Driver & Vehicle Standards Agency

Vehicle Market Surveillance Unit

Results of the 2018 Vehicle Emissions Testing programme

Moving Britain Ahead

July 2019

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Executive Summary

1 This is a time of rapid change for the motor industry as it transitions to the different and more rigorous testing requirements which underpin the Worldwide Harmonised Light vehicle Test Procedure (WLTP) and Real Driving Emissions (RDE) approaches. Together, these represent a step change in the way in which emissions are regulated. Manufacturers therefore need to innovate and make use of new technologies to continue to meet regulatory requirements.

2 The vehicles tested in the 17/18 programme were type approved under the NEDC (New European Drive Cycle) system and so did not need to adhere to the testing approach of WLTP or the standards set by the RDE regulations and the conditions under which they need to be met. Nevertheless, we tested each vehicle against both WLTP and RDE requirements in order to understand how they perform under real world conditions and evaluate manufacturers' progress in moving towards the new regulatory approach. We expect manufacturers to be ambitious in striving to reduce emissions as quickly as possible.

3 Some of the vehicles tested showed emissions levels just outside the regulatory limits, or poor performance in tests which were not part of the type approval process for that particular vehicle at the time it was brought to market. We followed up with manufacturers to understand why this might be the case. In these marginal cases, we are not challenging the validity of the vehicles' approvals, but rather whether they are in conformity with those and consequently whether further action needs to be taken by the manufacturer. Given the number of years a vehicle typically spends on UK roads, it is important to understand how it performs on emissions over time. Where there are marginal failures, the approach of the MSU is to advise manufacturers of this, to ask them to explain why it might be the case and to consider appropriate action.

4 Where there are more significant test failures which are a cause for concern, a number of actions may be appropriate, including further testing and analysis, the manufacturer applying a technical fix or initiating a recall of affected vehicles. Disappointingly, there was a trend of petrol cars with poor control of CO emissions during fuel enrichment as found in WLTP track tests. Similarly, there were multiple NO_x exceedances for diesel cars during RDE and WLTP track tests. While this is disappointing, manufacturers have given assurances that future models, designed for the introduction of WLTP and RDE, will perform better in these scenarios. Details of conversations with manufacturers, and of any actions they are taking as a result, are described in the results section.

5 Looking ahead to the future testing programme, the Department for Transport expects to see manufacturers bringing in significant improvements to their new models, in anticipation of the move to RDE.

1. Introduction

1.1 The Market Surveillance Unit (MSU) was established by the Department for Transport in summer 2016 to oversee and manage a programme of continued testing of vehicles and components. This followed the revelations that the Volkswagen Group had deliberately cheated on emissions tests.

1.2 The MSU is based within the Driver and Vehicle Standards Agency (DVSA) and works closely with the Vehicle Certification Agency (VCA). Its role is to check that new products placed on the UK market comply with the relevant legal obligations; this is often referred to as 'in-service' testing.

1.3 This report follows on from the Market Surveillance Unit's Vehicle Emissions Testing Programme 2017, published last year. This 2019 report provides results from the 28 vehicles tested in the 2018 Vehicle Emissions Testing Programme, which included diesel cars, petrol cars, light vans, trucks, public service vehicles (PSVs) and a plug-in hybrid electric vehicle (PHEV). Vehicles tested met the Euro 6 and Euro VI European emission standards. The underlying data will be made available shortly.

1.4 It is very important that the testing results of the MSU are transparent and published in full. Where vehicles were found to have performed poorly, we invited manufacturers to meet with us to discuss our findings. Each manufacturer was given the opportunity to explain the reasons why the vehicle tested performed so poorly.

1.5 The Government continues to take improvement of air quality seriously. The Department for Transport published *Road to Zero*, which sets our plans to end the sale of new conventional petrol and diesel cars and vans by 2040. We will position the UK as the best place in the world to develop, manufacture and use zero-exhaust-emissions vehicles and, during the transition, we will ensure that the cleanest conventional vehicles are driven on our roads.

1.6 The Government took steps last year to strengthen our powers to take action in the event of wrongdoing, with the Road Vehicles (Defeat Device, Fuel Consumption and Type Approval) Regulations 2018 coming into force on 1st July 2018. Under these tough new regulations, manufacturers will face heavy fines if they supply vehicles deigned to cheat emissions tests in the UK, with penalties of up to £50,000 for each new vehicle fitted with a defeat device.

2. Establishing the testing programmes

2.1 The testing programme was designed to check the pollutant emissions produced by a selection of the most popular vehicle types used on UK roads. We focused on testing both diesel and petrol cars, light duty vans, trucks and public service vehicles (PSVs). From each of these categories we selected a representative sample of vehicles to test. The programme also provided us with the opportunity to measure the carbon dioxide (CO_2) emissions produced by the selected vehicles.

2.2 The amount of CO_2 a car emits is directly related to the amount of fuel it consumes. Fuel economy is the relationship between the distance travelled and fuel consumed.

2.3 The primary aim was to assess if the vehicles complied with the standards to which they were approved. For the cars and vans the testing was also designed to assess how the real world performance of these vehicles compared against the newly introduced Real Driving Emissions (RDE) standards. The RDE legislation sets a legal limit for NO_x that vehicles must comply with in real world testing in addition to passing a laboratory test, now the Worldwide Light Harmonised Test Procedure (WLTP).

2.4 WLTP tests are longer and tougher than the previous NEDC (New European Driving Cycle) assessments. WLTP is designed to give motorists a more accurate indication of how much fuel their cars will use and the pollutants emitted during driving.

2.5 All new cars sold in the UK since 1 September 2018 have been required to meet the WLTP standard. From 1 September 2019 all new cars sold in the UK will also have to meet RDE nitrogen oxide (NOx) standards.

2.6 The cars and vans that we tested in this programme were not required to comply with these RDE & WLTP requirements, as they were all approved before the introduction dates, and so this part of our testing was to improve our own understanding rather than assess compliance.

2.7 While this report does not provide a comprehensive study of the entire vehicle fleet, between this and our previous publications, we have significantly enhanced our knowledge of the emissions of the vehicles on UK roads.

Choosing our sample of vehicles

Cars and vans

2.8 The cars and vans were chosen predominantly on the basis of their UK sales and then refined to ensure a suitable range of manufacturers were covered. To make this assessment we considered the total new registrations for each vehicle for the period 2016-17.

Trucks and PSVs

2.9 New truck and bus registrations accounted for less than 2% of the total number of registrations in Great Britain in 2017. In 2017 there were 2,564,300 new cars and 371,700 light vans registered, compared to 52,000 heavy good vehicles and 9,000 buses and coaches. There was also considerable variability within that small sample of truck and bus vehicles in terms of the weight category and number of axles. For this year's testing programme, we concentrated on the most popular category, namely 2 and 3 axle rigid bodied vehicles, and selected test vehicles from the range of manufacturers.

Sourcing suitable vehicles

2.10 We were clear that the vehicles needed to be sourced independently of the manufacturers to make sure that they were representative of those in use on our roads and that they had not been subject to any special preparation or modification which could make the test results unrepresentative. For this reason, we sourced vehicles from hire fleets. This was not possible for buses so we hired them from operators.

2.11 The cars and vans assessed in the programme were checked for any defects that may impact upon the emissions control system before being tested. The fuel was drained and replaced with standard laboratory reference fuel, which was kept consistent across all tests. These vehicles were tested on the New European Drive Cycle (NEDC (cold)) test, in accordance with their original type approval requirements. The further testing was not legislative and was conducted for information purposes.

2.12 The trucks and PSVs were tested in accordance with the in-service emissions testing requirements as set out in EU regulations. This means that these vehicles were tested on the road and using market fuel.

Number of tests

2.13 Our testing was designed to check the compliance of an individual vehicle. Sampling only one vehicle means that our results show a snapshot of the emissions performance from the vehicles, rather than providing a definitive result for each model. Where unexpected results were found, we reviewed the data and, if necessary, conducted additional tests. In some of these cases, it was appropriate to source a second vehicle to identify whether there might be an issue with a particular model across the wider fleet.

Testing locations

2.14 The testing was undertaken at a selection of commercial emission test laboratories across the UK. For the cars and vans the WLTP (track) testing was undertaken from the Vehicle Certification Agency's (VCA) site in Nuneaton. RDE tests were carried out either by VCA or at a commercial laboratory, using Portable Emissions Measuring System (PEMS) equipment owned by VCA or the laboratories. We did not conduct testing in laboratories that are owned by vehicle manufacturers.

3. Undertaking the testing

Cars and vans

3.1 The testing programme was designed first to check that the cars and vans we had selected complied with the official laboratory test that they were approved to - the NEDC (cold) test. Further testing was constructed around a variation of this cycle and of the new Worldwide Harmonised Light Vehicles Test Procedure (WLTP). Vehicles were tested in emissions laboratories and on test tracks to assess how the emissions results under these circumstances varied compared to the official laboratory test.

3.2 Further tests were conducted on public roads to assess the emissions performance of the vehicles in typical real world conditions.

Preparing vehicles for the dynamometer

3.3 Modern vehicles are equipped with a range of electronic systems, often fitted to improve safety, which rely on a number of sensors on the vehicle to perform correctly. Some of these sensors may detect implausible situations when a vehicle is driven on a chassis dynamometer in a laboratory. For example, the vehicle speed sensor indicates that the vehicle is moving but the wheel speed sensors detect that only the driving wheels are rotating. These contradictory signals may cause the vehicle to default to a safe operating mode and this may prevent it from undertaking the laboratory test.

3.4 In order to allow laboratory testing, some vehicles are equipped with a 'dyno mode' which suppresses this function and enables the vehicle to be driven on the chassis dynamometer. When the vehicles are initially type approved, these 'dyno modes' may be in operation, however legislation does not allow engaging dyno mode to improve the effectiveness of a vehicle's emissions control system in order to pass the test.

3.5 To understand these functions it has been necessary, in some cases, to allow the manufacturer to access the vehicle being tested. We are considering how we might test further vehicles in our next testing programme without allowing such access.

Laboratory testing

3.6 We first carried out the official legislative NEDC (cold) test for each vehicle as part of our initial check that its emissions system was functioning as it had been when that model was presented for type-approval. This test is known officially as the "Type I" test but we have referred to it as the NEDC (cold) as the engine is not warmed up prior to the test. The vehicle is given a standard pre-conditioning test, then left in a temperature controlled room so that the whole vehicle including engine oil and coolant is 'soaked' to a temperature between 20 and 30°C, as specified in the EU type approval regulations. Following that the official test is run with emissions measured from engine start.

3.7 We then ran a variation of the NEDC test. This test aimed to assess how well a vehicle controlled its emissions in comparison to its performance on the official NEDC (cold) test. This variation, referred to as NEDC (hot), is the same test cycle, but starting with a fully warmed up engine.

3.8 This year we only ran a NEDC (hot) test which followed the NEDC (cold) test. We did however look at the variation of results dependent upon the time elapsed and procedure adopted between cold and hot test.

3.9 In the laboratory we attached PEMS equipment to each vehicle and used this alongside the laboratory emissions measurement system to validate that the result from the PEMS equipment was comparable to the laboratory result. This gave us confidence in the accuracy of the later track and road testing.

Track testing

3.10 The track test element of the programme was designed to replicate, as far as practicable, testing in a laboratory. We conducted tests on a track, measuring emissions using the PEMS equipment fitted to each of the vehicles. We recreated the WLTP (track) test by providing the driver with a screen showing a trace of the speed versus time that they needed to maintain for each section (as is done in the laboratory test). The track tests were designed to check that the vehicle's emissions did not increase disproportionately (compared to the laboratory NEDC test) when running the now legislative WLTP test.

On road testing

3.11 The final part of our testing was an on-road RDE test. This is the test that new types of cars and other light duty vehicles have been required to comply with from September 2017, to ensure that they properly control exhaust emissions in real world use. This element involved driving the vehicle for approximately 1.5 hours over a test route on public roads. The route included urban, rural and motorway driving and tests were carried out during the day in normal traffic conditions. The results presented in this report are the overall emissions for the whole RDE trip (in grams per kilometre for NO_x and number per kilometre for particle number emissions). These figures have not been processed using the data normalisation tools, EMROAD or CLEAR, and are therefore labelled as 'basic' RDE results.

3.12 Under RDE legislation, if temperatures drop below 3°C, this is considered ‘extended’ conditions and the emissions results for the test are divided by a factor of 1.6. For transparency reasons in this report we are presenting ‘raw’ RDE results which have not been post-processed and have not had additional factors such as the extended conditions factor applied if appropriate.

Heavy duty vehicles

3.13 The legislative requirements for heavy duty vehicles are different from the light duty requirements. New types of heavy duty engines and vehicles have been tested in the real world to obtain their type approval since 31 December 2012. Real world testing could be introduced earlier for larger vehicles, because there is more space to fit the necessary PEMS equipment (which has since been developed further to reduce its size allowing it to be fitted to cars and vans). The vehicles in this programme underwent real world testing.

3.14 Heavy duty vehicles are not tested on a chassis dynamometer at type approval in the same way as light duty vehicles. Instead, as well as on road PEMS testing, more controlled and repeatable emissions testing is conducted on the engine alone, using an engine bench dynamometer. In this testing, the engine is tested out of the vehicle and without a transmission system.

On road testing

3.15 The vehicles were set up with the PEMS equipment and we undertook a real world test that complied with the legislative requirements. This lasts for approximately 2.5 hours and includes urban, rural and motorway driving. There are set parameters that the test must stay within to ensure that each vehicle is representatively tested.

3.16 The emissions measured in the real world test using the PEMS are normalised to the laboratory engine test using carbon dioxide as an assessment of the amount of 'work done'. This enables mass emissions per unit of energy (measured in kilowatt-hours, kWh) to be calculated. The result is then compared to the laboratory limit to determine whether it is within the conformity factor specified in legislation.

3.17 The conformity factor is the maximum permitted ratio of the normalised PEMS emissions test result in g/kWh compared to the emissions limit specified for type approval engine testing. For heavy duty vehicles, the NO_x conformity factor is 1.5, recognising that the on-road PEMs test covers a much wider range of operating conditions than the dynamometer engine test and that real world on-road emissions measurements will be subject to greater margins of uncertainty.

Manufacturer meetings

3.18 During our testing programme whenever we recorded notably high emissions results for a given vehicle we contacted the manufacturer. We invited them to meet with us to discuss the results. We asked them to explain the results we had measured and to describe the emissions control strategies used in their vehicles.

3.19 These discussions provided insight into the various reasons why a vehicle may achieve the legal emissions limit when tested on the official test cycle, but may emit significantly higher emissions in other situations.

4. Results

4.1 Following the testing of the cars and vans, we arranged for independent analysis of the data to quality assure our testing. We also reviewed the data for any unexpected results that may have suggested the presence of prohibited defeat devices. This involved reviewing the emissions profile from each of the laboratory and track tests.

4.2 The cars and vans were only required to comply with the legislative laboratory test, but we conducted a variant of this and reviewed the data from this test for unexpected results. We also compared the track and real world results against the European Commission's guidance for market surveillance testing which recommends a maximum acceptable conformity factor compared to the laboratory limit.

4.3 For the heavy duty vehicles the test data was analysed using the method in the heavy duty legislation for in-service emissions testing and conformity factors.

4.4 Following the initial tests, we determined which of the vehicles required further investigation and invited the relevant manufacturers to meetings to discuss our results. In some cases we conducted additional testing to verify our original data.

4.5 The summary results for all the vehicles tested are shown below. Where vehicles required further investigation, this is set out with the detail of what we originally found, any further testing that we conducted, and the outcomes of our discussions with the manufacturers. From this we have drawn our conclusions about the compliance of each vehicle. A complete list of vehicles tested can be found at Annex B.

Petrol cars & plug-in hybrid electric vehicles (PHEV)

4.6 We tested 6 petrol passenger cars and one PHEV in this programme. Legislative laboratory test results showed they all complied with the regulatory limits. The petrol vehicles selected included both direct and indirect fuel injection engines. The results of the NEDC (cold) test for each vehicle are shown in figure 4-1.

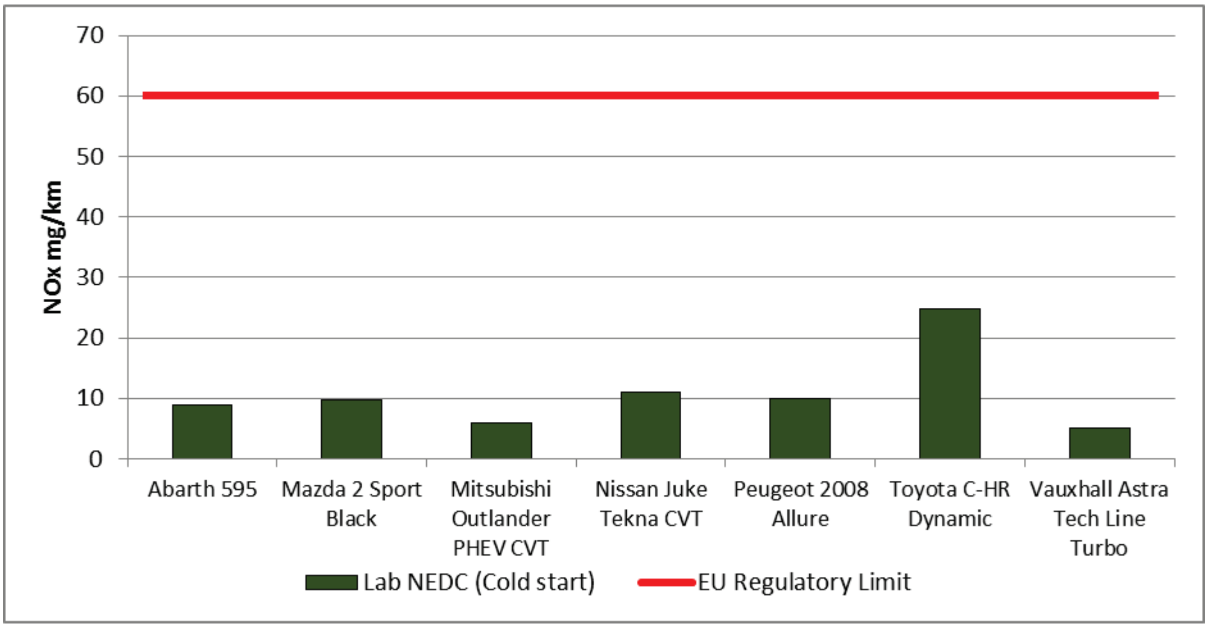

Figure 4-1: Laboratory NEDC (cold) results for petrol cars and PHEV compared to the regulatory limit

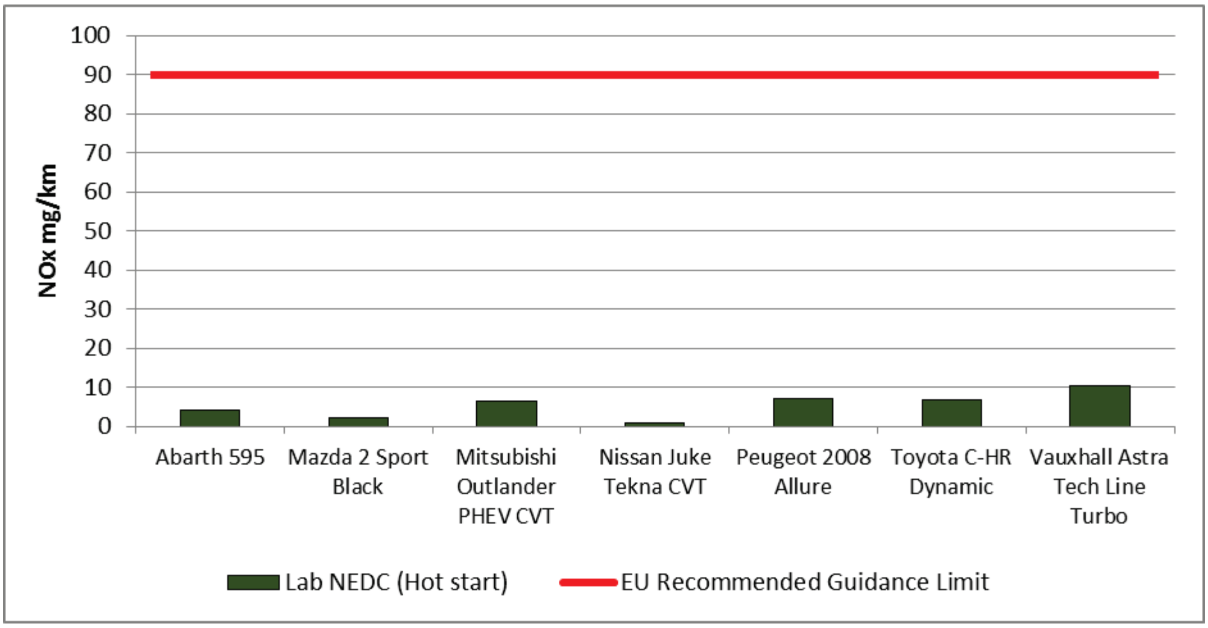

Figure 4-2: Laboratory NEDC (hot) results for petrol cars and PHEV compared to the EU recommended guidance limits

4.7 The results from the WLTP (track) testing showed that, in all cases, NO_x emissions were within the guideline limits of five times the laboratory test limit, which the European Commission proposed in the guidance that they published on 26 January 2017. Figure 4-3 shows the results of the vehicles when tested on one of the WLTP (track) tests we conducted.

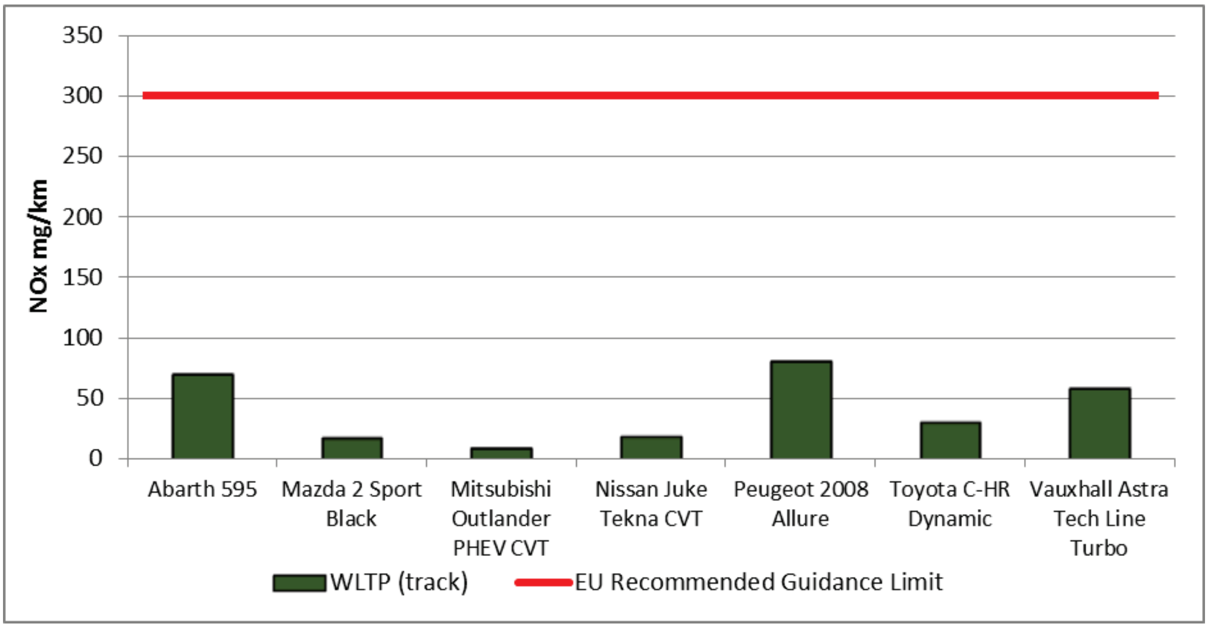

Figure 4-3: WLTP (track) results for petrol cars and PHEV compared to the EU recommended guidance limits

4.8 We observed an increase in NO_x emissions for the Peugeot 2008 and the Vauxhall Astra Tech Line Turbo when these vehicles were tested in real world conditions. However, both vehicles were well within the recommended guidance limits. See figure 4-4.

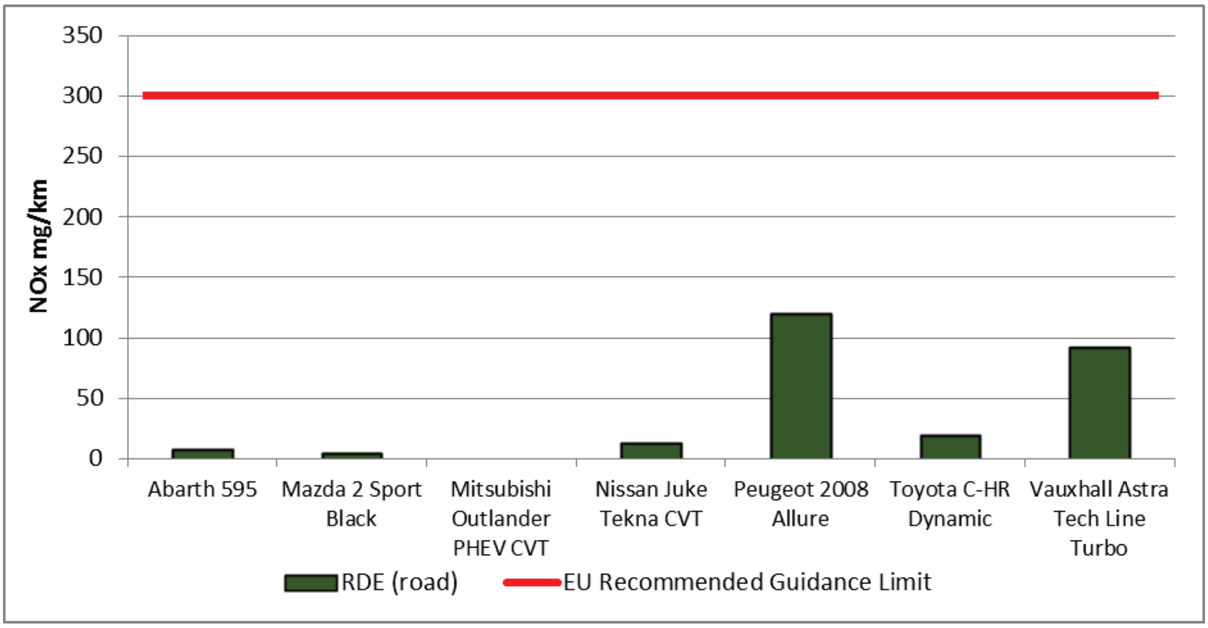

Figure 4-4: RDE (road) results for petrol cars and PHEV compared to the EU recommended guidance limits

4.9 As of September 2017, all new types of petrol and diesel cars have been required to control NO_x emissions to within 2.1 times the NEDC (cold) test limit when tested in accordance with the RDE test procedure. All the petrol cars in this testing programme were within the limit.

4.10 In addition to NOx, a range of other regulated pollutants were measured, both in the laboratory test cycles and in real world testing on the track and road. Whilst all vehicles met the regulated limits within the laboratory test cycles it was observed that several vehicles produced much higher levels of CO during the WLTP (track) test. See figure 4-5. To better understand the reason for these significantly higher CO emissions levels, we wrote to the manufacturers for them to provide explanations. This is explained further in the following sections.

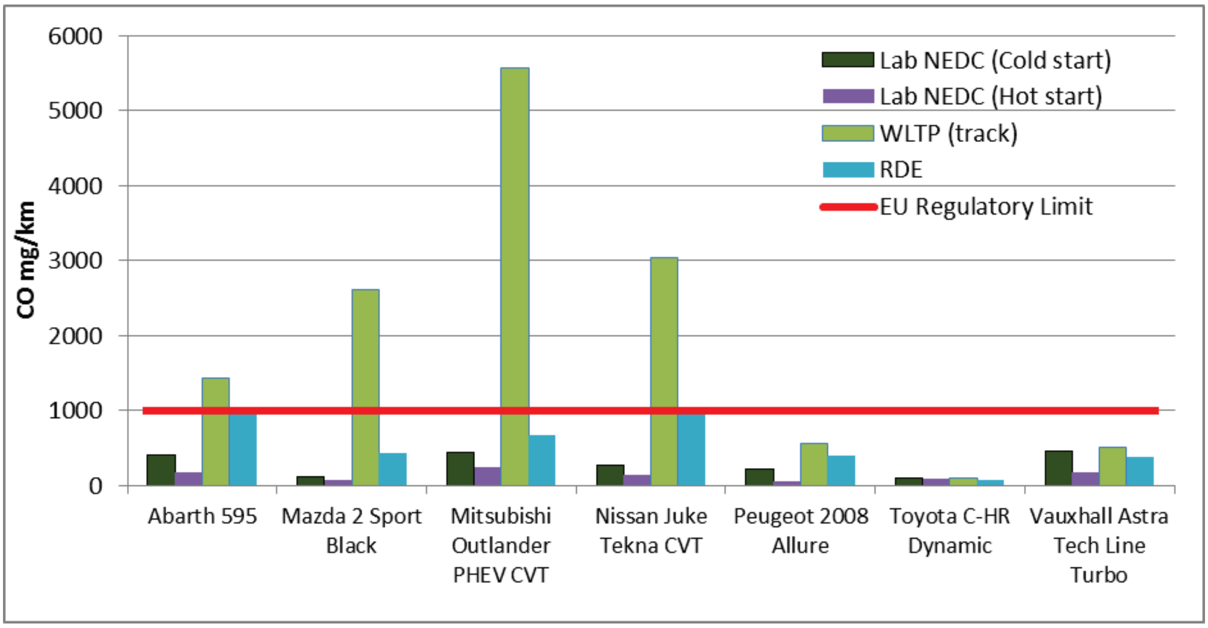

Figure 4-5: WLTP (track) results for petrol cars and PHEV compared to the EU recommended guidance limits

Nissan Juke 1.6 petrol CVT

4.11 Outside of the laboratory on both RDE and WLTP (track) tests the level of CO emission was surprisingly high with RDE testing at near to the NEDC certification limit (1000mg/km) and WLTP (track) testing at 3 times. Analysis of the WLTP (track) data showed one main area of particularly high CO emission occurring at high acceleration and high speeds i.e. 100-130 kph.

4.12 Nissan informed us that the likely cause of the elevated levels of CO measured during track and road testing is that the engine calibration entered into “fuel enrichment”. Fuel enrichment strategies involve the injection of additional fuel to avoid the overheating of engine and exhaust components, particularly during high speed or more aggressive driving. The fuel-rich conditions that are produced in turn lead to elevated exhaust CO emissions. Although such strategies are permitted where there is a risk of damage to the engine or exhaust components their use should be minimised in order to limit excessive emissions during normal driving conditions.

4.13 Nissan shared with us that as part of their continuing development there is on-going improvement of emissions technology that they place in their vehicles. A hardware change has been made to the Euro 6d TEMP derivative to include a larger volume of the underfloor catalyst with a higher precious metal loading.

4.14 These improvements will mean there is a tightening of the conditions in which fuel enrichment is used (known as the fuel enrichment map) from Euro 6b to Euro 6d. Whilst the Euro 6b vehicle meets the NEDC legal limits, Nissan informed us that they have worked on improving the accuracy of the calculations used to determine the limits and durability of materials within its vehicles. This has helped redefine the maximum temperature which the engine can withstand for the Euro 6d variant so that enrichment will occur less. We anticipate that these improvements will result in lower CO emissions for their future vehicles.

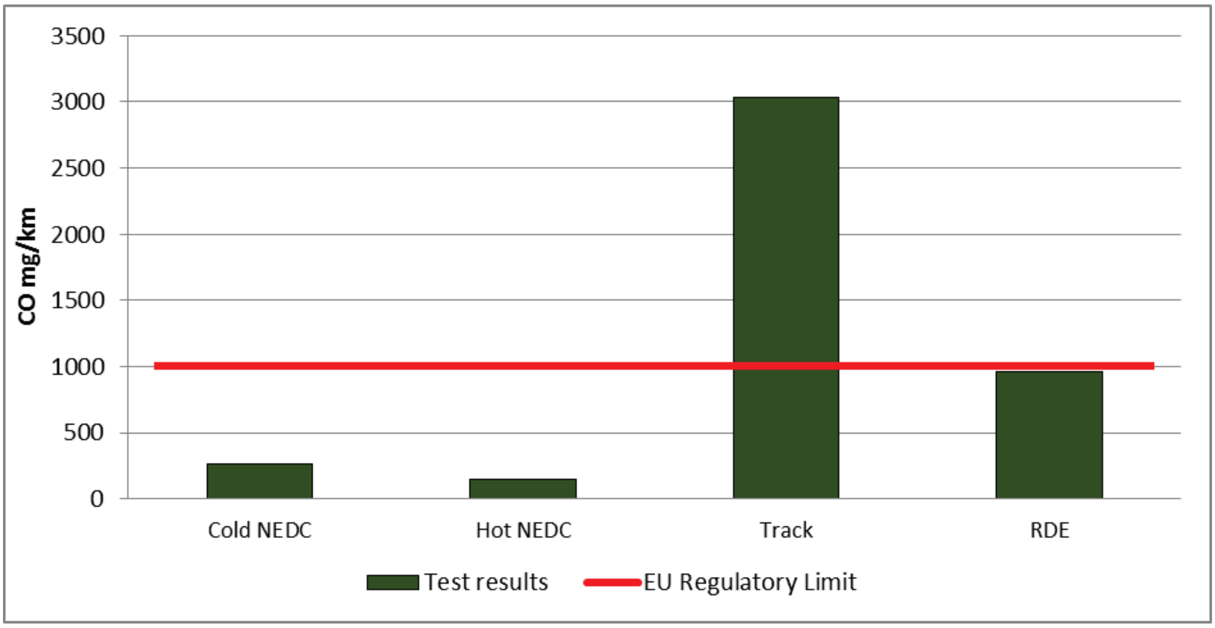

Figure 4-6: CO emissions for the Nissan Juke Tekna CVT. Limit shown is the regulatory limit for the NEDC (cold) test

Fiat Abarth 595 1.4T

4.15 The NEDC (cold) and NEDC (hot) test results showed the vehicle complied with the legislated limit. Unfortunately, we found that during both RDE and WLTP (track) tests, the vehicle emitted higher levels of CO than expected. For the RDE testing, the vehicle's CO emissions were just over 1000 mg/km (the NEDC certification limit) and for the WLTP (track) testing it was 1.5 times this limit. We asked FCA (Fiat Chrysler Automobiles) to comment on the causes of the elevated level of CO and if the engine calibration entered into fuel enrichment.

4.16 FCA explained that there were three main conditions where fuel enrichment may occur; a) At engine start in cold conditions; b) when the ECU senses the catalyst temperature exceeds its safety threshold; c) the engine operates in conditions that are prone to cause strong pre-ignition and abnormal combustion.

4.17 FCA advised that the resulting high CO emissions from our tests may be due to the conditions described in b) and c) when high accelerations were performed in high gear, causing the engine to work at full torque. FCA confirmed that in those particular conditions described in b) and c) above, enrichment is used to protect the engine from damage. FCA advised that they have refined the enrichment control logic between Euro 6b and Euro 6d. FCA contended that the change of enrichment control logic between the Euro 6b and Euro 6d was not dictated by an emission control constraint, more a refinement of the logic aimed at getting a more accurate identification of risk conditions, controlling parameters and better modulation of countermeasures. This should result in improved CO emissions for their Euro 6d vehicles. Despite the Euro 6b and Euro 6d vehicles sharing the same engine and after-treatment hardware, FCA are not planning on making the upgrades available for existing Euro 6b vehicles.

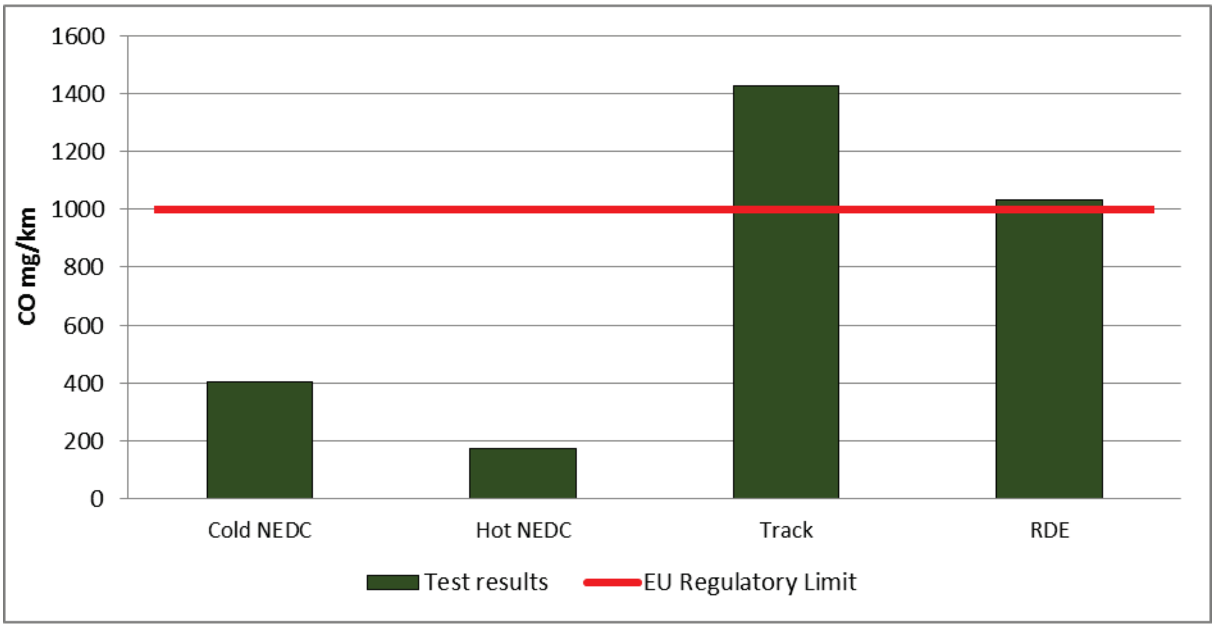

Figure 4-7: CO emissions for the Abarth 595. Limit shown is the legislative limit for the NEDC (cold) test

Mazda 2

4.18 The Mazda 2 performed well in the laboratory and RDE tests. However, when tested on the WLTP (track), the level of CO emission was 2.5 times the regulatory limit, the third highest amongst the petrol and PHEV cars tested in the 2018 programme. As in the case of the Abarth 595 and the Nissan Juke we suspect that the engine calibration entered into fuel enrichment and that there was CO breakthrough at high exhaust gas velocity.

4.19 This was identified late in the testing programme and we have not yet had the opportunity to discuss with Mazda the results. We will do so shortly and include conclusions in a later report.

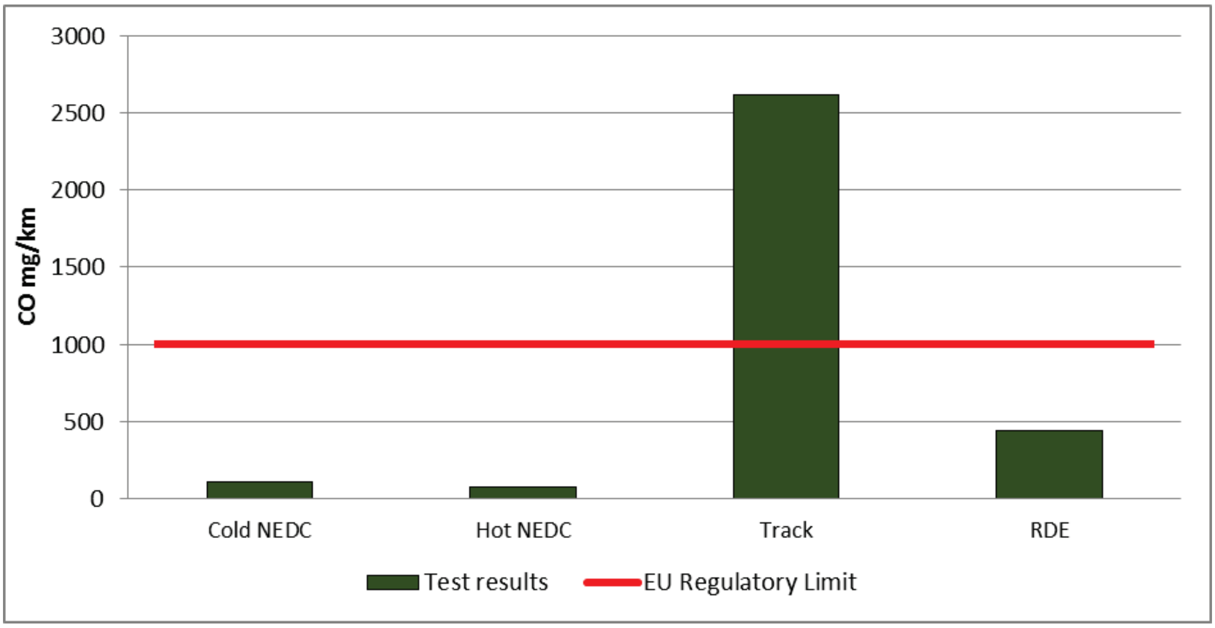

Figure 4-8: CO emissions for the Mazda 2. Limit shown is the legislative limit for the NEDC (cold) test

Mitsubishi Outlander PHEV

4.20 A 2017 Mitsubishi Outlander PHEV (plug-in hybrid electric vehicle) was selected for testing this year. Although both the laboratory testing and RDE testing resulted in low levels of CO emissions, the WLTP (track) testing produced extremely high levels of CO emissions.

4.21 As this vehicle is a plug-in hybrid electric vehicle it was tested in two different modes, known as charge sustain and charge deplete, based upon the level of battery charge. In both modes the emissions of CO were found to be very high within the track testing.

4.22 While we acknowledge these tests are not type approval requirements for Euro 6b vehicles, the results were nevertheless much higher than for other vehicles tested and we asked Mitsubishi to help us understand why this might be.

4.23 Mitsubishi explained that these results were as they had expected as the vehicle was not designed or approved to WLTP. Similar to what was reported by other manufacturers, Mitsubishi told us that they use a fuel enrichment strategy at high engine loads to protect the exhaust system from high temperatures. Conditions within the WLTP (track) testing were of sufficiently high load that enrichment was occurring, thereby resulting in high CO emissions.

4.24 We will look to test further plug-in hybrid electric vehicles in future programmes to ensure new vehicles are compliant with WLTP and RDE.

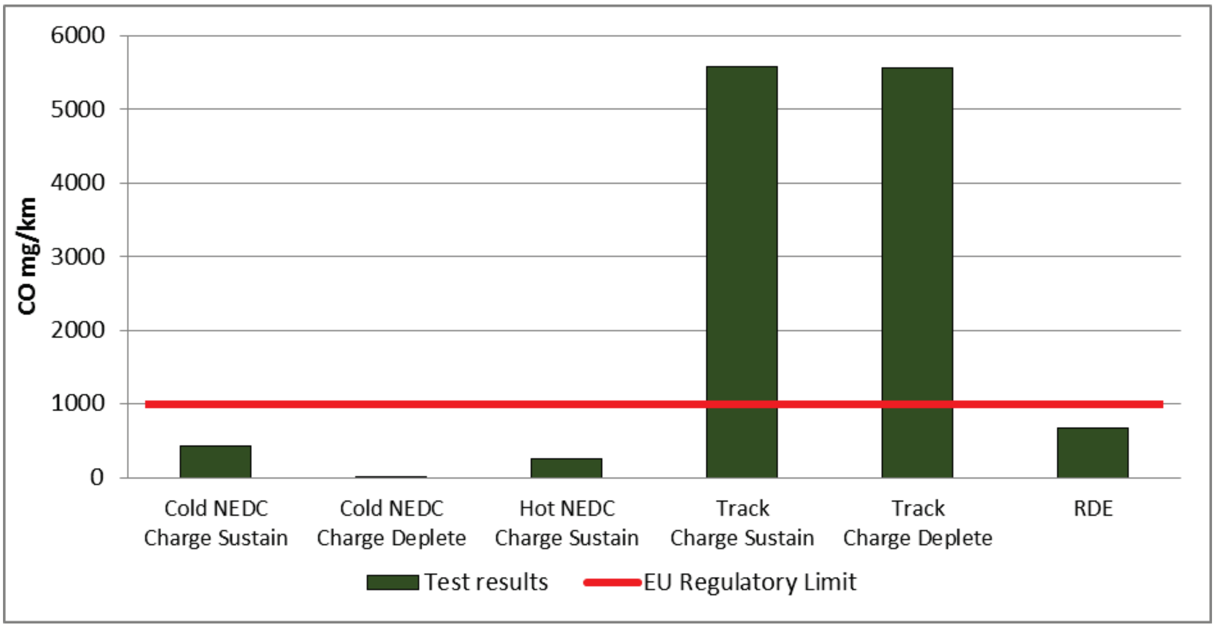

Figure 4-9 Laboratory NEDC (cold & hot), WLTP (track) and RDE CO emissions for PHEV car compared to the EU regulatory limits

4.25 Overall it seems that poor control of CO emissions during periods of fuel enrichment is a common trend for a number of the petrol vehicles tested in this year's programme. Whilst it is disappointing that such high levels of emissions are occurring for these vehicles we expect that recent changes to the regulatory requirements, including the introduction of WLTP and RDE, will significantly reduce this occurrence due to a broader coverage of driving behaviours within the testing. This includes more dynamic driving and higher accelerations, which are the situations in which enrichment is likely to occur on the road.

Diesel Cars

4.26 We tested 9 diesel passenger cars in this year's programme. When tested using the legislative laboratory test cycle, we initially found both the Vauxhall Astra SRI CDTi and the Volvo XC60 to be non-compliant. The results of the initial NEDC (cold) test for each vehicle are shown in figure 4-10.

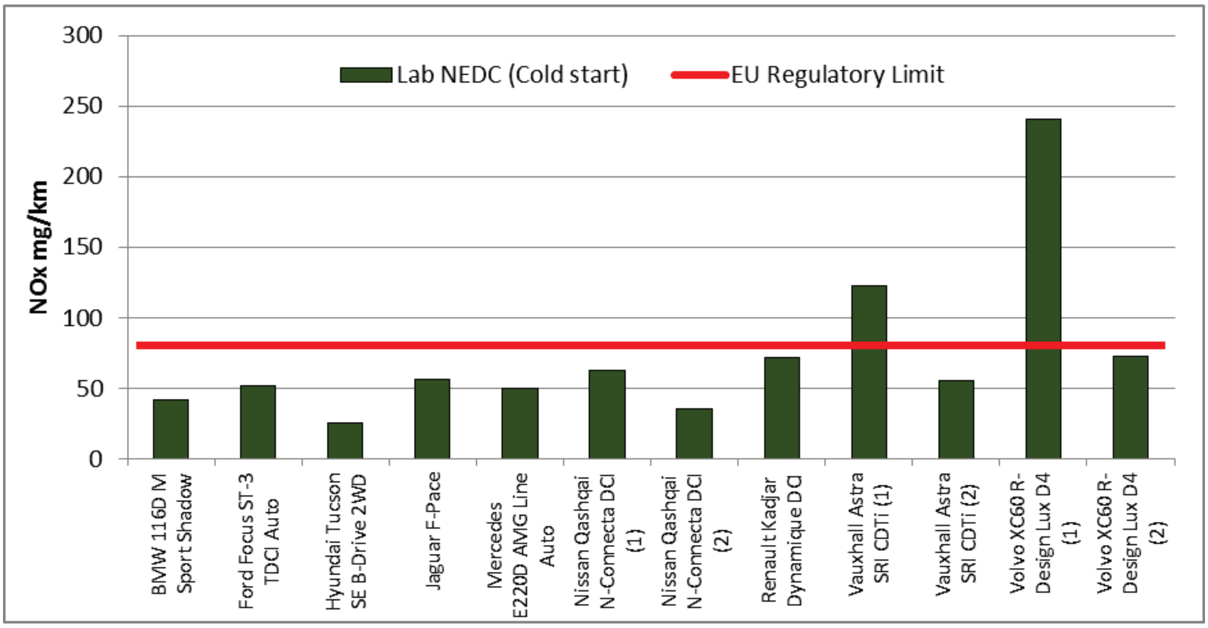

Figure 4-10 Laboratory NEDC (cold) results for diesel vehicles cars compared to the EU regulatory limits

4.27 We also tested the vehicles under the NEDC (hot) and found that 50% emitted a level of NOx above the recommended guidance limit. The results of the NEDC (hot) test for each vehicle are shown in figure 4-11 below.

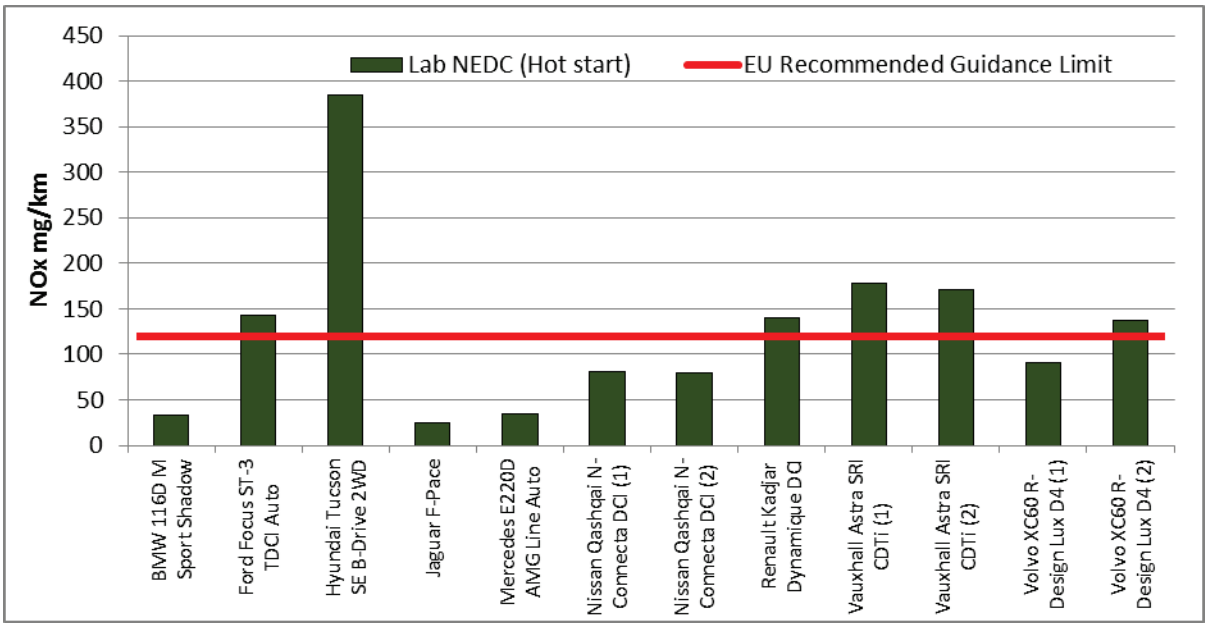

Figure 4-11: Laboratory NEDC (hot) results for diesel vehicles compared to the recommended guidance limits

4.28 NO_x emissions levels within the WLTP (track) testing were notably high, with emissions up to 20 times the limit for the legislated test cycle. It is likely that these increased emissions levels compared to the RDE test can in part be explained by the shorter test length, which allows less time for warm up of catalysts within the exhaust, and the highly transient nature of the vehicle speed during WLTP (track). The results of the WLTP (track) and RDE test for each vehicle are shown in figure 4-12 and 4-13 below.

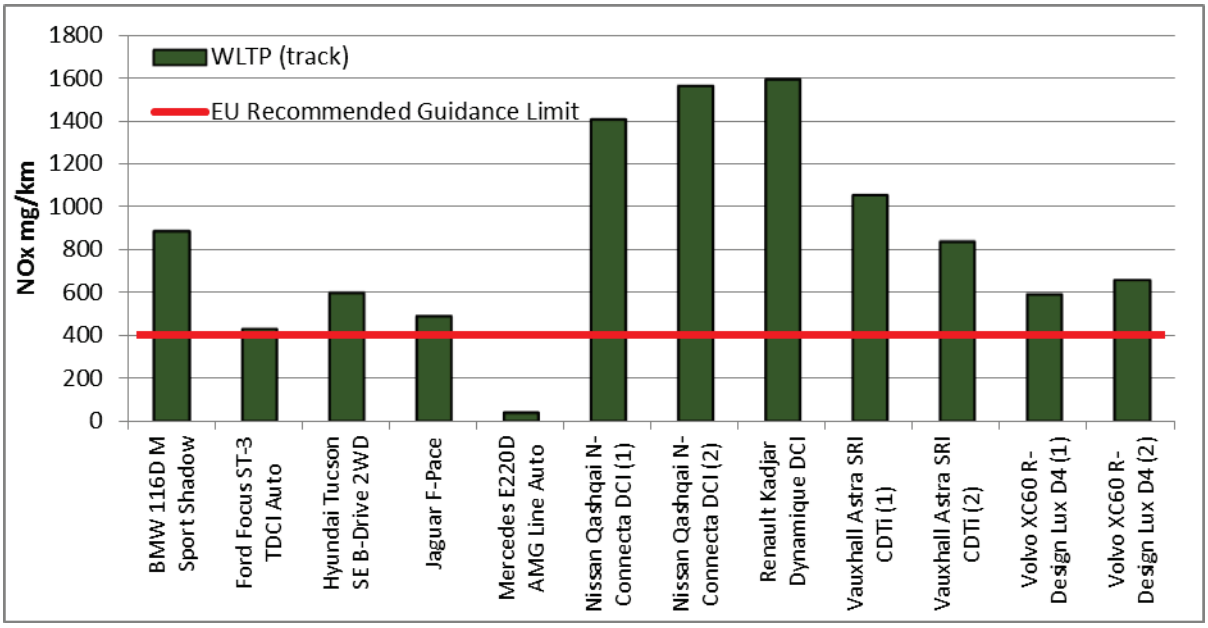

Figure 4-12: WLTP (track) results for diesel cars compared to the EU recommended guidance limits

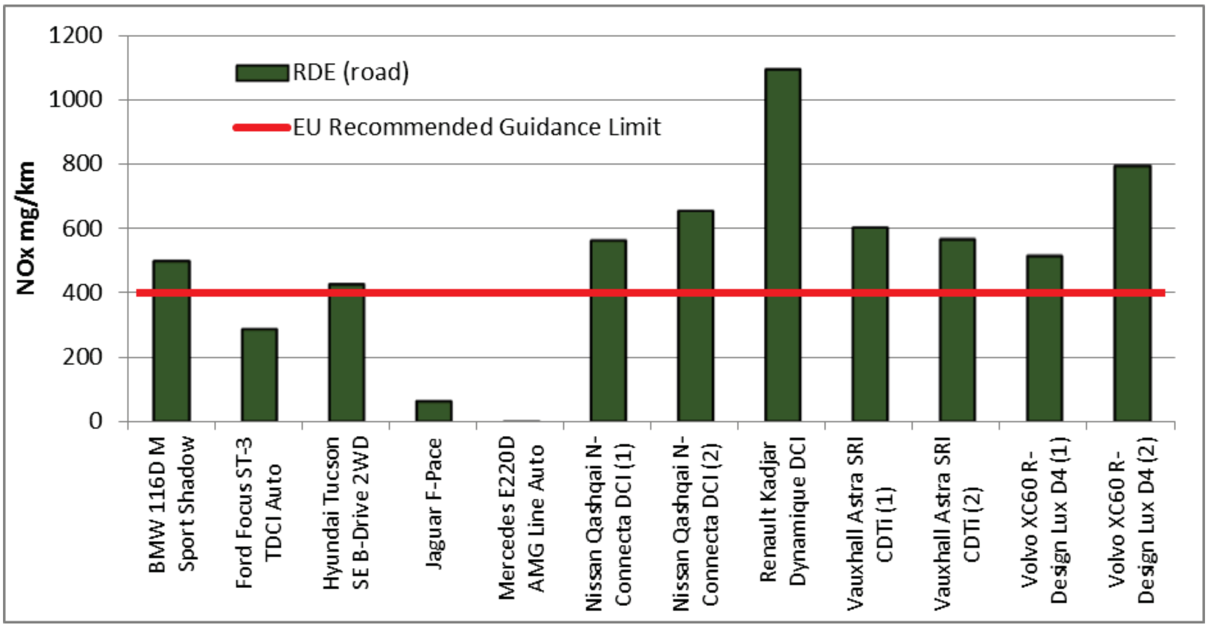

Figure 4-13: RDE (road) results for diesel cars compared to the EU recommended guidance limits

4.29 In order to gain a better understanding of the reasons for non-compliances and high levels of NO_x within NEDC laboratory, WLTP (track) and RDE testing we invited a number of manufacturers to discuss the results further.

Renault Kadjar Dynamique 110 dCI

4.30 When tested over the NEDC (cold), the vehicle failed. We retested and it failed again. We tested it for a third time and it passed.

4.31 The NEDC (hot) test shows high NO_x emission and exceeds the Commission guidance of 1.5 times the NEDC (cold) certification limit (138.8 g/km test vs 120 g/km guidance).

4.32 The vehicle was further tested over RDE and WLTP (track) cycles and the results were disappointing. Both tests delivered NO_x values far in exceedance of the Commission's guidance of 5 times NEDC regulatory limit. The RDE NO_x result was found to be over 13 times the regulatory limit and the WLTP NO_x (track) results were almost 20 times the regulatory limit. Both results were the worst NO_x levels that we have seen in this programme.

4.33 Testing showed no clear evidence of a Diesel Particulate Filter (DPF) regeneration on either test. The vehicle is fitted with a lean NO_x trap (LNT) and we found that there were a number of active deNO_x events, where NO_x is purged from the LNT, usually between 1400 – 1500rpm & 60 – 80kph.

4.34 Renault explained that their Conformity of Production (CoP) data is generally good, but that it is possible to find a vehicle which produces NO_x over the legislative limit, due to variability. The vehicle is equipped with a high and a low pressure exhaust gas recirculation (EGR) system.

4.35 To improve the emissions performance of the model, Renault has developed a level 1 update for older vehicles (launched prior to June 2016) and a level 2 update for newer ones (launched after June 2016), both of which, they claim, reduces NOx output.

4.36 Renault said they could not improve the emissions further than ‘level 1’ NO_x update for the older Euro 6b vehicles but they were proactively trying to upgrade these vehicles in the market. The Kadjar dCi campaign was launched in Europe on the 5th June 2018 and a direct mailing (between July and October 2018) was sent by Renault UK to each UK customer informing them that their vehicle will be updated at a Renault dealership. In 2018, Renault had completed 30% of updates (5,742 manual & 3,004 automatics).

4.37 However, the vehicle tested was already fitted with a level 1 NO_x upgrade, which makes the results even more shocking.

4.38 Renault have developed a level 2 upgrade, which they claim reduces NO_x emissions by 75%. This update has been included, prior to sale, in all newer vehicle models with Euro 6b Diesel applications launched after mid-June 2016. Disappointingly, Renault are not making this update available to older vehicles. They have told us this is because it may have a negative impact on the reliability and performance of these vehicles, including its CO_2 output.

4.39 The production of this vehicle stopped in September 2018 and the new Euro 6d temp Kadjar is fitted with a Selective Catalytic Reduction (SCR) system replacing the LNT, which should more effectively reduce NO_x emissions in real world conditions.

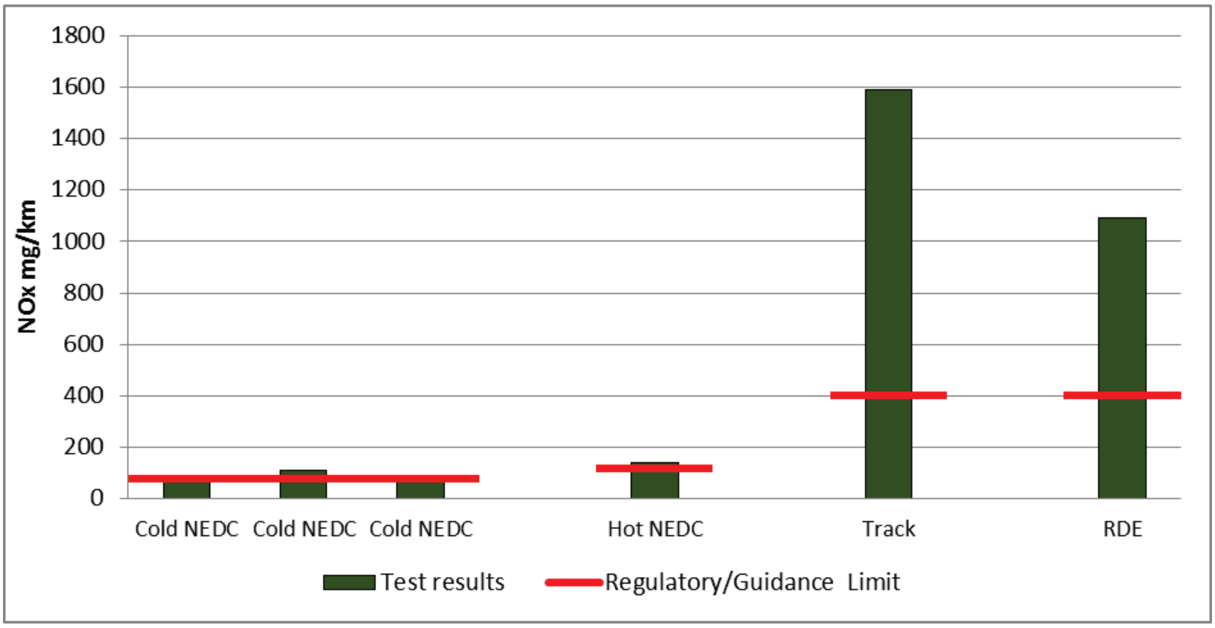

Figure 4-14: NO_x emissions for the Renault Kadjar Dynamique DCI. Limit shown is the legislative limit for the NEDC (cold) test and the recommended guidance limits for the other tests

Nissan Qashqai

4.40 In the case of the Nissan Qashqai, this vehicle passed the NEDC (cold) and NEDC (hot) tests.

4.41 However, both RDE and WLTP (track) tests delivered NO_x emission levels, in exceedance of the Commission guidance (5 times the NEDC legislative limit). The WLTP (track) test result was found to be more than 17 times the legislative limit. This significant exceedance shows that this vehicle is not sufficiently well designed to control NO_x in real world conditions.

4.42 The high levels of NO_x indicated that there may have been a possible problem as the vehicle passed the laboratory tests. We found no clear evidence of a DPF regeneration on any test. Therefore, a second vehicle was tested to see how it behaved.

4.43 The second vehicle passed the NEDC (cold) test on the second attempt but also recorded high NO_x readings on both WLTP (track) and RDE tests.

4.44 On sharing the results with Nissan, they explained that the high pressure exhaust gas recirculation (EGR) functions within a specific range of temperature. At lower temperatures, the function of the EGR will be reduced. This can result in increased NOx in real world conditions as is demonstrated in the RDE testing.

4.45 Nissan said that they had vastly improved their emissions strategies since 2015 and that a Qashqai with an SCR system was launched in the summer 2018 (Euro 6d temp). They said that they cannot further improve the emissions on this technology.

They explained the level 1 and level 2 NO_x upgrades (as with the Renault Kadjar) but said that these had been improvements made to production vehicles and that it is not possible to do a recalibration for existing customers as they want to focus their energy and resources on the new models. Nissan agreed that the WLTP (track) results seemed high but as they had not carried out any of their own testing on this, they were unable to provide us with detailed comments.

4.46 We find Nissan's approach on addressing these extremely high emitting vehicles unacceptable as we are aware that Renault who uses a similar engine in the Kadjar, issued a voluntary offer to customers visiting a Renault dealership to implement a NO_x upgrade (see paragraph 4.36).

4.47 We will look to test a Euro 6d temp Nissan Qashqai in next year's programme to ensure these new vehicles are compliant with WLTP and RDE.

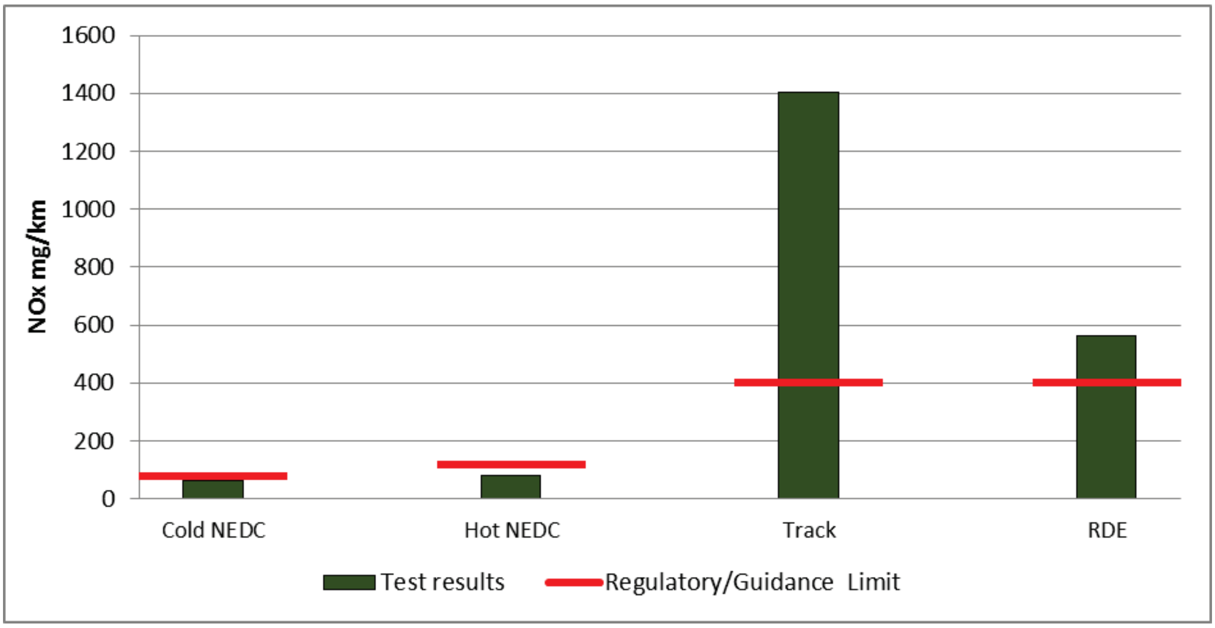

Figure 4-15: NO_x emissions for the Nissan Qashqai N-Connecta DCI (vehicle 1). Limit shown is the legislative limit for the NEDC (cold) test and the recommended guidance limits for the other tests

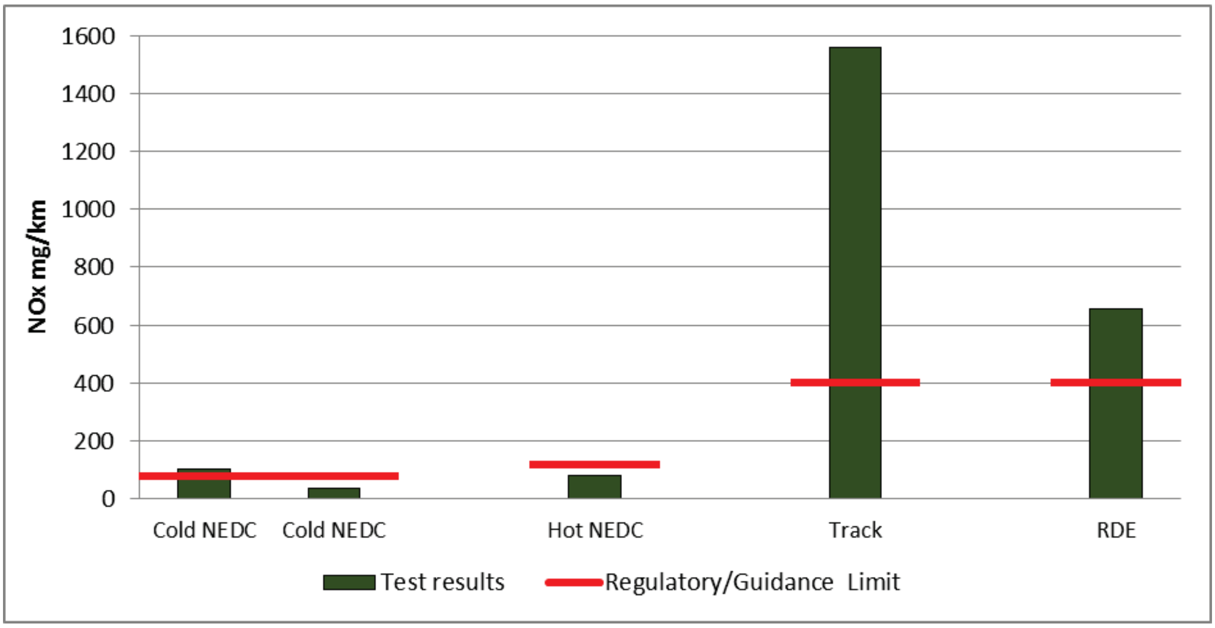

Figure 4-16: NO_x emissions for the Nissan Qashqai N-Connecta DCI (vehicle 2). Limit shown is the legislative limit for the NEDC (cold) test and the recommended guidance limits for the other tests

BMW 116D M Sport

4.48 This vehicle comfortably passed the NEDC laboratory tests.

4.49 We found that when conducting the WLTP (track) and RDE tests, NO_x emissions were significantly higher than the Euro 6 laboratory test limit for this vehicle. The WLTP (track) result was of particular concern with NO_x emissions over double the commission guidance. However, there was evidence that the vehicle had attempted to complete a DPF regeneration whilst completing the WLTP (track) test.

4.50 While RDE and WLTP (track) was not a legislative approval requirement when this vehicle was approved, we invited BMW to explain why these results were so high.

4.51 BMW advised that they had conducted their own tests. They had asked Dekra (independent automotive inspectors) to conduct an RDE test. The first test found very low NO_x, but DPF regenerations occurred in 7 subsequent tests, which resulted in higher NO_x emissions.

4.52 BMW advised that the PEMS system used during the test influenced the back-pressure (resistance to air flow) which is measured in the Engine Control Unit. This could cause the DPF to regenerate more frequently as the system believes it has more soot accumulated within the filter than it actually has.

4.53 It was agreed with BMW to retest the vehicle. The NEDC (cold) test again showed compliance. The result for the second NEDC (hot) test was double what it had been for the initial test but still within acceptable limits.

4.54 RDE data shows almost identical performance between the original test and retest (498mg/km NO_x original, vs 556mg/km retest) and both results are in line with the BMW data.

4.55 WLTP (track) data shows a significant improvement in NO_x performance with the retest (980mg/km original, vs 524mg/km retest). A significant portion of the difference between the 1st and 2nd tests appears to be due to DPF regeneration in the original test and large spikes of emissions during LNT deNO_x events.

4.56 Although the WLTP retest shows a reduction in NO_x, it is disappointing that the WLTP and RDE figures are still in exceedance of the recommended guidance limits.

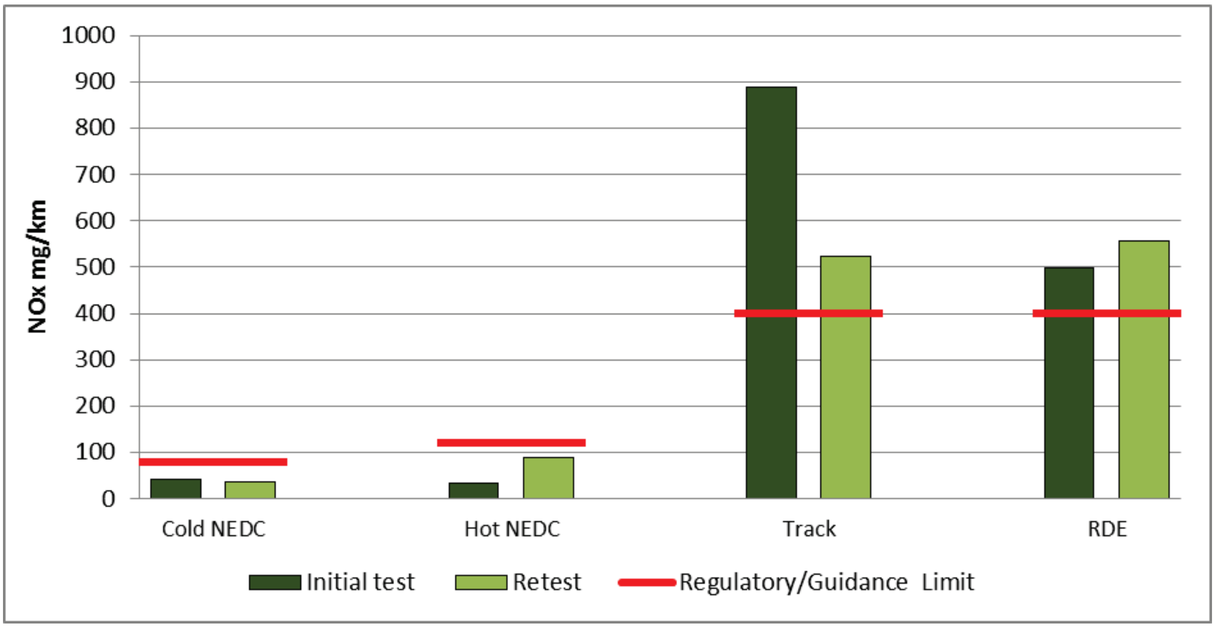

Figure 4-17: NO_x emissions for the BMW 116D M Sport Shadow. Limit shown is the legislative limit for the NEDC (cold) test and the recommended guidance limits for the other tests

Ford Focus ST-3 TDCI auto

4.57 The vehicle passed the NEDC (cold) test but the NEDC (hot) test results showed high NO_x emissions of 142.9 mg/km, which exceeds the commission guidance of 1.5 times NEDC (cold) legislative limit g/km.

4.58 The vehicle exceeded guideline NOx limits during the WLTP (track) test but met them during the RDE test.

4.59 When we shared our findings with Ford, they explained that the hot NEDC result should have been 26 mg/km of NO_x. They observed two Lean NO_x Trap (LNT) purges on our drive cycle. They believed the LNT lost all of its storage capacity on the hot NEDC which is not what they would expect of this vehicle. Ford requested that the vehicle undergo retesting. They stated that vehicle idling between the cold and hot NEDC tests could have caused the high NO_x level. VCA explained that the procedure is to key off between these tests to avoid idling and that there is no pre-conditioning before the hot test. Ford said that the WLTP NO_x and CO_2 emissions were higher than they would expect, but that the results showed two periods of high load within the testing in which the emissions control was at its limit. They explained that the automatic transmission may be causing it to run at higher engine loads.

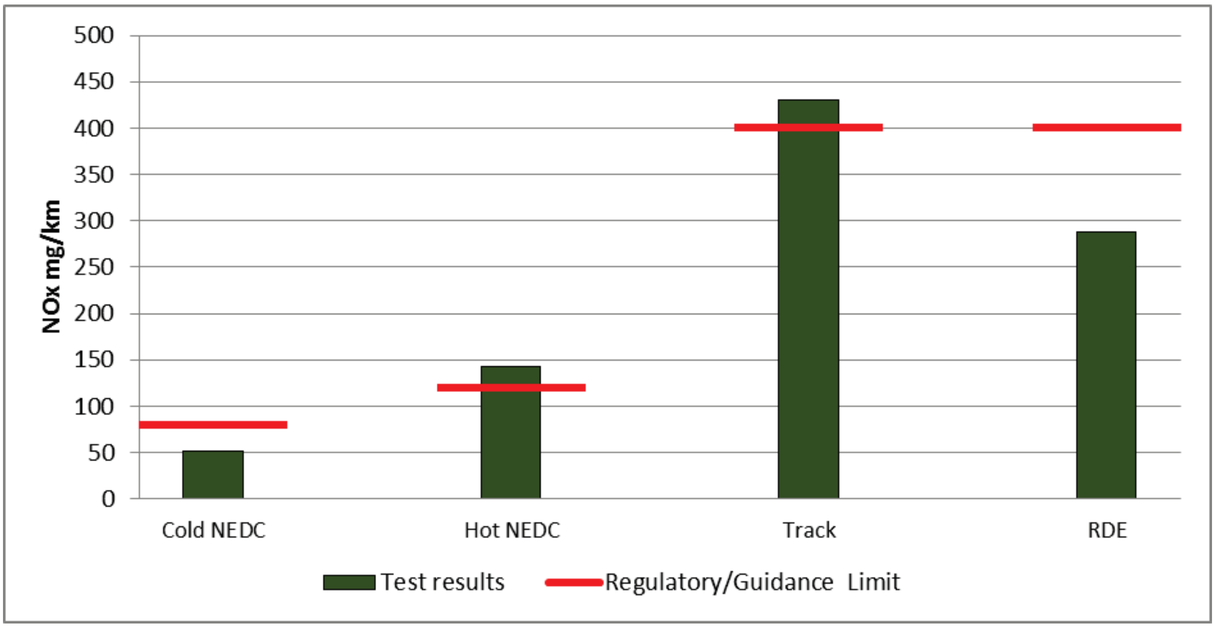

Figure 4-18: NO_x emissions for the Ford Focus ST-3 TDCI Auto (initial). Limit shown is the legislative limit for the NEDC (cold) test and the recommended guidance limits for the other tests

4.60 The vehicle underwent NEDC (hot and cold) retesting and results showed that it was within guideline limits. The results were as follows; NEDC (cold) were under limits; initial NEDC (hot) under 1.5 times the regulatory limit; 2nd NEDC (hot) under lab limit.

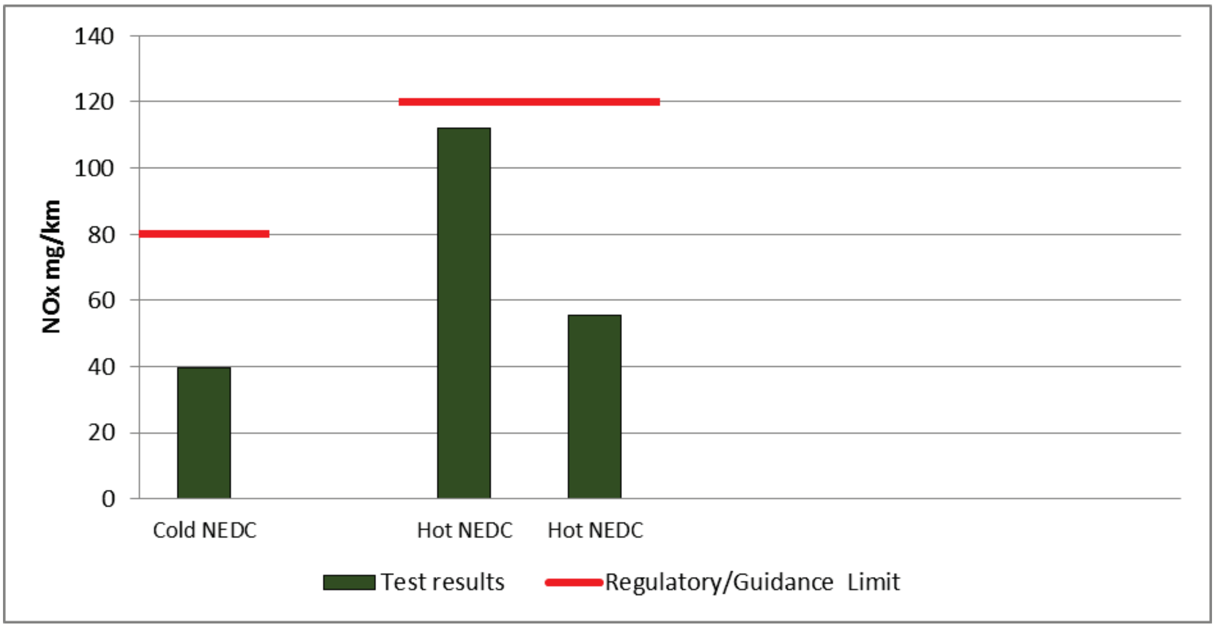

Figure 4-19: NO_x emissions for the Ford Focus ST-3 TDCI Auto (retest). Limit shown is the legislative limit for the NEDC (cold) test and the recommended guidance limits for the other tests

Hyundai Tucson SE B-Drive 2WD

4.61 Our initial tests of the Hyundai Tucson on the NEDC (cold) resulted in NO_x emissions comfortably under regulation limit but the NEDC (hot) was found to be higher than expected, at over three times the regulation limit (however a DPF regeneration was suspected to have occurred during testing). Results from the WLTP (track) and RDE tests also exceeded the commission guidance.

4.62 When we met with Hyundai to discuss these results, they explained that they also acknowledged the strange behaviour of NO_x and Hydrocarbon (HC) at the end of the NEDC (hot) test cycle. They believed that there was a DPF regeneration during the test. When asked why the Lean NO_x Trap (LNT) could not deal with the higher NO_x Hyundai explained that LNT activity is dictated by the load on the vehicle.

4.63 Hyundai made the point that due to the increased number of accelerations and higher loads in the WLTP (track) test compared to NEDC the LNT performed poorly in certain areas of the test. They highlighted that the vehicle was approved in 2015 and so does not have the 'state of the art' technology that more modern vehicles do, although they are developing a new system with SCR.

4.64 Hyundai agreed that the WLTP (track) and RDE results are what they would expect from this vehicle, although they had never measured WLTP.

4.65 The vehicle underwent a retest at DfT's request due to possible regeneration of DPF during the NEDC (hot) test. A Hyundai Engineer attended under supervision of MSU. Prior to the NEDC (hot) test we carried out a forced regeneration of the DPF and checked for any fault codes; none were found and the regeneration was completed successfully. We retested the vehicle and were content that the high level of NO_x in the NEDC (hot) test was caused by a DPF regeneration. However, we remain disappointed with the level of NO_x in the real world conditions.

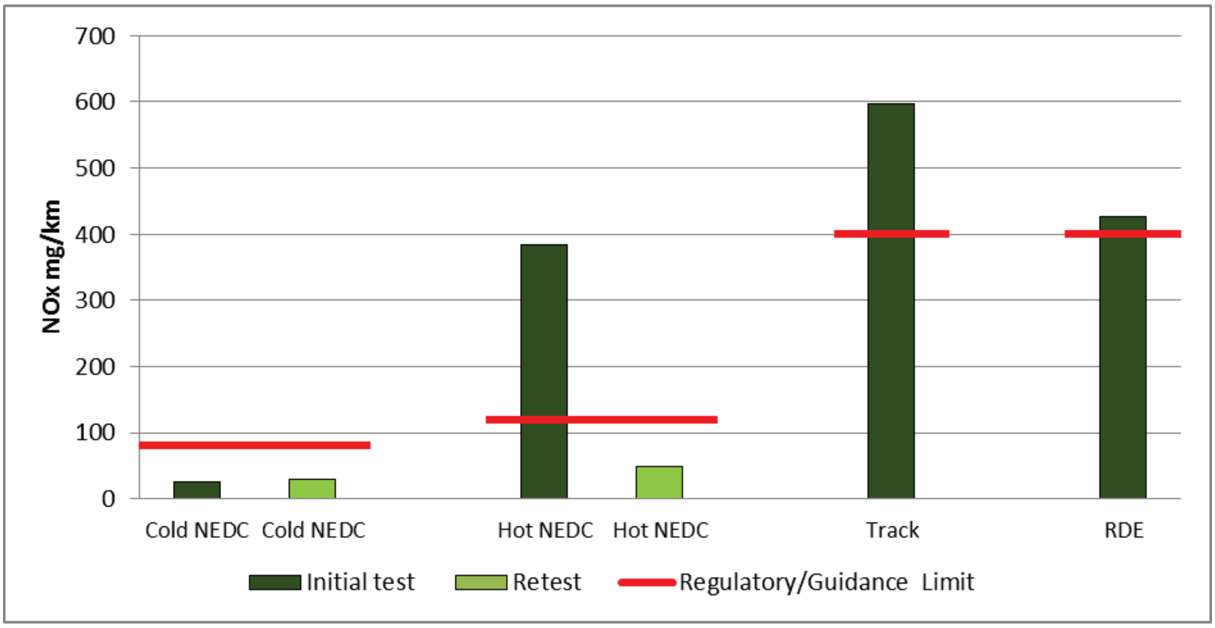

Figure 4-20: NO_x emissions for the Hyundai Tucson SE B-Drive 2WD. Limit shown is the legislative limit for the NEDC (cold) test and the recommended guidance limits for the other tests

Vauxhall Astra SRi CDTI

4.66 The testing results of the Astra raised concerns in terms of NO_x.

4.67 Initial tests showed that the Astra failed the laboratory NEDC (cold and hot) tests. We arranged for a second vehicle to be tested to check that it wasn't an issue with that specific vehicle. Although the second vehicle passed the NEDC (cold) test, it did exhibit significantly increased NO_x when running the NEDC (hot) test.

4.68 When we shared the results with Vauxhall they offered a number of possible explanations for the results, none of which were convincing.

4.69 We were surprised that NO_x emissions had increased to more than twice the legislative limit when tested on the NEDC (hot) cycle in a condition where the vehicle would not know it was under test. This is a standard cycle in which the vehicle is not driven aggressively. WLTP (track) and RDE test results also showed high NO_x. Vauxhall explained that they had not conducted a WLTP (track) cycle test for this vehicle so were unable to comment but they had carried out RDE tests and found similar results to MSU.

4.70 Vauxhall highlighted that the engines for these vehicles had been developed some time ago (2013/14) and were used in the previous generation Astra. Since that time, expectations have changed and all of their newer models contain an SCR system, rather than just LNT. Therefore, the high NO_x on the RDE test could be expected from a vehicle which had no SCR system.

4.71 On the request of the manufacturer, the vehicle was retested. Vauxhall engineers inspected the vehicle and downloaded codes/data from the ECU. The preconditioning and DPF regeneration were both carried out the same day. The vehicle was tested the next day; NEDC (cold) followed by NEDC (hot).

4.72 Vauxhall shared with us that they are currently working with the German approval authority, KBA, to develop a recalibration of the emissions control system to improve emissions performance. Vauxhall expect the recalibrated software to reduce NOx emissions in the real world by about 50%.

4.73 Approval of the modification is still pending. Following approval, Vauxhall will apply the modification to all vehicles across Europe, including the 13,864 vehicles in the UK. Vauxhall will offer this upgrade to UK customers via direct mail. Vauxhall have informed us that the upgrade will be free of charge for customers and will take approximately 30 minutes.

4.74 It was agreed with Vauxhall that we will test a recalibrated vehicle to validate whether emissions in the real world are reduced. We expect to publish the results in the next report.

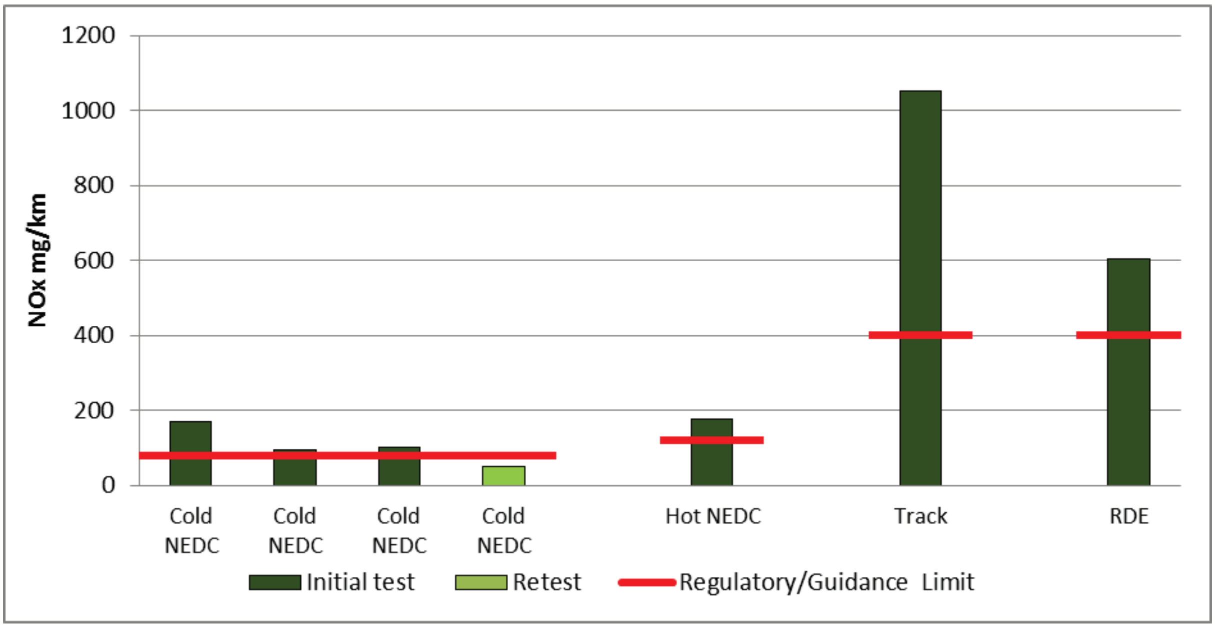

Figure 4-21: NO_x emissions for the Vauxhall Astra SRI CDTi (1). Limit shown is the legislative limit for the NEDC (cold) test and the recommended guidance limits for the other tests

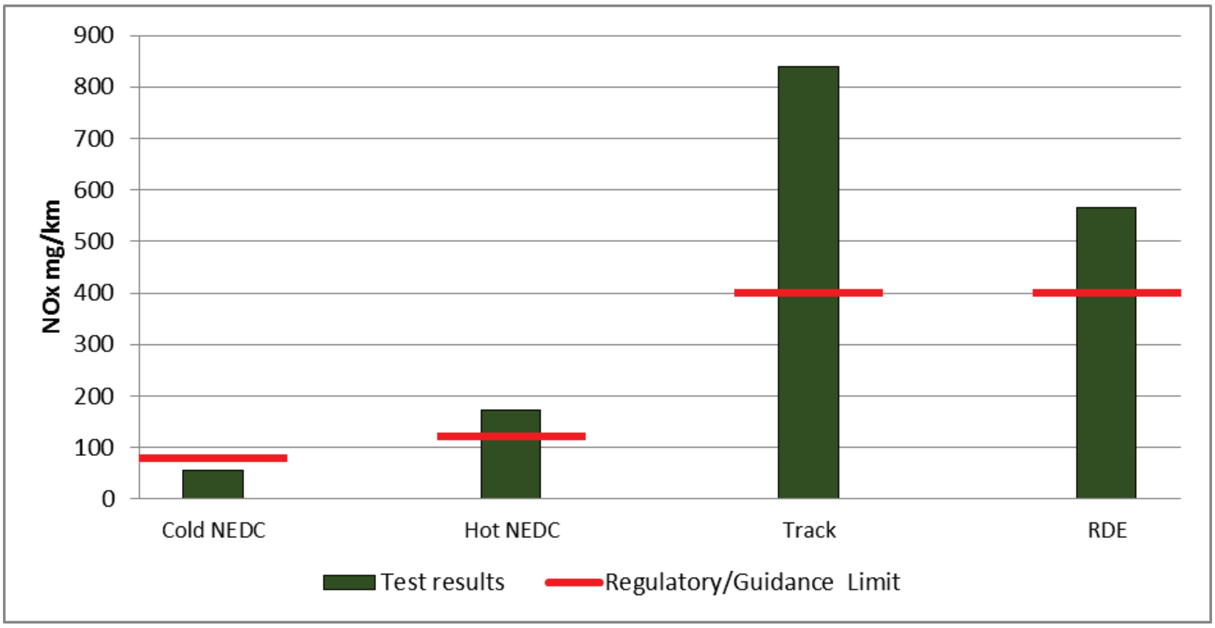

Figure 4.22: NO_x emissions for the Vauxhall Astra SRI CDTi (2). Limit shown is the legislative limit for the NEDC (cold) test and the recommended guidance limits for the other tests

Jaguar F-Pace Portfolio AWD

4.75 The Jaguar F-Pace's emission levels were comfortably below the limits on the legislative NEDC (cold) test. The results were also acceptable during the hot test.

4.76 The vehicle was further tested over RDE and WLTP (track) cycles. The RDE testing showed generally excellent results with NO_x and PM significantly below commission guidance.

4.77 The WLTP (track) testing however exhibited unexpectedly high levels of NO_x, the test being repeated to confirm the levels. On both test runs the NO_x level recorded exceeded the commission guidance of 5 times the NEDC certification limit, delivering 493 and 533 mg/km vs 400 mg/km guidance.

4.78 From the data recorded it was not clear if a DPF regeneration was occurring. We found that there was no unexpected rise in exhaust temperature and no increase in CO that are indications of a DPF regeneration. However, when we met with Jaguar Land Rover (JLR) to discuss these results, they stated that DPF regeneration was the cause of high WLTP (track) NO_x readings and shared their data.

4.79 The MSU has taken the decision to examine the vehicle in more detail to verify JLR's claims. We intend to include the final outcome of this investigation in our next report.

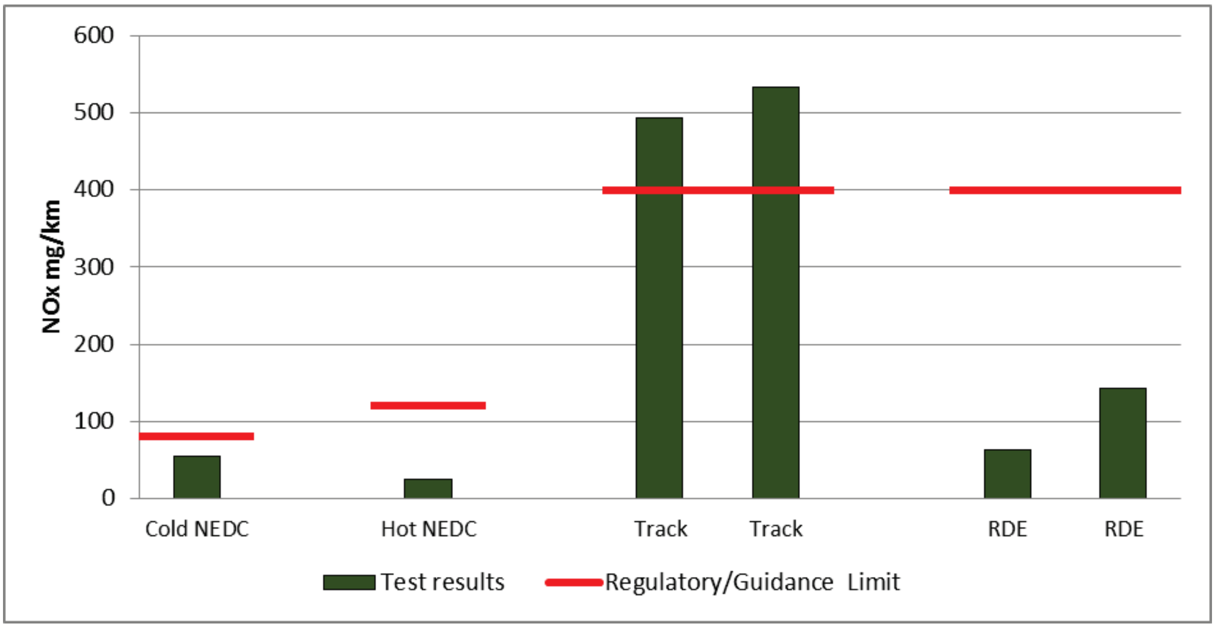

Figure 4-23: NO_x emissions for the Jaguar F-Pace. Limit shown is the legislative limit for the NEDC (cold) test and the recommended guidance limits for the other tests

Volvo XC60

4.80 Initial testing of the vehicle resulted in a failure to pass the NEDC (cold) test. We arranged for a second vehicle to be tested to check that the higher than expected figures were not due to a poorly performing vehicle. Both were tested cold and one vehicle tested hot. Although there were significant differences in emission response between the two vehicles we observed that neither vehicle could achieve a consistent NO_x value that met the legal requirement.

4.81 When we met with Volvo, they highlighted that their LNT storage capacity is temperature dependent and that there are no NO_x sensors in the Euro 6b vehicles. In addition, the EGR operation is limited in high torque and highly transient engine operation. They also noted that the behaviour of the system was as they would expect. The LNT was saturated with NO_x at the start of the test but the preconditioning had not been adequate to achieve optimum deNOx of the LNT. They advised that vehicle 1 had a regeneration event in the third NEDC (cold) test where the vehicle was removing soot from the DPF while also trying to remove sulphur from the LNT.

4.82 For vehicle 2, Volvo explained that the LNT was not as saturated as it was for vehicle 1, but a LNT deNO_x was aborted at the end of the test due to the temperature being too high. We found in the final test that the NO_x emissions were improved as the deNO_x had occurred.

4.83 Volvo advised that vehicle 1 had not performed as they expected but that vehicle 2 was within expected variations. They also thought that pre-conditioning prior to the tests should have dealt with the deNO_x issue. The following were also noted as factors that could have affected the results: the lack of stop-start; air-conditioner being active; alternator smart charge and driver behaviour.

4.84 Volvo said they would expect the vehicle to produce 400 mg/km in RDE conditions, but that it is possible to achieve higher results when driven aggressively. We agreed to retest vehicle 1 and to allow Volvo engineers to inspect the vehicle under MSU supervision. A DPF regeneration was carried out during the road test so that the LNT was not saturated with NOx.

4.85 Although the manufacturer offered an updated version of the engine calibration software, we decided it was important that the vehicle was tested with the original software to allow results comparison. The preconditioning was carried out in Dyno Mode (activated by a Volvo engineer) to ensure the battery would not overcharge, activate stop-start and deactivate non-essential activities such as the air conditioning.

4.86 NO_x levels in the repeated NEDC (cold) test met the legislative requirements. As the NEDC (hot) NO_x level was also found to be below the guideline limit of 1.5 times the legislation limit, the vehicle was now considered to be compliant.

4.87 Whilst recognising that the vehicle was now meeting its regulatory requirements, we remain disappointed in the levels of NO_x over the RDE & WLTP (track) tests and will be keeping this model under review to ensure there are no on-going issues with compliance.

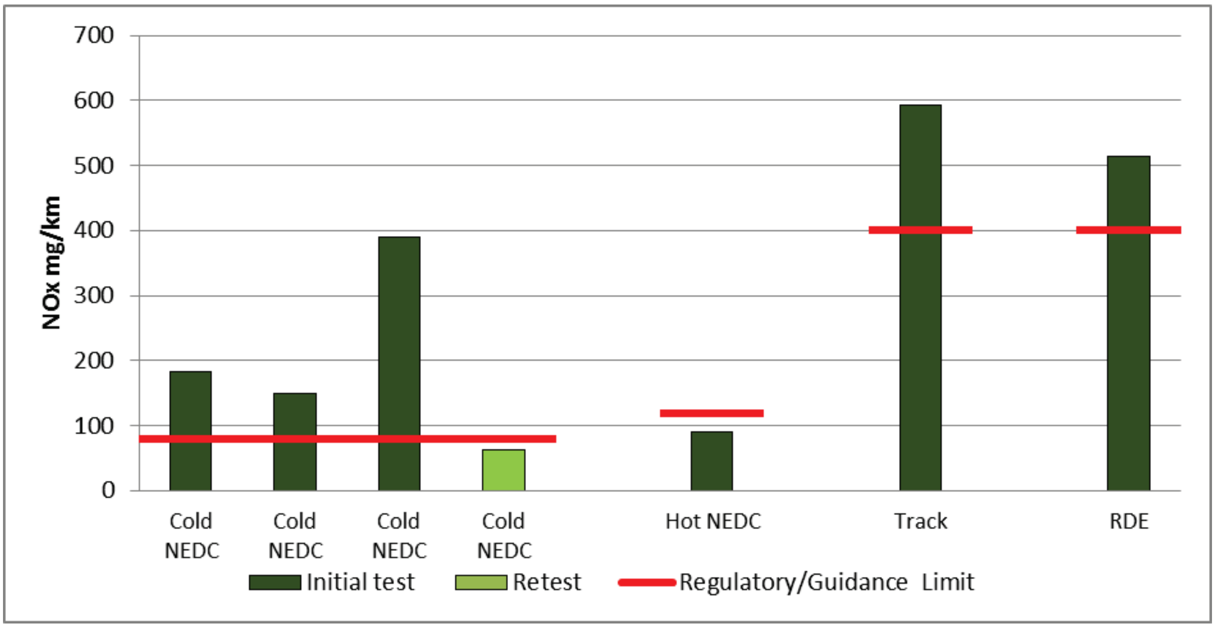

Figure 4.24: NO_x emissions for the Volvo XC60 R-Design Lux D4 (1). Limit shown is the legislative limit for the NEDC (cold) test and the recommended guidance limits for the other tests

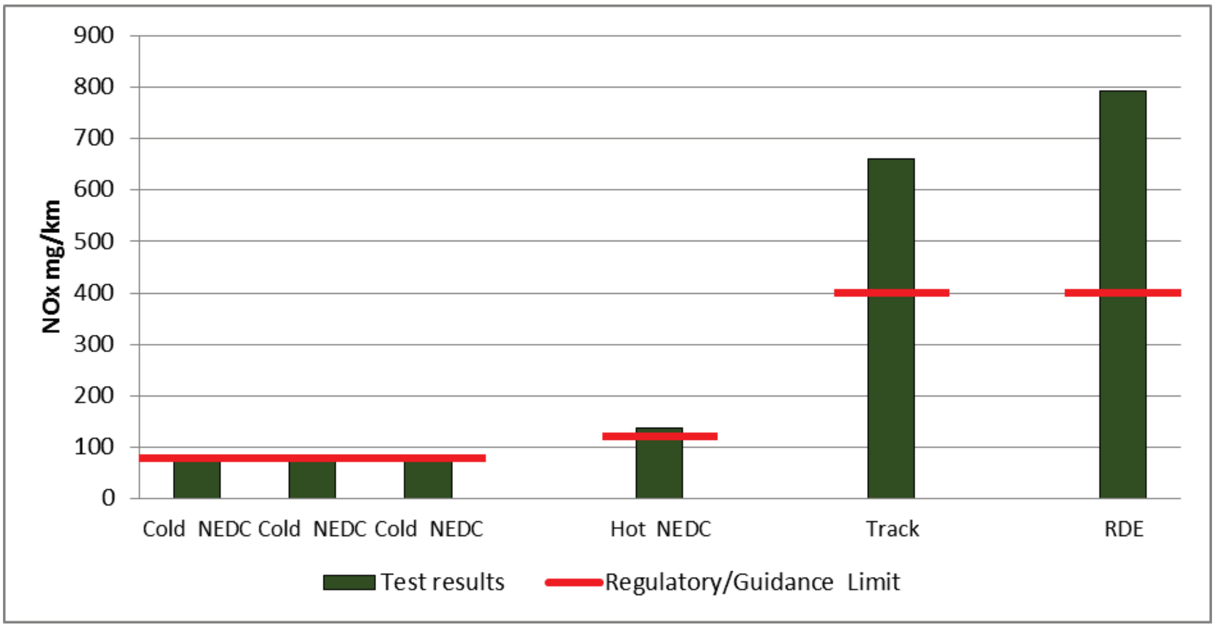

Figure 4-25: NO_x emissions for the Volvo XC60 R-Design Lux D4 (2). Limit shown is the legislative limit for the NEDC (cold) test and the recommended guidance limits for the other tests

Jeep Grand Cherokee

4.88 In 2017 we agreed with Fiat Chrysler Automobiles (FCA) that they would develop an in-service voluntary upgrade for their Euro 5 Jeep Grand Cherokee. This upgrade was expected to be offered to their customers on a voluntary basis in April 2018. The FCA has provided a prototype of the upgraded calibration to another European Authority in August 2018. This update is undergoing testing and FCA expects to implement the recalibration in the UK (1750 vehicles) as soon as it has been approved. We will test a recalibrated vehicle to verify the improvements when available.

Light Vans & Pick-Up Trucks

4.89 We tested two pick-up trucks and two light vans in this programme. Our test results showed that the Ford Transit Custom, Ford Ranger Wildtrak and the Mitsubishi L200 are compliant with the NEDC (cold) testing of 125 NO_x mg/km.

4.90 Although the Mercedes Vito passed the NEDC (cold) test, we found that this vehicle performed poorly in the NEDC (hot) and real world tests.

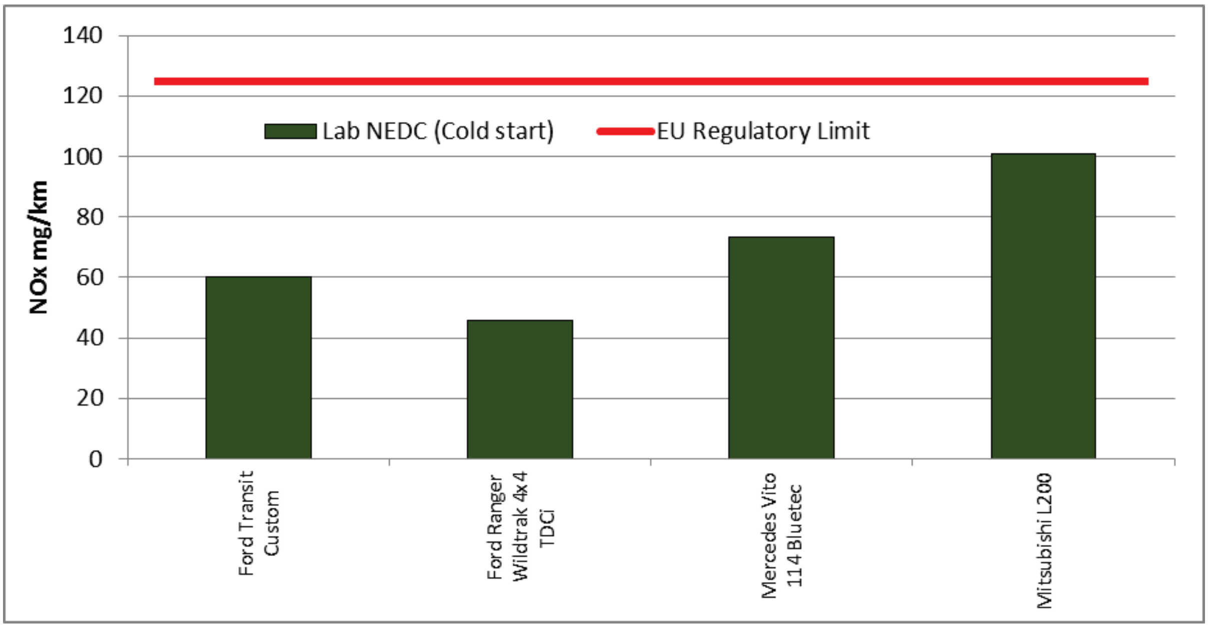

Figure 4-26: Laboratory NEDC (cold) results for diesel vans and pickups cars compared to the EU regulatory limits

Mercedes Vito

4.91 When tested on the NEDC (cold) cycle, the vehicle was well below the legislative requirements, but NO_x results for the NEDC (hot) and WLTP (track) tests were above the EU Commission's guidance. The RDE result at 458 mg/km was below the guide limit of 625 g/km, although higher than we would expect considering that the vehicle is fitted with twin SCR catalysts. We were concerned about the results, in particular with the difference between the cold and hot NEDC tests. We therefore invited Mercedes to explain the results.

4.92 When we met with Mercedes, they showed that the left hand drive (LHD) and right hand drive (RHD) vehicles had different structures in the after-treatment system. In the RHD variant, the DPF and Diesel Oxidation Catalyst (DOC) are positioned further away from the engine making it more difficult for them to reach and remain at a suitable temperature to treat emissions effectively.

4.93 Mercedes discussed their EGR strategy and the temperature bounds in which each of its components can operate. At low temperature, EGR is reduced to prevent damage to the engine. However, Mercedes confirmed that the level of EGR should not have affected the results for RDE and WLTP (track) tests at the temperature they were conducted.

4.94 They also described a number of factors affecting the operation of the SCR system. Mercedes said that the temperature during sections of the RDE testing would likely have been too low for the SCR system to operate and so no AdBlue dosing was occurring. This was assumed from the tailpipe temperature in the MSU data. When we asked why NO_x was also being released at the end of the test (by which time the SCR should have warmed up) Mercedes stated that this could have been due to the high speed / load conditions.

4.95 Mercedes conducted their own tests to determine why there was such a difference in NO_x between the hot and cold NEDC. They confirmed that after the cold NEDC test, a heat-up mode is engaged to allow the catalysts within the exhaust to reach a suitable temperature for emissions treatment. This mode requires a list of factors to be satisfied in order for it to engage. Under the conditions of the NEDC (hot), this mode did not engage, resulting in insufficient temperatures for the SCR system to treat NO_x emissions for significant portions of the test.

4.96 In May and August 2018, the KBA issued administrative orders addressed to Daimler AG (“Daimler”), stating that it considered that certain software functionalities used in a number of models, including the Vito model that we tested, constituted illegal emissions strategies. Daimler is contesting that finding. The KBA ordered Daimler to (i) stop first registrations of newly-produced affected vehicles until a software update is carried out that would remove the alleged defeat devices, and (ii) to recall affected vehicles that are already on the road in order to carry out this software update. Until the software update was available, the KBA did not prevent affected vehicles from being used on the road.

4.97 Mercedes issued a voluntary recall in November 2018 for all 16,778 affected Vito vehicles in the UK. As of January 2019, 4,949 (30%) of these vehicles had had the software update applied. Mercedes confirmed to us that they have frozen all sales of vehicles requiring recalibration and are applying the approved software update to unsold vehicles before they are released onto the market.

4.98 The KBA's findings confirm our own concerns with the test results of the Mercedes Vito. We remain concerned that these high-emitting vehicles continue to be driven on UK roads and will be retesting the vehicle following the software update.

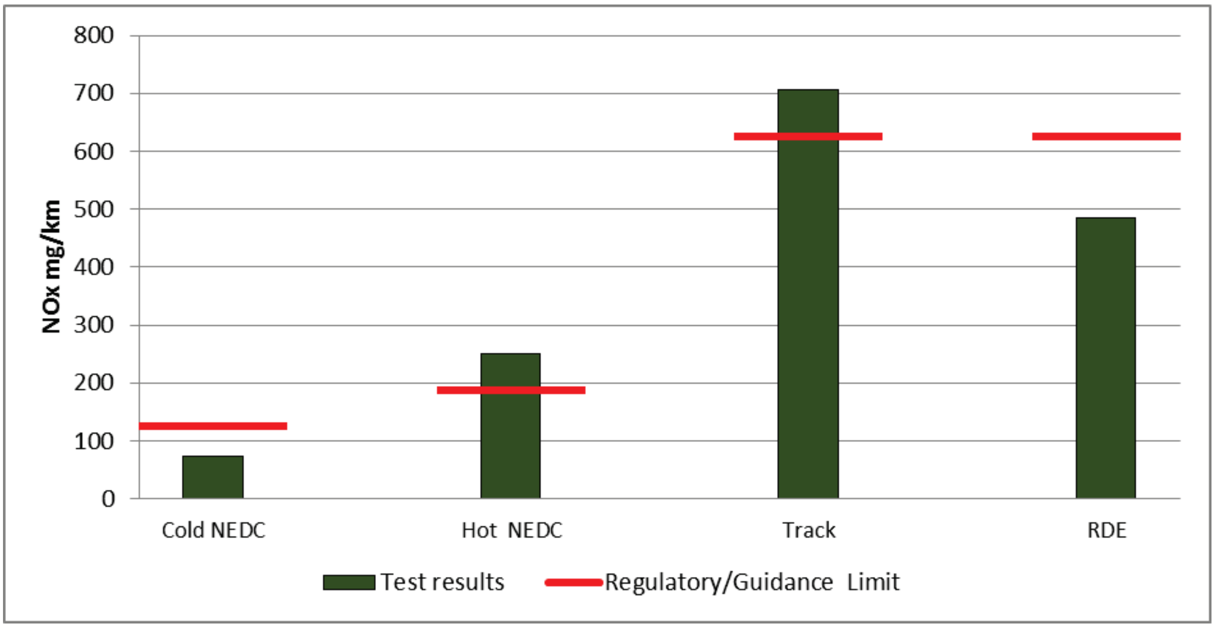

Figure 4.27 NO_x emissions for the Mercedes Vito 114 Bluetec. Limit shown is the legislative limit for the NEDC (cold) test and the recommended guidance limits for the other tests

Trucks

4.99 For heavy duty vehicles, testing was conducted in line with the Euro VI in-service, on-road emissions test as described in section 3.16. We tested 3 trucks in this programme. We found all of these to be compliant with the legislative limit.

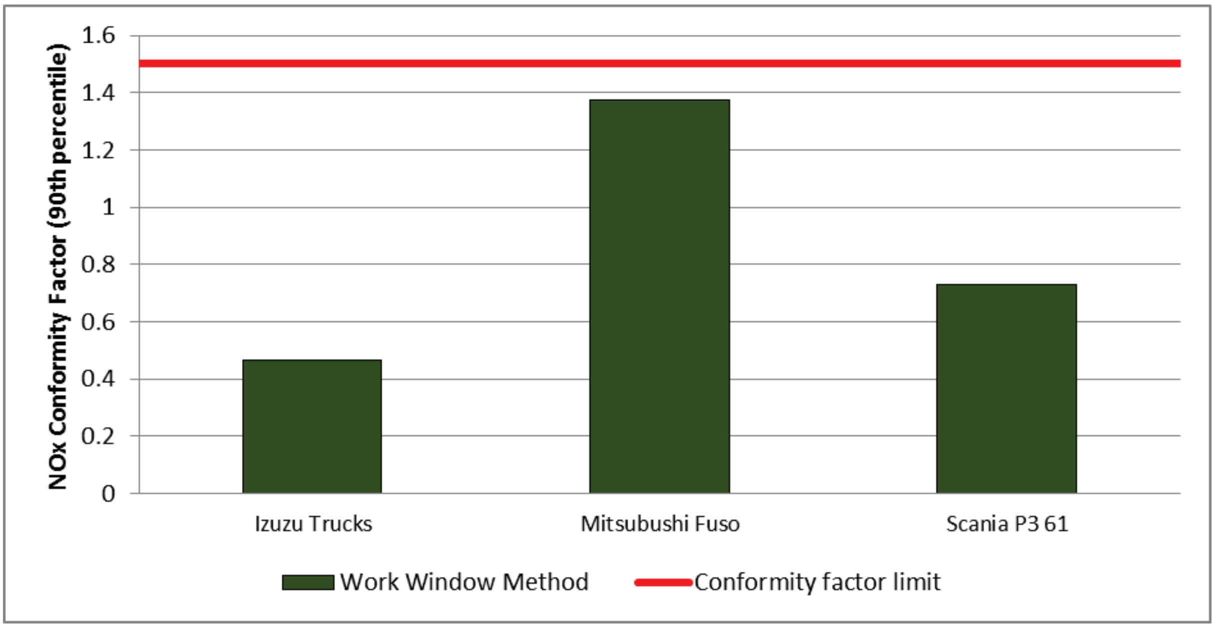

Figure 4-28: Results of the in-service, on-road emissions tests conducted on 3 HGVs. NO_x results have been calculated in line with the relevant conformity factors described in section 3.13

Public Service Vehicles

4.100 We tested 1 bus and 1 coach in this programme, the Scania Higer and the Iveco Sitcar Voyager. Test results for both vehicles show that they are compliant with the legal obligation.

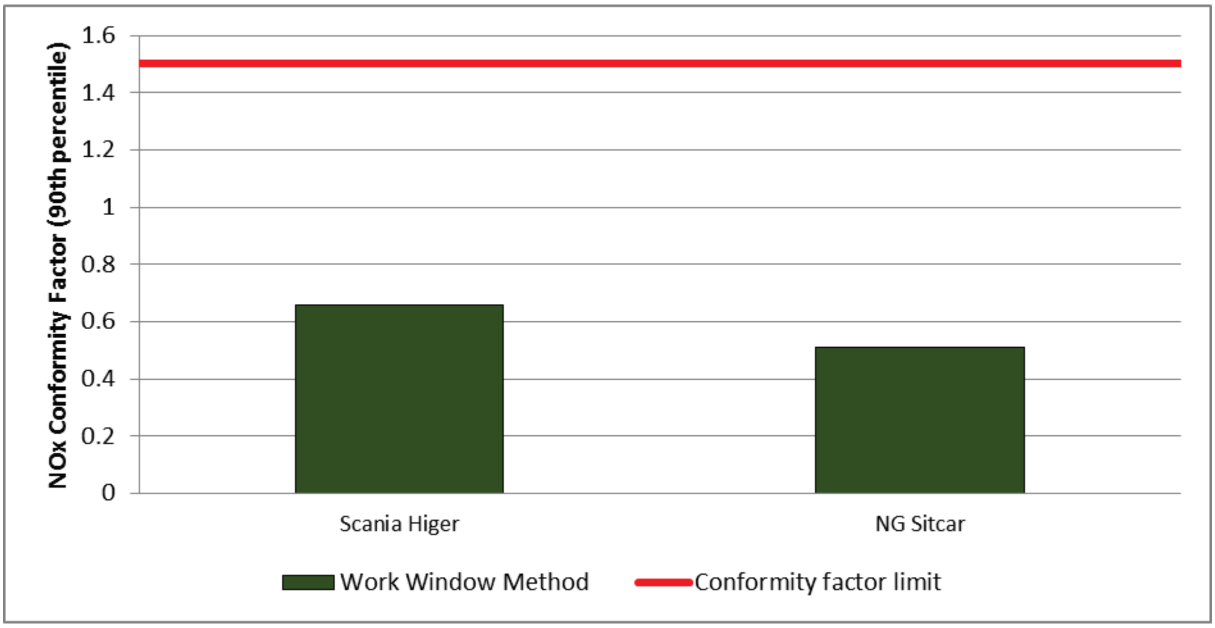

Figure 4-29: Results of the in-service, on-road emissions tests conducted on 2 PSVs. NO_x results have been calculated in line with the relevant conformity factors described in section 3.16

5. Carbon dioxide for cars and light vans

5.1 The results below compare the carbon dioxide result with the value stated on the Certificate of Conformity (CoC) for the cars and vans included in this year's test programme. There is no legal limit value for carbon dioxide for an individual vehicle, instead manufacturers must comply with a sales weighted fleet average for vehicles that are registered in the EU. The type approval value is also used for the vehicle's official fuel consumption figure.

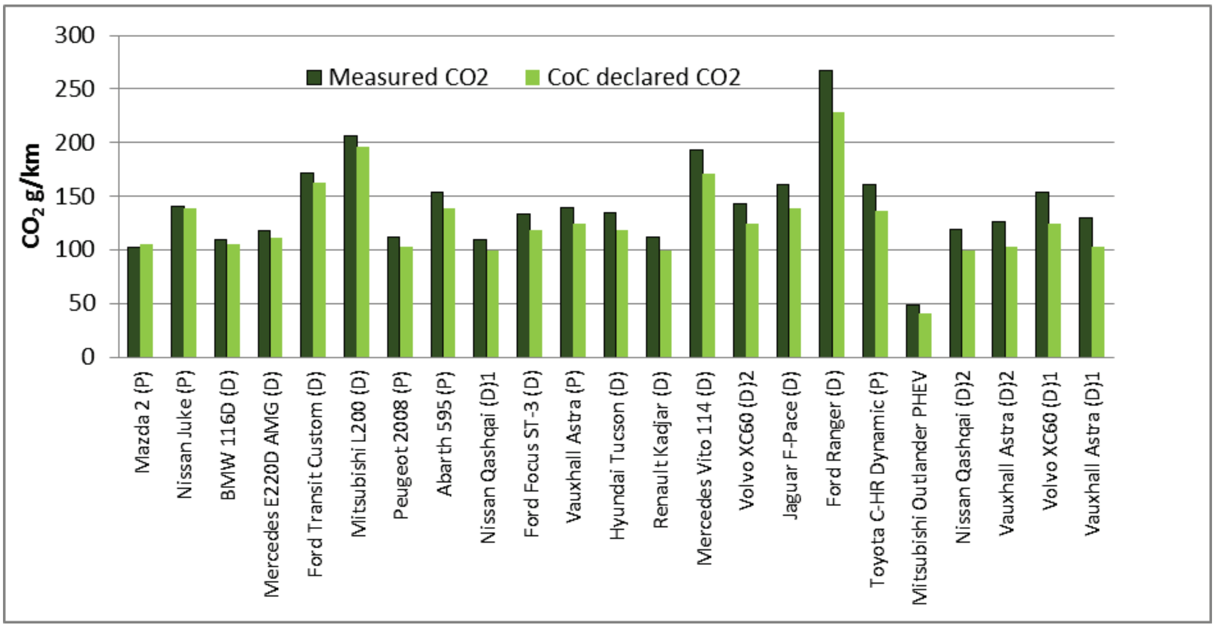

Figure 5-1: Type Approval and laboratory NEDC (cold) test CO_2 emissions

5.2 The vehicles in Figure 5-1 are listed in order of the difference between their test result and their type approval value. With the exception of the Mazda 2, all of the carbon dioxide values are higher than the type approval value despite being tested in accordance with the full legislative test procedure. The Volvo XC60 and the Vauxhall Astra CDTi had the biggest percentage differences to their type approval values. Figure 5-2 shows the difference in percentage of each vehicle's test result from its type approval value.

5.3 The divergence between NEDC (cold) carbon dioxide and fuel consumption values and those obtained in real world use has been a point of discussion for some time. From September 2017, the new Worldwide Harmonised Light vehicle Test Procedure (WLTP) has replaced the NEDC. This introduces a test cycle that is much more representative of real world driving and more stringent procedures for the test. As a result, it is expected to provide much more representative 'official' carbon dioxide and fuel consumption figures. However, none of the cars or vans tested in this report were type approved to the new WLTP requirements.

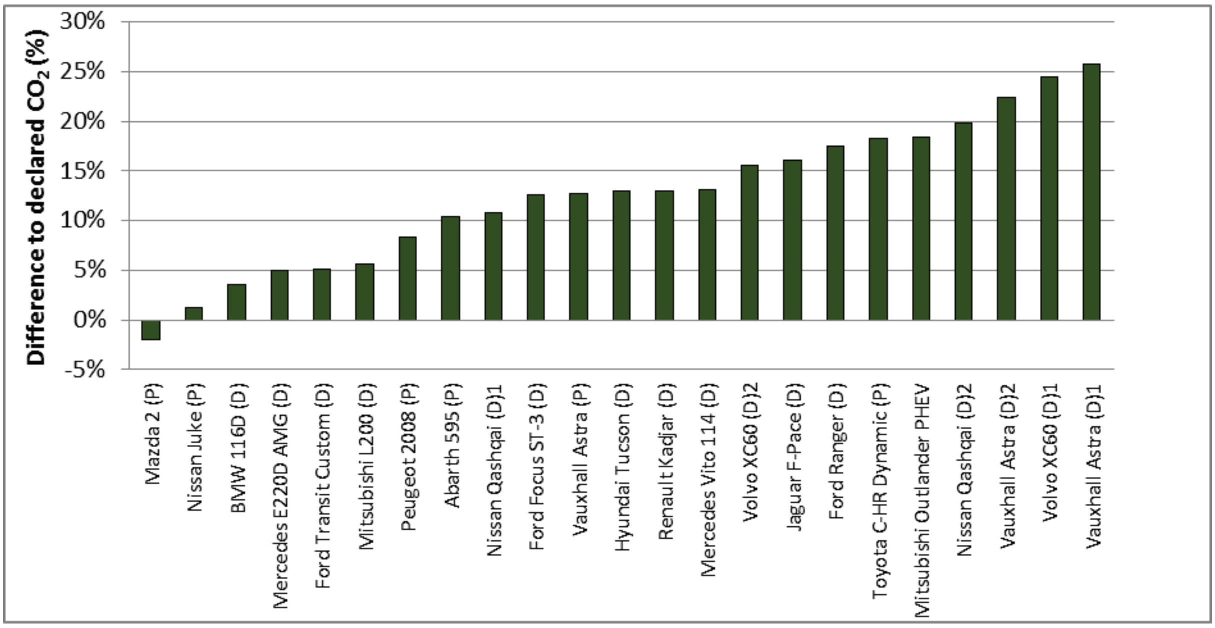

Figure 5-2: Percentage difference between the laboratory NEDC (cold) test CO_2 emissions and the type approval declared value

6. Conclusions and future testing

6.1 This testing of both diesel and petrol cars, plug-in hybrid, diesel vans, HGVs and public service vehicles, has shown us that vehicles in use on UK roads are generally compliant with the type approval requirements.

6.2 Despite this, we remain concerned by the poor real world emissions control of a number of the vehicles we tested this year. Their real world emissions are high and are directly contributing to the air quality problems we face and the resulting health impacts. We therefore intend to conduct a further programme of emissions testing across all categories over the next year.

6.3 Our CO_2 results show that not only are real world fuel economy figures far worse than the official figures, but for many of the cars and vans tested we were unable to match the published figures when tested on the official test cycle.

6.4 These emissions and fuel economy results demonstrate the importance of the new 'Real Driving Emissions' legislation and much stricter WLTP laboratory test procedure introduced in September 2017. We look forward to seeing industry bring forward cleaner vehicles with more representative fuel economy figures as soon as possible.

6.5 We have so far selected our vehicles based on their existing market share and so have tested most of the best-selling models on UK roads. The next vehicle emissions testing programme will comprise of new vehicle launches, existing models and manufacturers or models that had previously delivered poor results.

6.6 As Real Driving Emissions standards started to apply to new types of cars from September 2017, we will also be checking that these vehicles comply with the new requirements. Our existing real world testing has been to enhance our understanding of the difference between laboratory and real world performance and this has shown that we should expect to see substantial air quality benefits from vehicles which comply with these new requirements.

6.7 We will also be conducting testing programmes to check that vehicles and components comply with the other standards that they are required to meet, including safety performance for road vehicles and the emissions from Non Road Mobile Machinery (NRMM). We do not intend to share the details of these programmes in advance of publishing the results, as it is better that manufacturers and importers do not know where we are focusing our surveillance in any given period.

6.8 In addition to planned testing, the Market Surveillance Unit will investigate areas of potential non-compliance that are brought to our attention. We welcome any information or concerns from within the relevant industries or from members of the public. If you would like to contact the Market Surveillance Unit then please email marketsurveillance@dvsa.gov.uk. The information that you supply will be considered carefully and we will decide whether further investigation is needed. Whether we are able to share the outcome of that consideration and any further action taken will depend on the specific circumstances. We will take a judgement on whether it is in the public interest to do so. The Market Surveillance Unit is responsible for checking whether vehicles and components on the market meet the standards they were approved to. If your concern applies to an individual vehicle it would be best to contact the manufacturer or dealer. If you need to escalate your concern then this is likely to be to Trading Standards or the Motor Ombudsmen.

6.9 We are confident that the Market Surveillance Unit will continue to play an important role in ensuring that vehicles on the UK market comply with the standards that they are required to meet. We hope that the information contained in this and future reports will provide reassurance that the Government takes compliance extremely seriously.

7. Annex A Emissions reduction technologies

Exhaust Gas Recirculation (EGR)

7.1 EGR displaces intake air with inert exhaust gas. The presence of inert exhaust gas in the combustion chamber reduces both peak combustion temperatures and the amount of oxygen available. This in turn reduces formation of NO_x, but can also cause an increase in the emissions of particulate matter (soot).

7.2 There are a number of types of EGR available to the engine designer

- Internal EGR – this occurs within the combustion chamber/exhaust manifold interface and is set by the timing of the closing of the exhaust valve. Following the completion of the exhaust stroke, the exhaust valve remains open during the start on the induction stroke, causing some of the exhaust in the exhaust manifold to be drawn back into the combustion chamber. As there is no additional control over this, the amount of EGR that occurs is generally kept low.
- External EGR – some of the exhaust gas is directed through a pipe from the exhaust system back into the inlet manifold. The EGR flow is controlled by an EGR valve and is set according to a range of engine operating conditions and parameters. 'High pressure' EGR systems take exhaust gas from before the turbocharger. For Euro 6, 'low pressure' EGR systems are also being introduced, which take exhaust gas from after the diesel particulate filter.
- Cooled EGR – as per external EGR, but the recirculated exhaust gases pass through a cooler before re-entering the engine. This provides a further reduction in the combustion temperature.

7.3 EGR has been around for many years on both light-duty and heavy-duty engines. Use of EGR may lead to compromises on other vehicle characteristics for example particulate emissions, driveability, fuel economy or performance. However, a well-designed and calibrated EGR system will minimise any negative impacts.

Diesel Oxidisation Catalyst (DOC)

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7.4 A diesel oxidation catalyst (DOC) promotes the oxidation of several of the exhaust components. These are oxidised using oxygen, which is present in the diesel exhaust, in the presence of a catalyst. The components include:

- Carbon monoxide (forms carbon dioxide)
- Hydrocarbon (oxidised to carbon dioxide and water)
- Soluble organic fraction of particulate matter (SOF)

7.5 In addition to targeting regulated pollutants, a DOC can also control several non-regulated HC species such as aldehydes and PAHs as well as reducing the odour of the exhaust.

7.6 DOCs can also oxidise NO exiting the engine into NO_2. If a DOC is used on its own this increase in the more harmful oxide of nitrogen can have a negative impact on air quality. However, generation of NO_2 may prove to be a benefit when used prior to a DPF or SCR, by helping regeneration in the former and enhancing the emissions conversion performance of the latter.

Diesel particulate filter (DPF)

7.7 A diesel particulate filter is a device to remove the particulate matter from the exhaust gas of a diesel engine. They generally consist of some form of filter material which traps the particles as the exhaust flows through it. During use, soot will accumulate on the filter, increasing the back pressure in the exhaust. To allow continued efficient operation, this accumulated soot needs to be regularly removed. This can be achieved on the vehicle by process known as regeneration. There are a number of ways to achieve this, including:

- Increase the exhaust temperature through engine management (late fuel injection or injection during the exhaust stroke). Diesel particulate burns at about 600 °C, so this temperature needs to be maintained for the regeneration period (i.e. a period of high engine load needs to be sustained).
- The addition of a fuel borne catalyst, which reduces the combustion temperature of the particulate from 600 °C down to 350-450 °C. This requires a small additional tank to hold additive, plus the associated plumbing, but this is more energy efficient.
- Passive regeneration – the presence of NO_2, generated in the DOC, can also reduce the combustion temperature allowing the DPF to regenerate continuously, avoiding the fuel penalties associated with raising the exhaust temperature to initiate regeneration.

Lean NO_x Trap (LNT)

7.8 Unlike a petrol engine, a diesel engine's exhaust is 'lean' – a term meaning it has excess oxygen present. As a result, a standard catalyst cannot convert NO_x emissions. A lean NO_x trap is a device which looks similar to a standard catalyst, but which acts as a molecular sponge, chemically trapping NO_x emissions (by adsorption) rather than converting them. The amount of NO_x a trap can hold is dependent on its temperature. The optimum temperature window is typically around 250-450°C. However, once the trap is full, it can't adsorb any more NO_x. The trap must therefore be periodically 'purged' by briefly creating 'rich' conditions (excess fuel) in the exhaust. When this happens the trap releases and simultaneously converts the NO_x to nitrogen and water vapour. The frequency with which this happens will depend on the system and the driving conditions, but it is typically several times an hour.

Selective Catalytic Reduction (SCR)

7.9 SCR is an alternative catalyst system that is able to convert NO_x even under 'lean' exhaust gas conditions. The reaction takes place with ammonia (typically supplied as AdBlue) in the presence of a catalyst, either oxides of base metals (such as vanadium, molybdenum and tungsten), zeolites, or various precious metals. To be efficient, the SCR must be at its nominal operating temperature (350-450 °C) and it can reduce NO_x emissions by up to 95%. Critically, unlike the other systems described here, SCR relies on a consumable reagent (to provide the ammonia) and only reduces emissions whilst the catalyst is being supplied or "dosed" with this reagent. As a result, regulations require a visible and audible driver warning when reagent levels are low and that vehicle performance is restricted or engine restart is prevented if the driver fails to refill the system

7.10 The temperature of the SCR is determined primarily by the exhaust gas. Therefore, the placement of the SCR in relation to the engine and the engine's duty cycle are critical with respect to the SCR's performance. The SCR canister is relatively large. In addition to the SCR, the following are also required:

- AdBlue tank – the AdBlue dosing rate will vary by engine and vehicle but this tank will be sized to avoid vehicle owners having to refill too frequently. The tank also contains heaters and sensors.
- A dosing pump – to pump the AdBlue from the tank into the exhaust pipe just before the SCR.
- A control module – to control the amount of AdBlue added.
- Pre and post SCR NO_x sensors – to ensure that the SCR system is operating correctly.

7.11 Although readily available, the main design constraint is the amount of space needed for the installation.

Ammonia catalyst

7.12 SCR requires ammonia, derived from the AdBlue. The ideal ratio of ammonia to NO_x is 1:1. However, under certain conditions, the SCR efficiency might be low (e.g. low temperatures, high exhaust flow rates etc.). Under these conditions, the ammonia might not be all used and some of it may exit the SCR – known as ammonia slip

7.13 To prevent the release of ammonia, an additional catalyst is placed immediately after the SCR. There are various terms for these devices, including:

- AOC: ammonia oxidation catalyst
- ASC: ammonia slip catalyst
- CUC: clean up catalyst

7.14 Any ammonia can either be oxidised to NO_x (not really desirable) or it can be selectively oxidised to produce water and nitrogen. The ammonia catalyst is often packaged in the same can as the SCR.

Combination devices

7.15 Almost all diesel engines these days are turbocharged. The resulting emissions will be dealt with using a combination of techniques. This commonly includes:

- EGR + DOC + DPF
- EGR + DOC + LNT + DPF
- EGR + DOC + SCR + DPF

7.16 In the future, the introduction of Real Driving Emissions regulations may result in manufacturers using EGR + DOC + LNT + SCR + DPF. The combination of LNT and SCR technologies can provide improved NO_x control over a wider temperature range and has already been introduced for diesel vehicles in the US market.

8. Annex B – Summary of vehicles tested

Petrol Cars

Manufacturer	Model	Engine	Euro Level	Type Approval Authority	EGR	TWC	GDI
Abarth	595	1368	6b	e3	N	Y	N
Mazda	2 Sport	1496	6b	e1	N	Y	Y
Peugeot	2008 Allure	1200	6b	e2	N	Y	Y
Toyota	C-HR	1197	6b	e11	N	Y	Y
Nissan	Juke	1598	6b	e11	N	Y	N
Vauxhall	Astra	1399	6b	e4	N	Y	N
Mitsubishi	Outlander	1998	6b	e1	Y	Y	Y

Diesel Cars

Manufacturer	Model	Engine	Euro Level	Type Approval Authority	EGR	DOC	SCR	DPF	LNT
Mercedes	E220	1950	6c	e1	Y	Y	Y	Y	N
Vauxhall	Astra CDTI	1598	6b	e4	Y	Y	N	Y	Y
BMW	116D	1496	6b	e1	Y	Y	N	Y	Y
Hyundai	Tucson	1685	6b	e11	Y	Y	N	Y	Y
Volvo	XC60 R	1969	6b	e9	Y	Y	N	Y	Y
Jaguar	F-Pace	1999	6b	e11	Y	Y	N	Y	Y
Ford	Focus	1997	6b	e13	Y	Y	Y*	Y	Y
Renault	Kadjar	1461	6b	e2	Y	Y	N	Y	Y
Nissan	Qashqai	1461	6b	e11	Y	Y	N	Y	Y

*passive SCR

Light Vans & 4x4

Manufacturer	Model	Engine	Euro Level	Type Approval Authority	EGR	DOC	SCR	DPF	LNT
Ford	Transit 270	1995	6b	e1	Y	Y	Y*	Y	Y
Mercedes	Vito	2143	6b	e1	Y	Y	Y	Y	N
Ford	Ranger	3198	6c	e11	Y	Y	Y	Y	Y
Mitsubishi	L200	2442	6b	e1	Y	Y	N	Y	N

*passive SCR

Trucks

Manufacturer	Model	Engine	Euro Level	Type Approval Authority	EGR	DOC	SCR	DPF
Mitsubishi	Fuso	2998	VI	e4	N	Y	Y	Y
Isuzu	N75.150	2999	VI	e4	Y	Y	Y	Y
Scania	P3 61	9290	VI	e4	Y	Y	Y	Y

Public Service Vehicles

Manufacturer	Model	Engine	Euro Level	Type Approval Authority	EGR	DOC	SCR	DPF
Scania	Higer	13000	VI	e4	N	Y	Y	Y
Iveco	Sitcar	2998	VI	e3	Y	Y	Y	Y

Key for Type Approval Authorities:

e1 = Germany
e2 = France
e3 = Italy
e4 = Netherlands
e6 = Belgium
e9 = Spain
e11 = UK
e13 = Luxembourg

Key for emissions control systems

EGR = Exhaust Gas Recirculation
DOC= Diesel Oxidation Catalyst
DPF = Diesel Particulate Filter
SCR= Selective Catalytic Reaction
LNT = Lean NO_x Trap
TWC = Three Way Converter