Scenario development to inform air quality action planning in Ealing:

Nitrogen oxides (NO_x) emissions from road transport

Introduction

This note summarises some key points from recent work carried out to inform air quality action planning in Ealing. In particular it investigates how future exhaust emissions of nitrogen oxides might change as the road vehicle fleet evolves over the next few years, and what impact a number of theoretical 'what if' scenarios might have to reduce exhaust emissions and potentially improve local air quality.

Why do we need to be concerned about poor air quality?

Poor air quality has a significant negative impact on human health. The two main air pollutants in London are nitrogen oxides (NO_x) and particulate matter. This note focuses on NO_x.

NO_x is primarily made up of two components - nitric oxide (NO) and nitrogen dioxide (NO_2). From a health perspective, NO_2 is of most concern. However NO easily converts to NO_2 in the air, so to reduce concentrations of NO_2 it is essential to control emissions of total NO_x. Nitrogen dioxide is a respiratory irritant which may exacerbate asthma and possibly increase susceptibility to infections. The World Health Organisation concluded that the evidence suggests that ambient concentrations of NO_2 have direct effects on public health, particularly for respiratory outcomes.

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Air quality in Ealing

A number of geographic locations within Ealing currently exceed the legal annual mean NO_2 limit value of 40µg/m^3. For this reason, and because of high levels of particulate matter, the whole of the London Borough of Ealing was declared an Air Quality Management Area in 2000.

Road transport is responsible for about 46% of nitrogen oxides emissions in England. It is particularly associated with diesel engines, although older petrol engines can also emit high levels of nitric oxide.

Measuring nitrogen oxides (NO_x) emissions from road traffic

In 2012, surveys were carried out at a small number of locations in Ealing and Central London to measure the nitric oxide (NO) and nitrogen dioxide (NO_2) concentrations in road vehicle exhaust gas emissions. The surveys utilised 'remote sensing' measurement techniques to measure the chemical composition of exhaust plumes as vehicles drove past.

So we know how much NO_x was being emitted from road traffic in 2012, but what about the future?….

Of course, the road traffic fleet is constantly changing. It is hoped that newer passenger cars and vans will emit less NO_x than older vehicles. The new 'Euro 6' emissions standard which comes into force for new car sales in September 2015 has much tighter NO_x emission limits for diesel vehicles.

Similarly, the new 'Euro 6'[†] emissions standard for heavy goods vehicles which is being phased in between now and December 2016 also has much more stringent NO_x emission limits.

However, it takes time for new vehicles to replace older vehicles in the fleet. For example, the average age of a passenger car in Ealing is just under eight years, whereas the average age of a van is just over five years.

For Euro 5 diesel passenger cars and light vans, the NO_x limit value is 180 mg/km, measured using the current European testing procedure for vehicle type approval.

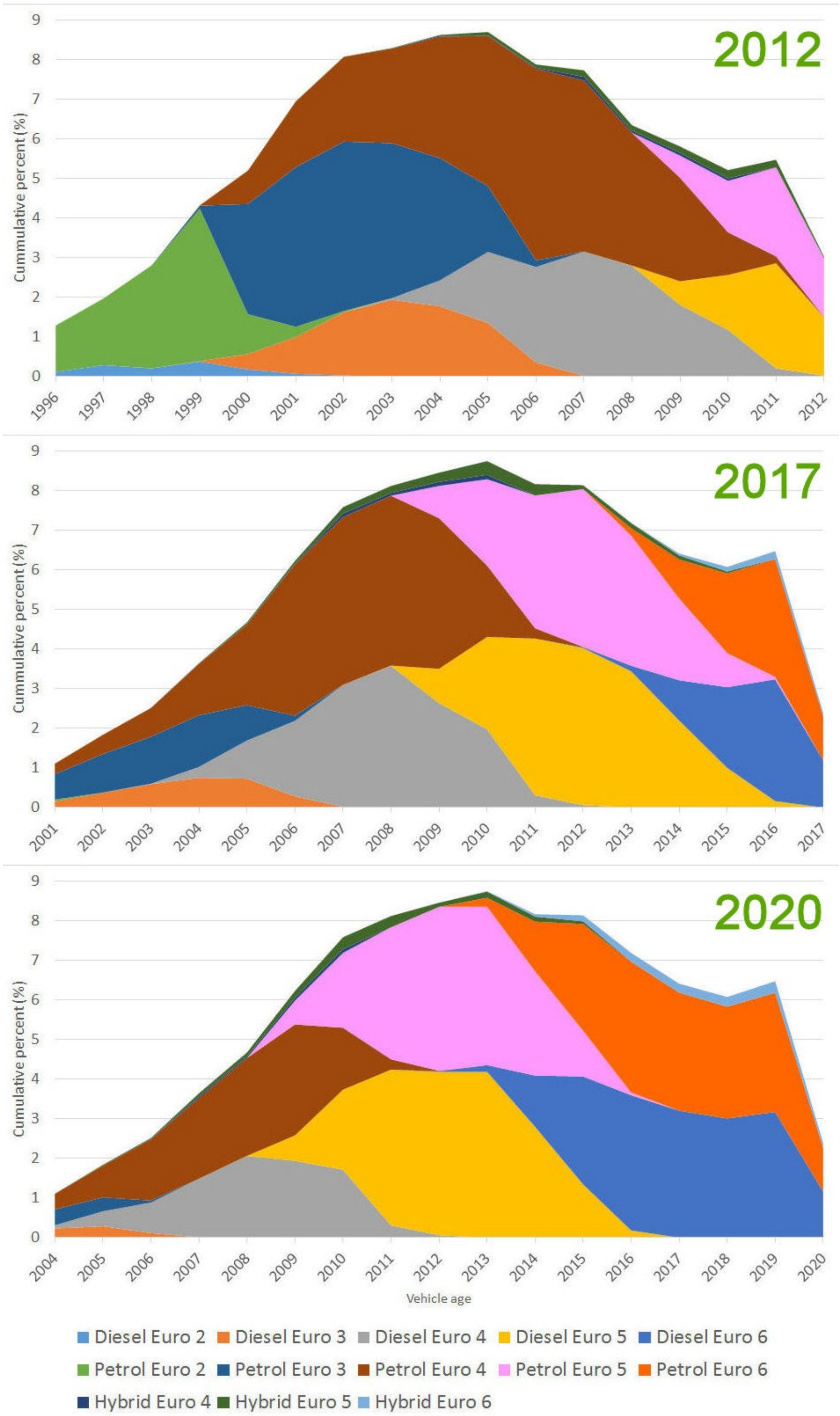
At Euro 6, this NO_x limit value for diesel passenger cars and light vans is reduced to 80 mg/km. i.e. a reduction of about 56%.

If we assume that this reduction in type approval NO_x limit values results in a proportionate reduction in NO_x emissions from Euro 6 diesel passenger cars and vans in 'real-world' driving, we can estimate the likely impact of the introduction of Euro 6 on local air quality in Ealing.

[†] There is a convention in European emissions legislation to utilise Arabic numerals for light vehicle Euro standards, and Roman numerals for heavy vehicle Euro standards. Arabic numerals have been used throughout this note for clarity.

Evolution of the passenger car fleet in Ealing to 2020

Penetration of Euro 6 vehicles over time, and removal of older vehicles.



Case study areas in Ealing

Five representative case study areas were identified in Ealing for the analysis.

Acton High Street

Haven Green

Horn Lane

A40 Western Avenue (from Park Royal to Savoy Circus)

Western Road, Southall

Scenario investigation

Business as usual

Assuming a traffic growth rate of 1% per annum, and the expected evolution of the passenger car and van fleet, it is estimated that total NO_x emissions from cars and vans in the case study locations will reduce by between 12% and 14% between 2012 and 2017, and by between 21% and 26% between 2012 and 2020. Interestingly, a large part of this reduction is due to the retirement of large numbers of older petrol engine cars between 2012 and 2017 that emit relatively high levels of nitric oxide. Total NO_x emissions from diesel passenger cars are higher in 2017 and 2020 than in 2012, due in large part to the ongoing impact of Euro 5 diesel cars.

What if? - We introduced a diesel car and van scrappage scheme?

It has been demonstrated in the remote sensing surveys that NO_x emissions from diesel cars and vans (Euro 5 standard and earlier) are high. Therefore, this scenario calculates the likely impact of introducing a voluntary scrappage scheme for these vehicles at year 2017. Two scrappage options have been considered. The first option assumes that there is a voluntary 10% take up of the scheme; the second option assumes that there is a voluntary 20% take up. The scheme assumes that scrapped Euro 5 and older diesel cars will be replaced by a mix of petrol and Euro 6 diesel cars, and that scrapped Euro 5 and older vans will be replaced by Euro 6 diesel vans. With a 10% take up of the scheme, total NO_x emissions from cars and vans in 2017 are estimated to reduce by about 5% (relative to 2017 'business as usual'); with a 20% take up, total NO_x emissions are estimated to reduce by about 11%.

What if? - We reduced the numbers of new diesel cars purchased?

This scenario assumes that some form of policy intervention is introduced to reduce the attractiveness of new diesel cars relative to other fuel types. It assumes that sales of new Euro 6 diesel cars will be reduced by 25%, relative to the base scenario at 2017, and that sales of alternative fuel Euro 6 compliant cars (petrol, hybrid) will increase pro rata. Under current legislation, sales of new Euro 5 cars end on August 30th 2015; the implicit assumption is that the scenario intervention will not be introduced until September 2015 at the earliest. With this scenario, it is estimated that total NO_x emissions from passenger cars in 2017 reduce by about 1% (relative to 2017 'business as usual'). The relatively insignificant impact of this scenario at 2017 illustrates the challenge of dealing with the legacy of vehicle sales which have already taken place, and the relatively long time periods required for interventions influencing purchasing decisions to have a significant impact on overall light vehicle fleet emissions. This is a function of the average age of passenger cars operating on the highway network in Ealing. This is not an argument for not influencing purchasing decisions for environmental benefit; such interventions may be part of a wider package of policy measures to improve local air quality. However, it is a recognition that such policies would have an influence over a longer time scale, given the average age of the passenger car fleet, and the rate of fleet turnover.

Scenario investigation

What if? - We encouraged drivers to switch off engines when stationary?

Surveys carried out within the case study areas in Ealing in 2013 have revealed that between 8% and 40% of journey time was spent stationary, for example waiting at traffic signals. Perhaps more significantly, between 6% and 33% of total journey time on these sections of route was observed to be spent stationary for periods of 10 seconds or more. This has the effect of creating significant air pollution ‘hotspots’ on the highway network, typically in the vicinity of junctions, in addition to contributing to the wider NO_x air quality problem.

For this scenario, it is hypothesised that if all (or a significant proportion of) car and van engines were consistently switched off during these stationary episodes, there would be a significant reduction in the absolute emissions of NO_x into the local atmosphere at these emission ‘hot spots’ (in addition to reductions in other pollutants and greenhouse gases). Specifically, the scenario assumes that if a stop within a journey has a duration of longer than 10 seconds, the vehicle engine is switched off for the duration of the stationary episode that is greater than 10 seconds. Hence, the scenario has no impact on stops of 10 seconds duration or less. Of course, some drivers already switch of engines during stops, but the proportion who do so, and their decision making processes, are unknown. The scenario can be characterised as quantifying the difference in emissions between (a) all light vehicle drivers not switching off their engines, and (b) all light vehicles drivers systematically switching off their engines during longer duration stops, within the rules set out above. With this scenario, it is estimated that total NO_x emissions from passenger cars and vans in 2017 reduce by up to 8% (relative to 2017 ’business as usual’). This scenario differs from the other scenarios considered in that its impact will vary spatially, with significantly higher benefits observed in locations where stopping is most prevalent, for example adjacent to junctions and traffic lights. One of the particular benefits of this scenario is therefore that it explicitly targets known emission ‘hot spots’.

Scenario investigation

What if? - We introduced an Ealing 'Ultra Low Emission Zone—ULEZ'?

A Low Emission Zone (LEZ) already operates in London. Larger vans, minibuses and other specialist diesel vehicles currently need to meet Euro 3 emissions standards for particulate matter. Lorries, buses, coaches and other specialist heavy vehicles currently need to meet Euro 4 emissions standards for particulate matter. TfL LEZ regulations currently do not apply to passenger cars.

This 'what if?' scenario assumes that an ultra-low emission zone (ULEZ) is introduced in Ealing by 2017. In the scenario, the zone applies to all light vehicles (passenger cars, taxis, and vans). Analysis has shown that nitric oxide emission rates from diesel cars, vans, and taxis are generally relatively high up to and including Euro 5. In addition, nitric oxide emissions across the case study areas in 2017 from Euro 4 and earlier petrol cars are still quite significant, but decrease with the introduction of the Euro 5 standard. Nitrogen dioxide emissions from light vehicles are dominated by diesel cars and vans. NO_2 emission rates from diesel engines remain high up to and including Euro 5, and are only assumed to decrease significantly with the introduction of the Euro 6 standard.

It was therefore decided to set the compliance criteria for the 'what if?' Ealing light vehicle ULEZ scenario as being Euro 6 for diesel light vehicles, and Euro 5/6 for petrol light vehicles. This is applied in the analysis to all passenger cars, vans, and taxis. It is assumed that vehicles are replaced on a like-for-like basis, adopting the compliant Euro standard for the ULEZ. The light vehicle ULEZ 'what if?' scenario was calculated to reduce total NO_x emissions from light vehicles by approximately 52% relative to the 'Business as usual' 2017 situation, by far the most effective individual light vehicle scenario considered.

But what about buses?

The TfL bus fleet is one of the few elements of the road vehicle fleet in the case study areas which is under direct public influence. Bus service contracts are negotiated between TfL and the various bus companies, specifying the types of vehicle technology to be utilised on particular services or groups of services. The characteristics of the bus fleet are therefore strongly influenced / determined by TfL policy, and in recent years TfL has been very active in improving the environmental performance of the fleet.

For example, TfL have stated that the retro-fitting of selective catalytic reduction (SCR) to older Euro 3 buses reduces NO_2 emissions by around 54%, and reduces total NO_x emissions by 88%, based on test results. TfL further state that Euro 6 buses are expected to have 95% lower NO_x emissions compared to Euro 5 buses. At the time of writing, TfL had the following specific plans:

- All TfL buses are planned to meet a minimum of Euro 4 standard for particulate matter and NO_x by 2015;
- SCR systems had been retro-fitted to 1,015 Euro 3 buses as of May 2014. An additional 400 SCR systems were to be retro-fitted to Euro 3 buses during 2014;
- The remaining Euro 3 buses will be replaced with Euro 4 buses by 2015;
- TfL have a target to introduce 1,700 hybrid buses (including 600 New Routemasters) by 2016.

For the purpose of generating future year 'what if?' scenarios, the following additional assumptions were made regarding the future development of the TfL bus fleet in Ealing to 2017 and 2020:

- All TfL buses operating in Ealing will meet a minimum of Euro 5 standard for NO_x by 2020, with a 50% reduction in existing Euro 4 buses between 2014 and 2017.
- Existing Euro 3 buses which have been retro-fitted with SCR emissions control technology are assumed to be retained to 2017, but will be replaced by 2020 with Euro 6 and Euro 6 hybrid.

With the above assumptions, at 2017, total NO_x emissions from TfL buses operating in the Ealing case study areas are calculated to reduce by approximately 22% relative to 2014. At 2020, the reduction relative to 2014 is calculated to be approximately 47%.

….and Heavy Goods Vehicles?

In this context, goods vehicles refers to vehicles designed for the carriage of freight which are heavier than vans (generally above 3.5 tonnes gross). It should be noted that the European emissions regulations for light duty vehicles and heavy duty vehicles are quite distinct in a number of aspects. Specifically, heavy duty NO_x emissions are defined in terms of grams per kilowatt hour (kWhr), rather than the mg/km metric utilised for light duty vehicles. In addition, Euro 6 heavy duty emissions are quantified over the new World Harmonised drive cycles. Hence, in comparison to Euro 5, Euro 6 has adopted a more stringent emissions measurement regime, the objective being to make the measurements more consistent with 'real-world' operating conditions.

The Euro 6 NO_x emissions limits are significantly more stringent than the previous Euro 5 regulations. The Euro 5 NO_x emission limit over the previous European Transient Cycle (ETC) is 2.0 g/kW.hr, whereas the Euro 6 NO_x emission limit over the World Harmonised Transient Cycle (WHTC) is 0.46 g/kW.hr, i.e. about a 77% reduction. The Euro 6 emission standard for NO_x is being phased in over a period of time, from January 2013 until full implementation in January 2017.

Utilising our knowledge of the composition of the present day heavy vehicle fleet in Ealing, and its historical rate of fleet renewal, the likely change in NO_x emissions can be estimated.

At 2017, the heavy duty freight vehicle total NO_x emissions over all case study areas combined are calculated to be approximately 27% lower than 2012; at 2020, the NO_x emissions are calculated to be approximately 55% lower than 2012. The relatively faster rate of reduction of goods vehicle NO_x emissions when compared to light vehicle emissions, with respect to time, is due to two factors; (a) the relatively larger assumed step change in NO_x emissions in the transition from Euro 5 to Euro 6 for goods vehicles; and (b) the relatively faster rate of commercial vehicle fleet turnover (i.e. the goods vehicle fleet is younger than the passenger car fleet).

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The likely overall impact on NO_x emissions

It has been previously stated that, on average, 46% of NO_x emissions in England are attributable to road transport. However, according to the London Atmospheric Emissions Inventory (LAEI), the value in Ealing is 43.3% at 2012. If we assume that the changes in road transport emissions in Ealing from light vehicles, heavy vehicles, and buses, as a result of fleet evolution and the 'what if?' scenario interventions impact on this 43.3% value, we can calculate in a broad brush manner the likely change in overall NO_x emissions by case study area in 2017, and consequently, likely changes in air quality. This is presented below in the form of an index relative to year 2012, assuming no change in non road transport sources of NO_x emissions.

NO_x Index	Acton High Street	Haven Green	Horn Lane	A40	Western Road
2012 (Index=100)	100	100	100	100	100
2017 Business as usual	92.2	90.5	91.4	90.8	89.1
2017 Scrappage 10%	91.6	89.9	90.4	90.0	88.4
2017 Scrappage 20%	91.0	89.2	89.5	89.2	87.7
2017 Reduce diesel	92.1	90.4	91.3	90.7	89.0
2017 Switch off engines	91.3	89.2	87.5	90.1	87.1
2017 ULEZ	85.8	84.1	81.8	83.1	82.2

Of course, such an aggregate approach will hide significant local spatial variation. Near road, roadside and kerbside air quality monitoring locations, and in particular air quality 'hotspots' adjacent to junctions and queuing traffic, are likely to benefit from larger local reductions, as measured for example by diffusion tubes, because of the local concentration of road traffic related activity. Hence, the magnitude of any measured reduction in NO_x will depend at least in part on the spatial location of the measurement site.

Impact on future local NO_2 concentrations

The annual local air quality monitoring program in Ealing has regularly identified a number of geographic locations within the Borough which exceed the legal annual mean NO_2 limit value of **40µg/m³**. Such local monitoring is typically carried out using diffusion tubes. The tables below present the annual mean NO_2 concentrations as observed in the case study areas in 2012, and the likely changes in NO_2 concentrations assuming 'Business as usual' fleet evolution to 2017 and 2020, and light vehicle scenario interventions at 2017. These values are estimated, taking into account the overall relative proportions of road (43.3%) and non-road (56.7%) NO_x emissions in Ealing as derived from the London Atmospheric Emissions Inventory.

Acton High Street	Location	
NO_2 µg/m³ annual mean	88 High Street	182 High Street
2012 Observed	**54.7**	**48.9**
2017 Business as usual	**47.9**	**43.2**
2020 Business as usual	**41.1**	37.4
2017 Scrappage 10%	**47.4**	**42.7**
2017 Scrappage 20%	**46.8**	**42.3**
2017 Reduce diesel	**47.9**	**43.1**
2017 Switch off engines	**47.1**	**42.5**
2017 ULEZ	**42.4**	38.5

Haven Green	Location			
NO_2 µg/m³ annual mean	8 Spring Bridge Road	Gordon Road	41-42 Haven Green	Haven Green Court
2012 Observed	**66.8**	**47.2**	**52.1**	**50.4**
2017 Business as usual	**55.9**	**40.6**	**44.4**	**43.1**
2020 Business as usual	**45.7**	34.4	37.2	36.2
2017 Scrappage 10%	**55.2**	**40.2**	**43.9**	**42.6**
2017 Scrappage 20%	**54.5**	39.7	**43.4**	**42.1**
2017 Reduce diesel	**55.8**	**40.5**	**44.3**	**43.0**
2017 Switch off engines	**54.4**	39.7	**43.3**	**42.1**
2017 ULEZ	**48.5**	36.1	39.2	38.2

It can be seen that at 2017, even with a significant intervention such as the 'Ultra Low Emission Zone' scenario, a number of the monitoring locations are still expected to have an annual mean NO_2 concentration of greater than the legal limit value of 40µg/m³, and this of course assumes that Euro 6 vehicle emissions technology is as effective as we hope it will be. If Euro 6 does not perform as well as we hope, then the local NO_2 concentrations at 2017 and 2020 are likely to be higher than the values presented here. A small number of monitoring sites, where current annual mean NO_2 concentrations are in excess of 60µg/m³ (such as the A40 Western Avenue AQMS), will possibly still be in breach of the legal limit value at 2020, even with significant scenario interventions, due to the volume and composition of local road traffic.

Impact on future local NO_2 concentrations

Some 'what if' scenario interventions are calculated to be more effective in certain locations than others. For example, the 'Switch off engines' during long stops scenario is more effective in case study areas where queuing is particularly prevalent and intense, such as on the Horn Lane northbound approach to the junction with the A40 Western Avenue. Locations with intense bus or heavy goods vehicle operations will benefit from the assumed reductions in NO_x emissions as new vehicles enter the fleet, but again this assumes that Euro 6 will be effective.

Horn Lane	Location	
NO_2 µg/m^3 annual mean	156 Horn Lane	Horn Lane AQMS
2012 Observed	**40.7**	**54.7**
2017 Business as usual	36.0	**47.2**
2020 Business as usual	31.4	39.9
2017 Scrappage 10%	35.5	**46.4**
2017 Scrappage 20%	35.0	**45.6**
2017 Reduce diesel	35.9	**47.1**
2017 Switch off engines	33.9	**43.8**
2017 ULEZ	30.8	38.9

A40 Western Avenue	Location			
NO_2 µg/m^3 annual mean	Wendover Court	Western Ave AQMS	98 Western Avenue	6 Western Avenue
2012 Observed	**56.0**	**75.1**	**51.8**	**70.8**
2017 Business as usual	**47.7**	**62.8**	**44.4**	**59.4**
2020 Business as usual	39.3	**50.1**	36.9	**47.7**
2017 Scrappage 10%	**47.0**	**61.7**	**43.8**	**58.4**
2017 Scrappage 20%	**46.3**	**60.7**	**43.2**	**57.4**
2017 Reduce diesel	**47.6**	**62.6**	**44.3**	**59.2**
2017 Switch off engines	**47.1**	**61.8**	**43.9**	**58.5**
2017 ULEZ	**40.8**	**52.5**	38.2	**49.8**

Western Road, Southall	Location	
NO_2 µg/m^3 annual mean	18 Western Road	Featherstone School
2012 Observed	**41.9**	**42.4**
2017 Business as usual	35.6	36.0
2020 Business as usual	29.7	30.0
2017 Scrappage 10%	35.2	35.6
2017 Scrappage 20%	34.9	35.2
2017 Reduce diesel	35.6	35.9
2017 Switch off engines	34.5	34.9
2017 ULEZ	31.7	32.0

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Finally

This analysis has been based on the assumption that Euro 6 vehicle emissions technology will deliver the hoped for reductions in exhaust emissions of NO_x (NO and NO_2). Earlier emissions control technologies (e.g. Euro 5) have largely failed to deliver the expected reductions in such emissions in the real world, so it is advisable to be cautious. It would be wise to continue to monitor systematically local air quality at an appropriate level of spatial resolution to measure changes over time. It would also be wise to monitor systematically road vehicle exhaust emissions in Ealing to confirm (or otherwise) the expected reductions in NO_x emissions from Euro 6 vehicles as they progressively enter the fleet over time.

The decision to take additional local or national action to reduce exhaust emissions from road vehicles, through interventions such as scrappage schemes or ultra low emission zones, will need to be based on an objective assessment of the costs of implementation, and the benefits to society in terms of, for example, public health and wellbeing.

This analysis assumes no change in non road transport sources of NO_x emissions in Ealing, for example domestic gas consumption, industry, or rail. Such sources should not be overlooked when developing a strategy and action plan to improve air quality in Ealing.

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