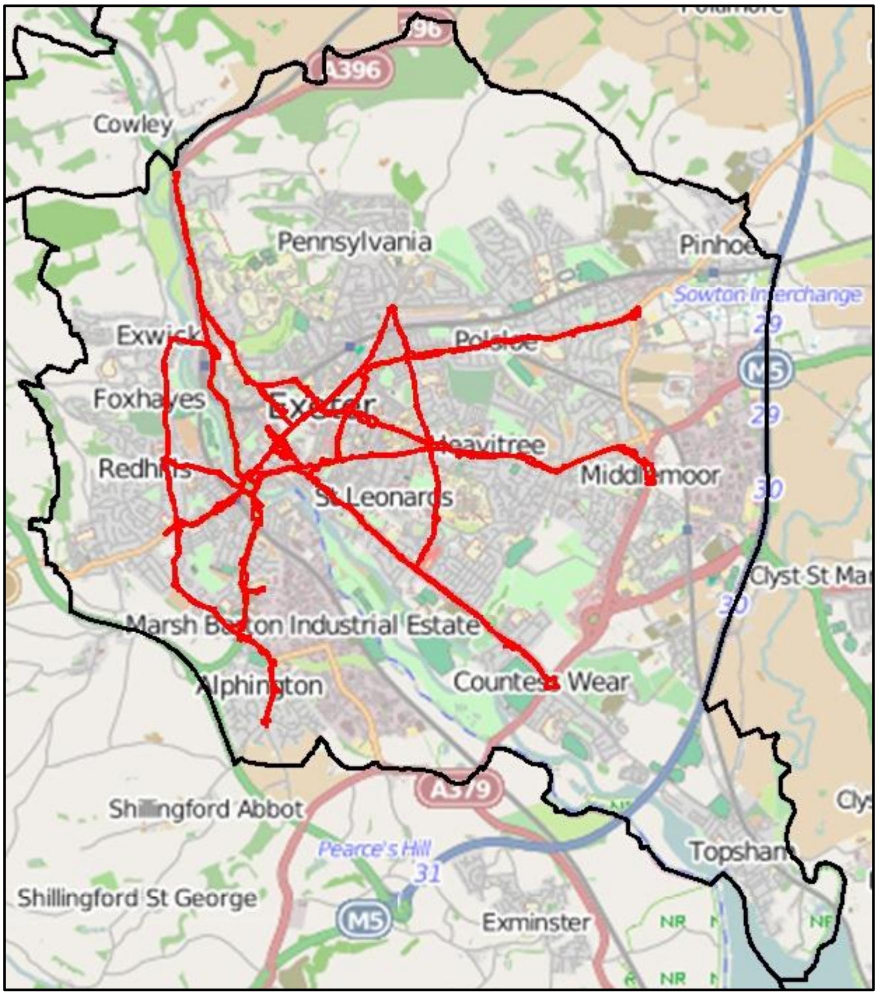
The actions that are contained in the LES lite and LES full option are described in later in the Appendix, under the section on Impact of the Low Emission Strategy.

2 Current Emission Inventories

2.1 Baseline Emissions Inventory A (Emissions from road network)

In 2007, Exeter City Council declared an Air Quality Management Area (AQMA) due to exceedences of the annual air quality strategy objective value of 40 µg/m^3 NO_2. This AQMA replaced the existing four AQMAs and included 11 new exceedence areas. The AQMA covers the main traffic routes into the city centre and was amended in 2011 to include the short-term (hourly) NO_2 objective.

FIGURE 2.1 EXTENT OF EXETER CITY COUNCIL'S SINGLE AQMA.



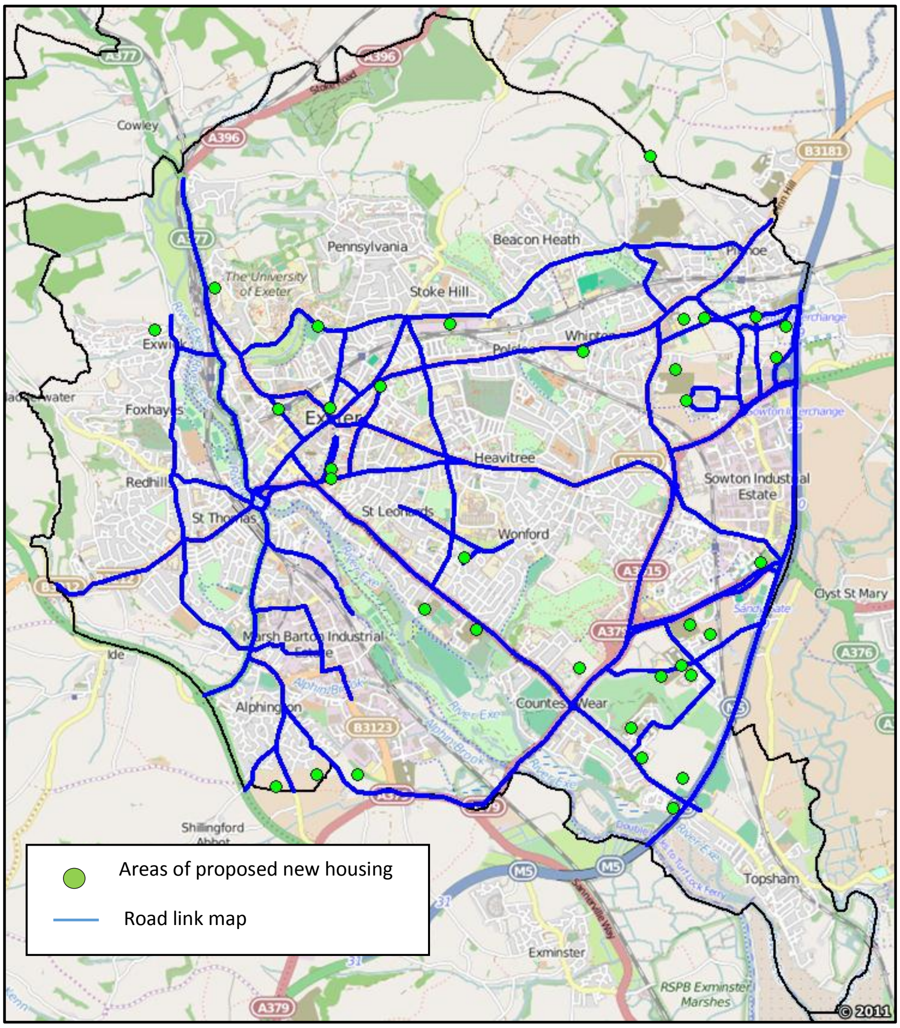
The first step in building the inventory was to determine the road network. To do this, the necessary Geographical Information System (GIS) data was acquired from ECC to set the boundary conditions and map the assessment area. The study team then worked with ECC and the County Council to obtain traffic data for the relevant roads in the assessment area. For the emissions modelling, traffic data were required in the format of daily (24 hourly) traffic flows, average speeds and vehicle composition.

Several sources of traffic data were analysed for this task including annual daily traffic (ADT), speed and composition data from the County's automatic traffic counts for the year 2013, modelled peak time traffic flows from the County, flow and speed data from earlier years from previous ECC air quality review and assessments and 2012 traffic flows and composition for trunk roads including the

M5 motorway from the Department for Transport (DfT). In addition, information was obtained from ECC on areas of new development such as industry and new housing proposed for the next five years.

These data were compiled to produce a road link map incorporating 146 separate road links including the key routes into the city and other roads of interest, such as those around the new proposed developments. The map below illustrates these roads as well as the location of housing developments over 25 dwellings in size.

FIGURE 2.2: ROAD LINK MAP FOR EXETER LES



A number of assumptions and estimates were made to produce the baseline traffic data and these are outlined in the table.

TABLE 2.1: ASSUMPTIONS AND ESTIMATES MADE TO PRODUCE THE BASELINE ROAD LINK MAP.

Issue	Requirement	Solution
Modelled data provided morning peak (AM), inter-peak (IP) and afternoon peak (PM) traffic flows	24 hourly traffic flows	Scaling factors were derived by comparing modelled flows with observed traffic flows on the same road during the same peak periods. The scaling factors were applied to each link to obtain a 12 hour flow (x2.9 for AM, x6 for IP

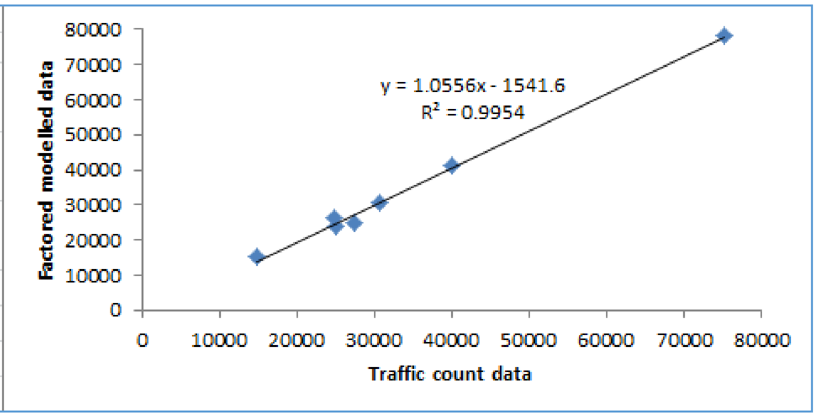
Issue	Requirement	Solution
		and x2.8 for PM). The 12 hour flows were converted to a 24 hour flow by a factor of 1.2 based on observed data and to an annual average daily total (AADT) by a factor of 0.9[1] One way traffic flows were multiplied by 2 to obtain two way traffic flows. The resulting correlation showed that this method was an acceptable one to apply to all road links. See **Error! Reference source not found.**.
2012 data for trunk roads (DfT)	2013 base year	Assumed that the DfT traffic counts for 2012 applied to 2013, i.e. that there were no changes in flow. There is evidence that traffic flows have declined in the last few years within Exeter[2]. The DfT traffic database shows that traffic flows in 2011 were slightly higher than in 2012 in Exeter.[3]
Data from previous years from Exeter's Further Assessment of Air Quality (ECC, 2006)	2013 base year	Data were factored to 2013 using the TEMPRO database using a local factor. For example for 2006 to 2013, this factor was 1.030.
Roads with no traffic flows or composition	2013 traffic flows and compositions for all road links	Professional judgement was used to make estimates based on several factors such as traffic flow/composition on similar types of roads (e.g. other B roads), flows on roads nearby and total flows based on the numbers of buses.
Roads with missing speed data	Average speeds for all road links	Professional judgement was used to make estimates based on the speed limit with reduced speeds closer to junctions.
Modelled speed data for AM, IP and PM periods	Average speeds required over 24 hours in km/h	Average speeds calculated by determining the average for one hour across 24 hours, based on 2 hours data in AM, 20 hours in IP and 2 hours in the PM period.
Road links with known queues	Representation of congestion traffic in the model	ECC provide information on a number of roads where there were known queues at peak times[4]. These were included as queue links within the map. For the dispersion model, they will be run with a flow of 5 km/hour and traffic flow of 30,000.
No data on the number of Hackney carriages on each road	AADT of taxis	It was assumed that approximately 1% of the AADT were taxis. This seemed reasonable as there are 65 vehicles in the fleet. On a road such as Alphington Road with an AADT of 30,000,

1 Source – Mouchel data
2 Personal communication, Stuart Jarvis (DCC)
3 http://www.dft.gov.uk/traffic-counts/area.php?region=South+West&la=Devon
4 Personal communication, Alex Bulleid (ECC)

ISSUE	REQUIREMENT	SOLUTION
		THIS EQUATES TO 4-5 TRIPS PER DAY.

TABLE 2.2: CORRELATION BETWEEN TRAFFIC COUNT DATA AND FACTORED MODEL DATA.

Site	Count site	Model site
Topsham Road	24974	23707
Honiton Road	24843	26245
Rydon Lane	30684	30565
Alphington Road	27372	24943
M5	75293	78197
Sidmouth Road	39996	41265
PInhoe Road	14782	15461



It was initially hoped that automatic number plate recognition (ANPR) cameras could be used to obtained information on the local fleet in Exeter. Unfortunately these data were not found to be available. Therefore, the fleet mix (i.e. Euro emission standard) for all vehicle types other than buses was assumed from the National Atmospheric Emissions Inventory (NAEI) for 2013. Information on the bus fleet by route was obtained from ECC for Stagecoach, First, Carmel, Dartline, Country Bus, Turners and Western Greyhound operators. These data were analysed to estimate the Euro emission standard based on the date of first registration.

This was combined with information on the numbers of buses per day to obtain a fleet weighted bus fleet. The table compares the Exeter bus fleet with that assumed in the NAEI for 2013. The two bus fleets are relatively similar, although there are fewer of the older buses (Euro I and II) operating in Exeter and are no Euro VI buses in the Exeter fleet.

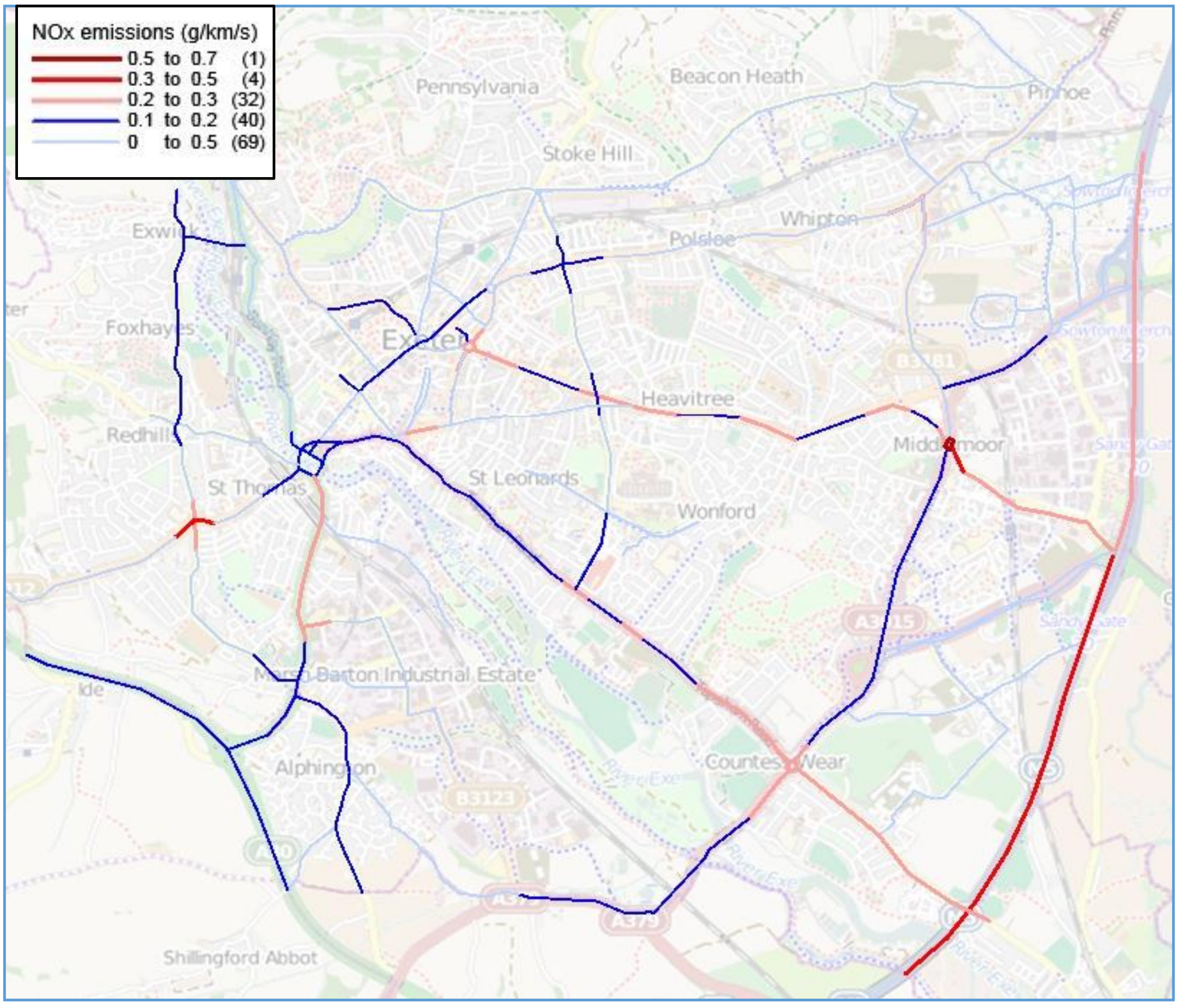
This weighted bus fleet was applied to all road links in the inventory. This seemed to be a reasonable approach rather than applying different bus fleets to different road links as it was not known if or how bus operators switched buses between routes. Also, the Emission Factor Toolkit (EFT) does not allow different fleets to be applied to different links, so it would be an onerous task to set up and run the tool separately for up to 146 road links.

TABLE 2.3: WEIGHTED BUS FLEET FOR EXETER COMPARED TO THE DEFAULT NAEI FLEET, 2013

EURO EMISSION STANDARD	PROPORTION OF BUSES IN EURO STANDARD	
	EXETER BUS FLEET	NAEI BUS FLEET
PRE-EURO I	0.0	0.0
EURO I	0.005	0.01
EURO II	0.03	0.08
EURO III	0.32	0.30
EURO IV	0.18	0.18
EURO V_EGR	0.12	0.10
EURO V_SCR	0.35	0.29
EURO VI	0.0	0.04

The EFT (version 6)[5] was therefore set up for 2013 with the traffic data to obtain emission rates of NO_x and PM_{10}. For carbon dioxide (CO_2), the previous version 5.2 was used because version 6 only calculates these emissions from tailpipe emissions of petrol and diesel vehicles only. The EFT was also run to determine the percentage contribution of each vehicle type on each road link. The thematic mapped emission rates are provided below for the three pollutants respectively.

FIGURE 2.3: NO_x EMISSION RATES (G/KM/S) BY ROAD LINK



[5] http://laqm.defra.gov.uk/review-and-assessment/tools/emissions.html#eft

FIGURE 2.4: PM_{10} EMISSION RATES (G/KM/S) BY ROAD LINK

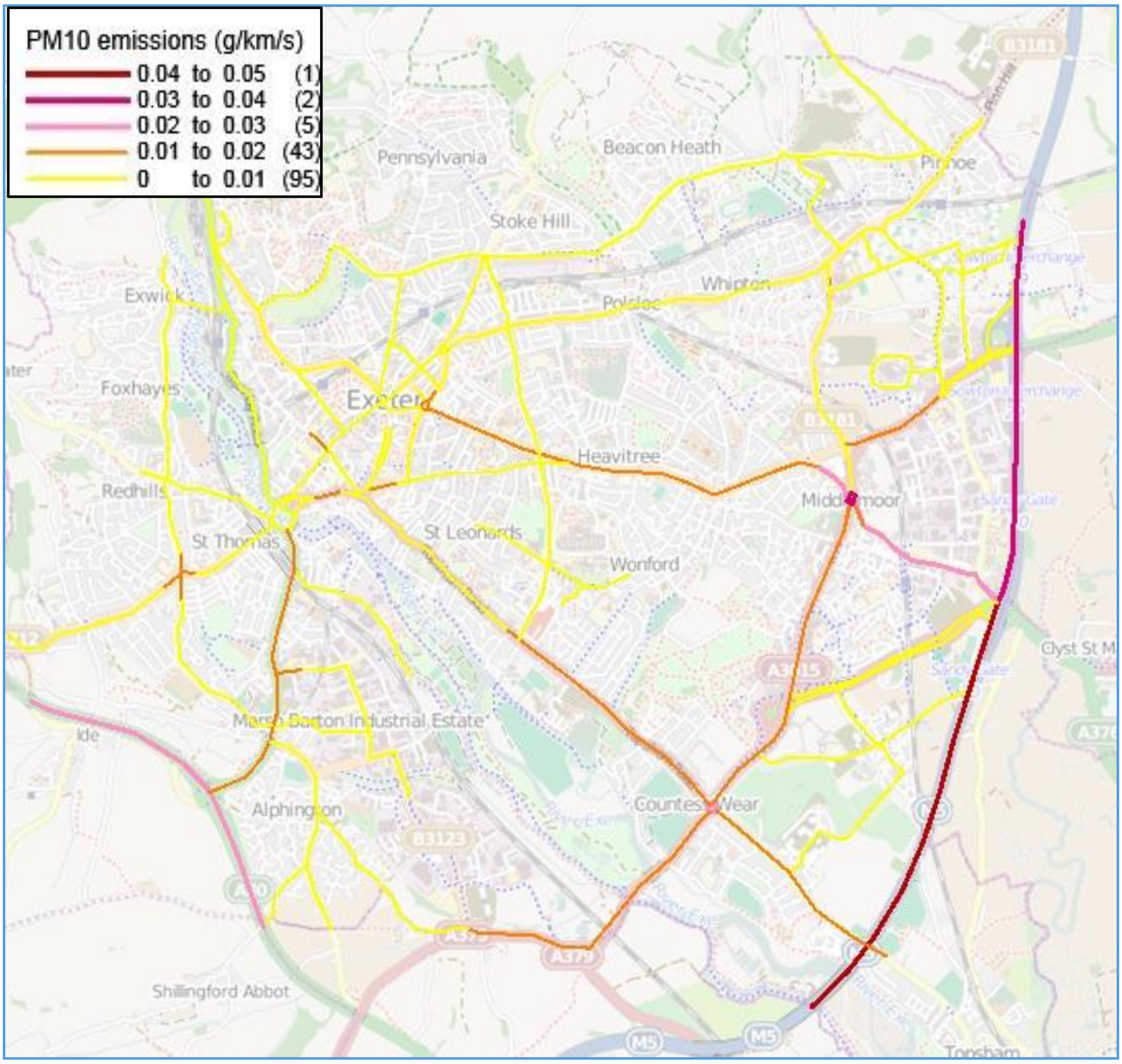
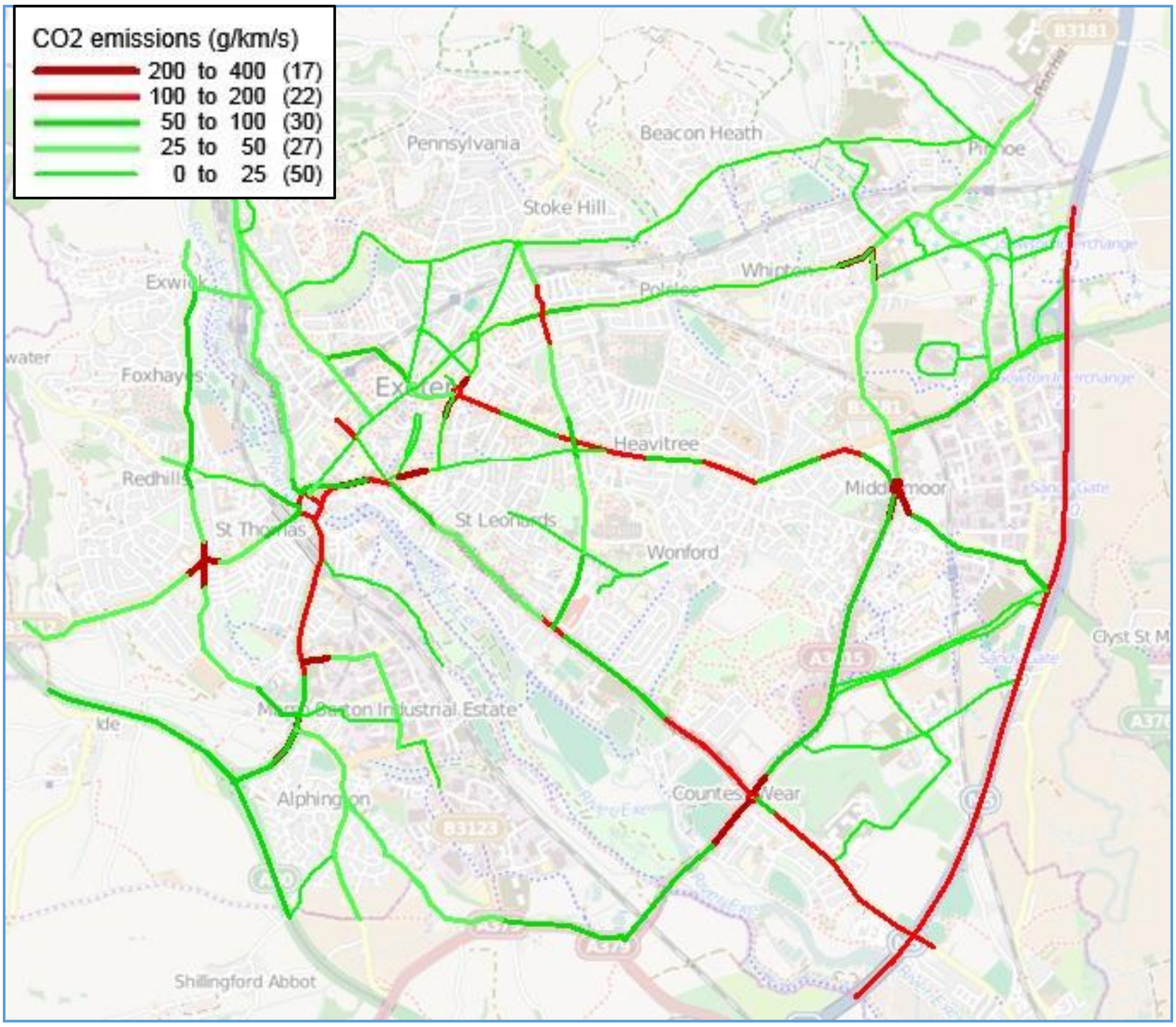


FIGURE 2.5: CO_2 EMISSION RATES (G/KM/S) BY ROAD LINK.



These three maps show that emissions of all three pollutants follow the same pattern with the greatest emissions found on those roads with the highest traffic flow or those with the lowest speeds, such as at junctions. These roads include the M5 motorway, Topsham Road, parts of Alphington Road and Heavitree Road towards the city centre and junctions or roundabouts such as Middlemoor, Cowick Street and Western Way,

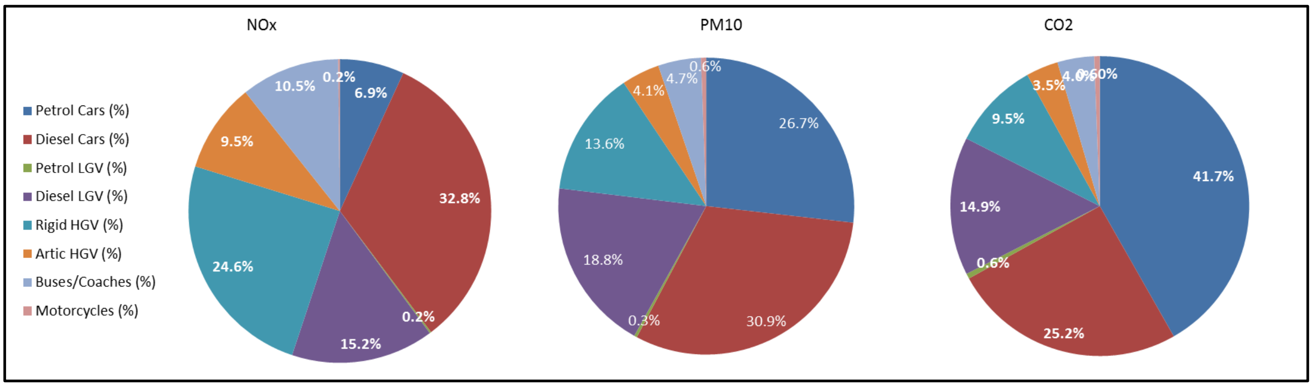
In terms of the contribution from different vehicle type, the data showed that the greatest contribution to NO_x emissions was generally found to be from cars as the vehicle kilometres (vkm) travelled was far greater than from other vehicles. However on certain roads, buses were a key source of emissions, such as Cowick Street and on other roads such as Cowley Bridge and Alphington Road, there is a large contribution towards emissions from heavy goods vehicles (HGVs). Light goods vehicles (LGVs) also make a noticeable contribution on some of the roads, such as Cowick Lane and Alphington Street. The contribution to emissions from motorbikes is considered to be negligible across the road network.

TABLE 2.4: NO_x EMISSIONS ATTRIBUTABLE TO DIFFERENT CATEGORIES OF VEHICLES (TO THE NEAREST PERCENT).

Road Segment	NO_x Emission (g/km/s)	Percentage contribution to emissions by vehicle type					
		Car	LGV	Rigid HGV	Artic HGV	Bus	Motor bike
Cowick Street	0.105	38	13	7	2	41	0
Alphington Road	0.351	40	16	25	9	11	0
Topsham Road	0.337	40	9	16	6	29	0
Pinhoe Road	0.074	53	15	9	3	19	0
Heavitree Road /Honiton Road	0.232	47	15	14	5	20	0
Cowick Lane/Church Rd	0.109	44	25	17	6	7	0
Cowley Bridge	0.099	41	14	21	6	18	0

The difference between the contributions of vehicle types to emissions of all three pollutants is illustrated for Alphington Street below. The pie charts show that the contribution of petrol cars is highest for CO_2 and lowest for NO_x. The contribution of heavy duty vehicles (lorries and buses) to NO_x emissions is also found to be the highest.

FIGURE 2.6: EXAMPLE OF SOURCE CONTRIBUTION OF NO_x, PM_{10} AND CO_2 EMISSIONS AT ALPHINGTON STREET, 2013



2.2 Baseline Emissions Inventory B (Emissions from council vehicles)

The second inventory that was developed considers emissions associated with Council based vehicle activity. Unlike Emissions Inventory A, this inventory determines total annual emissions from these vehicles according to vkm driven rather than being spatially resolved to a road network. This is because spatial differentiation of impacts from a vehicle group of this size is likely to be negligible.

This inventory includes details of the following fleets:

- **Council owned vehicles**. ECC's Cleansing and Fleet Manager provided the study team with a comprehensive list of all Council vehicles (road and non-road). Information on vehicle type, fuel, date of first registration, assumed Euro emission standard and annual mileage were provided. Details of 93 road vehicles, the majority of which are diesel vans or lorries were entered into the inventory database according to Council department including Parks, Refuse and Car Parking.

- **Grey fleet (Employee owned vehicles used for work purposes).** Employees fill out mileage travelled each month via their expense payment system. Details of the mileage, vehicle make and model were available for 950 vehicles and these were included in the inventory database according to the Department (Section). In the absence of information on their fuel, these vehicles were assumed to be petrol fuelled.

- **Taxi fleet.** The Council licences 65 diesel Hackney Carriages and 280 private hire taxi cars. A list of vehicles was provided from the Council and an estimate of annual mileage for both types of vehicles was given. For the Hackney Carriages, details of the vehicle type, engine size and fuel were obtained in order to include in the tool and generate emissions. For private hire cars, the team assumed that they are all diesel vehicles with an engine size between 1.4-2l except for a few cars where specific data were available on the vehicle. The assumed Euro standard is based on the date of first registration (from the registration number). The Council has estimated that the mileage for Hackney Carriages is between 70-80,000 miles per year and 30,000 miles per year for private hire cars.

TABLE 2.5: ANNUAL EMISSIONS FROM COUNCIL BASED FLEET, 2013.

FLEET TYPE	ANNUAL EMISSIONS (KG)			ANNUAL MILEAGE (KM)	NUMBER VEHICLES
	NO_x	PM_{10}	CO_2		
COUNCIL OWNED VEHICLES	1.44	0.023	325.95	1,010,245	93
GREY FLEET	0.02	0.0003	32.14	203,669	228
HACKNEY CARRIAGES	4.44	0.119	993.20	7,843,875	65
PRIVATE HIRE TAXIS	7.31	0.179	1,610.25	13,515,600	280

2.3 Baseline Emissions Inventory C (Noise)

This road link database provided by Baseline Emissions Inventory A was used as the basis to produce a semi-quantitative inventory to look at noise impacts.

For each road link, a Basic Noise Level (BNL), which is a noise level 10 metres from the road edge, was calculated using the Calculation of Road Traffic Noise (CRTN), (DfT, 1988). The noise levels obtained from this process are expressed in terms of LA10 which is the A-weighted (i.e. adjusted for the response of the human ear) level that is exceeded 10% of the time. In addition these levels were adjusted (Abbott and Nelson, 2002), to give an approximate value for Lden (averaged over noise limit unit for day-evening and night), the weighted average noise level for the day as defined by the European Noise Directive (EC, 2002).

In performing these calculations the following assumptions and modelling parameters were used:

- The LA10 noise levels best represent traffic noise and can be defined over either an 18 hour (06:00 to 00:00) or 1 hour period. Where the traffic flow represents a 24 hour period these figures were used, meaning that these levels are an over-estimate. However the noise levels are not particularly sensitive to a few extra vehicles in the 00:00 to 06:00 period; for example a decrease in traffic volume of 20% is required for the noise levels to drop by 1 dB(A) and an audible change in noise level is broadly considered to be around 3 dB(A). Where the traffic flow represents a 1 hour period the noise levels reflect this hour of the day.

- The noise calculation requires the fleet to be split into light and heavy vehicles. Buses, coaches and HGVs were classified as heavy goods vehicles and all other vehicles types as light vehicles.
- The noise calculation methodology is only valid down to 20 km/h. Where the average speed for the link is below this level a speed of 20 km/h was used in the modelling.
- All roads were assumed to be flat
- Noise levels were calculated at a height of 1.2m which is standard for many roadside noise measurements.
- An unobstructed view of the road and hard ground was assumed.
- No surface correction was applied, meaning that the level of tyre/road noise is assumed to be broadly equivalent to that from a newly laid Hot Rolled Asphalt (HRA) surface. If the actual road has an aged HRA the noise levels will likely be a bit higher and if the road has a thin surface the noise levels will likely be lower.

Apart from some high levels next to the M5 motorway (above 80 dB(A), the calculated results show levels between around 60 and 70 dB(A) which are fairly typical for moderately busy roads in the UK, as shown for some example roads in the table. The Noise Insulation Regulations consider entitlement to grants when the noise is increased by over 1 dB(A) at properties where the existing noise is already at least 68 dB(A). World Health Organisation guidelines for community noise (WHO, 1999) suggest potential annoyance above 55 dB(A) but this is rarely achieved in urban areas. It is important also to note that these levels are representative of areas 10 metres from the roadside. Housing receptors located further away from the road will obviously experience less noise from the road. It is estimated that there is approximately 3 dB(A) less for a doubling of the distance from the road.

TABLE 2.6: CALCULATED NOISE LEVELS AT SELECTED ROADS, 2013.

ROAD SEGMENT	**LA(10) 18 HOUR, DB**	**LDEN, DB**
COWICK STREET	69.7	68.5
ALPHINGTON ROAD	71.6	70.2
TOPSHAM ROAD	70.9	69.6
PINHOE ROAD	68.2	67.1
HEAVITREE ROAD /HONITON ROAD	70.8	69.6
COWICK LANE/CHURCH RD	68.3	67.2
COWLEY BRIDGE	69.6	68.5
M5 SOUTH BOUND	81.4	79.5

3 Future baseline emissions inventories

The 2013 baseline inventories were updated to represent the situation in in the future year of 2018. This year represents the medium term situation with regards to proposed developments and allows for a number of potential measures in the LES to be progressed.

3.1 Baseline inventory A (Emissions from road network 2018)

As the starting point to scale the baseline data from 2013 to 2018, the County provided an updated traffic model for the year 2017 which took into account predicted changes to traffic flow and speeds based on potential growth in the city. The data were manipulated in the same way as for 2013 to obtain 24 hourly annual daily flows and average speeds and these were compared to the 2013 data to obtaining scaling factors to apply to obtain 2017 data. The change in traffic growth across the modelled network was found to exhibit a normal distribution and the average scaling factor for traffic growth across all roads was +14%. As advised by the County, a national figure of 1.7% from the TEMPRO Version 6 database was then applied to the predicted 2017 data to get to the future baseline year of 2018. Application of these combined factors assumed a greater traffic growth than would have been assumed if a factor from TEMPRO had been used for Exeter City. From 2012 to 2017 this TEMPRO factor (adjusted to represent local growth) was 5%.

The final figures that were used to scale the data depending on the location of the roads within Exeter, with areas in the Central and Western region predicted to experience less traffic growth than the East of Exeter. The traffic growth on trunk roads is predicted to be less than in the East of the city.

TABLE 3.1: TRAFFIC SCALING FACTORS FROM 2013 TO 2018

ZONE	CHANGE IN TRAFFIC (%)	CHANGE IN AVERAGE SPEED (%)
CENTRAL	+12%	-1%
EASTERN	+19%	-6%
WESTERN	+13%	-2%
TRUNK ROADS	+15%	-2%

Data from Stagecoach, the main bus operator in Exeter were obtained on the likely bus fleet by 2018. This fleet is compared to the predicted national fleet given in the EFT. The comparison shows that the Exeter bus fleet is relatively similar to the national predictions, but has a higher proportion of Euro V buses, and a lower number of Euro VI buses.

TABLE 3.2: PREDICTED BUS FLEET, 2018 COMPARED TO THE NAEI.

EURO EMISSION STANDARD	PROPORTION OF BUSES IN EURO STANDARD	
	EXETER BUS FLEET	NAEI BUS FLEET
PRE-EURO I	0.00	0.00
EURO I	0.00	0.00
EURO II	0.00	0.02
EURO III	0.00	0.10
EURO IV	0.06	0.09
EURO V_EGR	0.13	0.07
EURO V_SCR	0.42	0.22
EURO VI	0.39	0.49

Using traffic flows and information the length of each road, an estimate of the total distance travelled by vehicle type along the modelled road network each year was made. The total distance travelled by all vehicles in 2018 is predicted to be 720 Million vehicle kilometres. The data obtained shows that the distance travelled by cars was far greater than all other vehicles. The annual vehicle kilometres estimated by Hackney Carriages in this manner was similar to the results from Inventory B.

TABLE 3.3: DISTANCE TRAVELLED BY VEHICLE TYPE, BY YEAR (2018).

ANNUAL VEHICLE KM TRAVELLED BY VEHICLE TYPE					
CAR	TAXI (HACKNEY CABS)	LGV	HGV	BUS/COACH	MOTORBIKE
586 MILLION	7.2 MILLION	86 MILLION	25MILLION	8.7 MILLION	7.3 MILLION

The revised traffic and bus fleet data were input into the EFT v6 for 2018 and this was run to calculate emissions of NOx and PM_{10} (CO_2 was run in v5.2 as before), broken down by vehicle type. In terms of the differences between overall emissions between the two years, the results showed that CO_2 emissions from the road increased for 2013 to 2018 by an average of 9-10% across the network, with the largest increases seen on the M5 motorway and main routes to the east of the centre – these increases were due to the increase in traffic flow and therefore fuel consumption (traffic flow increased by an average of 16% across the network). Emissions of local air quality pollutants were reduced by approximately 10% across the network.

FIGURE 3.1: REDUCTION IN ROAD NO_X EMISSIONS ON INDIVIDUAL ROAD LINKS FROM 2013 TO 2018.

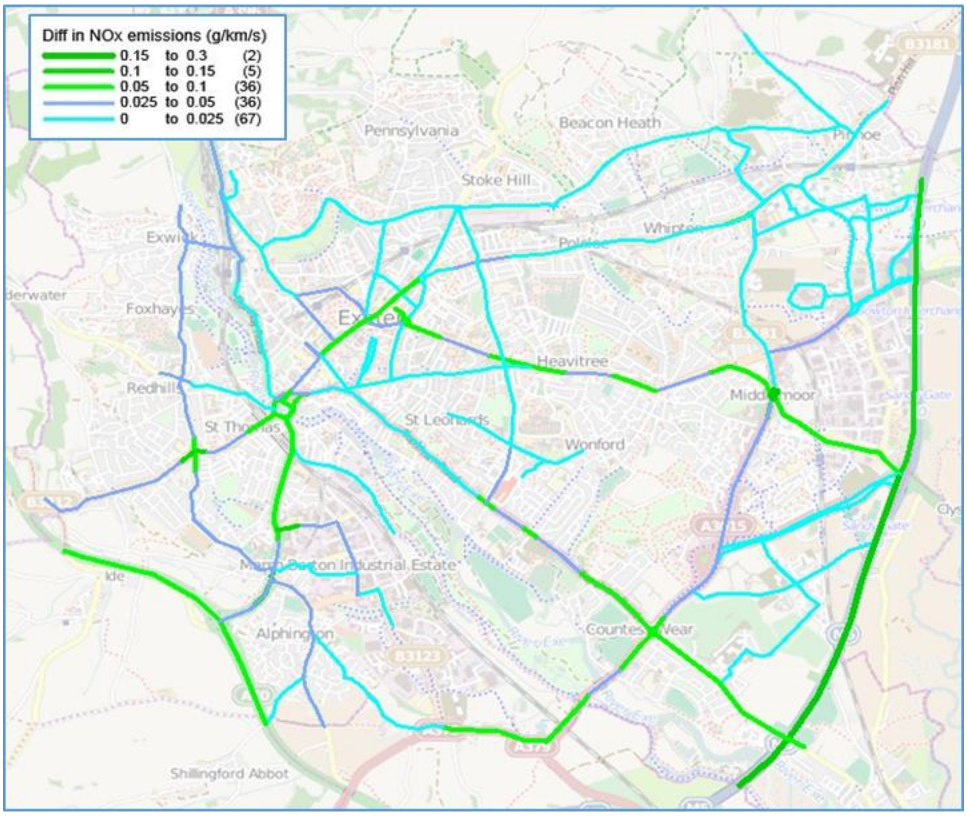


FIGURE 3.2: REDUCTION IN ROAD PM10 EMISSIONS ON INDIVIDUAL ROAD LINKS FROM 2013 TO 2018.

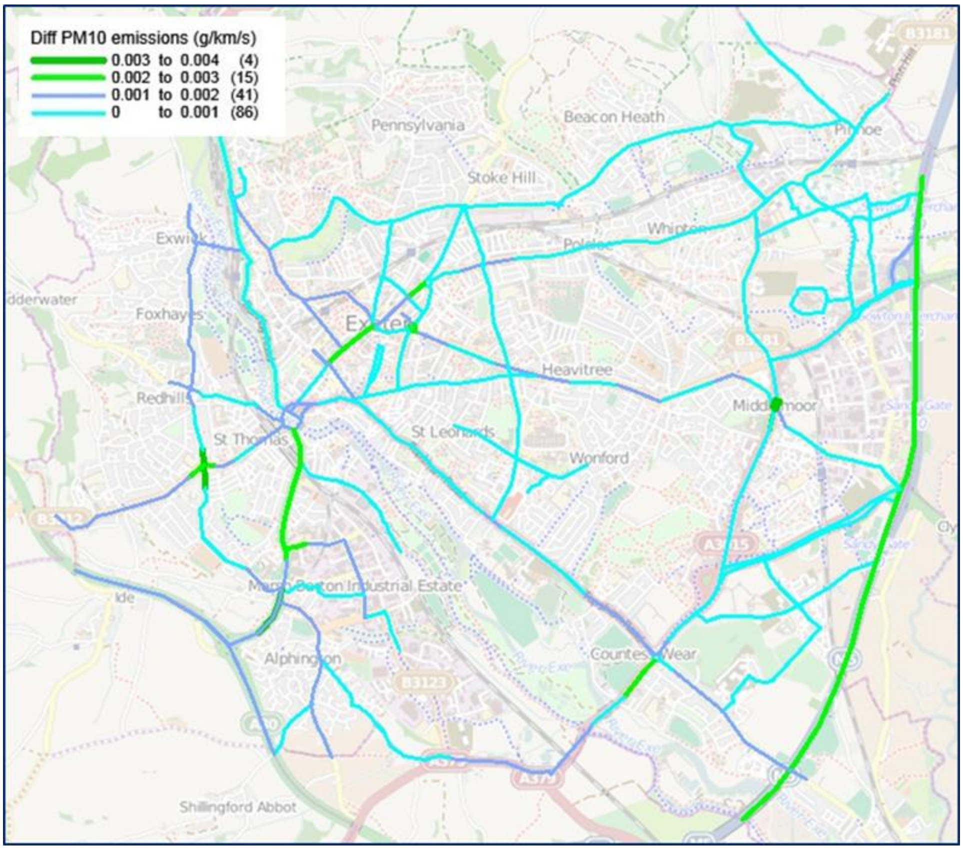
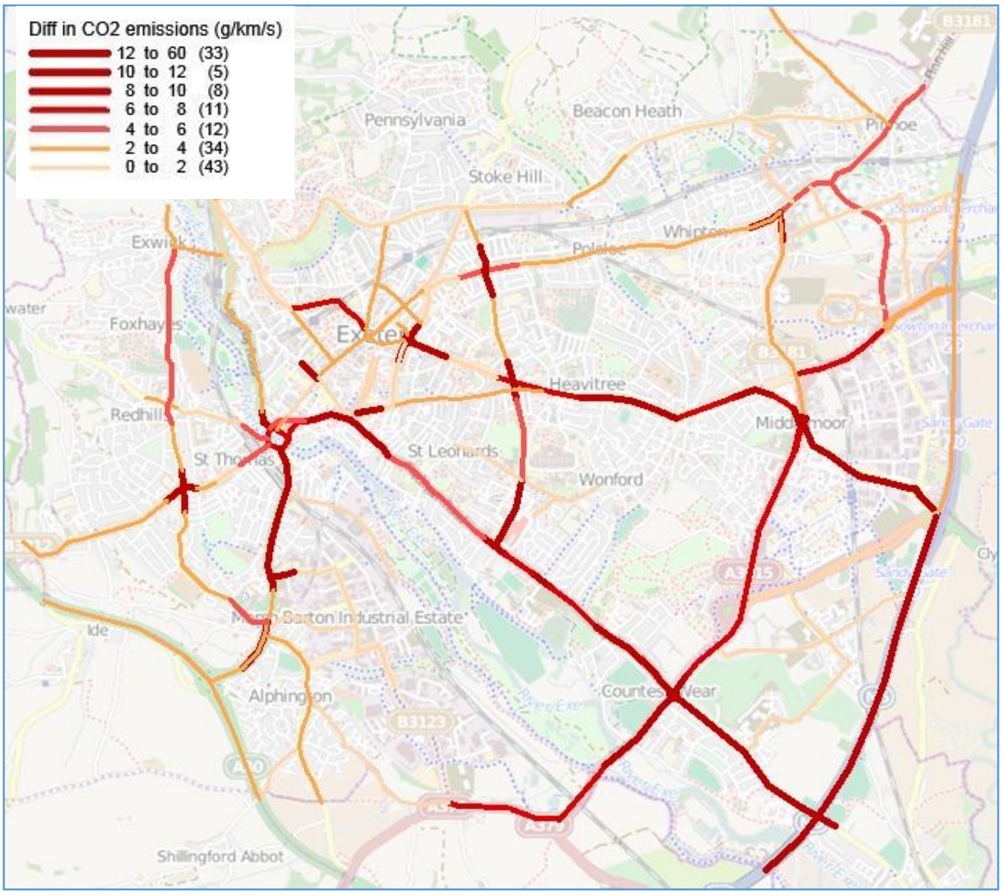
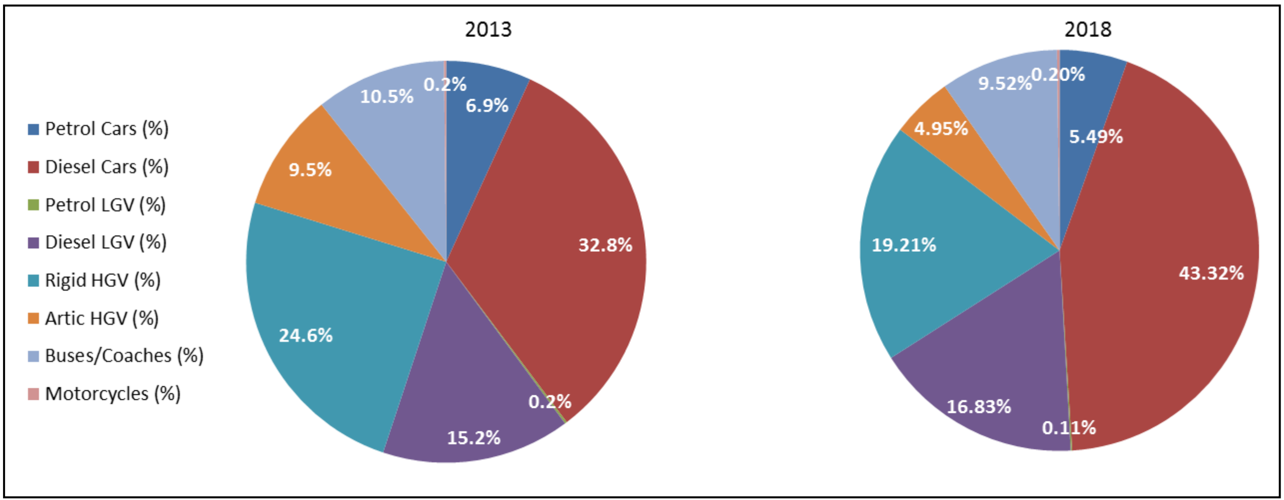


FIGURE 3.3: INCREASE IN ROAD CO_2 EMISSIONS ON INDIVIDUAL ROAD LINKS FROM 2013 TO 2018.



In terms of source contribution, the data shows that the contribution of diesel cars increases in 2018 (with the contribution of petrol cars declining) compared to 2013 whereas the contribution from other vehicle types, such as HGVs and buses decreases. This is illustrated as an example for NO_x emissions at Alphington Street.

FIGURE 3.4: SOURCE CONTRIBUTION OF NO_x EMISSIONS BY VEHICLE TYPE, 2013 AND 2018, ALPHINGTON STREET.



3.2 Baseline Inventory B (Emissions from Council vehicles 2018)

Information from the Council was obtained for those vehicles that are likely to be replaced or no longer in use in 2018 in their own fleet. A number of assumptions were made regarding the future fleet renewals, which were primarily based on assumptions in the NAEI. Although the number of Council owned vehicles is predicted to increase by 5 vehicles, the annual mileage is predicted to be lower. The annual mileage of the grey fleet and taxis is predicted to stay the same. Overall, due to the improvements in the vehicle fleet, the emissions are predicted to be lower than the baseline of 2013. For example, NOx emissions from Hackney carriages and private hire taxis reduced by more than 20% and PM_{10} reduced by nearly 90% and emissions from the Council owned fleet reduced by 19% for NOx and 23% for PM_{10}. CO_2 emissions reduced by around 10% across all fleet types.

TABLE 3.4: ANNUAL EMISSIONS FROM COUNCIL BASED FLEET, 2018.

FLEET TYPE	ANNUAL EMISSIONS (TONNES) AND PERCENTAGE CHANGE FROM 2013			ANNUAL MILEAGE (KM)	NUMBER VEHICLES
	NO_x	PM_{10}	CO_2		
COUNCIL OWNED VEHICLES	1.16	0.017	98	91,8850	98
GREY FLEET	0.012	0.0003	228	203,669	228
HACKNEY CARRIAGES	3.38	0.013	65	7,843,875	65
PRIVATE HIRE TAXIS	5.28	0.024	280	13,515,600	280

3.3 Baseline Inventory C (Noise 2018)

A baseline inventory for noise was re-calculated based on the traffic data for 2018. On average there was a 0.5-0.6 increase in dB compared to 2013 which represents less than a 1 percent increase. It is noted that it is likely that in the future year of 2018 there may be an overall reduction in background noise. However, the calculation method used for this study does not take into account changes in background noise in the same way as that for air quality modelling. Therefore this increase in noise levels close to the roadside is solely due to the increase in traffic flow predicted for the future baseline.

4 Impact of the Low Emission Strategy

This section provides details of the methodology followed to determine the likely impacts of the Low Emission Strategy. These impacts are provided in terms of changes to emissions, air quality concentrations and noise compared to the baseline in 2018.

4.1 Test options

In terms of emissions and air quality, only the impacts of those measures in a LES that were considered to be quantifiable were considered. These included those measures that may led to a cap on traffic flow (for example through modal shift), increases in average speed in a more free-flowing network (for example through parking controls or changes to signals) use of alternative fuels, by the public (including along a low emission corridor) Council vehicles, bus and HGV operators (through provision of refuelling infrastructure). The impact of two scenarios were tested, the first was a "LES-lite" option which contained a small number of more potentially more achievable changes to the traffic and fleet and a more detailed "LES-Full" option whereby a greater number and more ambitious measures were tested. These changes were applied to the traffic fleet across the entire modelled road network.

TABLE 4.1: SUMMARY OF LES TEST OPTIONS

LES LITE OPTION	LES FULL OPTION	ACHIEVED THROUGH POTENTIAL LES MEASURES
TRAFFIC GROWTH FROM 2013 CAPPED TO 6% FOR CARS AND VANS ONLY	TRAFFIC GROWTH FROM 2013 CAPPED TO 6% FOR ALL VEHICLES	MODAL SHIFT TO WALKING AND CYCLING PROMOTION OF DEVON METRO RAIL PARK AND SHARE SCHEMES
10% INCREASE IN SPEED FOR BUSES AND HGVS	10% INCREASE FOR ALL VEHICLES	REDUCTION IN TRAFFIC FLOW (FREE-FLOWING TRAFFIC) SIGNAL IMPROVEMENTS BUS AND HGV PRIORITY LANES
100% BUS FLEET CONVERTED TO RUN ON BIODIESEL B30 FUEL	50% BUS FLEET (SINGLE DECKER) RUNNING ON BIOMETHANE (ASSUMED TO BE EQUIVALENT TO EURO VI)	SUPPORT BUS OPERATORS TO IMPROVE THEIR FLEET AND INVESTIGATE ALTERNATIVE FUELS AND RE-FUELLING STATIONS
	10% OF ARTICULATED HGVS RUNNING ON BIOMETHANE (ASSUMED TO BE EQUIVALENT TO EURO VI)	COUNCIL TO IDENTIFY OPPORTUNITIES FOR ALTERNATIVE FUELS IN THEIR OWN FLEET AND RE-FUELLING STATIONS. WORK TO RE-INTRODUCE A FQP
100% OF HACKNEY CARRIAGE FLEET EURO 6 EMISSION STANDARD	75% OF HACKNEY CARRIAGE FLEET EURO 6 EMISSION STANDARD, 25% ELECTRIC	IMPROVEMENTS IN TAXI AGE AND EURO STANDARDS THROUGH LICENSING AGREEMENTS
	20% OF CARS AND VANS TO BE ELECTRIC	INTRODUCTION OF LOW EMISSION CORRIDORS PROMOTION OF ALTERNATIVE FUELS IN EXETER

4.2 Emissions results

Similarly to the baseline inventory, the impact on NO_x and PM_{10} emissions was calculated using the EFT v6. In the absence of emission factors for biomethane in the EFT, it was assumed that emissions of the single decker buses and articulated HGVs running on biomethane were equivalent to Euro VI and this was specified in the fleet. For the option to convert buses to run on biodiesel B30, a factor of 0.886 was applied to PM10 emissions as provided by AEA. B30 NOx emissions remained as for the baseline. For CO_2, emissions were calculated using the previous version of the EFT as before. Factors of 0.535 to those HGVs and 0.23 for single decker buses were applied to take into account the emission reductions due to biomethane (based on work done by TTR for LowCVP on biomethane use by HGV).

The headline results in terms of the changes in total annual emissions across the network are given below. In terms of the local air pollutants, as shown previously there is a predicted reduction in emissions between 2013 and 2018. The maximum possible reduction from the introduction of a LES in 2018 would be a reduction of 40 -45% compared to the 2018 baseline. This would only be possible if all the measures in the LES full option are successfully and fully implemented. For the more conservative LES Lite test, the results showed a reduction in NO_x of 7% over the 2018 baseline due to traffic and speed changes. There was a slightly larger reduction in PM_{10} emissions due to the introduction of B30 into the bus fleet. In terms of CO_2 emissions, there is a predicted increase in emissions of 11% between 2013 and 2018 due to the increase in traffic flow of around 16% across the network. The introduction of a LES Lite option in 2018 could bring these emissions back down to the 2013 level and the introduction of a LES Full option would result in a 27% reduction compared to the 2018 baseline.

TABLE 4.2: PREDICTED CHANGE IN ANNUAL EMISSIONS DUE TO THE IMPLEMENTATION OF THE LES

TEST	**ANNUAL EMISSIONS (T/Y) AND CHANGE FROM 2018 BASELINE (%)**		
	NO_x	**PM_{10}**	**CO_2**
2013 BASELINE	*409.2*	*27.8*	*155,751*
2018 BASELINE	330.9	26.9	173,546
2018 LES LITE	306.1 (-7%)	24.5 (-9%)	156,275 (-10%)
2018 LES FULL	200.5 (-39%)	15.45 (-45%)	127560 (-26%)

4.3 Air quality results

To illustrate the impact of these options on local air quality concentrations, the emissions for each road link as calculated in the EFT were input into the dispersion model ADMS-Roads to predict annual mean NOx, NO_2 and PM_{10} concentrations. The modelling was focused on specific receptors, located at the front of residential properties along two representative road corridors – Heavitree Road and Alphington Road. These corridors were chosen for the modelling as monitored concentrations are known to exceed the annual mean NO_2 objective and both roads are possible sites for the introduction of low emission corridors. To represent sources not explicitly included in the modelling (i.e. roads sources outside of the area, emissions from industry and the rural background contribution), suitable background values for NO_2 and PM_{10} were taken from the Defra background maps based on 2011 data[6].

The first step in the modelling process was to verify the performance of the dispersion model against monitored concentrations. This was done using the emissions from Baseline Inventory A for 2013.

6 http://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html

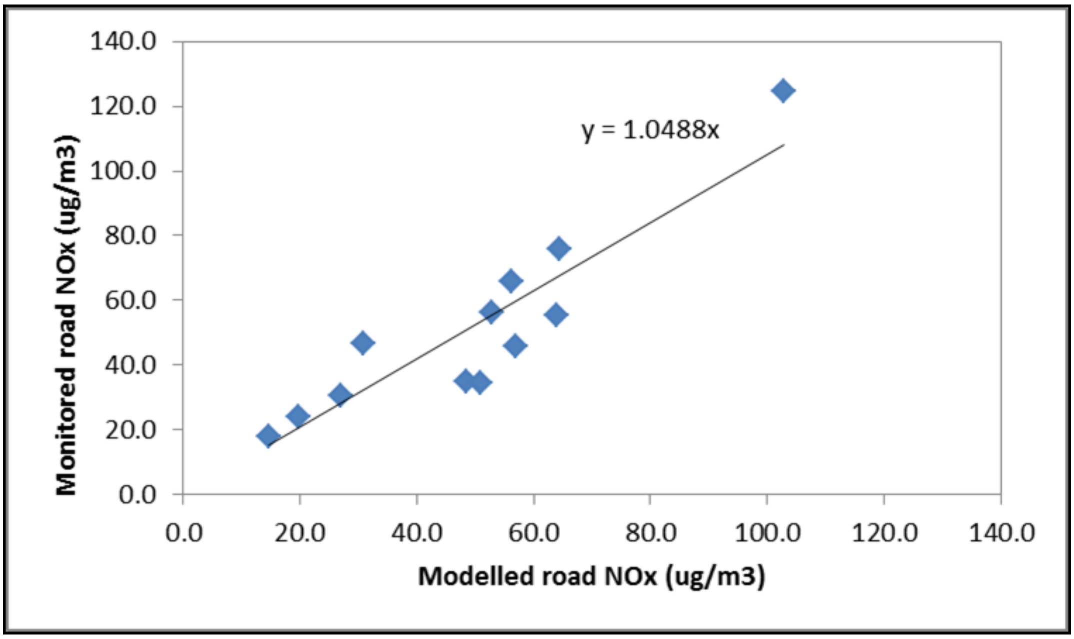
The verification process followed the methodology given by Defra's Technical Guidance (Defra, 2009). Modelled outputs of road NO_x concentrations were compared with those calculated from the monitoring sites using the calculator[7] available on the LAQM tools section of the UK Air Quality Archive website. The results of the model verification are given below. The model was found to generally under-predict road NOx concentrations compared to the monitored values and therefore a model adjustment figure of 1.0488 was applied to all modelled values. The adjusted results were considered to show good overall agreement and the final NO_2 concentrations were within 25% of the monitored values. Therefore, the same adjustment factor was therefore applied to modelled PM_{10} concentrations and concentrations in the future year of 2018. Due to these differences in the output, there is a level of uncertainty in the modelled results which needs to be taken into account when considering the results.

TABLE 4.3: MODEL VERIFICATION AND MODEL ADJUSTMENT, 2013.

Site	**2013 annual mean concentration (µg/m³)**						**Difference in NO_2 (%)**
	Back-ground NO2	**Modelled road NOx**	**Monitored road NOx**	**Adjusted modelled road NOx (x1.0488)**	**Modelled NO_2**	**Monitored NO_2**	
Heavitree In	14.2	14.7	17.8	15.4	22.02	23.19	-5%
Alphington Rd Out	12.7	48.6	34.8	50.9	36.38	29.53	19%
Topsham Rd Barrack R	11.9	27.0	30.6	28.4	25.91	26.94	-4%
Cowick St In	12.7	19.8	24.0	20.7	23.1	24.66	-7%
Cowick St Out	12.7	52.8	56.5	55.3	38.14	38.58	-1%
Western Way	14.2	56.2	65.8	58.9	40.91	43.49	-6%
Alphington St	12.7	64.5	75.7	67.7	42.86	45.78	-7%
East Wonford Hill	11.7	102.9	124.5	107.9	55.75	60.83	-9%
Fore St Out	12.6	50.8	34.3	53.3	37.23	29.24	21%
Pinhoe/ Blackboy	11.1	56.86	45.94	59.6	38.43	32.90	14%
York Rd	11.8	63.839	55.24	67.0	41.84	37.33	11%
Red Cow Village	11.9	30.76	46.78	32.3	27.7	33.97	-23%

*Concentrations in bold exceed the annual mean NO_2 objective

[7] http://www.airquality.co.uk/archive/laqm/tools.php



The results of the modelled NO_2 concentrations along the road corridors are summarised in the table and examples are provided to illustrate the impact of the LES options in the maps below. The table provides the numbers of properties exceeding the objective (i.e. above 40 $\mu g/m^3$) and number of properties likely to exceed (between 36-40 $\mu g/m^3$) for the baseline and LES options. The maximum modelled concentration in the 2018 baseline is 50 $\mu g/m^3$ at two properties on Heavitree Road. The results show that in the Alphington Road, 43 of the 146 properties are likely to exceed the objective without the LES in 2018. With the LES lite option, there is only a small reduction in concentrations at properties of around 1% which results in the concentration at two properties declining from above 40$\mu g/m^3$ to just below. In Heavitree Road, 42 properties are likely to exceed the annual mean objective in 2018 and a reduction of 1% reduces concentrations at one property to below the objective. With a full LES in place, concentrations are predicted to reduce by over 20% on average, resulting in all modelled properties along the Alphington Road meeting the annual mean objective and 2 properties still likely to exceed the objective in Heavitree Road. For PM10, the modelled concentrations are predicted to meet the annual mean objective in the baseline and with the two LES options.

TABLE 4.4: SUMMARY OF MODELLED NO_2 CONCENTRATIONS ALONG ROAD CORRIDORS

CONCENTRATION ($\mu g/m^3$) IN RELATION TO THE OBJECTIVE	NUMBER OF PROPERTIES					
	ALPHINGTON ROAD			HEAVITREE ROAD		
	BASELINE	LES LITE	LES FULL	BASELINE	LES LITE	LES FULL
EXCEEDING (ABOVE 40)	25	23	0	35	34	0
LIKELY TO EXCEED (36-40)	18	20	0	8	8	2
NOT EXCEEDING (<36)	103	103	146	206	207	247

FIGURE 4.1: HEAVITREE ROAD CORRIDOR: 1. MODELLED ANNUAL MEAN NO_2 CONCENTRATIONS AT PROPERTIES, 2018 BASELINE

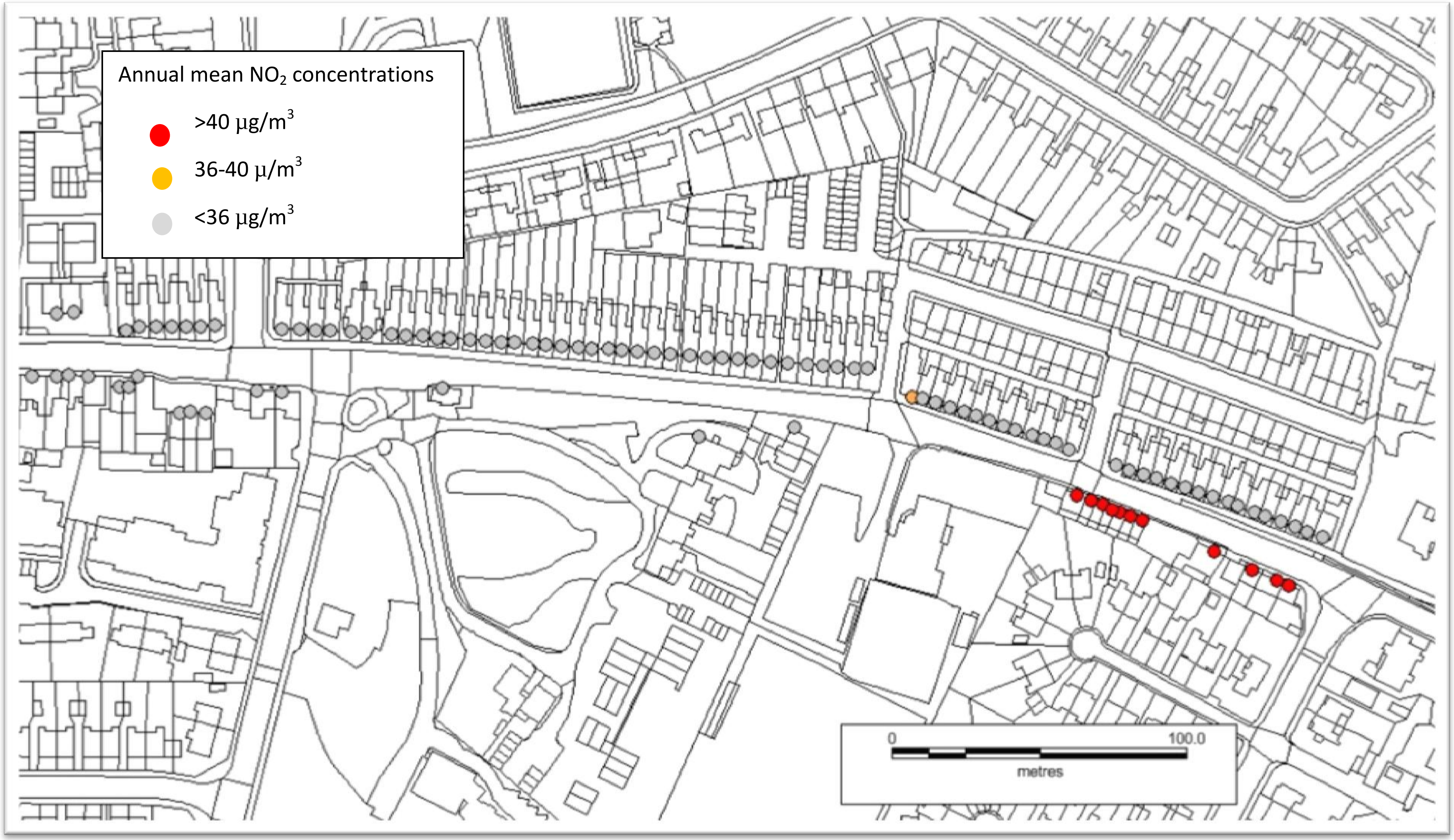


FIGURE4.2: MODELLED ANNUAL MEAN NO_2 CONCENTRATIONS AT PROPERTIES, 2018 LES LITE OPTION

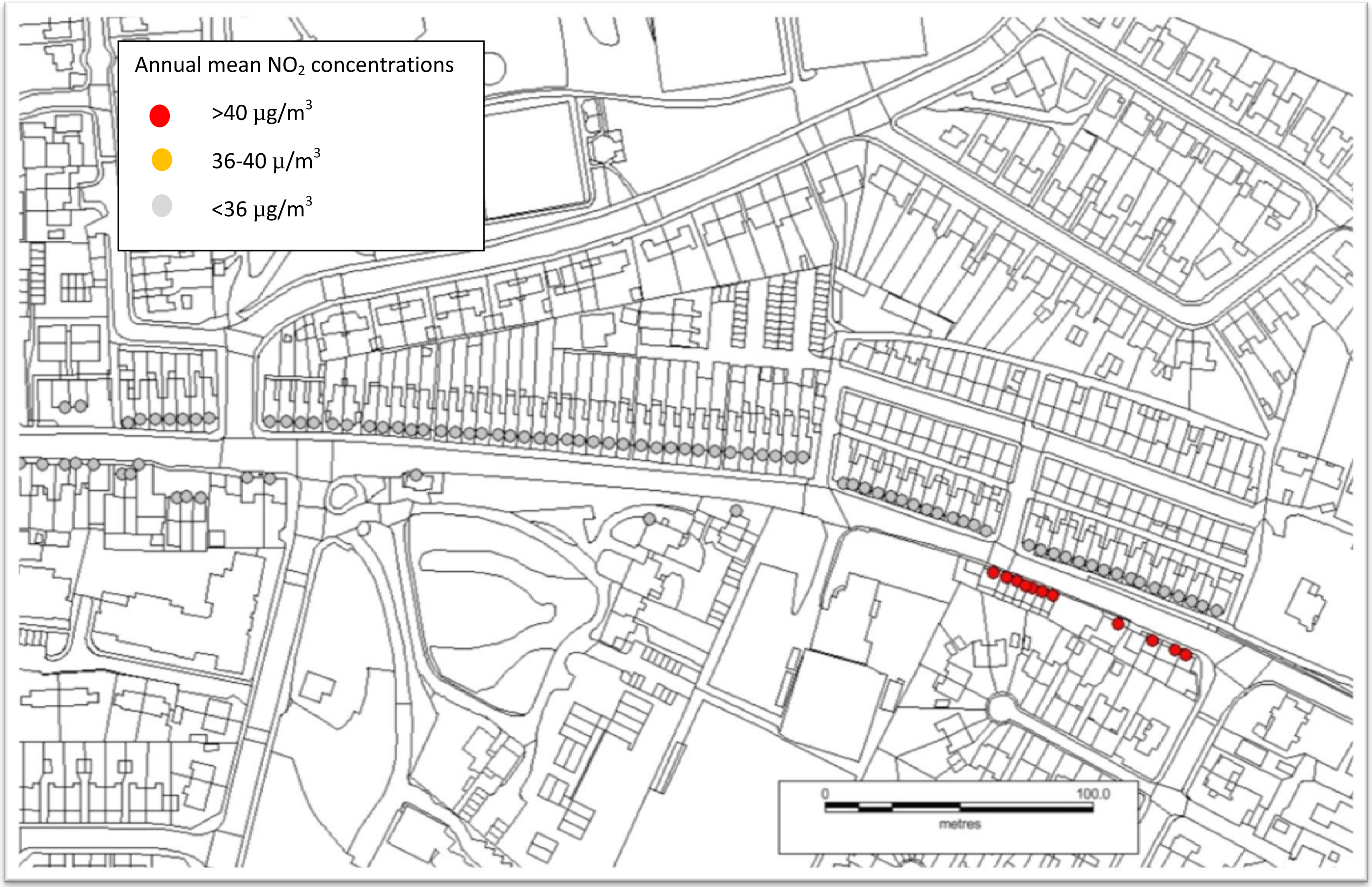


FIGURE 4.3: MODELLED ANNUAL MEAN NO_2 CONCENTRATIONS AT PROPERTIES, 2018 LES FULL OPTION

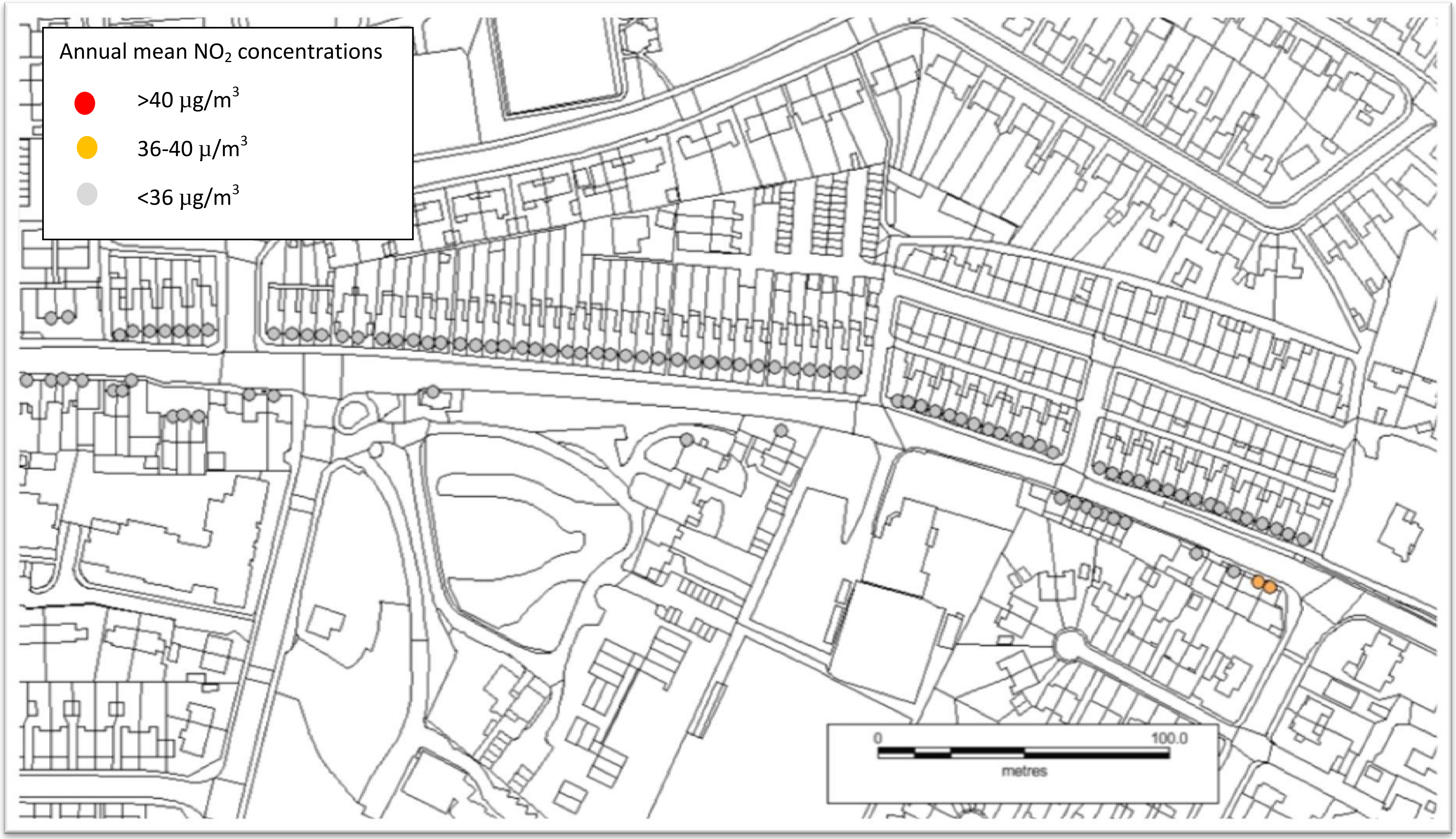


FIGURE 4.4: ALPHINGTON ROAD CORRIDOR: 1. MODELLED ANNUAL MEAN NO_2 CONCENTRATIONS AT PROPERTIES,2018,BASELINE

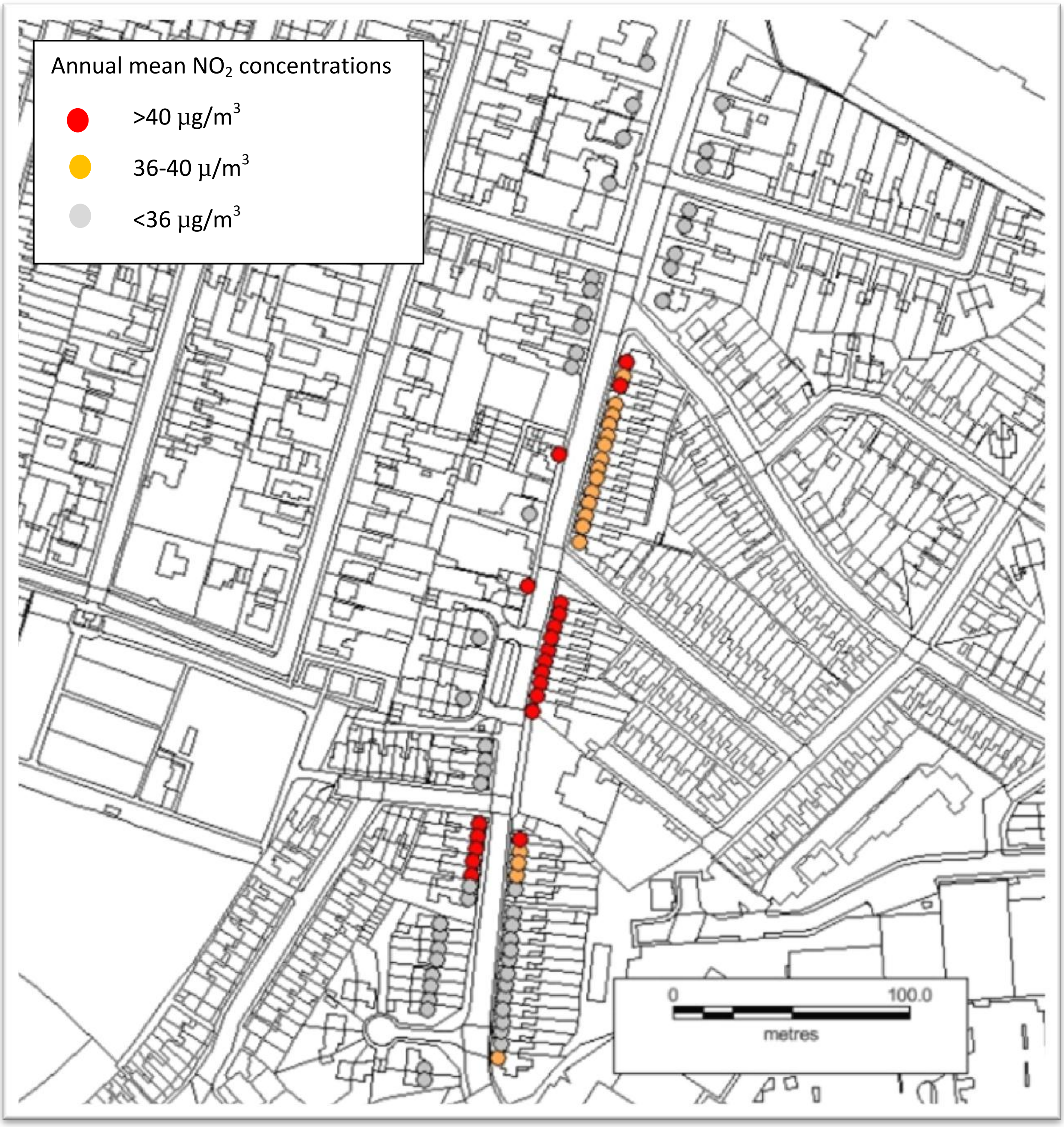


FIGURE 4.5: MODELLED ANNUAL MEAN NO2 CONCENTRATIONS AT PROPERTIES, LES LITE OPTION

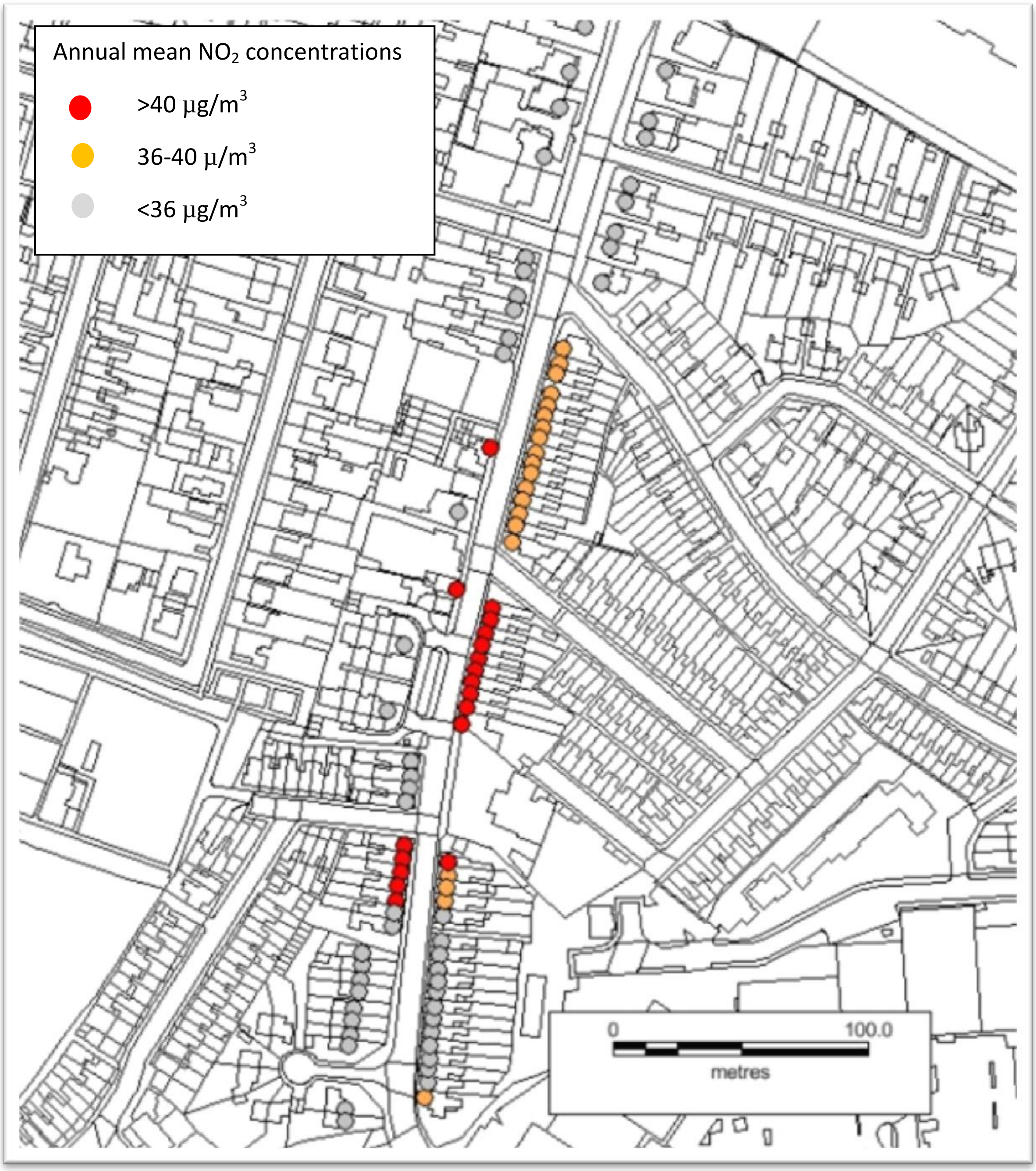
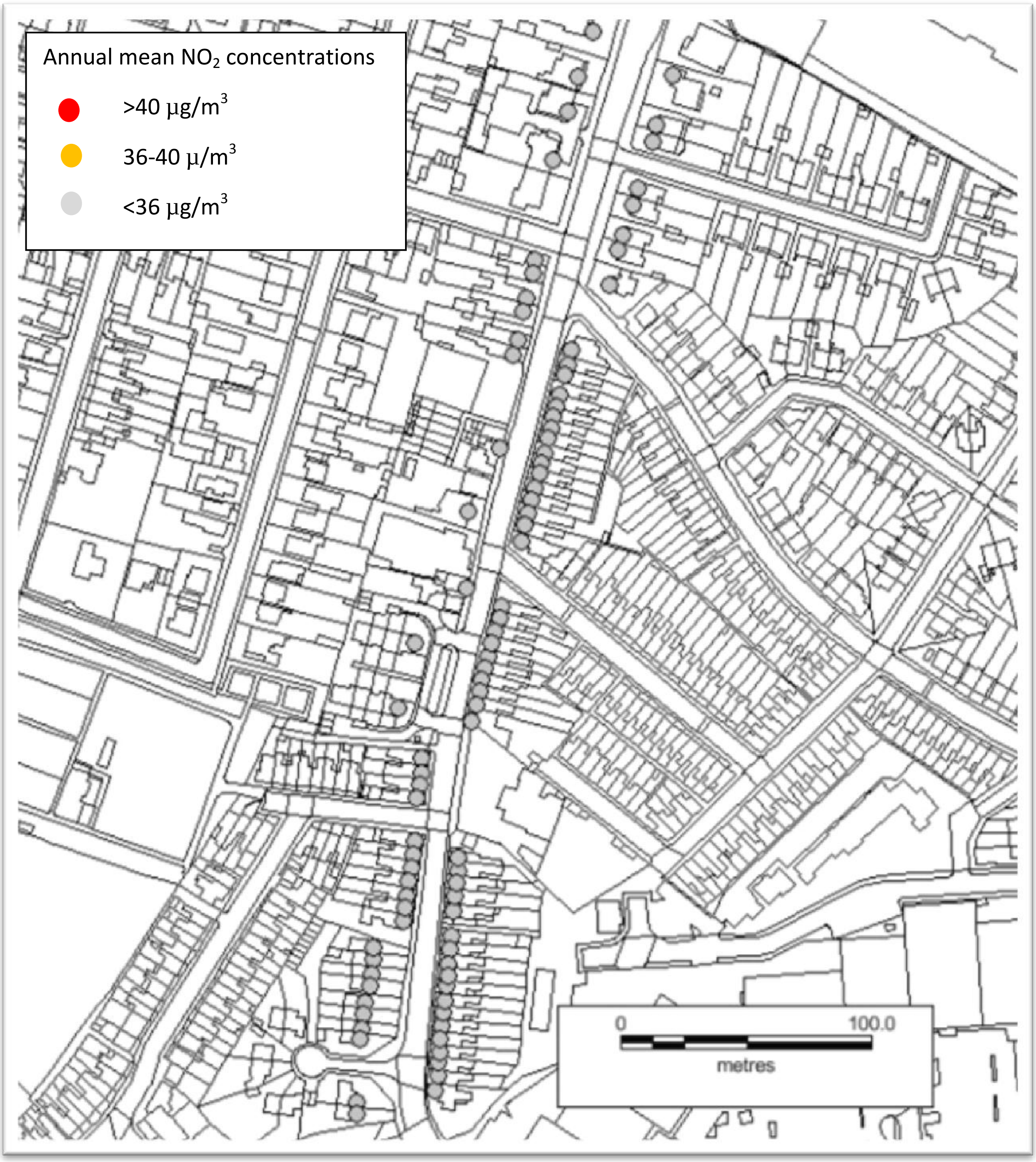


FIGURE 4.6: MODELLED ANNUAL MEAN NO_2 CONCENTRATIONS AT PROPERTIES, LES FULL OPTION



Note, all receptors are under <36 µg/m³ hence no colour dots on this image.

4.4 Results for Council fleet

A number of changes that are likely to be made to the Council fleet in 2018 have been tested independently using the data collected for inventory B. These include the following polices:

- Replacement of 5 large refuse collection vehicles (RCVs) with 15 smaller RCVs and removal of five vans from the Council owned fleet.

- All of the employees grey fleet to be replaced by electric pool vehicles from the Council owned fleet
- Upgrades to the Hackney carriage fleet to be 75% Euro 6 and 25% electric vehicles.

It is noted that there are no additional changes above the continued fleet improvements assumed in the baseline for the private hire taxi fleet. The impacts of these changes on emissions are given in the table below. There is a small reduction in emissions from the Council fleet, which is primarily due to the replacement of the 228 grey fleet vehicles with electric pool cars. There are more significant emission benefits seen from introducing Euro 6 and electric vehicles into the Hackney carriage fleet, particularly for NOx emissions which are predicted to be reduced by 62%. It is noted that the impact of this measure has also been included as part of the LES testing on the road network.

TABLE 4.4: CHANGES TO EXHAUST EMISSIONS FROM COUNCIL AND TAXI FLEET, 2018.

FLEET TYPE	ANNUAL EMISSIONS (T/Y) AND PERCENTAGE CHANGE FROM 2018 BASELINE			ANNUAL MILEAGE (KM) AND PERCENTAGE CHANGE FROM 2018 BASELINE
	NOx	PM10	CO2	
COUNCIL VEHICLES AND GREY FLEET	1.162 (-1%)	0.0175 (-1%)	292.9 (-9%)	1,122,508 (0%)
HACKNEY CARRIAGES (75% EURO 6, 25% ELECTRIC VEHICLES)	1.27 (-62%)	0.008 (-38%)	626.0 (-26%)	7,843,875 (0%)

4.5 Results for Noise

The calculations for the Baseline Inventory C were updated with the new traffic situation predicted with the LES using the same CRTN methodology as before. On the whole, the noise levels were 0.1-0.6 dB quieter although there were a few links which had a small increase of 0.1-0.2Db, such as the A30. However, this level of change is considered 'negligible' in terms of noise impacts. In terms of the benefits of alternative fuels on the noise levels of vehicles, there is no data that suggest that the use of biomethane will alter the noise levels. Electric cars are obviously quieter, by about 1 dB at 50 km/h, less at higher speeds, more at lower speeds. With 25% taxis and 20% cars/vans converted to electric in the full LES option, the total traffic noise will only fall by a fraction of this and, again this is considered to be 'negligible' across the road network.

5 Conclusions

The evidence from the data collated in the emissions inventories suggest that there will be an improvement in emissions and concentrations of the local air quality pollutants; NO_2 and PM_{10} between 2013 and 2018 without the introduction of a LES. The anticipated improvements (as provided in the Emission Factor Toolkit) for the vehicle fleet outweigh any increase in emissions due to more traffic on the roads. It is noted that the EFT predicts that Euro 6 emission standards which come into force for all new cars from September 2015 will make up around 40% of the car fleet by 2018. Type approval emission tests suggest that these offer a 67% reduction in NO_x emissions compared to Euro 5 emissions so provide a significant benefit. However, these predicted improvements may not be as large if it is found that Euro 6 vehicles do not penetrate the fleet as quickly as expected and emissions from real-life driving are actually higher than shown from type approval tests. Despite this improvement in emissions, the air quality modelling has shown that in 2018, there are still exceedences of the annual mean NO_2 objective at residential properties close to busy roads. Therefore, there remains the need to improve air quality and protect people's health.

As CO_2 emissions are directly related to fuel consumption, emissions are expected to increase in the 2018 by over 10% compared to the 2013 baseline due to the predicted increases in traffic flow. The increase in noise from traffic in 2018 is considered to be negligible and may be offset by a reduction in background noise.

The modelling suggests that the introduction of selected measures proposed in the LES (as shown by the LES Lite) option is likely to reduce NO_x and PM_{10} emissions by between 7-9% and CO_2 emissions by 10%. The dispersion modelling has shown that these emission reductions result in a maximum reduction in annual mean NO_2 concentrations at selected individual receptors of 3% and average reduction of 1%. This change is only likely to reduce exposure to concentrations above the annual mean NO_2 objective by 1 or 2 properties along a corridor.

However, if a much more ambitious LES could be introduced by 2018, then this is likely to have a much greater benefit to emissions and air quality. Some of the predicted improvements over the 2018 baseline of the LES Full option are summarised below:

1. A reduction in road traffic NO_x emissions by 39% and PM_{10} emissions by 45%;
2. A reduction in annual mean NO_2 concentrations at selected receptors along a road corridor by an average of 24%;
3. A reduction in the area of exceedence above the annual mean NO_2 objective and associated improvement in exposure. For example, concentrations between 40-50 $\mu g/m^3$ in the baseline are likely to be reduced to levels below the objective of $40 \mu g/m^3$
4. A reduction in road traffic related noise levels by up to 0.6dB on many roads;
5. A reduction in road traffic CO_2 emissions by 26%.

6 References

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