HS2 Phase One - Study on the use of low emission vehicles in London during construction of HS2

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1 Executive Summary

1.1 Background to the study

1.1.1 High Speed 2 (HS2) Ltd has made commitments to the London Borough (LB) of Camden:

- for all heavy duty vehicles (HDVs, vehicles weighing over 3.5 tonnes) entering Greater London (specifically, the Greater London Low Emission Zone) to be at least as clean in terms of emissions to air as the latest currently available diesel engines, which are referred to as Euro VI engines;
- to explore a requirement, for all light duty vehicles (LDVs, vehicles weighing less than 3.5 tonnes) used during construction to be Euro 6 (the cleanest LDV engines) by 2020; and
- to explore a requirement, for a proportion of LDVs entering worksites to have even lower emissions than Euro 6, which are referred to as ultra-low emission vehicles (ULEVs).

1.1.2 Euro VI/6 vehicles are those that meet the latest European standards for pollutant emissions and are consequently those petrol and diesel powered vehicles that currently emit the lowest levels of air pollutants.

1.1.3 When this commitment was made, it was noted that certain exemptions would be required and it was agreed that a study would be carried out to determine what and when (if any) exemptions would be required. These exemptions could apply, for instance, if there were insufficient vehicles available, if suitable vehicles did not exist (i.e. for very specialised types of activity) or if a requirement for their use would unfairly affect Small or Medium sized Enterprises (SMEs). If exemptions were found to be needed the study should determine what vehicles types would need to be exempted. It was agreed by HS2 Ltd that the outcomes of this study would be shared with various stakeholders, including LB Camden.

1.1.4 All non-road mobile machinery (NRMM) plant and vehicles have been excluded from this study, because HS2 Ltd has already set separate commitments for the use of NRMM within the construction sites. It should be noted that certain vehicles that fall under the NRMM regulations are also authorised to travel on road; these have also been excluded from the scope of this study since the emission standards for Euro VI/6 are not applicable.

1.1.5 Ove Arup and Partners Ltd (Arup) was therefore commissioned by HS2 Ltd to undertake the study required and to examine the potential costs and benefits of the commitment. The study has further examined how the commitment would be monitored during the construction period, so that stakeholders could be confident that these measures had been effectively implemented.

1.1.6 This report has been produced taking into account feedback from stakeholders including Transport for London and the London Borough of Camden, over several working group meetings.

1.2 Air quality laws and policies

1.2.1 Air quality is an important environmental issue and there is legislation in place at European, national and regional level that set air quality standards to protect human health and the natural environment. There are also policies in place at national and regional level aimed at improving air quality. Some of these policies will affect the construction works particularly in London where, for instance, the previous Mayor of London agreed to implement an Ultra Low Emission Zone (ULEZ) corresponding to the current Congestion Charging (CC) Zone and the latest UK Government Air Quality Plan requires a Clean Air Zone in the current London-wide Low Emission Zone (LEZ). Both of these measures will restrict the use of certain types of vehicles in London; they are currently not due to be implemented until 2020. The new Mayor of London is currently consulting on further measures to improve air quality in London, which include a spatial extension of the ULEZ and its earlier implementation in 2019.

1.2.2 The proposals of HS2 Ltd are consistent with these further measures and in some respects require earlier compliance than the new Mayor has proposed. The commitment made by HS2 Ltd to use less polluting vehicles from 2017 is therefore ahead of the current national and regional measures proposed. It should be noted that HS2 Ltd had already made a commitment to use Euro VI HGVs for transporting excavated materials in the low emission zones.

1.3 Estimation of the likely vehicle fleet required during the early years of construction

1.3.1 The first part of the study estimated the numbers of vehicles that would be expected to be used during the first six years of construction (it is considered that after this time, legal requirements for low emission vehicles will by then supersede any additional requirements of HS2 Ltd).

1.3.2 A detailed study of the number of construction vehicle trips expected to be generated between 2017 and 2033 was carried out for the Environmental Statement (ES) as amended. These are estimates based on the day with the highest increase in traffic predicted to occur within each year of construction being applied to all days of that year. For this study, the information in the ES was analysed in further detail to provide information on the types and numbers of vehicles likely to be used (i.e. the required vehicle fleet). Five main categories of construction activity were considered: (1) concrete deliveries, (2) demolition material, (3) waste and (4) excavated material removal, and (5) miscellaneous activities (such as utility works and site preparation).

1.3.3 In the early stages of the construction (2017/18) the main activities are associated with miscellaneous activities and demolition works. It is only at the end of 2018 that vehicles associated with concrete and excavated materials begin to increase. The majority of the excavated material movements occur after 2020. In the years up to 2020, the peak daily traffic is below 500 movements on roads around Euston Station. One vehicle movement is equal to a single vehicle travelling to or from a site, hence a round trip from base to site and back to base is two movements. In addition, the number of round trips does not equal the number of unique vehicles (the vehicle fleet) required to deliver the materials or activities required, because one vehicle is likely to make more than one return trip in a day.

1.3.4 The total number of HGVs needed for a peak day of activity at Euston increases from 121 in 2017 to 212 in 2022. For Community Forum Areas (CFAs) 3-6, the total number of HGVs for a peak day of activity varies between 475 in 2018 and 116 in 2022. It should be noted that these are initial estimates and should not be used as a limit to the number of vehicles travelling to and from a site.

1.4 Availability of low emission HGVs in London and surrounding areas

1.4.1 In order to put the number of HGVs required for construction into context, this study looked at the likely number of suitable Euro VI HGVs that would be operating in London during the early years of construction (2017-2022) and whether contractors and their sub-contractors would find it difficult to meet the low emission vehicle commitment made by HS2 Ltd.

1.4.2 HS2 and Arup contacted trade associations and utility companies for their views regarding the availability of suitable vehicles. Their general response was that trade associations would not welcome a requirement for Euro VI vehicles ahead of the legal timetable, as they considered this may disadvantage some of their members. However, none of these bodies were able to provide any data regarding the nature of vehicles currently used by their members. Many utility companies have already adopted vehicles into their fleet that are lower emitters than Euro VI/6 (e.g. British Gas have committed to making 10% of their fleet electric by 2017).

1.4.3 An estimate of the number of suitable vehicles available in and around London was derived from data provided by Transport for London (TfL) and publically available sources, such as the national emissions inventory and the Department for Transport. It was considered that there was likely to be over 50,000 Euro VI vehicles (both rigid and articulated HGVs) operating in the London area by 2017 (these are not necessarily the London fleet and will include vehicles from outside London, as well as those originating and/or registered in London). Not all of these will be associated with construction activities, but it is likely that there would be sufficient HGVs, of a suitable type, available to meet the commitments made by HS2, without any undue constraint on potential suppliers. It was also considered that no exemption would be required for SMEs as again, there would be sufficient suitable vehicles already in use. As noted earlier, the new Mayor of London has announced they wish to introduce further measures to improve that will encourage the use of Euro VI vehicles in London.

1.5 Ultra low emission vehicles (ULEVs)

1.5.1 When examining the availability of ULEVs there are fewer options available, particularly for larger vans and heavy goods vehicles. Given the power requirements needed for the heavier vehicles, ULEV HGVs are unlikely to be widely available for this project in the early years of construction.

1.5.2 However, ULEVs are available for many types of cars and vans and it is proposed that targets of 100% for cars and 75% for vans of contractor vehicle movements are set from 2017. These are aspirational targets, not minimum requirements. Contractors should establish a baseline as soon as they start works and show continuous improvement until compliance is reached. In order to ensure that moving towards low CO_2 emission vehicles also benefits local air quality, in relation to NOx emissions, targets for vehicle types (including favouring the use of petrol over diesel and moving away from the internal combustion engine) are also proposed.

1.6 Exemptions

1.6.1 As discussed above, there may be some cases where exemptions will be required. Certain vehicles are not considered in the scope of the commitment made by HS2 Ltd. These include vehicles associated with activities (a) over which HS2 Ltd has no control (e.g. postal deliveries) and (b) which are not connected with the construction of HS2 (e.g. British Gas accessing HS2 land for work unconnected with HS2). These vehicles do not form part of the commitment and do not need exemptions to enter an HS2 site. They should not be included in the reporting of compliance. Exemptions should be implemented with the aim of reducing air pollutant emissions as far as reasonably practicable.

1.6.2 Having examined the types of vehicles likely to be used and how they will be operated, three main exemptions are required. The grounds for exemption are summarised as follows:

- **Specialism:** Certain vehicles undertake highly specialised tasks that can only be undertaken by that type of vehicle; examples include large mobile cranes, certain piling rigs and pile drivers, pulverising and crushing machinery, augers and road removal equipment. However, most of this equipment will be brought to site on another vehicle (e.g. a low loader). On the rare occasion where a specialised vehicle comes to site under its own power, is not classified as NRMM (and therefore is not subject to Euro VI type approval) and this vehicle cannot comply with the Euro VI emission standard, it will be exempt from the Euro VI requirement.
- **Unforeseen circumstances:** Contractors and their sub-contractors should provide Euro VI compliant vehicles according to their transport plan and forecasts. However, there will be times when construction activities need to be rescheduled or redesigned at short notice. This could be for a variety of reasons, including at the request of HS2

Ltd, because of site conditions (e.g. frozen ground, water-logging, snow cover), or because of third party considerations (e.g. noise sensitive activities). This may mean that Euro VI compliant vehicles cannot be supplied in the timeframe required. In such circumstances, these vehicles shall be exempt from the Euro VI requirement, as long as justification is provided and agreed by the appropriate contractor/sub-contractor.

- **Triviality:** Compliance with the Euro VI emission standard is focussed on managing and improving air quality. A single vehicle making a few trips a year therefore has a very small impact on ambient concentrations of NO_2 and PM_{10}. If a contractor requires a certain vehicle to travel to an HS2 site no more than 24 times in any 12-month rolling period, then this vehicle can be exempted as long as that exemption is sought prior to the first visit for a calendar year and justification is given that lies without that of specialism or timing. An exemption shall be granted for the calendar year in which the vehicle is first recorded entering a site and must be renewed annually with justification as to why this vehicle cannot and has not been replaced by a Euro VI compliant vehicle.

1.6.3 HS2 Ltd should give consideration to the duration and validity for which an exemption can be granted and how to ensure that a consistent exemption policy is applied. A periodic review of the policy will be required to ensure that it is appropriate and relevant to the construction activities being undertaken. For example:

- An exemption could be granted for a specified period in which the vehicle needs to be used on site.
- Exemptions could require renewal in the event a vehicle moving to a different site or leaving and wanting to revisit the original site.
- Exemptions could be granted for a unique vehicle accessing a single site. This may include multiple visits to a site on one or more days or a single entry to a site where the vehicle stays on site for longer than one day.

1.6.4 Justifications as to why a vehicle needs an exemption and if relevant, why the exemption needs to be renewed, should always be specified by the applicant. There may be certain circumstances where an exemption cannot be granted in advance and in this case, a retrospective exemption could be granted provided that:

a. the relevant documentation is submitted for consideration within 2 working days of the vehicle arriving at site;

b. the vehicle falls within the grounds for an exemption; and

c. the reasons for the retrospective application are recorded.

1.6.5 It is expected that exemptions will be minimised and should not account for more than 8% of unique vehicles on an annual basis in the early years of construction, decreasing in subsequent years as more of the vehicle fleet are upgraded or replaced. Contractors should establish a baseline and show continuous improvement against it. Allowances for exemptions based on frequency should not be carried over between calendar years.

1.6.6 HS2 Ltd has identified the need for a transition period for the HGV management process to be applied at the start of construction and during which record-keeping systems can be set up. HS2 Ltd may consider setting a transition period for learning and practice change, during which there is likely to be more retrospective applications for exemptions and/or the engine type of some vehicles may not be determinable (and hence determining whether a vehicle was Euro VI or not). This transition period will allow for the monitoring and compliance regime to be fully set up whilst works are progressed and be adapted should any issues arise. However, in order to get the best balance between practicality and air quality, this transition period should be as short as possible and not exceed 12 months from the start of the construction works that fall under the Bill. HS2 Ltd may also consider varying the reporting requirements during this time (e.g. extending the deadlines to allow collation of data).

1.7 Cost and benefits of the commitments

1.7.1 The potential costs associated with the commitment were also examined. Given that the number of vehicles likely to be required for the HS2 construction activities will only be a small fraction of the total fleet operating in and around London, the most likely cost to HS2 Ltd for imposing a requirement for Euro VI vehicles would be zero (£0). It is considered that contractors are unlikely to have to procure new vehicles specifically for the construction of HS2.

1.7.2 However, to estimate the possible range of costs of providing Euro VI HGVs to HS2 Ltd (some of which might be assigned to HS2 by contractors), Arup has used a hypothetical maximum cost scenario. It is considered that this case is unrealistically pessimistic and is therefore **more** than the maximum possible cost to HS2 Ltd.

1.7.3 The hypothetical maximum scenario assumes that all the vehicles required for construction of HS2 (2017-2022) would need to be purchased new and the whole cost be passed onto HS2 Ltd. Using this approach the maximum London wide costs would be approximately £21 million for Euston works (CFA1) (approximately £6 million excluding those required for excavated materials) and £51 million for CFAs 3-6 (approximately £18.7 million excluding those required for excavated materials).

1.7.4 The damage costs of the air quality impacts resulting from construction of the scheme were also estimated using a standard approach used on highway schemes (known as WebTAG). This study assumed that HGVs associated with the transport of excavated material would be Euro VI compliant, with other activities using more polluting HGVs. The outcome of this analysis was that predicted costs of air quality impacts in London (2017-2026) would be approximately £3.2 million. The effect on this damage cost of using Euro VI compliant HGVs or ULEVs for lighter vehicles has not been estimated, but it would reduce this figure closer to zero.

1.8 Monitoring and compliance

1.8.1 Ensuring that contractors (including their sub-contractors) adhere to HS2 Ltd's requirements is very important. Therefore, HS2 Ltd has considered how it could monitor and measure compliance. It is proposed that HS2 Ltd will require contractors to have a vehicle monitoring system for all construction activities. It is recommended that HS2 Ltd requires the contractors to include in this system suitable data to monitor compliance of the vehicle emissions commitment made. An essential part of the data collected will be the Euro standard with which the vehicle complies. Where there is a possibility of using a GPS tracking system, this should be investigated as a possible improvement to compliance by preventing non-compliant vehicles departing their starting point.

1.9 Working with other major projects and organisations

1.9.1 HS2 Ltd are also working to influence the market to improve the use of lower and zero emission vehicles. This is through their membership of a number of organisations, as well as setting requirements for contractors in their Traffic Management Plans to achieve certain levels of accreditation in schemes such as FORS (Fleet Operators Recognition Scheme) or the Freight Transport Association (FTA) Truck Excellence scheme.

1.9.2 It is HS2 Ltd's aim to be an exemplar project that aims to minimise the air quality impacts during construction. This will be assisted through the use of the measures proposed in their commitments to LB Camden and the exemptions proposed.

2 Abbreviations and descriptions

Abbreviations

Abbreviation	Explanation
AADT	Annual Average Daily Traffic *[flow]*
ADMS-Roads	Atmospheric Dispersion Modelling System for Roads
ANPR	Automatic Number Plate Recognition
AP	Additional Provisions *[to the Hybrid Bill]*
AQ	Air quality
AQMA	Air Quality Management Area
AQP	Air Quality Plan
BEV	Battery Electric Vehicle
CAFE	Cleaner Air for Europe
CAZ	Clean Air Zone
CC	Congestion Charging *[Zone]*
CFA	Community Forum Area
CNG	Compressed Natural Gas
CO	Carbon monoxide
CO_2	Carbon dioxide
CPA	Construction Products Association
Defra	Department for the Environment, Food and Rural Affairs
DfT	Department for Transport
DMRB	Design Manual for Roads and Bridges
DVLA	Driver and Vehicle Licencing Agency
EC	European Commission
EEC	European Economic Community
ES	Environmental Statement
EST	Energy Saving Trust
ETM	ERM, Temple, Mott MacDonald *[Environmental consultants partnership]*
EU	European Union

Abbreviation	Explanation
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
FORS	Freight Operators Recognition Scheme
FTA	Freight Transport Association
g	grams
g/kWh	grams per kilowatt hour
g/vkm	grams per vehicle kilometre
GBS	Government Buying Standards
GLA	Greater London Authority
GPS	Global Positioning System
HDV	Heavy Duty Vehicle
HGV	Heavy Goods Vehicle
HS2	High Speed 2
ICCT	International Council on Clean Transportation
IP	Information Paper
ISC-RDE	In-Service Conformity Real Driving Emissions *[testing]*
ISO	International Standards Organisation
kg	kilogram
km	kilometre
KPI	Key Performance Indicator
kW	kilowatt
kWh	kilowatt hour
LB	London Borough
LDV	Light Duty Vehicle
LEZ	Low Emissions Zone
LGV	Light Goods Vehicle
LNG	Liquefied Natural Gas
LCVP	Low Carbon Vehicle Partnership
mg	milligram *[1/1000th of a gram]*

Abbreviation	Explanation
MPA	Mineral Products Association
mph	miles per hour
MW	Megawatt *[1 million watts]*
NAEI	National Atmospheric Emissions Inventory
NAQS	National Air Quality Strategy
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen *[nitric oxide and nitrogen dioxide]*
NPPF	National Planning Policy Framework
NPS	National Policy Statement
NRMM	Non-road Mobile Machinery
OS	Ordnance Survey
PEMS	Portable Emissions Monitoring System
PEV	Plug-in Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
PM	Particulate matter *[all sizes]*
PM_{10}	Particulate matter less than 10μm in diameter *[fine particles]*
$PM_{2.5}$	Particulate matter less than 2.5μm in diameter *[very fine particles]*
RDE	Real Driving Emissions *[testing]*
RE-EV	Range Extended – Electric Vehicle
RHA	Road Haulage Association
RTMP	Route-wide Traffic Management Plan
SCM	Supply Chain Management *[team in HS2]*
SES	Supplementary Environmental Statement *[to the Hybrid Bill's ES]*
SME	Small and Medium-sized Enterprises
SMMT	Society of Motor Manufacturers and Traders
SMR	Scope and Methodology Report
SPG	Supplementary Planning Guidance
t	tonnes *[metric]*
TEN-T	Trans-European Transport Network *[of infrastructure]*

Abbreviation	Explanation
TfL	Transport for London
TNO	Netherlands Organisation for Applied Scientific Research
µg	Microgram *[1/1000000th (one millionth) of a gram]*
UK	United Kingdom *[of Great Britain and Northern Ireland]*
ULEV	Ultra-Low Emission Vehicle
ULEZ	Ultra-Low Emissions Zone
VCA	Vehicle Certification Agency
vkm	Vehicle kilometres
VMS	Vehicle Management System
VRN	Vehicle Registration Number
WebTAG	Web-based Transport Analysis Guidance
WHO	World Health Organization
WLTP	Worldwide harmonised Light vehicles Test Procedure
ZEC	Zero *[tailpipe]* Emission Capable *[vehicle]*
ZEV	Zero Emission Vehicle

Key Definitions

Term	Explanation
Ambient air quality standards and other criteria	Criteria are set for air quality by a number of organisations and in a number of different laws and guidance. Air quality limit values are set by the European Union in Directives and are then adopted into UK law via primary and secondary legislation. The limit values are set for each pollutant and specific ways and dates for EU members to demonstrate compliance are prescribed in the Directive (and then also in the laws of the member state). Defra[1] describe the various terms as follows: • ***Air Quality Standards*** *are concentrations recorded over a given time period, which are considered to be acceptable in terms of what is scientifically known about the effects of each pollutant on health and on the environment. They can also be used as a benchmark to indicate whether air pollution is getting better or worse.* • *An exceedance is a period of time (defined for each standard) where the concentration is higher than that set out in the Standard. In order to make useful comparisons between pollutants, (the Standards may be expressed in terms of different averaging times), the number of days on which an exceedence has been recorded is often reported.* • *An* ***objective*** *is the target date on which exceedences of a Standard must not exceed a specified number. [UK terminology, not legally binding]* • ***EU Limit values*** *are legally binding EU parameters that must not be exceeded. Limit values are set for individual pollutants and are made up of a concentration value, an averaging time over which it is to be measured, the number of exceedences allowed per year, if any, and a date by which it must be achieved. Some pollutants have more than one limit value covering different endpoints or averaging times.* • ***Target values*** *– are used in some EU Directives and are set out in the same way as limit values. They are to be attained where possible by taking all necessary measures not entailing disproportionate costs.* Generally objectives and limit values have the same numerical value but the date for compliance may be different (e.g. the UK objectives generally have the same or a later date for compliance than the EU limit value).
Euro 1, 2, 3, 4, 5, 6	Vehicle emission standards for LDVs (≤3.5T gross vehicle weight)
Euro I, II, III, IV, V, VI	Vehicle emission standards for HDVs (>3.5T gross vehicle weight)
HGV and HDV	Heavy (>3.5T) vehicles that carry goods are HGVs, heavy duty vehicles (HDVs) include HGVs and those vehicles designed to carry people (such as buses and coaches).
LGV and LDV	Light (≤3.5T) vehicles that carry goods are LGVs, light duty vehicles (LDVs) include LGVs and those vehicles designed to carry people (such as cars and taxis).
LoCITY	LoCITY is an initiative set up by Transport for London (TfL) and is an industry-led programme to (a) increase the availability and affordability of viable low emission commercial vehicles in the UK; (b) improve the availability of refuelling infrastructure and support last mile logistics by engaging with businesses, fleet operators and vehicle manufacturers to develop and deliver match-funded demonstration projects; and (c) provide advice and resources to the business community, freight and fleet operators and the public sector.

Term	Explanation
NRMM	Non-Road Mobile Machinery (including for industrial, agricultural and construction site use e.g. cranes, generators, tractors) that are designed to work on construction sites but may sometimes also be licenced to travel on the public roads. Euro 1-6 or I-VI emission standards do not apply (even if the vehicle is licenced to travel on the public highway; emission standards are set Stage IIIA, IIIB, VI etc.
Particulate matter (PM, PM10, PM2.5)	Particulate matter (sometimes called particles or particle pollution), is a complex mixture of very small particles and liquid droplets. Particle pollution is made up of a number of components, including nitrates, sulphates, carbon, organic chemicals, metals, sea salt and soil. The size of particles is directly linked to their potential for causing health problems. Large particles tend to settle on surfaces and may cause nuisance or damage to the surface. If still airborne they can be breathed in but tend to be trapped in the nose, mouth or throat and are generally not cause for health concerns. Particles that are smaller than 10 micrometres (µm, i.e. 1/1000th of a millimetre) in diameter can pass into the lungs. Particles smaller 10µm are termed PM10, smaller than 2.5µm as PM2.5; smaller groupings (e.g. PM1.0) also exist. Generally the smaller the particle the further into the respiratory system it can travel and the more it may affect human health.
Stage IIIA, IIIB, IV	European emissions standards for non-road mobile machinery (NRMM).
Traffic flows (AADT, unique vehicles, vehicle fleet, 2-way flow)	Traffic flow data in this study are given in daily movements which means that a single vehicle entering a site comprises two movements – one for the journey from base to site and one for the return journey back to base from site. This flow is termed 2-way flow and may be expressed as an annual average daily traffic (AADT) flow, peak day, peak hour or some other measure. Dividing the daily flow to a site by two therefore gives the number of vehicles that would be visiting a site in a day. However, this number is usually not the number of different (or unique) vehicles visiting a site as many types of activity use a vehicle that could visit the site several times in a day. Part of the work undertaken for this study was to identify the likely number of unique vehicles that would be needed to deliver the services and materials required. The number of different/unique vehicles required is termed the vehicle fleet.
ULEV	There are several definitions of ULEV in use. For the purposes of this study and the commitments made by HS2 Ltd, the following definition applies, as advised by HS2 Ltd: *"emissions lower than 75 gCO2/km and zero-emission range greater than 10 miles, or for an electric vehicle range greater than 60 miles"*. Because the vehicle emits zero or low emissions of CO2 it will also emit zero or low emissions of other combustion pollutants (e.g. NO2 and PM) although the classification does not propose limits for these pollutants.

3 Introduction

3.1 Background information

3.1.1 Ove Arup and Partners Ltd (Arup) has been commissioned by HS2 Ltd to undertake a study to identify any potential constraints and propose exemptions for the use of Euro VI vehicles in London during construction of the Phase One scheme, and to explore the wider potential for the use of low emission vehicles to protect air quality in and outside London.

3.1.2 HS2 Ltd published a policy in early 2015 that *"in order to mitigate impacts on local air quality, in areas where there is action in place to meet EU limit values through the introduction of Low Emission Zones (such as the London Low Emission Zone), HS2 Ltd will require Heavy Duty Vehicles entering these designated Zones during construction, for the purposes of transporting excavated material, to be powered by Euro VI (or lower emission) engines"* (Information Paper E13 – Management of traffic during construction).

3.1.3 In a letter to the London Borough (LB) of Camden dated 30 November 2015, HS2 Ltd stated that:

"6.2 The Secretary of State will require that all Heavy Duty Vehicles (with a weight greater than 3.5 tonnes) relating to the construction of the HS2 works entering the London Low Emission Zone will be powered by Euro VI (or lower emission) engines. The Secretary of State will require the Nominated Undertaker to explore the potential for adopting:

- *a. a London Borough of Camden-specific requirement benchmark for the percentage of contractor ultra low emissions light vehicles below 3.5 tonnes entering worksites, and*
- *b. a London Borough of Camden-specific requirement that all vehicles used during the construction of the scheme be powered by Euro VI/6 (or lower emission) engines by 2020. This information will be provided to the London Borough of Camden before the petitioning period for the House of Lords."*

3.1.4 Since giving this assurance, a number of questions were raised over the potential ambiguity in the assurance and the potential for unintended consequences. In a letter dated 26 February 2016 and accepted by LB Camden, HS2 Ltd stated that the work in assurance 6.2 should be a study including:

- *a. Consideration of any reasonable specific specialised vehicle exemptions to assurance 6.2 above, taking into account market availability and usage patterns. As per the wording of assurance 6.2, the study will take as its starting point that all heavy duty vehicles should be Euro VI; the study will present evidence as required to show where this is not possible. Where Euro VI vehicles are shown to be unavailable, commitment will be made to use the 'next best' Euro V standards throughout.*

b. *Consideration of the implications of imposing Euro VI engines onto SMEs (in line with assurance 6.2a above) in the short to medium term and how to ensure these groups are not excluded from the opportunities of the HS2 project. Consideration of exempting trivial usage in the compliance regime, with reference to scoping work undertaken by TfL with regards exemptions policy and the impact on SMEs of the forthcoming London Ultra Low Emission Zone.*

c. *Exploring the potential for:*

   a. *adopting a London Low Emission Zone-specific benchmark for the percentage of ultra-low emissions light vehicles below 3.5t entering worksites operated by HS2 contractors by 2017.*

   b. *a London Low Emission Zone specific requirement that all vehicles operated by HS2 contractors used during the construction of the scheme be powered by Euro VI/6 (or lower emission) engines by 2020.*

   c. *working with other similar projects and potential of influencing the market in relation to impacts on air quality resulting from construction vehicles.*

d. *Consideration of monitoring and compliance regimes and value for money. Where Euro VI vehicles will be available and the only factor affecting their usage by HS2 contractors is cost, the study must show why the cost implications are severe enough to override the wording of assurance 6.2.*

3.1.5 The scope of this study is therefore to address the points detailed in the letter of 26 February 2016. Similar commitments have also been made to the London Borough of Hillingdon, while TfL have also requested a commitment from HS2 Ltd for the use of Euro VI vehicles from the start of construction. This study addresses the whole of London and therefore any future assurances as a result of this study should apply across London.

3.1.6 All non-road mobile machinery (NRMM) plant and vehicles have been excluded from this study. It should be noted that certain vehicles that fall under the NRMM regulations are also authorised to travel on public roads. These are, however, excluded from the scope of this study since Euro VI/6 compliance is not applicable; there is a separate EU emissions control regime for these vehicles. HS2 Ltd has already set separate commitments for the use of NRMM within the construction sites in Information Paper (IP) E31, published in March 2016.

3.1.7 Statutory undertakers are generally those companies that supply water, gas, electricity and telecommunications or control sewerage, but there are other less obvious ones, for example London Underground, which may need access to equipment for communications or power. These organisations (or those in possession of a street works licence) have a legal right to carry out street works. Any vehicles associated with these utility works (that are already permitted) are excluded from this study. However, any utility works that are carried out on behalf of HS2 Ltd through powers in the Hybrid Bill are included in this study.

3.1.8 This report has been produced taking into account feedback from stakeholders including Transport for London and the London Borough of Camden, over several working group meetings.

3.2 HS2 Phase One Environmental Statement

3.2.1 Air quality and transport impacts from the scheme have been published in the following documents:

- Hybrid Bill Environmental Statement[2] (referred to as 'main ES') [Nov 2013];
- Supplementary Environmental Statement and Additional Provision 2 ES[3] (referred to as 'SES and AP2 ES') [July 2015];
- Supplementary Environmental Statement 2 and Additional Provision 3 ES[4] (referred to as 'SES2 and AP3 ES') [Sep 2015]; and
- Supplementary Environmental Statement 3 and Additional Provision 4 ES[5] (referred to as 'SES3 and AP4 ES') [Oct 2015].

3.3 Structure of the report

3.3.1 The report is structured as follows, addressing each point from the letter to LB Camden dated 26 February 2016:

- Section 4 provides general background information for air quality and vehicle emissions (see also Appendix A: Air quality standards and legislation);
- Section 5 provides a summary of an analysis of construction traffic data and breakdown of vehicle types and usage for CFAs 1 to 6 (see also Appendix B: Types of construction vehicles and Appendix C: Vehicle Emissions);
- Section 6 provides a summary of an air quality appraisal for CFAs 1 to 6 (see also Appendix D: Air quality appraisal – WebTAG);
- Section 7 provides a summary of a research on market availability of Euro VI HGVs, as well as a discussion on SMEs (see Appendix E: Market research questionnaire);
- Section 8 provides a summary of ultra low emission vehicles and suggested targets for adoption by HS2 Ltd (see Appendix F: ULEVs);
- Section 9 provides a summary of the monitoring and compliance regime to be adopted by HS2 Ltd during construction of the scheme;
- Section 10 provides a discussion about exemptions to the use of Euro VI HGVs during construction of the scheme, as well as monitoring of non-compliance;

- Section 11 provides a discussion on other major projects and ways that HS2 Ltd could influence the market for the early adoption of Euro VI HGVs;
- Section 12 provides a discussion on the potential costs to HS2 Ltd from the use of Euro VI HGVs;
- Section 13 provides the conclusions of this study: and
- Appendix G gives references used in this report.

4 Background Information

4.1 Introduction

4.1.1 The commitment to use Euro VI/6 vehicles is driven by a desire to minimise the impact on local air quality from the HS2 scheme. This section sets the context for the study by describing:

- The health impacts of air pollution;
- The relevant air quality standards;
- The work carried out to assess baseline air quality and the impact of the HS2 scheme on local air quality;
- The way in which emissions from vehicle exhausts are regulated;
- The UK government's Air Quality Plan (2015);
- Upcoming policies relating to air quality in London; and
- The consideration given to small and medium-sized enterprises.

4.2 Health impacts of air pollution

4.2.1 The World Health Organization (WHO) has estimated that, worldwide, 3.7 million premature deaths in 2012 could be attributed to exposure to poor air quality and 200,000 of these were in Europe[6.] The most common reasons for these deaths were heart disease and stroke (in almost 80% of the cases), followed by lung diseases.

4.2.2 In the UK, it has been estimated that poor air quality contributed to almost 29,000 premature deaths[7] in 2008 from exposure to anthropogenic $PM_{2.5}$ concentrations. Defra recently also estimated that 23,500 premature deaths in the UK can be attributed to health effects from exposure to NO_2 concentrations[8]. This estimate is based on research by the Committee on the Medical Effects of Air Pollution (COMEAP)[9,] which states that:

> *"Studies have shown associations of nitrogen dioxide in outdoor air with adverse effects on health, including reduced life expectancy."*

4.2.3 In London, it has been estimated that poor air quality contributed to approximately 9,400 premature deaths[10] in 2010 from exposure to both $PM_{2.5}$ and NO_2 concentrations.

4.2.4 The Royal College of Physicians recently published a report[11], in collaboration with the Royal College of Paediatrics and Health, highlighting the newly recognised effects, from birth to death, of persistent air pollution. The aim of the report is to raise awareness of these issues affecting health throughout a lifetime, from both indoor and outdoor air pollution. It identifies the impacts and estimated costs of air pollution in the UK and possible future impacts. Using the results of previously published studies, it reports that there are 40,000 premature deaths in the UK each year due to the impact of outdoor $PM_{2.5}$ and NOx concentrations. The cost to individuals and society is estimated to be more than £20 billion annually for the UK.

4.3 Air quality standards

4.3.1 Air quality standards for various pollutants have been set by European legislation (limit values) and transposed into national law in the UK. The EU limit values are based on recommendations by WHO. The main pollutants of concern in London are nitrogen dioxide (NO_2) and particulate matter (PM_{10} and $PM_{2.5}$). The standard for annual mean concentrations of NO_2 and PM_{10} is 40µg/m³ and for $PM_{2.5}$ is 25µg/m³.

4.3.2 The standards for short term concentrations are 200µg/m³ as an hourly limit for NO_2 and 50µg/m³ as a daily limit for PM_{10} concentrations. These limits should not be exceeded more than 18 and 35 times a year respectively. No short term limit has been set by the EU or UK legislation for $PM_{2.5}$ concentrations. Further information on air quality standards and legislation can be found in Appendix A.

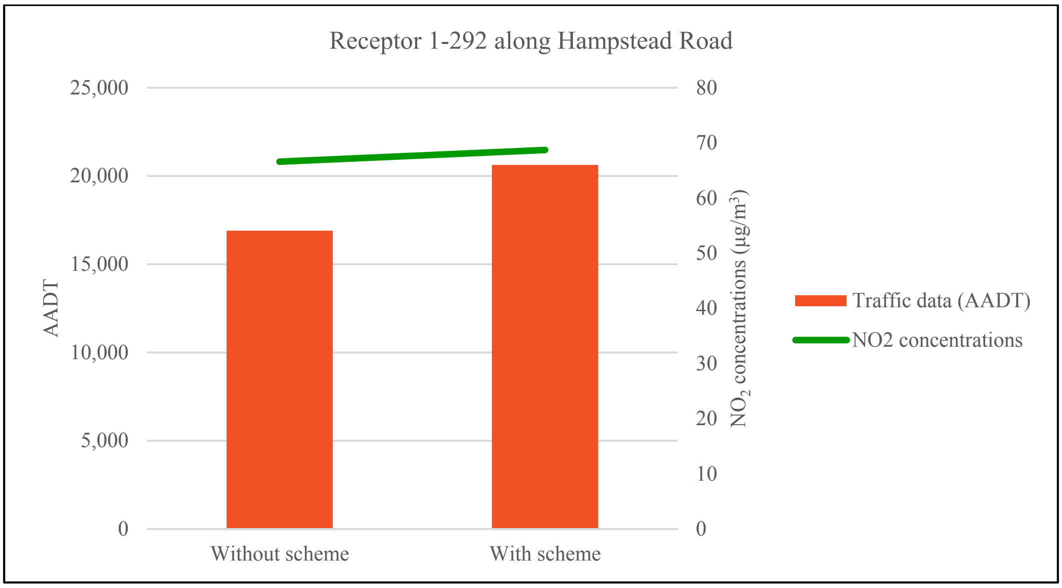
4.4 HS2 Phase One air quality assessment

4.4.1 The air quality assessment undertaken for the HS2 Phase One scheme has been published within the main ES as amended. This includes assessment of dust emissions (non-combustion related) during construction and assessment of vehicles emissions during construction and operation of the scheme. The assessment of traffic emissions was undertaken for NO_2 and PM_{10} concentrations against the relevant standards, as described in section 4.3.

4.4.2 No significant effects were predicted from dust emissions (non-combustion related) during construction. In relation to traffic emissions, significant air quality effects (beneficial and adverse) were predicted from changes in NO_2 concentrations within Greater London (Community Forum Areas (CFAs) 1, 2, 3, 4 and 6). Significant effects from changes in PM_{10} concentrations were predicted in central/inner London (CFA 1). No significant effects were predicted elsewhere along the route. The significant effects relate to the scale of works in the urban area, where existing air quality is already poor and there are traffic changes on heavily used roads.

4.4.3 The predicted change in NO_2 concentrations within CFAs 1 to 3 range from a decrease of 2.5µg/m³ to an increase of 3.3µg/m³, while in CFAs 4 to 6 from -2.9µg/m³ to +4.5µg/m³. As an example, a receptor (ID 1-292) along Hampstead Road near Euston Station has been predicted to experience a change of +2.1µg/m³ in annual mean NO_2 concentrations during the 2017 construction year. This change has been added to the future predicted baseline of 66.6µg/m³ and therefore the receptor is anticipated to experience substantial adverse impacts. The changes in traffic flows along Hampstead Road for the same construction scenario are anticipated to be +3,719 vehicles as annual average daily traffic (AADT) (Figure 1).

Figure 1: Example receptor for air quality assessment



4.5 Vehicle emissions

4.5.1 Emissions from on road vehicles are regulated by European law through a series of Directives, the first of which was in 1970[12]. The stages of emissions regulations are referred to as Euro 1 to 6 (Arabic numeral) for light duty vehicles (LDVs) and Euro I to VI (Roman numeral) for heavy duty vehicles (HDVs). Each stage applies from a certain date (see Table 20 and Table 21in Appendix C). New vehicles that do not comply with the emission standards cannot be sold in the EU.

4.5.2 Older vehicles do not need to be retrofitted before they are resold. There are currently no formal type-approval standards for retrofitted vehicles and so it is not sensible at this stage for HS2 Ltd to try to encourage this route for compliance with Euro VI; it is not possible to identify retrofitted vehicles from their number plate.

4.5.3 The commercial lifetime of a vehicle depends on the type of vehicle and the use to which it is put. Some commercial vehicles may be replaced every 3 years if put under heavy use, while others may remain in use for 10 years or more.

Vehicle classification

4.5.4 Table 1 shows the vehicle types and weights that comprise LDVs and HDVs. The vehicles are also classified as light goods vehicles (LGVs) and heavy goods vehicles (HGVs) where appropriate. The distinction between HDVs and HGVs is that HGVs carry goods, whereas HDVs may carry goods or passengers. The same applies for the distinction between LDVs and LGVs. The EU definition of vehicle category[13,14] used for vehicle and drive licensing, as well as for vehicle taxation is also given in Table 1. For the purposes of this study, the focus is mainly HGVs and LGVs.

4.5.5 The DfT defines a series of vehicle categories to which emission standards are applied. Passenger vehicles are Category M, while other LDVs and HDVs are Category N. Category N vehicles are those "with at least four wheels designed and constructed for the carriage of goods"[15]. The types N1, N2 and N3 refer to the size of the vehicles. N1 vehicles have a maximum gross vehicle weight of 3.5 tonnes, N2 vehicles are between 3.5 to 12 tonnes and N3 vehicles are over 12 tonnes.

4.5.6 HGVs are further split into rigid and articulated vehicles. Rigid vehicles have a rigid cargo body fixed to the driver's cab, while articulated vehicles consist of a tractor unit (front section) and a trailer (rear section) joined by a permanent or semi permanent joint (kingpin). Examples of the vehicle types in relation to construction related activities are provided in Appendix B.

Table 1: Definition of light and heavy vehicle types

Vehicle duty type	Goods vehicle type	Vehicle type	DfT Vehicle category
LDV	–	Passenger cars, no more than 8 seats in addition to the driver	Category M
	LGV	Light commercial vehicles ≤1,305 kg	Category N1-I
	LGV	Light commercial vehicles 1,305–1,760 kg	Category N1-II
	LGV	Light commercial vehicles >1,760 kg, ≤ 3,500 kg	Category N1-III and N2
HDV	HGV	(Lorry) HGV Rigid > 3,500 kg; <12,000 kg	Category N2
	HGV	(Lorry) HGV Rigid > 12,000 kg	Category N3
	HGV	(Lorry) HGV Articulated >14,000 kg; <50,000 kg	Category N3
	–	Bus < 5,000 kg, more than 8 seats in addition to the driver	Category M2
	–	Bus > 5,000 kg, more than 8 seats in addition to the driver Coach > 15,000 kg, more than 8 seats in addition to the driver	Category M3

EU vehicle emission standards

4.5.7 The Euro standards were introduced in 1992 for passenger cars (Euro 1) and HGVs (Euro I) and in 1994 for LGVs (Euro 1). Earlier vehicles (1988-1992) are termed pre-Euro. The standards are enforced using a system of type approval, whereby whole vehicles, vehicle systems, and separate components are confirmed, by an independent third party (the Approval Authority) as meeting the specified performance standards. In the UK the Approval Authority is the Vehicle Certification Agency (VCA).

4.5.8 It is important to note that the standards do not specify the technology (e.g. diesel, particle trap) to be used. For LDVs, the regulated emissions are carbon monoxide, NOx, total hydrocarbons, non-methane hydrocarbons, particulate matter and the number of particles emitted per kilometre driven. For HDVs, the regulated emissions are carbon monoxide, NOx, hydrocarbons and particulate matter. The Euro standards for light and heavy vehicles are presented in Appendix C.

Real world driving emissions

4.5.9 While vehicle emission standards have been tightened, it had been observed for several years that NO_2 concentrations measured at roadside locations and locations that are not near to main roads or other major sources of emissions (referred to as background locations), were not decreasing over time as rapidly as expected. In some cases, concentrations of NO_2 were not decreasing at all.

4.5.10 Real world, on-the-road, tailpipe emissions can be measured using Portable Emission Measurement Systems (PEMS). Using PEMS and other methods to measure exhaust concentrations, it was found that diesel vehicles, in particular diesel cars/LGVs, while meeting the standard for type approval in test conditions, were emitting at higher concentrations in real use. This affected Euro 4 and Euro 5 cars/LGVs in particular. The situation was made worse by a rapid increase in diesel cars in the UK fleet (e.g. from 7.4% in 1994 to 28.9% in 2010), largely due to the incentive of lower vehicle excise duty, often referred to as "car tax" for diesel cars on the basis of their lower carbon emissions.

4.5.11 The UK company Emissions Analytics recently created the EQUA air quality index[16], which is a rating tool for Euro 5 and Euro 6 cars based on real-world NOx emissions. This aims to promote public awareness and understanding on the real-world emissions of various cars so that consumers can make an informed decision when buying a vehicle. The current listings suggest that most petrol engine cars meet the Euro 6 standard; however, most diesel engine cars do not. An index for light commercial vehicles is due to be published towards the end of 2016.

4.5.12 Further information on the issue of the under-performance of diesel vehicles in real world driving conditions, as well as relevant information from the EQUA air quality index are presented in Appendix C.

Upcoming changes to the vehicle emissions testing regime

4.5.13 In response to the growing awareness of the unrepresentativeness of the test cycle the EU will implement two changes. From 2017 a new test cycle will be used for LDVs, called the Worldwide harmonized Light vehicles Test Procedures (WLTP). This is a global harmonized standard and is intended to be more representative of real world driving than the current test cycles.

4.5.14 In addition to WLTP, the testing of Real Driving Emissions (RDE) will be introduced over the period 2017 to 2021. RDE will be an additional on-the-road PEMS test element of the type approval. When RDE is introduced in September 2017 just for new model **types**, the vehicles will be allowed to emit up to 110% more NOx (i.e. 2.1 times the Euro 6 limit) than the laboratory-based testing limit during the RDE. By September 2019 all newly licensed **vehicles** must meet the same limit (up to 110% more than the limit). By 2021 performance of newly licensed vehicles under RDE must be no more than 50% (of NOx) above the laboratory-based testing limit. Vehicles achieving emissions under these permitted variations from the laboratory-based testing limit would be compliant with the limit in force at that time.

4.5.15 The regulations implementing Euro VI[17,18] introduce a procedure for PEMS testing as a mandatory part of the type approval legislation in order to check the conformity of heavy duty engines with the applicable emissions certification standards during the normal life of those engines; this is called "In-Service Conformity" (ISC) and is a type of RDE testing. Further details can be found in a research report published by the European Union[19].

4.5.16 The details of RDE are not yet finalised nor is the mechanism by which the EC would further tighten the regulations, to ensure that ultimately vehicles will meet the original emission limit itself during RDE.

4.6 Air Quality Plan for the UK

4.6.1 The UK Supreme Court made a judgement[20] in April 2015, directing the UK Government to draw up plans for compliance with the EU limit values (the UK air quality objectives), for compliance to be 'as soon as possible'.

4.6.2 The judgement was the conclusion of several years of legal enquiry into the case brought in the UK Supreme Court by the Client Earth[21] campaigning organisation against the Secretary of State for the Environment, Food and Rural Affairs. The proceedings arose out of the UK's failure since 2010 to comply in certain zones with the NO_2 limit values. In 2013, the EU annual mean limit value for NO_2 was reported to be breached in 38 of the UK's 43 zones.

4.6.3 In response to the Supreme Court judgement Defra published a Draft Air Quality Plan for the UK[22] in September 2015, which was followed by the Air Quality Plan (AQP) in December 2015, which was partly revised in January 2016[23,24].

4.6.4 The AQP reports that on average, 80% of NO_X emissions at roadside location where the air quality limit is exceeded is from transport, with diesel vehicles being of greatest concern. This concern is due to the rapid growth in the proportion of diesel vehicles in the fleet nationally, at the same time as diesel vehicles on-the-road are failing to meet the NOx type approval standards and emit more NO_2 than petrol vehicles. The AQP measures are therefore targeted at reducing vehicle emissions.

4.6.5 The modelling undertaken to inform the AQP showed that compliance with the EU annual mean limit for NO_2 would be achieved by 2020 in 37 zones under the "business as usual" scenario, that is, without any specific action to improve air quality. For the five of the six remaining zones Defra predict compliance will be achieved by 2020 by the introduction of Clean Air Zones (CAZs) in Birmingham, Leeds, Southampton, Nottingham and Derby with some additional measures in Birmingham and Leeds. Those additional measures will include park and ride schemes, signage, changes in road layouts and provision of infrastructure for alternative fuels. Defra predict London will comply by 2025 if the Mayor of London's planned measures are implemented and a CAZ is introduced.

Clean Air Zones

4.6.6 A CAZ is a geographical area within which drivers will pay a charge to drive unless their vehicle meets the set standards. The emission standards that vehicles must meet as a minimum are given in Table 2. The level of charge for non-compliant vehicles would be set by the local authority at a level designed to reduce pollution, not to raise revenue beyond covering the costs of the scheme.

Table 2: CAZ emission standards for common vehicle types

Vehicle type	Emission limit (all pollutants)
Bus/coaches	Euro VI
HGV	Euro VI
Van (1.305 – 3.5 tonnes)	Euro 6 (diesel), Euro 4 (petrol)
Car/light commercial (up to 1.305 tonnes)	Euro 6 (diesel), Euro 4 (petrol)

4.6.7 A fuller description of vehicle types will be developed by Defra as part of the full CAZ design. Reducing vehicle emissions of existing vehicles through retrofitting and/or alternative fuels will be supported by the CAZ approach. All ultra low emission vehicles (ULEVs) will be allowed free access to the CAZs to send a strong signal to support their use. CAZs will also be able to provide additional incentives for ULEVs and zero emission vehicles (ZEVs), such as charge points and preferential parking. Different classes of CAZ have been defined by Defra and these are shown in Table 3.

Table 3: Definition of CAZ classes

CAZ Class	Vehicles included
A	Buses, coaches and taxis*
B	Buses, coaches and HGVs
C	Buses, coaches, HGVs and LGVs
D	Buses, coaches, HGVs, LGVs and cars

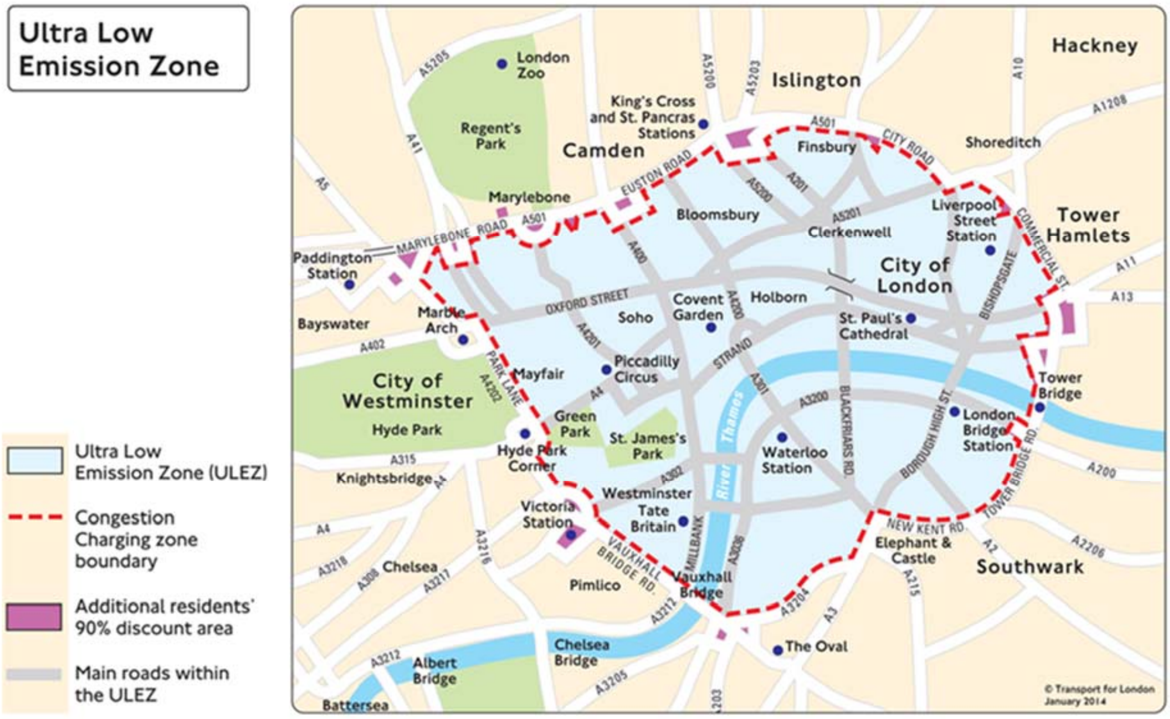
Note: *Taxis will generally also include private hire vehicles

Air Quality Plan for the Greater London Urban Area

4.6.8 The previous Mayor of London planned to implement an Ultra Low Emission Zone (ULEZ) from September 2020 for road traffic emissions in central London on the current boundaries of the Congestion Charging (CC) Zone[25] (Figure 2). Within this zone, all double decker buses will be hybrid diesel-electric and all single decker buses will be zero tailpipe emissions capable (ZEC); that is, hydrogen or pure electric. All taxis will also be required to be ZEC and operate as such within the zone. Cars and vans travelling within the zone will need to comply with the Euro 6 emissions standard if diesel and with the Euro 4 emissions standard if petrol. Heavy goods vehicles (HGVs), buses and coaches within the zone will need to comply with the Euro VI emissions standard.

4.6.9 Therefore, the ULEZ would be broadly equivalent to a Class D CAZ. London also has a Low Emission Zone (LEZ) in place across the Greater London area. Defra plans for a Class B or Class C CAZ to be implemented across Greater London, as a tightening of the existing LEZ. The new Mayor will be consulting on additional air quality measures, including those related to the ULEZ (see section 4.7).

Figure 2: Detailed map of the current boundary of the CC Zone and ULEZ extent



Government Procurement

4.6.10 Central Government maintains and updates a set of Government Buying Standards (GBS) for vehicles which sets down minimum mandatory and best practice standards requirements for cars, vans, buses and trucks. The GBS must be used by central Government departments and their related organisations, any of whom may follow even tighter standards. They may be used by any other organisation looking for a benchmark of good practice, and, as such, have a broader impact beyond the organisations for which they are mandatory.

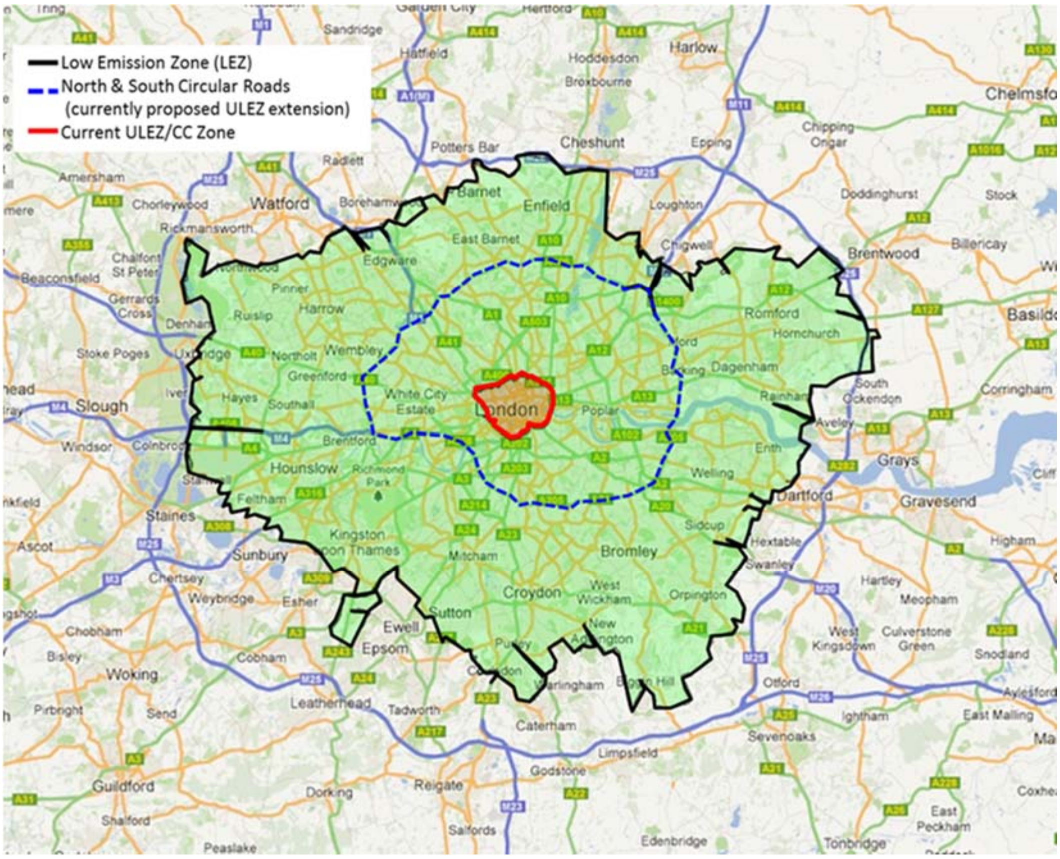
4.6.11 To date the GBS primarily addressed CO2 emissions but in 2016 the Government plans to publish updated standards for cars and vans and encouragement for ULEVs where appropriate. The revised standards will take into account NOx emissions as well as CO2, sending a clear message that reducing NOx emissions as well as CO2 emissions are important, so that the Government's purchasing power can support reductions in emissions of NOx and NO2.

4.7 Upcoming changes to air quality policies in London

4.7.1 On 5 July 2016 the new Mayor of London, Sadiq Khan, launched[26] a formal policy consultation on additional measures to tackle air pollution in London. The measures in the consultation include:

- A new emissions surcharge, i.e. an extra £10 charge (on top of the congestion charge) for the most polluting vehicles (pre-Euro 4/IV) entering the CC Zone in central London from 2017 (it would start operating towards the end of the year);
- The implementation of the ULEZ in September 2019 (instead of 2020);
- Extension of the ULEZ's spatial extent to include the North Circular Road and the South Circular Road (Figure 3) and for lorries, buses and coaches London-wide from 2020;
- All double decker buses to be ULEZ-compliant in central London in 2019 (instead of 2020);
- Implement clean bus control corridors to tackle pollution hotspots;
- Develop a detailed diesel scrappage scheme as part of a wider national scheme delivered by the Government; and
- Proposals to work with the Government to tackle air pollution on a national and international level.

Figure 3: London existing and proposed emission zones



4.8 SME Commitment

4.8.1 HS2 Ltd is committed to ensuring that small and medium sized enterprises (SMEs) are not disadvantaged in bidding for tenders on the HS2 project. An SME is defined in EU recommendation 2003/361 on the basis of staff headcount and a financial parameter: turnover or balance sheet total. The definition is given in Table 4. This definition of an SME is used by the EU in determining eligibility for support under many EU business support programmes, including research funding, competitiveness and innovation funding and similar national support programmes. There may also be fewer requirements or reduced fees for EU administrative compliance for SMEs.

Table 4: EU definition of an SME

Company category	Staff headcount	Turnover	OR	Balance sheet total
Medium-sized	< 250	≤ € 50 million	OR	≤ € 43 million
Small	< 50	≤ € 10 million	OR	≤ € 10 million
Micro	< 10	≤ € 2 million	OR	≤ € 2 million

Box 1: HS2 commitments to SMEs

"HS2 Ltd will be a catalyst for sustained and balanced economic growth across the UK and this has been enshrined as a Strategic Goal. The importance of SMEs is reflected in the ITT and in the Contract(s) to be awarded by:

a) The Contractor is required to ensure every procurement is fair, transparent and provides a competitive range of bids of which the winning tender maximises the opportunity for SMEs to Provide the Works; and
b) The Contractor's Fee will be withheld, in accordance with the incentive model, if all SME opportunities are not published on Compete For (Tenderers are referred to Part 6 below for further information on the incentive model).
c) Tenderers are referred to WI section WI0800 for further information on HS2 Ltd's requirements for SMEs for EWC."

HS2 Procurement Process Requirements:

"The Employer requires every procurement to be fair, transparent and competitive and maximise the opportunity for Small and Medium Enterprises (SMEs) to Provide the Works.

The Contractor shall tender all steel requirements in an open and transparent competition applying evaluation factors which include the social and environmental impacts.

Within one year, and annually thereafter, working with the HS2 Supply Chain team, the Contractor shall participate and support in the delivery of a 'Meet the Contractor' event, to open up supply chain opportunities and engage with prospective suppliers."

Use of CompeteFor:

"The Contractor shall advertise all subcontracted opportunities arising from the works using the CompeteFor web-sourcing portal unless otherwise accepted by the Project Manager.

The Contractor and its Subcontractors shall close all advertised opportunities on CompeteFor within 1 week following the award of the relevant contract."

4.8.2 SMEs are said to make up 99% of all businesses in the EU[27]. In the UK[28], 99.3% of all private sector businesses in 2015 were SMEs and these accounted for 16.3 million jobs (60% of the total private sector employment) and a turnover of £1.8 trillion (46% of the private sector turnover). SMEs are more likely to operate locally, employing people from the local area who in turn support other local businesses in their spending, it is considered important that SMEs have the opportunity to win business in large infrastructure projects.

4.8.3 The HS2 Suppliers Guide[29] describes the objective that, in the HS2 procurement process, any potential barriers that SMEs face should be reduced. HS2 expect 60% of contract opportunities in the supply chain to be awarded to SMEs. In order to simplify the procurement process, main contractors are required to use open procurement tools such as Contracts Finder and CompeteFor, advertising opportunities as they arise.

4.8.4 The commitment made to the LB Camden could be considered to place a disproportionate cost burden on small businesses, for which investment in new, clean vehicles would be a more significant part of its costs. Whereas a large operator with a multi vehicle fleet could upgrade part of its fleet for use on HS2 and deploy old vehicles on other jobs, an SME might operate a single vehicle which would need to be upgraded to be eligible for an HS2-related contract (see section 5 and section 7 for more discussion on SMEs and vehicle availability).

5 Construction traffic analysis

5.1 Introduction

5.1.1 This section reviews the traffic data published as part of the transport assessment within the main ES as amended. The transport assessment includes estimates of the likely numbers and types of vehicles for each year of construction activity. The traffic data used in this analysis are derived from those included within the transport and air quality assessments as published in the main ES as amended.

5.1.2 The estimates in the ES as amended are based on the day with the highest increase in traffic predicted to occur within each year of construction being applied to all days of that year. The traffic data for CFAs 1 to 3 assumes that all excavated material will be removed by road. There is currently further work commissioned by HS2 Ltd to investigate the potential for removing and importing some material by rail. Since the study is ongoing and no decision has been made to date, this study uses the assessments and assumptions in the SES and AP3 ES and does not pre suppose that material may be transported by rail.

5.1.3 Similarly, the study does not take account of the implications of a number of undertakings and assurances offered since the SES and AP documentation was published, with respect to potential reductions in peak traffic flows in the Old Oak Common and Ickenham/West Ruislip areas.

5.1.4 The numbers presented in this section relate to 2 way movements and not to the number of vehicles in the fleet. A single vehicle arriving and departing a site counts as two vehicle movements. Light vehicles have been assumed to be an extra 10% of the total heavy vehicle movements as an average across the whole route over the entire construction period.

5.2 CFA 1

5.2.1 The daily peak traffic data for the construction period at Euston (CFA 1) have been taken from the SES2 and AP3 ES transport assessment. The data showed that during the construction period at Euston, an increase of 730 HGVs on the local road network would be required as a maximum. This figure represents the maximum number of movements required at any one day during the highest peak in construction activities. To put this into perspective, the total number of vehicles travelling along Euston Road is 41,291 AADT, out of which 2,013 are HGVs (DfT traffic count 17,169)[30].

5.2.2 The daily peak traffic data has been further broken down into the following vehicle classifications using current understanding of the construction activities and Arup's professional judgement:

- Cars / LGVs less than 3.5 tonnes;
- Rigid HGVs 3.5 to 7.5 tonnes;

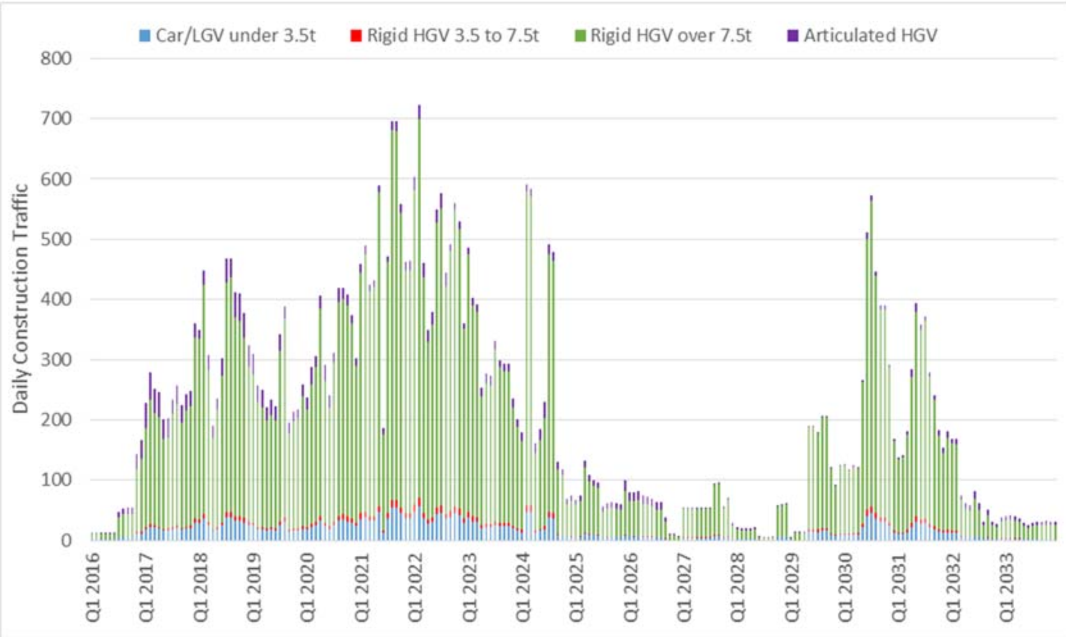
- Rigid HGVs over 7.5 tonnes; and
- Articulated HGVs.

5.2.3 It was assumed that for vehicles up to 7.5 tonnes there would be an 80/20 split between HGVs and LGVs respectively. It was further assumed that rigid HGVs over 7.5 tonnes would comprise the sum of vehicles for demolition, excavation, concrete and waste, together with approximately 80% of other miscellaneous activities, while articulated HGVs would comprise the sum of vehicles for Rebar (reinforcing bar) and approximately 20% of other miscellaneous activities.

5.2.4 The analysis identified that, on average, approximately 84% of vehicles associated with HS2 construction at Euston are rigid HGVs over 7.5 tonnes, 8% cars / LGVs less than 3.5 tonnes, 6% articulated HGVs and 2% rigid HGVs 3.5 to 7.5 tonnes. Figure 4 presents the breakdown of vehicle types for each year within the construction period as 2 way movements.

5.2.5 It can be seen that the rigid HGVs over 7.5 tonnes will form the majority for Euston. Over the entire Stage A and B1 construction programme, these vehicles are estimated to comprise, on average, 26% for concrete, 7% for demolitions, 36% for excavated material, 31% for other miscellaneous activities and less than 1% for waste disposal.

Figure 4: HS2 2 way daily construction traffic by vehicle type at Euston

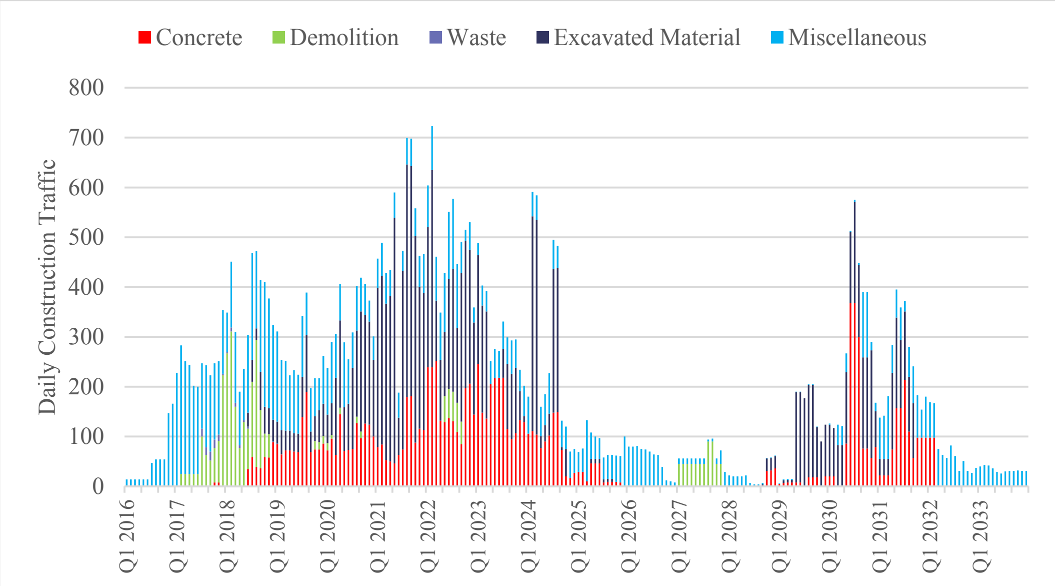


5.2.6 Figure 5 presents the breakdown of the peak daily traffic flows per activity for the duration of the construction programme in Euston. In 2017 and 2018 the majority of the works are associated with other miscellaneous activities, such as utility works, together with the removal of demolition material. Transport of concrete and excavated material begins to build up from the third quarter of 2018 with the majority of the excavated material vehicle movements occurring after 2020 and peaking in 2021. Generally, excavated material is dug out material from below ground level; demolition material is that resulting from above and below ground demolition of buildings and man made structures and can usually be reused or recycled; waste material may include contaminated material and is generally not suitable for reuse or recycling.

5.2.7 A calculation of the potential fleet size required for these works is presented in section 12.

5.2.8 As discussed in section 3, HS2 Ltd has a policy that Euro VI HGVs (above 3.5 tonnes) shall be used for the purpose of transporting excavated material in low emission zone locations. This policy has also been incorporated in the air quality assessment for Euston and London Met, as published in the SES2 and AP3 ES and the SES3 and AP4 ES.

Figure 5: HS2 2 way daily construction traffic by activity at Euston



5.3 CFAs 3 to 6

5.3.1 The daily peak traffic data for the construction period outside CFA1 has been taken from the SES and AP2 ES and the SES3 and AP4 ES transport assessments. An analysis has been provided for Victoria Road south of Bethune Road and Old Oak Common Lane in CFA 4 and for Swakeleys Road in CFA 6.

5.3.2 Figure 6 shows daily HGV construction movements from the Victoria Road compounds south of Bethune Road (CFA 4); the majority of vehicle movements are associated with excavated material, followed by concrete.

5.3.3 Figure 7 shows daily HGV construction movements for Old Oak Common Lane (CFA 4); the majority of vehicle movements are associated with excavated material, followed by waste and concrete.

5.3.4 The construction traffic numbers in CFA 4 remain the same in both the SES and AP2 ES and the SES3 and AP4 ES assessments.

Figure 6: HS2 2 way daily construction traffic from the Victoria Road main compounds south of Bethune Road in CFA 4)

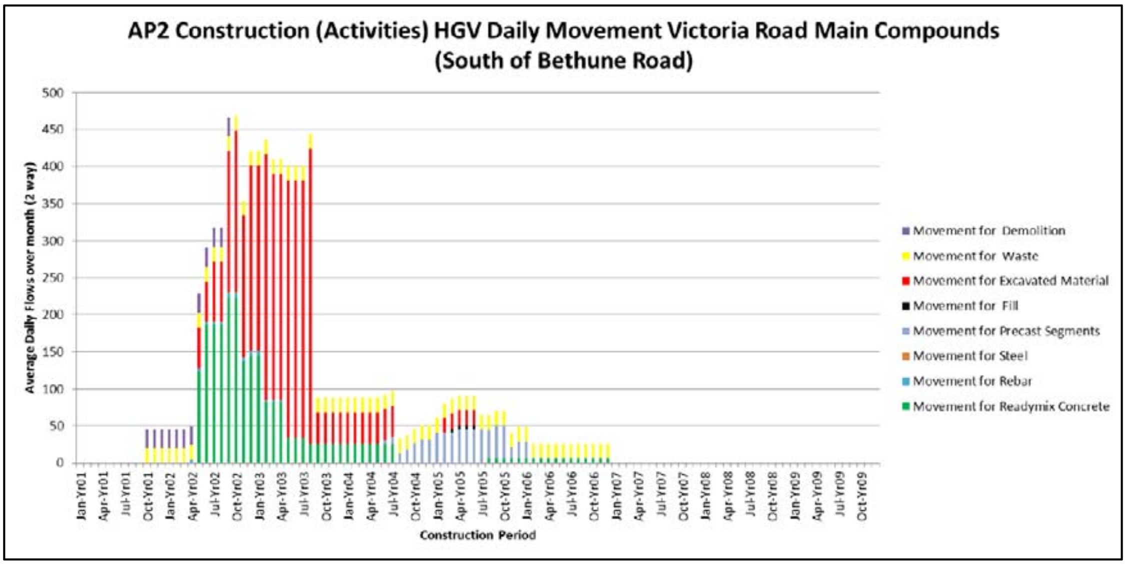
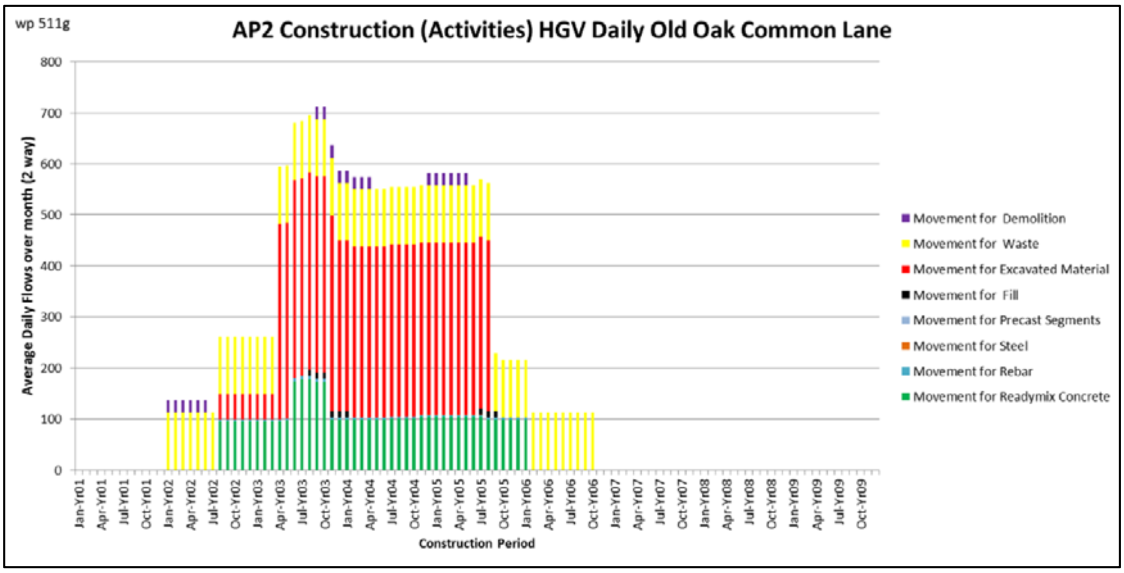


Figure 7: HS2 2 way daily construction traffic along Old Oak Common Lane in CFA 4



5.3.5 Figure 8 shows daily HGV construction movements for Swakeleys Road in CFA 6; the majority of vehicle movements are associated mass haul and movements associated with the Colne Viaduct south embankment. This is based on the SES and AP2 ES.

5.3.6 Figure 9 shows an updated graph of daily HGV construction movements for Swakeleys Road taking into account the proposed haul road in the area, as detailed in the SES3 and AP4 ES.

Figure 8: HS2 2 way daily construction traffic along Swakeleys Road in CFA 6 (SES and AP2 ES)

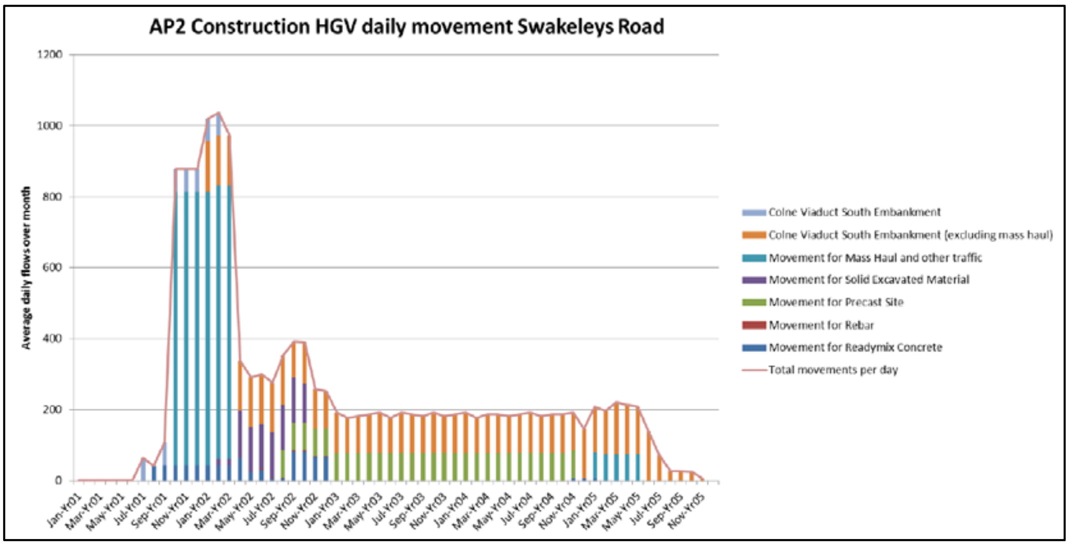
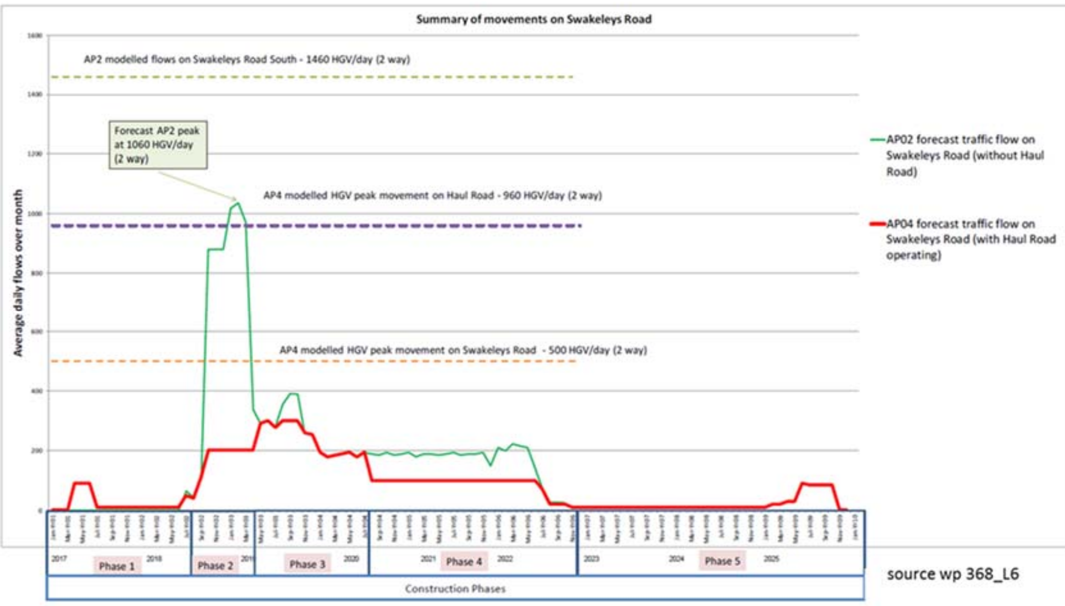


Figure 9: HS2 2-way daily construction traffic along Swakeleys Road in CFA 6 (SES3 and AP4 ES)



6 Air quality appraisal

6.1 Introduction

6.1.1 This section summarises three different methods that have been used to estimate the likely economic costs (and benefits) of the impacts to air quality:

- *WebTAG*: A WebTAG appraisal (PM10 and NOx) for affected roads within CFAs 1 to 6;
- *Defra CFAs 1-6*: Defra NOx damage costs for CFAs 1 to 6; and
- *Defra within M25*: Defra NOx damage costs within the M25 motorway using vehicle fleet calculations.

6.1.2 The first method uses the Government's toolkit, called WebTAG, which is a methodology designed for appraisals of transport schemes. The assessment determines the economic cost (or benefit) of the impacts to air quality. The WebTAG study did not consider the reduction in these costs that would result from all vehicles complying with the Euro VI emissions standard.

6.1.3 The impact on air quality has been quantified in monetary terms (£), based on the evidence of the harm to human health and the environment. This has been based on vehicle NOx emissions and changes to ambient PM10 concentrations resulting from vehicles. A cost is expressed as a negative amount of money, while a benefit as a positive amount.

6.1.4 The appraisal was based on the air quality assessment presented in the main ES as amended, whereby the traffic data was screened[31] using the DMRB criteria[A] to derive an affected road network study area. The costs presented from this method are, therefore, limited to those properties and sensitive receptors within 200m of the affected road network.

6.1.5 The second method uses the same reduced study area as the WebTAG appraisal, but with updated range of damage costs for NOx emissions, as published by Defra[32] in September 2015.

6.1.6 The third method calculates the overall costs of the scheme to local air quality within Greater London. This uses the Defra range of damage costs (as in the second method) and a calculation of the fleet size, total quantities of materials to be moved, the size of the HGVs moving the materials and an estimate of the likely distance travelled by each HGV. Further details on fleet size calculations are detailed in section 12.

[A] Change of ±1,000 AADT or change of ±200 HDVs or change of ±10kph daily average speed or change of ±20kph peak hour speed or change in road alignment by 5m or more.

6.2 WebTAG appraisal for CFAs 1 to 6

Methodology

6.2.1 The damage costs for this analysis have been taken from the WebTAG air quality valuation workbook[33]. They have a base year of 2010 and a discount factor is applied for future years. A change in PM_{10} concentrations at a residential property (representing long term exposure) is valued at £92.7 per household per 1μg/m^3 (central estimate). A change in the mass of NOx (in tonnes) emitted per year is valued at £29,000 per tonne for abatement costs (central estimate).

6.2.2 The economic valuation was, therefore, undertaken using the WebTAG air quality valuation workbook. The air quality impacts are valued using a combination of damage costs and marginal abatement costs following the methodologies described in Defra's Supplementary Green Book guidance[34].

6.2.3 It should be noted that the WebTAG workbook linearly interpolates and extrapolates the changes in NOx emissions and PM10 concentrations over the appraisal period to calculate the costs. The appraisal period is usually from the opening year of a scheme until a forecast year in the future. In this study, a forecast year was not available; the economic valuation has been undertaken for each assessed scenario during construction of the scheme (these are further described in Appendix D). The method was agreed with the Transport Assessment and Strategic Modelling (TASM) team in the DfT.

6.2.4 The costs therefore present a snapshot of each assessed year during the construction period of the scheme.

Analysis

6.2.5 For CFAs 1 to 3 three scenarios were assessed during the Stage A Construction period, following the air quality assessment in the main ES as amended. These were the three years (2017, 2018 and 2023) where the peaks in construction traffic are predicted. For CFAs 4 to 6 two scenarios were assessed for the Construction period, corresponding to a peak in construction traffic in 2021, following the air quality assessment in the main ES as amended. These were scenario T1 assuming that Old Oak Common Lane would remain open during construction, and scenario T2 assuming that Old Oak Common Lane would be closed. For all assessed scenarios, it was assumed that emission factors and background pollutant concentrations remain constant from 2017 into the future.

6.2.6 Table 5 presents the predicted NOx emissions (in tonnes) for the above assessment scenarios without and with the scheme, as well as the resulting contribution from the scheme itself (i.e. change in emissions). Table 6 presents a summary of the costs for NOx and PM10 for all assessed scenarios.

Table 5: Predicted change in NOx emissions (tonnes)

Scenario	Without scheme	With scheme	Change
CFAs 1 to 3			
Stage A Construction 2017	872	873	0.94
Stage A Construction 2018	872	875	3.45
Stage A Construction 2023	872	881	9.05
CFAs 4 to 6 (SES and AP2 ES)			
Construction 2021 scenario T1	1,585	1,591	6.52
Construction 2021 scenario T2	1,585	1,589	4.66
CFAs 4 to 6 (SES3 and AP4 ES)			
Construction 2021 scenario T1	1,585	1,583	-1.90
Construction 2021 scenario T2	1,585	1,580	-4.24

Table 6: Summary of economic valuation for CFAs 1 to 6 using WebTAG

Scenario	NOx emissions	PM10 concentrations	Net present value
CFAs 1 to 3			
Stage A Construction 2017	-£21,480	£38,608	£17,128
Stage A Construction 2018	-£75,896	-£18,464	-£94,359
Stage A Construction 2023	-£167,815	-£89,528	-£257,343
CFAs 4 to 6 (SES and AP2 ES)			
Construction 2021 scenario T1	-£129,414	-£42,052	-£171,466
Construction 2021 scenario T2	-£92,652	-£43,411	-£136,063
CFAs 4 to 6 (SES3 and AP4 ES)			
Construction 2021 scenario T1	£37,701	-£22,602	£15,099
Construction 2021 scenario T2	£84,171	-£23,685	£60,306

6.2.7 To derive an overall cost of air pollution resulting from the construction of the scheme between 2017 and 2026, it was assumed that each year would have the same costs as the previous one. For CFAs 1 to 3 where three construction years were assessed (2017, 2018 and 2023), costs between 2019 and 2022 were assumed to be the same as in 2018 for each year and costs between 2024 and 2026 were assumed to be the same as in 2023. For CFAs 4 to 6 where only one construction year was assessed (2021), costs were assumed to be the same for every year between 2017 and 2026.

6.2.8 The highest costs for CFAs 4 to 6 (i.e. SES and AP2 ES assessment and scenario T1 when Old Oak Common remains open) were selected from the available scenarios.

Conclusions

6.2.9 For CFAs 1 to 6, it is estimated that there will be £2.37 million costs based on NOx emissions and £0.83 million costs based on ambient PM10 concentrations. This gives a total cost of £3.20 million related to air quality changes resulting from emissions to air as a result of the construction of the scheme (expressed as net present value, i.e. in future, costs are expressed in today's money taking into account the effect of inflation over the modelled period 2017 to 2026).

6.2.10 These assumptions are likely to overestimate the actual values, as activities in the intervening years are likely to be lower than the years modelled.

6.2.11 These costs represent the total cost in terms of air quality damage attributable to the construction of the scheme in CFAs 1 to 6 (London) 2017 2026. The modelling assumed that excavated material would be moved using Euro VI compliant HGVs and other HGVs would not be Euro VI compliant. If some or all of the HGVs associated with other activities were Euro VI then the cost would move closer to zero. Using ULEVs would also reduce the cost closer to zero.

6.3 Defra NOx damage costs for CFAs 1 to 6

6.3.1 The Defra air quality valuation approach includes a different set of damage costs which have been derived from a full impact-pathway approach assessment. The damage costs are provided for NOx emissions for different geographical locations and sources of pollution. In relation to road traffic in London, there are three categories of damage costs as presented in Table 7.

Table 7: Defra NOx damage costs for transport in London

Location and source	Low estimate	Central estimate	High estimate
Transport central London	£46,462	£115,405	£184,648
Transport inner London	£47,475	£118,688	£189,901
Transport outer London	£31,010	£77,526	£124,041

6.3.2 For the analysis in this report, the air quality costs are presented as a range from low to high costs, with a central estimate, consistent with the Defra damage costs. Due to the extent of the air quality study area from central up to outer London, it was not appropriate to use only one location of the Defra damage costs. Therefore, the lower end of the air quality costs has been calculated using the lowest value from the table, i.e. £31,010 for transport in outer London. Similarly, the highest end of the range has been calculated using the highest value from the table, i.e. £189,901 for transport in inner London. For the central estimate, an average of the values has been used from the inner and outer London locations, i.e. £98,107.

6.3.3 An uplift and a discount factor for future years has also been applied as per Defra's guidance. The resulting air quality costs for the assessment scenarios described in section 6.2, are presented in Table 8.

Table 8: Summary of NOx economic valuation for CFAs 1 to 6 using Defra damage costs

Scenario	Low estimate	Central estimate	High estimate
CFAs 1 to 3			
Stage A Construction 2017	-£28,382	-£89,791	-£173,805
Stage A Construction 2018	-£102,288	-£323,609	-£626,395
Stage A Construction 2023	-£249,710	-£790,014	-£1,529,193
CFAs 4 to 6 (SES and AP2 ES)			
Construction 2021 scenario T1	-£185,092	-£585,580	-£1,133,479
Construction 2021 scenario T2	-£132,514	-£419,236	-£811,496
CFAs 4 to 6 (SES3 and AP4 ES)			
Construction 2021 scenario T1	£53,921	£170,590	£330,202
Construction 2021 scenario T2	£120,384	£380,861	£737,214

6.3.4 To derive an overall cost of air pollution resulting from the construction of the scheme between 2017 and 2026 using these damage costs, the same approach was used as described in section 6.2, whereby it was assumed that each year would have the same costs as the previous one.

6.3.5 The resulting air quality costs (based on NOx emissions) for CFAs 1 to 6 is estimated to be between -£3.4 million to -£20.8 million with a central estimate of -£10.7 million (expressed as net present value).

6.4 Defra NOx damage costs within the M25

6.4.1 In order to calculate the air quality costs of the scheme for HGV travel within the M25, a different method was used whereby fleet estimates were made for the required HGVs to undertake the relevant construction activities. To convert the number of traffic movements (as detailed in section 5) to the fleet of vehicles required, certain assumptions were made in relation to the distance travelled for each HGV (from origin to an HS2 site and back), which in turn determines the maximum number of return trips a vehicle could make in a day. In more detail, the following steps were undertaken to estimate the likely range of damage costs for NOx emissions:

1. Estimate total quantities of the various materials (concrete, excavated material etc.) over the whole construction period (2017-2033 in CFA 1 and 2017-2026 in the rest of the CFAs) (these were already estimated as part of other work connected with HS2) (see Table 9).
2. Using the capacity of each type of vehicle (e.g. 6 tonnes for concrete), estimate the total number of round trips required.
3. Add the estimates of number of trips and distance travelled for each trip to give a total number of vehicle kilometres likely to be travelled during the construction period.
4. Use an average emissions factor (grams of NOx per km travelled) to estimate the total amount of NOx emitted by HGVs associated with the scheme's construction within the M25 (see assumptions below for methodology of how this average emissions factor has been estimated).
5. Use the mean of the Defra damage costs for inner and outer London (see Table 7 in previous section) to derive the range in total damage costs resulting from NOx emissions over the whole construction period (low, central and high estimates).

6.4.2 The following assumptions have been made in this analysis:

- Distances travelled by each HGV are only within the M25. If an HGV travels wholly within the M25, then the total distance has been included. However, if an HGV travels partly on or outside the M25, then only the distance travelled **within** the M25 has been included in the calculations.
- An average speed of 25kph has been used for the emissions calculations (speeds are likely to be lower in central/inner London and higher in outer London). NOx emissions have been taken from the National Atmospheric Emissions Inventory[35] (NAEI) for a rigid 26-28 tonne HGV as follows:
  - Euro VI HGV: 1.15g/km
  - Euro V HGV (with selective catalytic reduction – SCR): 3.7g/km
  - Euro V HGV (with exhaust gas recirculation – EGR): 9.2g/km
- Estimates of likely HGV engine type (Euro V, Euro VI etc.) for each year are available from the NAEI. The following split was used for the fleet calculations: 75% Euro VI HGVs and 25% Euro V HGVs (further split into 75% SCR and 25% EGR). However, HS2 Ltd have made a commitment to use Euro VI HGVs for all construction activities, unless they are exempted. It is expected that exemptions would be less than 8% of

vehicles (but not necessarily 8% of journeys). There are likely to be more non-Euro VI vehicles in the earlier years of construction and fewer to nearly none as the construction period progresses. Two scenarios have therefore been assessed:

a. 100% of HGVs transporting excavated material are Euro VI and the other vehicles use the above split of 75% Euro VI and 25% Euro V; and

b. 100% of HGVs are Euro VI for all activities.

- Emissions from LDVs have not been included in these calculations. Detailed breakdown estimates of LDVs are not available, other than being approximately 10% of the total traffic movements (as per main ES as amended). The activities undertaken by LDVs are far more varied than HGVs and so distances travelled are not easy to estimate. Additionally, since emissions of NOx are considerably lower per km than those for HGVs, the effect of excluding the LDVs from the damage cost calculations is likely to be small and would not significantly affect the overall estimate.

6.4.3 It should be noted that work is currently being undertaken by HS2 Ltd to review the number of HGV movements allowed in certain locations in the light of commitments made to the local authorities during and following the House of Commons Select Committee process (e.g. cap on Swakeleys Road within CFA 6 and Materials by Rail study in CFA 1). The numbers presented here are prior to any such adjustment; any revised numbers as part of these studies are likely to be lower than those presented here.

Table 9: Quantities of materials and distance travelled during construction

Activity	Quantity (ktonnes)	Load per HGV (tonnes)	Number of HGV trips	Total distance (million veh km)
CFA 1				
Demolition material	153	5	30,640	1.42
Excavated material	1,175	8.5	138,200	11.1
Concrete	565	6	94,180	1.30
Steel reinforcement	85	30	2,825	0.226
Miscellaneous	*various*	*various*	102,000	3.79
Total (CFA 1)			**367,800**	**17.8**
CFAs 3 to 6				
Demolition material	261	5	30,730	2.82
Excavated material	3,620	8.5	426,000	39.0
Concrete	882	6	147,100	6.95
Steel reinforcement	101	30	3,369	0.269

Activity	Quantity (ktonnes)	Load per HGV (tonnes)	Number of HGV trips	Total distance (million veh km)
Waste	472	8.5	55,470	5.01
Total (CFAs 3-6)			**662,600**	**54.0**
CFAs 1 to 6				
Total (CFAs 1-6)			**1,030,000**	**71.8**

6.4.4 For HS2 construction work associated with CFAs 1 to 6, the total distance travelled within the M25 during the construction period is estimated to be 71.8 million vehicle kilometres. Based on the Defra cost estimates the total damage costs for NOx are given in Table 10.

Table 10: Summary of NOx damage costs (£million) within the M25

Scenario	Low estimate	Central estimate	High estimate
100% Euro VI for Excavated material and 75/25 split of Euro VI/V for other HGVs			
CFA 1	1.2	3.1	5.0
CFAs 3 to 6	3.2	8.6	13.0
Total (CFAs 1-6)	4.7	11.7	18.7
All HGVs 100% Euro VI			
CFA 1	0.8	2.0	3.2
CFAs 3 to 6	2.4	6.1	9.8
Total (CFAs 1-6)	3.2	8.1	13.0
Damage cost saving resulting from HS2's commitment on 100% Euro VI *(i.e. subtracting the costs in the 'All HGVs Euro VI scenario' from the first scenario)*			
Total (CFAs 1-6)	1.4	3.6	5.7

6.4.5 The central cost estimate for NOx damage costs within the M25 is £11.7 million (range of £4.7 million to £18.7 million) assuming that all excavated material is transported with Euro VI HGVs and there is a 75/25 split of Euro VI/V for other vehicles. If all HGVs are assumed to be Euro VI, then the central estimate is £8.1 million (range of £3.2 million to £13.0 million).

6.4.6 If the two scenarios are compared, then the likely damage cost saving resulting from achieving 100% Euro VI over the whole construction period is £3.6 million as a central estimate (range of £1.4 million to £5.7 million).

6.5 Summary of air quality costs

6.5.1 Each of the three methods used estimates the total emissions of NOx and the likely damage costs resulting from these emissions. However, each method does not aim to estimate the same thing. The main differences to note before summarising the three methods are as follows:

- *WebTAG* only includes roads that are deemed to be affected by the change in traffic caused by construction of the HS2 scheme, which means traffic on certain roads (within CFAs 1-6) is not included. The method does not include any traffic outside CFAs 1-6.
- *Defra CFAs 1-6* includes the same traffic as the WebTAG method and so excludes emissions from certain roads within CFAs 1-6 and does not include any traffic outside CFAs 1-6.
- *WebTAG and Defra CFAs 1-6* use a different method, model domain and traffic assumptions compared to that used by the Defra within M25 scenario to estimate emissions. Therefore, the three scenarios cannot be compared in terms of overall NOx emissions.
- *WebTAG* uses difference damage costs to the other two methods.

6.5.2 Table 11 gives a summary of the air quality damage costs resulting from the three methods used to assess emissions from the construction of HS2 within London.

Table 11: Summary of associated damage costs (£million)

Scenario	WebTAG	Defra CFAs 1-6	Defra within M25	
			Mix of Euro V/VI	100% Euro VI
Low estimate	n/a	3.4	4.7	1.4
Central estimate	2.4	10.7	11.7	3.6
High estimate	n/a	20.8	18.7	5.7

6.5.3 It can be observed that all costs are of a similar magnitude. WebTAG shows a lower cost than using the Defra cost estimates, as would be expected based on the cost per tonne of NOx specified by each method. In the *Defra within M25* scenario, the use of 100% Euro VI HGVs reduces NOx emissions and, therefore the damage costs, to around 30% of when a mix of Euro V/VI HGVs are assumed to be in use. However, it is likely that the *Defra within M25* mix of Euro V/VI scenario overestimates the NOx emissions (and therefore damage costs), as almost all vehicles within the M25 are likely to be Euro VI or better in the later years of construction.

7 Market availability of suitable vehicles

7.1 Introduction

7.1.1 As part of understanding the likely impact of commitments made by HS2 Ltd, it is necessary to understand the number of vehicles required for construction of the scheme (i.e. the fleet size and not the number of vehicle movements), but also the likely numbers of suitable vehicles in the market. Many of the vehicles associated with the construction of HS2 will start their journey close to the construction site they are serving. For the construction activities within London, it is likely that the vehicles will come from in and around London. Some vehicles will, however, need to travel from further away, e.g. because they are specialised vehicles that may not be available from near the site or for logistical reasons controlled by the contractor.

7.1.2 In order to put this into context, this section firstly looks at the vehicles currently in use in the UK and then overall trends in replacement of older vehicles with newer and Euro VI emission standard compliant ones. Data relating to London has also been examined to determine the types of vehicles entering the CC Zone (TfL data). In addition, publicly available data (e.g. the DfT website) has been reviewed for London and the south east.

7.1.3 HS2 Ltd has further undertaken a study of trade associations to understand their perspective on the use of Euro VI vehicles. Publically available information from a cross section of utility companies has also been reviewed. Discussions have also been had with utility providers currently working on major infrastructure projects in London. These discussions were in confidence and so have only been reported in unattributed summary format.

7.2 Survey of trade association and traders

7.2.1 By way of assessing the market position, the HS2 Supply Chain Management (SCM) team conducted, in confidence, a study of various organisations connected to the construction industry, but not the actual construction contracting companies (due to current commercial/contracting and procurement activities). A survey was designed to test the views of participating organisations on the possible impact of imposing a requirement for Euro VI/6 compliant vehicles to be used during construction of the scheme earlier than is required by law (see Appendix E for the questionnaire).

7.2.2 The SCM team engaged with specific bodies that represent the construction industry in some way, including logistics and haulage trade associations. Participating organisations expressly noted they found it difficult to respond to the questionnaire in the detail it required, due to a lack of data available to them; however, they all provided indicative feedback based on their understanding of the market relevant to their organisation.

7.2.3 It should be noted that trade and other bodies tend to have a broad range of members in terms of size and capability and they have to represent them all and so it is the opinion of

Arup that the opinions expressed may not be representative of the capability of **all** members to comply with Euro VI/6 prior to the requirements of low/ultra low emission zones. As discussed in section 4.7, earlier compliance and a larger geographical area is being proposed by the new Mayor of London.

7.3 Key findings

7.3.1 A summary of the views expressed to HS2 Ltd by the various surveyed organisations is presented below:

> *The organisations stated that the transport industry was not likely to be able to support the early adoption of a Euro 6/VI vehicles emission policy, due to the potential excessive burdens and cost such policy would place on industry. One noted that:*
>
> > *"We cannot and would not support mandatory early prior to legal requirements adoption of Euro VI technology as a term of contract by members unless they were attached to long term business contracts with HS2."*
>
> *Trade Associations noted that with an expected increase in demand for construction materials to be transported by HGVs, introducing additional requirements could cause sub contractors to "lose appetite" for HS2 work, due to a high demand elsewhere in the industry.*

7.3.2 It is the opinion of Arup that these comments do not per se illustrate that suitable vehicles may not be available and is more likely to represent a possible reluctance on the part of the trade associations to support additional requirements that may impose additional cost on some of their members. The feedback to HS2 Ltd concludes the following:

> *Given that the global construction market is increasing, that lead times for vehicles are currently 6 9 months, and without certainty of long term contracts with HS2 Ltd, it was considered unlikely organisations would bear the cost burden of upgrading viable vehicles.*
>
> *Organisations average a 6 7 year vehicle renewal cycle, however, this can be extended particularly by SMEs (Small and Medium Sized Enterprises). It was also noted that vehicles are often sold down a supply chain meaning SMEs do not always purchase brand new vehicles. On this basis Trade Associations believed extending the ability to use Euro V vehicles could enable more SME involvement in the HS2 project as organisations could face "high risk when writing off the value of a relatively new and serviceable vehicle prematurely," which many SMEs may not be able to afford. This conclusion was not based on any real data analysis and was expressed as the opinion of the interviewees.*
>
> *Trade Associations did broadly acknowledge that this would be a business decision for organisations to take. Potential mitigation to the implementation of a mandatory Euro VI requirement on HS2 would be:*
>
> - *more certainty given on the delivery schedule and when vehicles would be required, than is currently typical in the construction industry; and*

- *the use of a staggered smart target, increasing the percentage of Euro VI vehicles required on the project year by year.*

7.3.3 It is Arup's view that these opinions are likely to be designed to protect the whole membership of each participating trade organisation and are not necessarily representative of all individual members. Data exists on HGVs in use in London and UK new vehicle registrations that indicate that there are many thousands of Euro VI/6 compliant vehicles in use already, although it is recognised that many of these vehicles will not be associated with the construction industry. That many HGVs are already Euro VI compliant is to be expected and it would not be sensible to assume that all users will replace their vehicles just before the requirements of the various emission control zones come into force.

7.4 London fleet information

7.4.1 The likely composition of the total London vehicle fleet in terms of Euro emission standards has been analysed to determine the likely impact of any HS2 policy on the vehicles that must be used during construction of the scheme.

7.4.2 Data from a variety of sources have been reviewed in order to understand the composition of the historical vehicle fleet both in the UK and more locally in and around London. In addition, predictions of how this will change over time have been taken into account in order to estimate the uptake of new vehicles (with lower or zero emissions) into the fleet.

7.4.3 According to the Department for Transport[36], 2015 was the first year since 2005 that new registrations of vehicles exceeded three million in Great Britain. Vehicle registrations in 2015 were 8% higher than in 2014. At the end of 2015 there were 37.6 million vehicles licensed for use on roads in the UK of which 31.2 million (83%) were cars. Van numbers were 4.7% higher in 2015 (compared to 2014) and HGVs were 2.0% higher over the same period; reversing the trend from previous years since 2009 (when the recession/global economic crisis caused HGV numbers to decline in the UK). The table below summarises the numbers of licenced vehicles by type in the UK including those in London and the South East (excluding London).

Table 12: Licenced vehicles (thousands, rounded) in the UK by region (Dec 2015)37

Vehicle type	London	South East (excluding London)	United Kingdom
Cars	2,640 [8.5%]	4,970 [16.0%]	31,200 [100%]
LGVs	217 [5.8%]	611 [16.4%]	3,740 [100%]
HGVs	21 [4.1%]	68 [13.4%]	506 [100%]
Total(a)	3,050 [8.1%]	5,960 [15.9%]	37,600 [100%]

Percentages are expressed as a total of the UK total for each category listed under vehicle type.
(a) Total also includes motorcycles, buses and coaches, and other vehicles (i.e. ambulances, hackney carriages, diggers, lift trucks, rollers 3-wheelers and agricultural vehicles).

7.4.4 A total of nearly 30,000 new ultra-low emission vehicles were registered for the first time in 2015 (0.9% of all new registrations). This is a rapid increase on previous years (e.g. in the year to end Dec 2013 there were around 5,000 ULEVs newly registered).

7.4.5 A range of factors influence the vehicle fleet:

- Smaller vehicles tend to be more fuel efficient and therefore cost less to run;
- Diesel vehicles tend to be more fuel efficient (but more polluting in terms of local air quality);
- Lower excise duty for cars producing less carbon dioxide (CO_2).

7.4.6 The number of diesel cars continues to grow (by Dec 2015 there were 11.4 million (37.8%) diesel cars and 0.31 million alternative fuel (gas/electric/hybrid electric/bio-fuel) cars licenced in the UK. By Dec 2015 there were 3.7 million vans registered of which 96% were diesel. There were 0.48 million HGVs registered in the UK with an average gross weight of 21.8 tonnes, all diesel powered. By Dec 2015 in the UK 23% of LGVs and 27% of HGVs were under 3 years old (13% of LGVs and 14% of HGVs were more than 13 years old). The average age of an LGV was 8.1 years and 7.5 years for HGVs[B].

7.4.7 TfL provided data for the proportion of each type of vehicle in central, inner and outer London as well as the numbers of unique vehicles[C] entering the London CC Zone in 2013. TfL have rounded these numbers and in their projections assume that the same number of unique vehicles will be present within the CC Zone until at least 2020. It has been assumed that this will remain constant until 2025 at least. The number of unique vehicles presented in Table 13

[B] Some owners will have a shorter replacement time and others longer depending on the type of vehicle and the duty to which it is put. Some vehicles owned by large haulage companies replace their vehicle tractor units approximately every 3 years, other companies with specialised vehicles may replace them every 10 years of more.
[C] Unique vehicles in a year, is based on the Automatic Number Plate Recognition (ANPR) system records in the London CC Zone database. When a vehicle enters the CC Zone this creates a unique record for that vehicle. Therefore, the recording by TFL of e.g. 118,000 unique HGVs in 2013 means that there were 118,000 unique vehicles entering the CC in 2013, some may have only entered once, some many hundreds of times.

indicates the total number of vehicles that entered the London CC zone. This will have included vehicles from inside and outside London, as well as visitors entering only once or multiple times in the year. The data are provided to give context to the overall fleet required for the construction of HS2.

Table 13: Unique vehicles in the London CC Zone (2013)

Type of vehicle	Unique vehicles[(a)]
HGVs	118,000[(b)]
Coaches	40,000
Cars	5,000,000
LGVs	660,000
Total	5,818,000

(a) Source: TfL personal communication (2016)
(b) Assumed to be 15% articulated and 85% rigid, based on NAEI data

7.4.8 TfL has also used actual and projected data to estimate the likely compositions in terms of Euro standards for vehicles in London from 2008 to 2025. These data have been combined with data from the National Atmospheric Emissions Inventory (NAEI) website on types of HGV (rigid and articulated HGVs – see section 2 and Appendix B) to estimate the likely composition of vehicles in London in various classes. The figures below show the likely split in terms of Euro standard for articulated and rigid HGVs for the years 2008 to 2025. Data are presented as a mean of the data available for inner and outer London. Some parts of London are estimated by TfL (for example) to achieve higher percentages of Euro VI earlier than indicated in the figures below.

Figure 10: Projected Euro emissions standard composition (London, articulated HGVs)

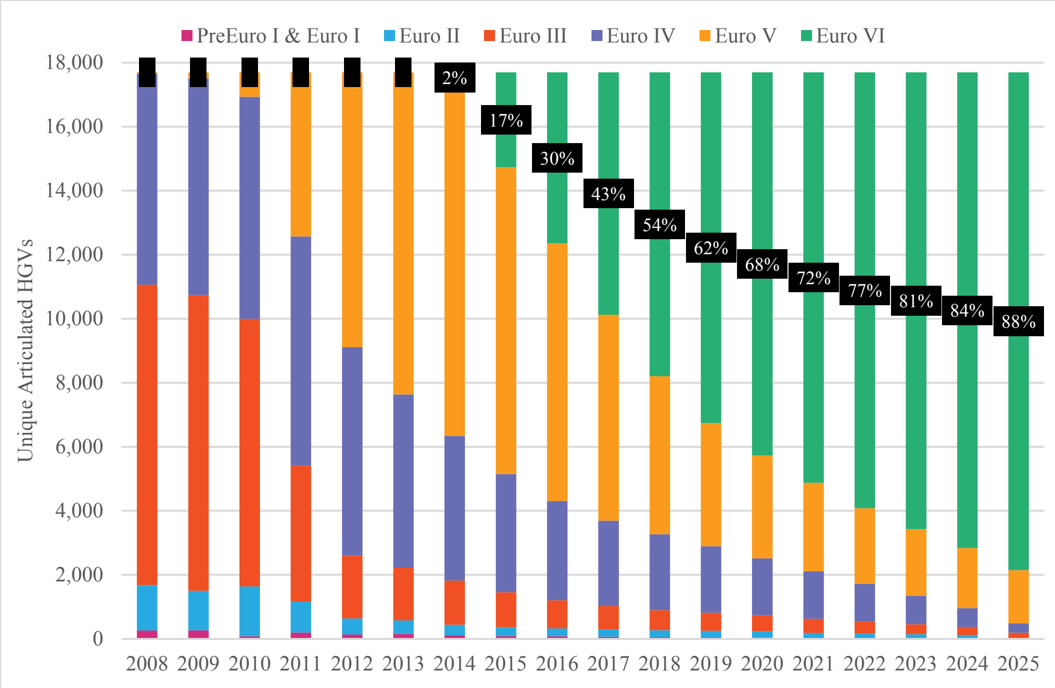
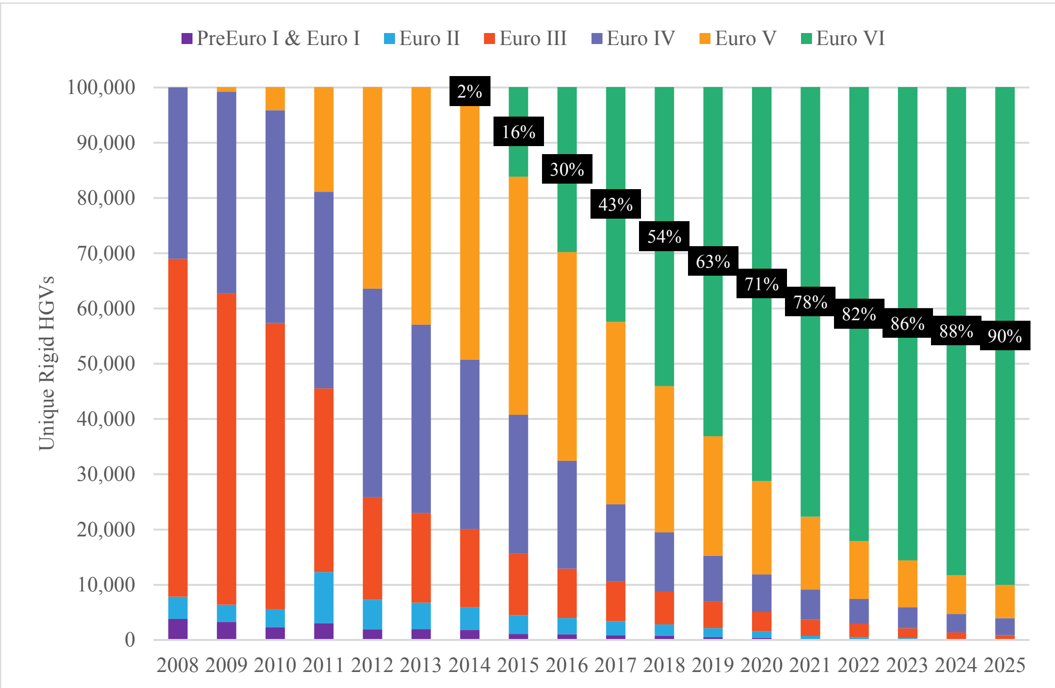


Figure 11: Projected Euro emissions standard composition (London, rigid HGVs)

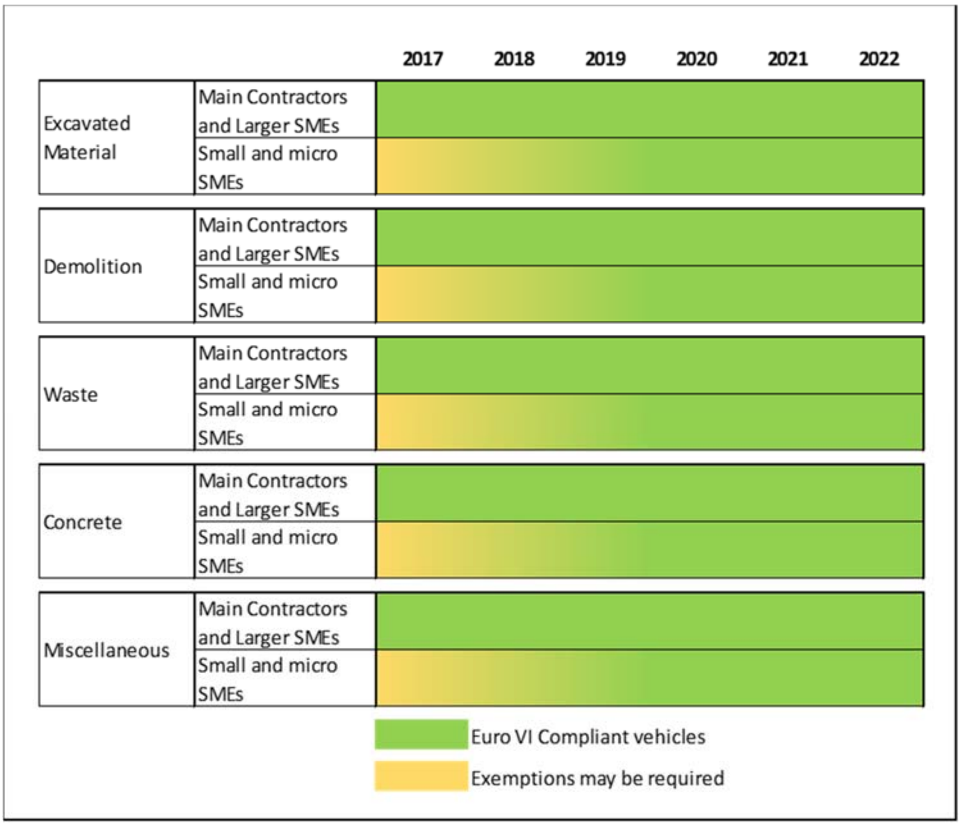


7.4.9 From these two figures it can be seen that, as early as 2017, it is estimated that there will be over 7,500 unique articulated Euro VI compliant HGVs and 42,700 unique rigid Euro VI compliant HGVs traveling within the London CC zone. It should be noted that from the data available it is not possible to determine the number of times each of these unique vehicles entered the CC zone; some may have only entered once in a year some many times. Many of these vehicles are also associated with activities other than construction (e.g. food deliveries). These data are provided only to give context to the likely numbers of Euro VI compliant vehicles in use to allow comparison to the vehicle fleet needed for the construction of HS2.

7.5 Contractor vehicles

7.5.1 HS2 Ltd Construction Directorate staff provided information about current availability of Euro VI HGVs in contractor companies (based on experience on other major infrastructure projects). These indicate that major contractors and larger SMEs are likely to have enough Euro VI compliant HGVs to satisfy HS2 demand from 2017. Smaller SMEs may not have adequate vehicles from the start of the HS2 construction programme. However, it is anticipated that within a few years all of their vehicles would be compliant with Euro VI. This is graphically presented in Figure 12. As detailed in section 10 certain exemptions may apply during the whole construction period.

Figure 12: Contractor availability of Euro VI HGVs (source: HS2 Ltd)



7.5.2 As noted in section 4.6, the new Mayor of London has announced he wishes to introduce new measures or bring forward proposed measures to improve air quality in London. If implemented, this is likely to result in a more rapid uptake of ULEZ compliant vehicles in London, resulting in a greater availability of suitable vehicles to work on the HS2 project.

7.5.3 Arup has obtained some information on the current and future plans of utility companies and statutory undertakers for fleet upgrades to lower emission vehicles. A summary of the findings is given below.

- A large contractor that works with Thames Water indicated they are currently using Euro VI HGVs for removal of excavated material within London. They also indicated that 100% ULEV (cars and vans <3.5t) in 2017 would be unachievable as would 100% electric cars and vans (<3.5t) – because of procurement time, vehicle availability and unsuitability of currently available vehicles (size, capacity, location of charging points etc.).
- British Gas made a public commitment that 10% of their 13,000 vehicles would be electric by 2017. Their study also showed that the cost saving of using an electric fleet was twice as much in London (up to 20% cheaper than diesel) as outside London (up to 10% cheaper than diesel). This is because of various factors including the way vehicles are used, exemptions for electric vehicles, higher fuel prices in London and the distance they travel[38].
- A telecoms contractor currently working with Arup and HS2 Ltd has a fleet of 92 vehicles which includes a mix of conventional, PHEV and electric cars and vans (they do not have HGVs). They plan to replace conventional vehicles with ULEVs over the coming 3 years. Hybrid and electric vehicles are generally allocated to staff working in London. ULEV vans are not seen as currently available and having trailed LPG vehicles they were found to be unsuitable for the work required (reasons are not given but are likely to be because of location of refuelling points, range and capacity of vehicles currently available). They currently (2016) have a full fleet of at least Euro 5 vehicles and are working toward full Euro 6 as each van is due for replacement (on a 3-4 year cycle).
- National Grid has targets to reduce their GHG footprint but nothing specifically relating to vehicle emissions is detailed in their annual report[39]. It should also be noted that many of the vehicles used in relation to the construction of HS2 works will be sub-contractors, and National Grid commented that at present they have no mandatory requirements for sub-contractors to use low emission vehicles.
- Murphy (a major contractor for e.g. British Gas) has introduced a variety of measures to increase fuel efficiency including progressively updating their fleet to ensure they meet or better the latest emission regulations. The introduction of Euro VI engines into their fleet has reduced overall emissions. Older vehicles in the fleet are being

retrofitted with diesel particulate filters. Both pure electric and hybrid vehicles have a presence on the Murphy fleet (seven fully-electric vehicles, two Nissan electric vans, two Nissan Leaf cars and three Vauxhall Ampera cars and 17 Toyota Hybrid Prius cars)[40].

- UPS (courier) has a large fleet[41] of alternative fuelled vehicles including fully electric 7.5t HGVs that are used within London (Figure 13). They have been trialling a range-extended vehicle that has a range of several hundred kilometres between charges. The non-range extended version has a range of around 100km and can easily complete an 8-hour day of London deliveries without recharging.

Figure 13: Photo of UPS electric vehicle (7.5 tonnes)

7.5.4 ULEVs may be more expensive than other more conventional vehicles but ULEVs also reduce costs by having lower running/fuel costs, reduced or zero vehicle excise duty/road tax and other low emissions discounts/grants.

8 Ultra-low Emission Vehicles (ULEVs)

8.1 Introduction

8.1.1 The main reasons for the move to Ultra Low Emission Vehicles (ULEVs) is a policy decision to reduce greenhouse gas (GHG) emissions. The UK government set a legally binding target to reduce carbon emissions by at least 80% by 2050 compared with 1990[42]. The domestic transport sector is calculated to contribute 21% to the UK's GHG emissions, with road transport being responsible for 92% of the domestic transport total[43]. Reducing GHG emissions from road vehicles is, therefore, an important contributor to achieving the UK's GHG target.

8.1.2 In the UK, the Office for Low Emission Vehicles (OLEV) published a plan, *Driving the future today*, in September 2013[44], for the continued establishment of the UK's ULEV market, helped by over £500 million of capital investment between 2015 and 2020. The Government's vision, outlined in the plan, is for almost every car and van (LDVs) in the UK to be a ULEV by 2050. Although the strategy focuses on cars and vans (LDVs) the government is also aiming to increase the rate of uptake of ULEVs in other vehicle sectors. There are currently hybrid, alternative fuel (e.g. hydrogen) and fully electric buses and HGVs on UK roads, but the government would like to see the uptake accelerated as would the London Mayor.

8.1.3 The main reason for the increase in ULEVs is GHG reduction, the definition of ULEVs in *Driving the future today*, is in terms of GHG emissions only:

> *"A ULEV emits extremely low (or zero) levels of carbon dioxide (CO_2) compared to conventional vehicles fuelled by petrol/diesel. They typically also have much lower or virtually nil emissions of air pollutants and lower noise levels. Since 2009, the Office for Low Emission Vehicles has considered ULEVs as new cars or vans that emit less than 75 grams of CO_2 from the tailpipe per kilometre driven, based on the current European type approval test. Other definitions exist that suggest 50g CO_2/km is a more appropriate threshold."*

8.1.4 For the purposes of this study, the following definition of ULEVs applies, as advised by HS2 Ltd: "emissions lower than 75gCO_2/km and zero-emission range greater than 10 miles, or for an electric vehicle range greater than 60 miles".

8.1.5 For local air quality it is the emissions of NOx that are of most importance. This section looks at various LEVs and ULEVs and consider which can deliver low NOx emissions.

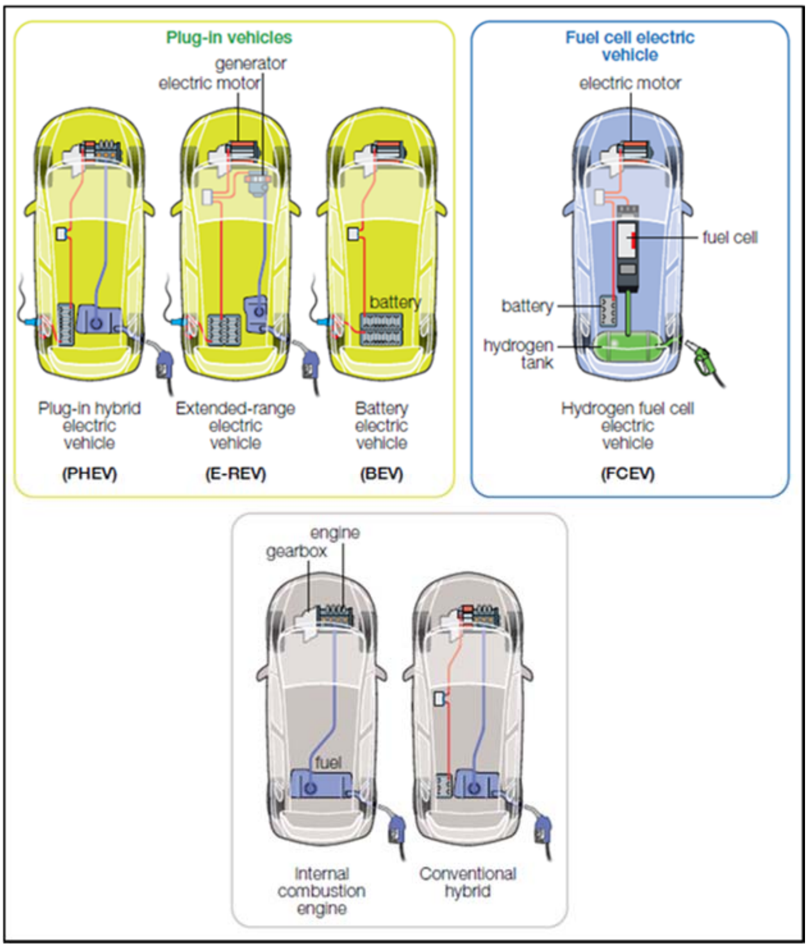
8.2 Vehicles that emit low levels of NOx

8.2.1 The various low (carbon) emission fuel/technologies have been ranked (in terms of NOx emissions) against diesel technology as shown in Table 14. The excellent class have zero tailpipe emissions of NOx. Figure 14 shows graphically the different types of ULEVs.

Table 14: Fuels and technologies ranked in terms of NOx emissions

Ranking	Fuel/ Technology
Excellent	• Electric - Battery (BEV), Plug-in Hybrid (PHEV), Range-Extended (RE-EV) and • Hydrogen - hydrogen fuel cell (FCEV)
Good	• Hybrids when they operate in electric mode. Petrol-electric hybrids are much preferred to diesel-electric hybrids • Methane: compressed natural gas (CNG), liquefied natural gas (LNG), biomethane • Specialist fuels: methanol, liquid air
Best of conventional	• Internal combustion engine – petrol
No benefit	• Internal combustion engine – diesel • Internal combustion engine – bio-diesel

Figure 14: Technology portfolio for cars and vans[44]



8.3 Uptake and Availability of ULEVs

8.3.1 Figure 15 presents the Low Carbon Vehicle Partnerships (LCVPs)[45] projected uptake of plug-in electric vehicles (PEV), natural gas vehicle and hydrogen vehicles. The projected uptake of liquid fuel vehicles is shown for comparison, but these vehicles are not usually low in NOx emissions.

8.3.2 PEVs are forecast to become the dominant low NO_X technology for ULEV, followed by hydrogen vehicles, for passenger cars and vans, but RE-EVs and PHEVs which will partly use liquid fuels (not low NOx technology) will be almost as popular as the PEVs and hydrogen vehicles combined. The uptake of natural gas as a fuel for passenger cars and vans is predicted to be low. The pattern is similar for HDVs, with PEVs and hydrogen vehicles becoming the most popular low NOx ULEVs, but the number of these will is less than the number of HDVs using liquid fuel (and for HDVs these will not necessarily be hybrids or range-extended vehicles).

8.3.3 LCVP predict that electric vehicles (PHEVs, BEVs and/or FCEVs) will become "mainstream" vehicle choices between 2020 and 2030, as long as the decarbonisation of the national electricity grid and the issue of smoothing peaks in electricity demand are resolved.

8.3.4 A stimulus for the use of LNG may occur due to the EU Directive on the deployment of alternative fuels infrastructure, which aims to facilitate the development of a single market for alternative fuels for transport in Europe. It has targets for various fuel and resupply networks including:

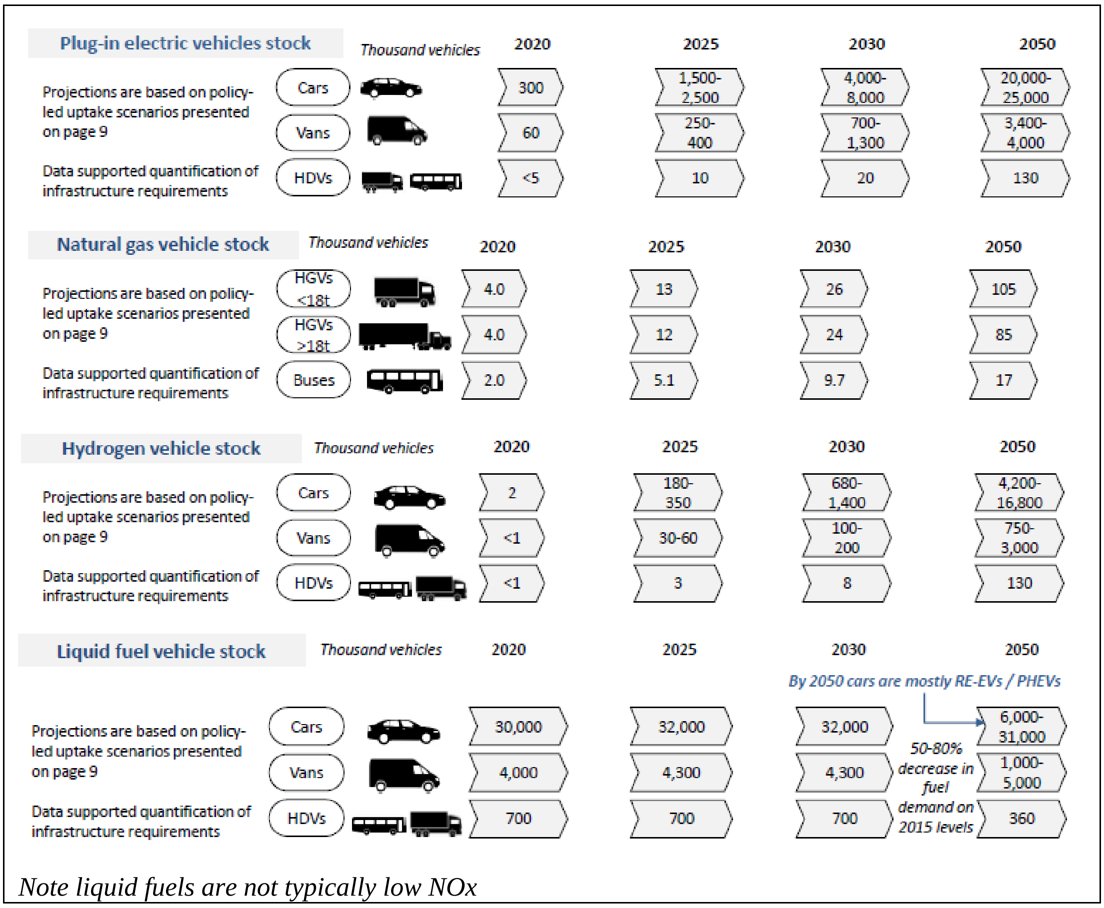
- Electricity recharging points in urban/suburban and other densely populated areas
  - at an appropriate number of publically accessible points
  - by end 2020
- LNG refuelling for heavy-duty vehicles
  - at appropriate number of points along the TEN-T core network (the Trans-European Transport Network of infrastructure)
  - by end 2025

8.3.5 Technical barriers to ULEVs have been summarised in the TfL LoCity initiative[46]:

- *For fleet operators:*
  - *A lack of motivation to reduce emissions beyond Euro VI/6*
  - *Limited supply of suitable alternatively fuelled vehicles*
  - *Insufficient public infrastructure*

  - *Obstacles to owning infrastructure*
- *For vehicle manufacturers*
  - *Low demand and insufficient public support*
  - *Range and payload constraints*
  - *High component costs*
- *For all stakeholders – a lack of clarity on priorities and definitions for low emission commercial vehicles and no long term policy framework*
- *For infrastructure providers*
  - *Difficultly establishing anchor demand to make the business case*
  - *Limited access to affordable and suitable land*
  - *Planning process may cause long delay*

Figure 15: Projected update of fuel/technology by vehicle type [45]



8.3.6 *Driving the future today*[44] reports that for large commercial vehicles a number of low emission power train technologies are commercially available or close to being commercially available, typically employing dual-fuel technology (LNG, CNG or biomethane), pure electric or hybrid diesel-electric. It notes that measures to reduce rolling resistance, aerodynamic resistance, driver training and improved logistical planning can achieve around a 10% reduction in fuel use and hence emissions. However, long haul trucks will be unlikely to suit ULEVs with an element of electric battery power as they tend to operate continuously with large payloads and the battery required to support such use would be too large and too heavy to be practical.

8.3.7 While buses may not be relevant to HS2 works, it should be noted that there are a range of alternative fuels in use running buses in London. These include CNG, biomethane and hydrogen. The OLEV study[44] confirmed a number of technologies are already able to provide significant improvements to bus CO_2 emissions, while offering bus operators a return on their investment in less than five years.

8.4 EST Study of ULEV Passenger Cars and Vans

8.4.1 The Energy Saving Trust (EST) was asked by HS2 Ltd to estimate the percentage of ULEV passenger cars and vans that HS2 should expect its contractors to use when visiting sites in London from January 2017 (Appendix F).[47]. The UK Government defines ULEVs in relation to those vehicles eligible for the Plug-In Grant. EST only considered those vehicles eligible for the grant, which includes small- and medium-sized vans while excluding most large-sized vans.

8.4.2 EST reports that there are only a few ULEV make-model of large vans available. EST recognised that if HS2 Ltd set targets for ULEVs on this basis there may be an incentive to buy large vans (for which ULEV is undefined) and avoid the requirement to purchase a small- or medium-sized ULEV van. However, the reverse situation could also occur, whereby if HS2 Ltd imposes a target on vans (when only one class is currently available as a ULEV), this could have the unintended consequence of contractors buying vans to meet this target that are not suitable for the role required. It should be noted that the Plug-In Grant while considering only carbon emissions (not NOx), also has a requirement for a zero (tailpipe) emission capable range of at least 10 miles, which will usually be achieved by use of a battery.

8.4.3 EST reported long lead times for the purchase of ULEVs (between 6 weeks and 5 months for most vehicles but some were up to 12 months) and uncertainty over cost, performance and after sales backup for one of the large van types. It should be noted that a lead time of up to 5 months is not long in the context of the overall HS2 construction programme but would preclude vehicle purchase for the start of early works in 2017. The current level of ULEV for cars and vans in a typical fleet was given as 1% which is in line with the percentage of first registrations of ULEVs in the UK as a whole. However, while 0.9% of newly registered cars in 2015 were ULEVs, the figure for vans was just 0.3%[37].

8.4.4 The LCVP *Low Emission Van Guide*[48] published in June 2015 gives a recent review of the "state-of-the-art" with respect to LEVs. While concentrating on carbon emissions it considers the impact on air quality, provides information on whole like costs, the market status, range, recharging times and ideal application. It also gives example of companies and organisations using the vehicles.

8.5 Comparison of European Policy on Electric Vehicles

8.5.1 A recent study by the International Council on Clean Transportation (ICCT)[49] examined the electrification of vehicles, incentives being put in place across Europe and barriers to mass market uptake. A summary of the main points is provided here.

8.5.2 The five largest electric vehicle (EV) markets in Europe (in order: Germany, UK, France, the Netherlands and Norway) accounted for 80% of all European EV registrations in 2014. The study focused on 10 cities with these 5 countries; it examined the fiscal incentives being implemented and the charging infrastructure being put in place. Amsterdam had the highest number of charging points (5.5) per 1,000 registered cars. London had one of the lowest numbers (0.6 per 1,000 registered cars).

8.5.3 Fiscal incentives were found to be the most important driver for EV uptake. However, these are not sufficient by themselves to ensure the uptake; other measures such as consumer awareness campaigns, preferential access to low emission zones and high-occupancy vehicle lanes also play a significant part.

8.5.4 Availability and visibility of charging infrastructure is also important (Figure 16 shows a charging point in central London). Consumer awareness is key to uptake and so along with the points mentioned above, policy design is important to ensure a coherent and co-ordinated (country-wide or at a local/city level) approach.

Figure 16: Electric charging point and parking space in Central London

8.6 The London ULEZ and Incentives for ULEVs

8.6.1 The previous Mayor of London proposed implementing a ULEZ in stages, reaching completion by September 2020, for the current CC Zone; the new mayor is proposing that this is brought forward sooner and is about to commence consultation on this and other ideas associated with improving London's air quality. Note: Euston lies just outside the CC Zone. In addition to the controls on vehicle emissions the Mayor aims to have all buses in the ULEZ to be hybrid buses and that taxis operating the ULEZ are ZEC. The provision of increase ULEV infrastructure through Source London will support these actions, for instance, the network of 850 publicly accessible charging points across London, which is Europe's largest urban charging network (see section 4.7 for a summary of the proposal of the new mayor of London).

8.6.2 The further actions being pursued by the Mayor have been well described in Overview document of the Air Quality Plan, which is reproduced in Box 2.

Box 2: Summary of Air Quality Initiatives by the previous Mayor of London

<u>Paragraphs 120-122 of the Air Quality Plan, Overview</u>

120. Overall, the Mayor has been taking forward a comprehensive and ambitious package of measures to bring London into compliance with NO_2 limit levels in the shortest possible time. This includes actions to:

- reduce emissions from buses. By 2016 NOx emissions from the London bus fleet will have been halved compared to 2008 due to the introduction of: 1,700 hybrid buses; the world's largest bus retrofit programme; and trials of new technologies such as electric and hydrogen buses;
- reduce emissions from taxis. The introduction of an age limit for taxis has retired more than 6,000 of the most polluting taxis, and from 2018 new London taxis will be required to be zero emission capable;
- reduce emissions from other sources. Air quality neutral requirements in planning provisions are reducing emissions from future developments; new minimum emissions planning standards for construction equipment will deliver a reduction in NOx emissions in this sector of around 40% relative to 2013 levels; and energy efficient retrofit programmes have reduced emissions from more than 500,000 buildings across the capital; and
- tackle local hotspots. A new £20m Mayor's Air Quality Fund is supporting London boroughs in tackling local air quality. The first round of funding of £6m is already supporting 42 projects in 29 boroughs.

121. In addition to these measures as part of the 2015 Spending Review settlement for Transport for London the Mayor put forward proposals to:

- ensure the bus fleet will meet the Euro VI standard;
- the remainder of the black cab fleet will become zero-emission capable; and
- the ULEZ being fully implemented.

122. Alongside these actions the Mayor has consulted on a new approach to Local Air Quality Management for London boroughs to reflect the capital's unique challenges and opportunities for innovative solutions to poor air quality. This system will help ensure that the boroughs' statutory responsibilities are simplified and clear and will also provide support, coordination and resource to help ensure consistent and effective action at the local level.

8.6.3 As noted earlier (section 4.7), the new Mayor has already announced his intention to introduce further measures to improve or accelerate the improvement in air quality.

Initiatives

8.6.4 In order to help industry prepare for the ULEZ and to increase the supply and uptake of ULEVs for commercial use, in January 2016 TfL launched an initiative called LoCITY. LoCITY is an industry-led programme comprising three workstreams:

- Work stream 1: to increase the availability and affordability of viable low emission commercial vehicles in the UK;
- Work stream 2: to improve the availability of refuelling infrastructure and support last mile logistics by engaging with businesses, fleet operators and vehicle manufacturers to develop and deliver match-funded demonstration projects; and
- Work stream 3 will provide advice and resources to the business community, freight and fleet operators and the public sector.

8.7 Sustainable procurement

8.7.1 The European Commission has developed Green Public Procurement (GPP) voluntary criteria to promote the procurement of goods, services and works with a reduced environmental impact throughout their life cycle[50]. The Clean Vehicles Directive[51] also aims to introduce clean and energy efficient vehicles in the market in order to improve the environmental performance of the transport sector.

8.7.2 The UK Government has established Government Buying Standards (GBS) for all government bodies. The mandatory GBS for cars and vans are the fleet average for new vehicles to be less than 130gCO_2/km for cars and less than 175gCO_2/km for vans. As best practice, the Government has also suggested that vehicles with exhaust gas emissions must comply with at least Euro 5 emissions standards for both cars and vans.

8.8 Suggested targets for LDV ULEVs in HS2

8.8.1 The assurances given by HS2 Ltd use the term 'benchmark'. In discussions it has become clear that this term is ambiguous and may be taken to mean a minimum standard or an aspirational target. Setting a minimum target may be a suitable approach. However, without adequate data on the contractor/sub-contractor fleets of ULEVs or the likely fleet average emissions for CO_2, a numerical minimum standard may be unachievable within the timeframe set or already achieved. Hence, it has been decided not to set a minimum standard, but instead to set an **aspirational target** that should be reviewed once data is available to ensure that they are appropriate and represent the HS2 Ltd's aim to be an exemplar project. This may involve tightening the target when it is shown to be achieved.

8.8.2 The targets proposed in this section are aspirational targets, not minimum requirements. Table 15 presents the proposed targets for LDV ULEVs to be applied by HS2 contractors during construction of the scheme. Contractors should aggregate data from all their sub-contractors and report at least annually with the target of showing continuous improvement until the target is reached and maintained. Vehicles that are used to enable an employee or sub-contractor to travel to their normal place of work should not be included in the statistics. However, any vehicle (whether owned/leased by the contractor or by the employee directly) that is used to travel during the working day in connection with construction of HS2 should be included in the statistics.

Table 15: Proposed HS2 contractor ULEV aspirational targets during construction

Vehicle Class	Target
ULEV Cars from 2017	100%
ULEV Vans from 2017 (Medium Vans, 2,000 to 2,600 kg)	75%
Fleet Average gCO2/km Cars - 2017	75 gCO2/km (decreasing by 5 gCO2/km every 3 years)
Fleet Average gCO2/km Vans – 2017	160 gCO2/km (decreasing by 20 gCO2/km every 3 years)

8.8.3 If, for example, all contractor cars were ULEVs by 2017, the fleet average would have to be (by definition of what a ULEV CO_2 emission is) less than 75 gCO_2/km. The current London fleet has an average CO_2 emission of around 110-200 gCO_2/km depending on fuel type and engine capacity.

8.8.4 As ULEVs are increasingly taken up by contractors, the fleet average associated with HS2 construction activities will decrease and will approach the ULEV definition of being below 75 gCO_2/km.

8.8.5 In setting targets for CO_2, consideration should also be given to the effect certain vehicle technologies can have on local air quality, particularly in relation to emissions of NOx. Whilst some ULEVs (e.g. electric) reduce all pollutants, some (e.g. biodiesel) are almost CO_2 neutral but produce at least as much NOx as other fuel types. Care needs to be taken therefore to select vehicle technology that reduces NOx as well as CO_2.

8.8.6 Hence, HS2 Ltd should encourage contractors to also consider the hierarchy of vehicles presented in Table 16 and aim to select 'Excellent' or 'Good' vehicles. This means focusing on electric vehicles and moving away from the internal combustion engines (particularly diesel) and:

- by the end of 2017 the contractor/sub-contractor LDV fleet should not include any diesel/biodiesel internal combustion powered vehicles (see items 1-2 in the table); and
- by the end of 2020 the contractor/sub-contractor LDV fleet should not include any diesel/biodiesel or petrol internal combustion powered vehicles (see items 1-3 in the table).

Table 16: Consideration of NOx and CO_2 emissions in vehicle selection

Ranking	Fuel / Technology
Best	10. Electric – BEV
↑	9. Hydrogen – FCEV
	8. Plug-in hybrid (PHEV) and range-extended (RE-EV) when operated in electric mode
	7. Petrol-electric hybrids at least Euro 4 when they operate in electric mode.
	6. Methane: CNG, LNG, biomethane
	5. Specialist fuels: methanol, liquid air
	4. Diesel-electric hybrids at least Euro 6 when they operate in electric mode.
	3. Internal combustion engine – petrol
	2. Internal combustion engine – diesel
Worst	1. Internal combustion engine – bio-diesel

9 Monitoring and compliance regime

9.1.1 Experience gained on the Olympics and Crossrail is that it would not be possible to prohibit the entry of vehicles with 'non-compliant' engines at the entrances to worksites. This is because it will not necessarily be immediately obvious that a vehicle's engine is compliant or not, but also that by turning a vehicle back without allowing it to perform the intended service/task, will generate extra emissions by making a redundant and then replacement trip. The better approach would be to engage with the contractor to minimise non-compliances.

9.1.2 The Euro VI standard became mandatory for new vehicles registered from September 2014, which means that a '64' plate or newer registration should have a Euro VI engine. Earlier registrations may also have these engines, because they can be introduced to the marker prior to becoming mandatory. Some vehicles have private plates, meaning that the year of registration is not apparent from the vehicle registration number. Older vehicles may also have been off the road and then re-registered with a new plate. However, these exceptions are likely to be a small percentage of the overall fleet and vehicle registration number (VRN) is likely to be a good first indicator of Euro VI compliance and could be used at the various site control points to engage with non-compliant vehicles as required.

9.1.3 In addition, if a vehicle has made the journey to site and is turned away this could have repercussions for the construction programme, as well as creating additional overall vehicle emissions as the prohibited vehicle returns to base and a replacement vehicle makes a return journey to site. Therefore, it is proposed that compliance action of the types of vehicles entering HS2 sites and being used by contractors will be retrospective. Data will be collected on the vehicles associated with the construction of HS2 and reported at appropriate intervals. The reporting should be frequent to begin with (monthly) and may be done with a decreasing frequency as performance becomes established and shows good progress towards full compliance. Data should be collected in a form that allows it to be aggregated over time and presented for appropriate geographical areas.

9.1.4 HS2 Ltd intends to introduce a booking system at all gates to/from all worksites; compounds, road-heads and lorry holding areas, so all movements will be comprehensively recorded, sometimes several times as vehicles move in and out of lorry holding areas before entering and departing sites. This booking system will be operational from the start of the main works contracts, although HS2 Ltd aim to implement it as early as possible on enabling works both as a tool to start to record movements and as a trial. Works undertaken outside an HS2 Ltd site (e.g. utility works on the public roads) will not be part of a booking system and information should be collected by contractors and their sub-contractors.

9.1.5 Data collection happens in two stages:

1. Prior to arrival (vehicle booking) at site, contractors will be required to submit data to the system. These data will include long range, weekly and daily plans (all by day) for

vehicles likely to be visiting each site. The information shall contain arrival and departure times, vehicle (vehicle type in certain categories e.g. van, rigid, artic, abnormal load, mobile plant) and load type. Further information e.g. vehicle registration number (VRN), operator and driver may also be entered but will not be mandatory as these data may be subject to change for a variety of reasons. These submitted data will be used at the gate booking stage to ease the data gathering when the actual vehicle arrives.

2. All actual data will be collected when the vehicle enters the site. This will include time, VRN, vehicle and load type, origin or destination, utilisation, operator, driver, vehicle safety features.

9.1.6 The data will be collected and analysed for a variety of purposes. Each contractor will see their own data and will be capable of reporting those data to HS2. In addition HS2 Ltd will have sight of all data and so will be able to produce scheme-wide summary reports as and if required. The approach will generate a lot of data and so reports will need careful design, will need to be automated/semi-automated and produced on a suitable frequency (e.g. monthly) to allow for the interface with other databases (e.g. Driver and Vehicle Licensing Agency, DVLA) to be executed (e.g. to derive Euro compliance data).

9.1.7 The system has been specified to link with external data sources, including driver training, automatic number plate recognition (ANPR) and records relating to recognitions scheme (e.g. Fleet Operators Recognition (FORS) or FTA's Truck Excellence scheme). Site reports including e.g. VRNs, vehicle type, utilisation, origin and destination could be supplied in formats to match various existing databases including that of the DVLA such that other data in those databases can be included in reporting. This route is being investigated for monitoring compliance with commitments made and exemptions to the vehicle emissions standards.

9.1.8 Prior to the introduction of the system contractors are not currently (within existing proposed terms of contract) required to collect or supply any data. However, compliance should be monitored from the start of activities and so HS2 Ltd should investigate ways to ensure that suitable data (including at least the VRN of each vehicle) and how information that can be collected at site entrances can be used to increase compliance and make contracting companies aware of issues prior to the periodic reporting of non-compliances.

9.1.9 Many vehicles currently in use have GPS (global positioning system) location tracking systems in place as part of contractor companies' fleet management and tracking. Some major construction sites also require GPS tracking as part of site vehicle flow management. The HS2 Code of Construction Practice requires, as appropriate:

> *"The introduction of a GPS vehicle location and tracking system for tipper lorries within the lead contractors' control to be used for the movement of materials and waste in bulk and/or appropriate tracking solutions for the measurement of HS2 related traffic flows."*

9.1.10 Tracking the whole vehicle fleet used for the HS2 scheme using GPS is likely to be prohibitively complex and expensive. Some activities may use hundreds of small operators with varying or no systems in place such that obtaining reliable, comprehensive GPS data in a common format may be impractical. However, if GPS is used by a contractor it can be a useful tool to track vehicles by type and may assist the contractor in ensuring that non-compliant vehicles do not start out on a journey to an HS2 site.

9.1.11 Reporting of data for HDVs and LDVs should be aggregated into annual (calendar) reporting of non-compliances and exemptions along with the other data that are committed to local authorities via the undertakings and assurances given by HS2 Ltd.

9.1.12 Once the baseline has been established over the first 2 months of starting their activities, contractors should demonstrate to HS2 Ltd that there is continuous improvement in a similar way to that required under environmental management standards (e.g. ISO 14001, ISO18001) until there is full compliance[D].

9.1.13 The contractor should develop an Action Plan and agree this with HS2 Ltd if:

a. if there is less than 100% Euro VI compliance; or

b. if compliance does not show improvement on the previous 3 months; or

c. if the number of exemptions increases on the previous 3 months.

9.1.14 Noting that construction activities will vary from month to month and so therefore will the types of vehicles used. Hence, there will be variations in which sub-/contractors are being used at any one site This may lead to fluctuations in the use of compliant vehicles and so there may be times when continuous improvement month on month is justifiably not achieved.

9.1.15 The target is 100% compliance which means all HGVs without exemptions are Euro VI and all non-Euro VI HGVs are agreed exemptions. Once this target has been achieved the improvement will be shown by a reduction in the number of exempted vehicles.

[D] It should be noted that over the duration of the construction period additional emission requirements may be imposed in London and so full compliance as stated here does not only mean compliance with Euro VI, but also any future additional requirements. Hence, continual improvement beyond Euro VI may be required.

10 Exemptions and non-compliance

10.1.1 The aim for HS2 Ltd, as detailed in section 3, is that all on-road HGVs used on the construction of the HS2 scheme in Camden will be Euro VI. Where this is not possible an explanation shall be provided along with evidence why. It will be for HS2 Ltd to determine the most suitable body/organisation(s) to grant, coordinate, record and track exemptions.

10.1.2 All heavy duty vehicles (HDVs) should be Euro VI compliant unless they need to be exempted on the grounds of specialism, timing and/or triviality. A vehicle need only be captured by one of these criteria to be exempt but may fall into more than one category, which will increase the justification for exemption.

10.1.3 An exemption would only be applied if the operator has informed the appropriate organisation prior to its arrival at site, given the reasons for its use and demonstrated to the satisfaction appropriate organisation that no alternative that would comply with the Euro VI emission standards can be provided. If the appropriate organisation does not agree to the exemption and the vehicle arrives at site this should be considered as a **non-compliance**.

10.1.4 In addition, it is expected that the decision on exemptions should be made with a view to maximising the use of Euro VI vehicles. On road NRMM are not subject to Euro VI type approval and so are not within the scope of these exemptions. Details of the various grounds for exemption, as applicable to all HGVs connected with the construction of HS2 within the London LEZ, are given below.

- **Specialism:** Certain vehicles undertake highly specialised tasks that can only be undertaken by that type of vehicle; examples include large mobile cranes, certain piling rigs and pile drivers, pulverising and crushing machinery, augers and road removal equipment. However, most of this equipment will be brought to site on another vehicle (e.g. a low loader). On the rare occasion where a specialised vehicle comes to site under its own power, is not classified as NRMM (and therefore is not subject to Euro VI type approval) and this vehicle cannot comply with the Euro VI emission standard, it will be exempt from the Euro VI requirement.
- **Unforeseen circumstances:** Contractors and their sub-contractors should provide Euro VI compliant vehicles according to their transport plan and forecasts. However, there will be times when construction activities need to be rescheduled or redesigned at short notice. This could be for a variety of reasons, including at the request of HS2 Ltd, because of site conditions (e.g. frozen ground, water-logging, snow cover), or because of third party considerations (e.g. noise sensitive activities). This may mean that Euro VI compliant vehicles cannot be supplied in the timeframe required. In such circumstances, these vehicles shall be exempt from the Euro VI requirement, as long as justification is provided and agreed by the appropriate contractor/sub-contractor.
- **Triviality:** Compliance with the Euro VI emission standard is focussed on managing

and improving air quality. A single vehicle making a few trips a year therefore has a very small impact on ambient concentrations of NO_2 and PM_{10}. If a contractor requires a certain vehicle to travel to an HS2 site no more than 24 times in any 12-month rolling period, then this vehicle can be exempted as long as that exemption is sought prior to the first visit for a calendar year and justification is given that lies without that of specialism or timing. An exemption shall be granted for the calendar year in which the vehicle is first recorded entering a site and must be renewed annually with justification as to why this vehicle cannot and has not been replaced by a Euro VI compliant vehicle.

10.1.5 HS2 Ltd should give consideration to the duration and validity for which an exemption can be granted and how to ensure that a consistent exemption policy is applied. A periodic review of the policy will be required to ensure that it is appropriate and relevant to the construction activities being undertaken. For example:

- An exemption could be granted for a specified period in which the vehicle needs to be used on site.
- Exemptions could require renewal in the event a vehicle moving to a different site or leaving and wanting to revisit the original site.
- Exemptions could be granted for a unique vehicle accessing a single site. This may include multiple visits to a site on one or more days or a single entry to a site where the vehicle stays on site for longer than one day.

10.1.6 Justifications as to why a vehicle needs an exemption and if relevant, why the exemption needs to be renewed, should always be specified by the applicant. There may be certain circumstances where an exemption cannot be granted in advance and in this case, a retrospective exemption could be granted provided that:

a. the relevant documentation is submitted for consideration within 2 working days of the vehicle arriving at site;

b. the vehicle falls within the grounds for an exemption; and

c. the reasons for the retrospective application are recorded.

10.1.7 It is expected that exemptions will be minimised and should not account for more than 8% of unique vehicles on an annual basis in the early years of construction, decreasing in subsequent years as more of the vehicle fleet are upgraded or replaced. Contractors should establish a baseline and show continuous improvement against it. Allowances for exemptions based on frequency should not be carried over between calendar years.

10.1.8 HS2 Ltd has identified the need for a transition period for the HGV management process to be applied at the start of construction and during which record-keeping systems can be set up. HS2 Ltd may consider setting a transition period for learning and practice change, during which there is likely to be more retrospective applications for exemptions and/or the engine type of some vehicles may not be determinable (and hence determining whether a vehicle was Euro VI or not). This transition period will allow for the monitoring and compliance regime to be fully set up whilst works are progressed and be adapted should any issues arise. However, in order to get the best balance between practicality and air quality, this transition period should be as short as possible and not exceed 12 months from the start of the construction works that fall under the Bill. HS2 Ltd may also consider varying the reporting requirements during this time (e.g. extending the deadlines to allow collation of data).

10.1.9 HS2 Ltd has a Route-wide Traffic Management Plan (RTMP) and this links to their Vehicle Management System (VMS). The VMS includes requirements and exemptions for vehicles, related to schemes such as FORS and CLOCS. The exemptions referred to in the RTMP allow for certain vehicles (e.g. postal delivery vans, courier deliveries, abnormal loads requiring a load movement order) to be admitted to site and logged, without a need to comply with the requirements of the VMS. All of the proposed exemptions in the RTMP could also be exempted from the Euro VI requirements, if required, with the exception of one category: *Vehicles accessing sites for welfare purposes (e.g. food and drink supplies, water bottles, toilet consumables).* Arup considers that vehicles of this type should comply with the Euro VI commitment and only be exempted if one of the grounds for exemption described above applies.

10.1.10 In order to manage the general requirements for construction vehicles, HS2's Route wide RTMP sets a threshold in Table 4.2 of the document for the frequency of visits of certain vehicles. It defines 'infrequent construction vehicles' as those making 'less than 5 visits in any rolling 12 month period'. The same frequency threshold was considered as the threshold to define trivial use of non-EURO VI HGVs, however this was believed to be too few, from the point of view of practical implementation and air quality management. Unlike for the safety requirements (e.g. CLOCS type safety additions to trucks) managed by the Route Wide Transport Management Plan, retrofit that can be verified by external inspection on-site is not possible for EURO VI vehicles, so a greater number of visits is believed to be necessary to be practicable as an exemption under triviality.

10.1.11 It is recommended that a standard exemptions form is developed by contractors (which may be held online, with online submission and approval) to streamline the process. This would be needed as soon as early works start and its use is likely to diminish as time passes and more Euro VI vehicles become available.

11 Working with other major projects and organisations

11.1.1 The HS2 project as a whole is a public transport infrastructure project designed to reduce transport related emissions to air. In addition, HS2 Ltd is seeking to reduce the emissions to air during construction by working with other major infrastructure projects and through work with multi-partner initiatives that aim to improve air quality.

11.2 Working with other major projects

Thames Tideway

11.2.1 HS2 Ltd has made informal contact with the Thames Tideway Environment team to propose working together to understand each other's requirements and present a common understanding to contractors.

11.2.2 Thames Tideway has committed to vehicle emission standards in their Code of Construction Practice (2014)[52]. The document states (Page 34, Section 5.2.1) that:

> *"The contractor shall apply the following lorry management requirements and vehicle measures to the contractor's own vehicles and those of subcontractors and suppliers:*
>
> *a. membership of TfL's Fleet Operators Recognition Scheme; the contractor and sub-contractors will register and attain bronze membership for the start of construction progressing to silver within six months…*
>
> *b. use of lorries that meet current best environmental standards, including Euro 6 emission standards, where appropriate (as a minimum, all hauliers shall adhere to the standard as set by the London Low Emission Zone at all times)".*

Other projects

11.2.3 HS2 Ltd will be working with other major projects, especially in London. Crossrail is almost complete and experiences have been shared with HS2 Ltd in relation to construction. Upcoming projects, such as Crossrail 2, also present HS2 with an opportunity to collaborate and influence the market.

11.3 Working with other organisations

11.3.1 HS2 Ltd is working informally and as a member of a number of organisations to increase and encourage the use of lower and zero emissions vehicles.

Low Carbon Vehicle Partnership

11.3.2 HS2 Ltd is a member of LCVP and is participating in various initiatives with other members. The LCVP[53] which was established in 2003, is a public-private partnership working to accelerate a sustainable shift to lower carbon vehicles and fuels and create opportunities for UK business. Around 200 organisations are engaged from diverse backgrounds including automotive and fuel supply chains, vehicle users, academics, environment groups and others. The LCVP produces a newsletter for members as well has other resources including surveys, research papers and other articles relating to current trends, best practices and initiatives by members.

Schemes for fleet standards

11.3.3 There are several schemes that set standards and have accreditation encompassing safety, fuel efficiency, vehicle emissions and improved operations. Fleet operations will be audited against an industry accepted scheme such as the Fleet operators Recognition Scheme (FORS) or the Freight Transport Association's (FTA's) Truck Excellence scheme. This will be by an approved certification body. Certain training courses are also approved by the schemes including courses related to driving techniques aimed at reducing emissions.

11.3.4 HS2 Ltd has set out requirements for contractors in their Route wide Traffic Management Plan (see sections 5.8 and 5.9)[54], as follows. UK contractors are required to do the following:

- *"Achieve and adhere to FORS Bronze level and achieve and adhere to Silver level (where relevant with respect to measures set out in Sections 5.8 and 5.9 of the route wide traffic management plan) within a period to be agreed with HS2 Ltd.*

  OR

- *Set out how the contractor will achieve and adhere to an alternative quality standard which must address the themes of the FORS standard, such as through new emerging standards.*

  AND

- *Set out how the standard will be set and implemented through the UK supply chain for vehicles regularly accessing site.*

  AND

- *Set our how the standard will be independently validated and audited, if not via FORS."*

11.3.5 The HS2 Route wide Traffic Management Plan also requires contractors to prepare Logistics Environment, Sustainability and Safety Management Plans (ESSMPs), which shall set out "*the principal contractor's proposals for minimising emissions and for reductions in carbon use through the supply chain for heavy and light vehicles when using the public highway*".

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11.3.6 This initiative from TfL is detailed in section 8. HS2 Ltd has applied to become involved in this programme.

12 Potential costs to HS2

12.1 Introduction

12.1.1 This section sets out the range of costs that might be incurred on behalf of HS2 Ltd to enable the commitments set out in section 3 to be met.

12.1.2 It is up to an individual contractor and their sub-contractors to deliver the required services in whatever way they choose; provided they are in compliance with the contractual terms. Because contracts have yet to be let it is not possible at this stage to know what vehicles will be available to contractors and what emission standard they are compliant with. Estimates have been made based on expert opinion (within Arup and HS2), publically available data, market research (see section 7) and data provided by Transport for London (TfL).

12.2 Methodology

Conversion of vehicle movements to vehicle fleet

12.2.1 Vehicle movements are based on estimates of the various activities (demolition, excavation, utilities etc.) on a monthly basis for the entire construction period. A single vehicle arriving and departing a site counts two vehicle movements. A vehicle can often make more than one return trip in a day and hence the number of vehicles required to undertake an activity is usually less than half of the number of 2-way movements.

12.2.2 The number of vehicles required is termed the vehicle *fleet.* The fleet will be specific to the activity being undertaken as well as the year in which the activity is being done. Any vehicle purchased would still be available for use in subsequent years.

12.2.3 An initial estimate has been made of a preliminary, theoretical fleet for each of the activities and each of the construction years from start of early works (2017) to 2022. The year 2022 is taken as the year beyond which it is expected that most vehicles operating in London would be Euro VI compliant anyway, because of legal requirements and replacements rates of vehicles. It should be stressed that this is an initial estimate and may change once contractors are appointed.

12.2.4 Assumptions used in the calculation include the following.

1. Average working day for concrete deliveries = 6 hours (also allow for days when large concrete slabs are poured = 10 hours).
2. Average working day for other vehicles = 9 hours (9am to 4pm).
3. Average size of concrete HGV = 6m^3

12.2.5 The steps used to estimate the fleet are as follows.

1. Consider each of the main activities (concrete, demolition, waste, excavated material and miscellaneous) separately. Determine the maximum daily flow for each main activity during a year (e.g. max for demolition might be January and concrete in December). Do this for each construction year.
2. Divide by 2 to convert movements to number of trips.
3. Estimate the round journey time (minutes) for each activity and each possible start, delivery and end point allowing for congestion, loading, unloading, waiting time and vehicle washing as appropriate.
4. Calculate the number of hourly trips (round trips/working day).
5. Calculate the time between each vehicle at site (known as *headway)* (60 minutes/number of hourly trips).
6. Estimate minimum fleet size (round trip journey time (minutes)/headway (minutes)).
7. Apply a contingency factor of +50% to account for standby vehicles, backup etc.
8. Add the estimated maximum fleet size for each main activity to generate a yearly maximum fleet requirement (this is a realistic scenario allowing for flexibility in the timing and overlap of the activities).

12.2.6 An example of the above steps is given below for concrete deliveries via the Camden route from Kings Cross.

1. Maximum number of concrete vehicle movements in 2022 on this route = 68
2. Divide by 2 = 34 trips
3. Round journey time = 80 minutes
4. Hourly trips = 34 trips/6 hours=5.7 trips per hour
5. Headway = 60 minutes/5.7 trips per hour = 10.6 minutes
6. Minimum fleet size = 80 minutes /10.6 (headway) = 7.5 vehicles
7. Add contingency factor (50%) and round up = 12 vehicles

12.2.7 This indicates that in 2022, in order to have 34 round trips a day delivering concrete from Kings Cross via Camden (northerly route) the contractor(s) is likely to have a core fleet of 8 vehicles with up to 4 more on standby i.e. ready on a call-off basis possibly with subcontractors or other suppliers.

This calculation is repeated for all other activities and other years and the following fleet is estimated. The theoretical fleet size (for Euston only) is given in Table 17 and for CFAs 3-6 (there are no relevant activities in CFA 2) in

12.2.8 Table 18.

Table 17: HGV fleet size 2017 2022 for works at Euston

Activity	2017	2018	2019	2020	2021	2022	Vehicle type
Concrete	0	12	22	39	37	53	Mixer (6m3)
Demolition	56	56	79	6	0	16	4-axle tipper (8.5m3)
Waste	8	8	3	2	0	0	
Excavated material	2	2	23	33	164	110	
Miscellaneous	55	55	55	42	21	33	
Total	121	133	182	122	222	212	Various
Average round journey / day / vehicle	1.9	1.7	1.8	1.9	1.5	1.8	*n/a*

Table 18: HGV fleet size 2017-2022 for works in CFAs 3-6

Activity	2017	2018	2019	2020	2021	2022	Vehicle type
Concrete	15	73	65	49	51	64	Mixer (6m3)
Demolition	8	14	8	8	8	0	4-axle tipper (8.5m3)
Waste	6	36	36	36	36	36	
Excavated material	162	301	297	196	164	0	
Miscellaneous	2	52	49	64	46	16	
Total	193	475	455	353	305	116	Various
Average round journey / day / vehicle	These data are not available in a suitable form for inclusion in this table						*n/a*

12.2.9 It should be noted that there may be exceptionally large concrete pours which might require additional vehicles and extended hours of operational, including a possibility of 24 hour working.

12.2.10 If the fleet data presented in Table 17 are compared to the vehicles operating in Euston (presented in section 5.2), it can be seen that the size of the fleet required for HS2 in Euston is a very small percentage (e.g. in 2017 a fleet of 121 vehicles is required compared to an estimate of over 42,700 rigid Euro VI compliant HGVs entering the London CC zone (accepting that only a proportion of these will be vehicles associate with construction activities)).

12.2.11 If the fleet data presented in Table 18 are compared to the vehicles operating in London (presented in section 5.3), it can be seen that the size of the fleet required for HS2 in CFAs 3-6 is a very small percentage (e.g. in 2018 a fleet of 475 vehicles is required compared to an estimate of over 20,600 licenced HGVs in London (and 68,000 in the south-east excluding London)). Data on Euro VI HGVs in London and the south-east were not available; it should also be noted that only a proportion of these will be vehicles associated with construction activities.

Cost estimates

12.2.12 Based on the review of market availability and contractor fleet data calculations the following has also been taken into account when estimating the likely costs.

1. Some of all of the capital expenditure may not be passed to HS2, this might in itself reduce the cost to HS2 by up to 100% (i.e. to zero).
2. Some Euro VI compliant HGVs vehicles undoubtedly already exist in the market and are in common use in London. Some or all of the fleet is therefore already available as Euro VI compliant and could be provided to HS2, this might in itself reduce the cost to HS2 by up to 100% (i.e. to zero). Contractors are already aware of the forthcoming drive to use Euro VI HGVs and so even if new HGVs needed to be purchased to meet the HS2 requirements this cost may be distributed over many other contracts (not with HS2) or may already be factored into any cost estimates used to bid for HS2 contracts.
3. Some contractors replace their vehicles on a mileage (e.g. after 200,000 kilometres) or a time basis (e.g. after 2 years). The vehicle has a resale value and this might reduce the cost to HS2 by 10-50% depending on the vehicle type and age.
4. It is possible that some or all of the HGVs may have a larger capacity for materials than assumed (e.g. 6m^3 were assumed in the calculations for concrete HGVs, but 8.5m^3 are currently already in use in London; bulk material HGVs may be larger than the 8.5m^3 assumed in the calculations). If this were the case then the number of round trips per day would be fewer than estimated. This would reduce the cost of the HGVs in proportion to the ratio of the volumes – hence if all concrete HGVs were 8.5m^3 size, then the cost of concrete HGVs would be around 25% of that stated here (noting that larger vehicles may be more expensive to buy than the small equivalent one).

12.2.13 Based on the market analysis, the estimated London Euro VI compliant HGV fleet and the likely fleet of vehicles required for HS2 construction in London it is extremely likely that the requirement for Euro VI can be met without incurring any direct cost to HS2 contracts. Contractors will have largely or wholly replaced enough of their vehicles with Euro VI compliant vehicles such that they can comply with the requirement for Euro VI and the requirements of the ULEZ (notwithstanding that some exemptions will be required as detailed in section 10).

12.2.14 Hence, the cost to HS2 of requiring Euro VI HGVs is likely to be close to zero (£0). In order to estimate the possible range costs of providing Euro VI HGVs to HS2 (some of which might be assigned to HS2 by contractors), Arup has estimated a hypothetical maximum scenario (Box 3).

12.2.15 In summary, the largest annual HGV fleet required represents the largest number of vehicles that would need to be purchased to satisfy requirement – vehicles purchased in one year would be available in subsequent years. For CFA1 a new fleet of around 222 vehicles (58 vehicles excluding those required for excavated materials) would cost between £21-22 million (£5.5-6 million excluding those required for excavated materials). For CFAs 3-6 a new fleet of 475 vehicles (174 vehicles excluding those required for excavated materials) would cost £51 million (£18.7 million excluding those required for excavated materials). It is considered that this case is unrealistically pessimistic and is therefore **more** than the maximum possible cost to HS2 Ltd.

Box 3: Assumptions used in the costing of the hypothetical maximum scenario (HGVs only)

Assumptions used in the costing

- All HGVs purchased new for the HS2 contracts.
- No HGVs compliant with Euro VI are available in the market to be provided to HS2.
- Contractors/sub-contractors will purchase outright all vehicles required to fulfil their contract with HS2 Ltd.
- All this cost will be passed to HS2 Ltd /none of the cost is passed to other clients who might be provided the vehicle under other contractors during or after the vehicle has been used for HS2.
- There is no resale value for the vehicle.
- Purchase of all fleet vehicles in the maximum year requiring the largest fleet.

HGVs purchase cost are estimated as follows:

- Concrete HGV (6m^3) = £150k
- Tipper HGV 4-axle (8.5m^3)[E] = £100k
- Miscellaneous = £100k

Not included in this cost is the saving that operators would make by upgrading to a newer vehicle (e.g. better fuel efficiency, lower tyre wear, fewer breakdowns and lower maintenance costs).

Using the HGV fleet and the assumptions above the *hypothetical maximum scenario* gives a maximum total capital expenditure in any one year of £21 million for Euston works (CFA1) and £51 million for CFAs 3-6. It would not be sensible to take the capital expenditure for each of the 6 years considered and add them together as once the vehicles are purchased they are available for use in successive years. For CFAs 3-6 the maximum fleet year (2018) also corresponds to the highest

[E] Used for excavated material, waste and demolition material.

number of vehicles in each of the activity classes. Hence, no larger fleet would be required. For CFA1 the maximum fleet for each activity type does not occur in the same year. If the maximum fleet for each activity type is taken to create the largest capital expenditure to purchase all vehicles (irrespective of year in which they would be needed), the total would rise from £21 million to £22 million. For the 'worst' year; recurring costs will be highly variable and will depend on contractor, with some replacing vehicles based on mileage run, years of operation or hours worked.

12.2.16 The cost of emissions in terms of air quality impacts has been assessed in section 6 and for CFAs 1 to 6 the cost was estimated at -£3.2million. This number would be reduced (but by how much is not known at present) if Euro VI were used by all HGVs.

12.2.17 Hence, in terms of value for money, one can compare the cost of HS2 requiring all HGVs to be Euro VI to the reduction in costs associated with HS2's air quality impacts. The costs of providing Euro VI vehicles and the air quality benefits are likely to be of a similar order (less than a few million pounds and probably close to zero (£0)) and so represent good value for money.

12.2.18 However, there will be some costs associated with measuring compliance and enforcing continuous improvement. This cost will be minimal if already part of the contractors' environmental management systems.

13 Conclusions

13.1.1 Based on the review of the vehicle stock in London and the likely vehicle fleet required for construction of HS2 it is very likely that most, if not all, of the HGVs on roads operating on behalf of HS2 can be Euro VI compliant. That is to say, at an overview level, the supply of Euro VI vehicles is estimated sufficient to meet the predicted demand from HS2.

13.1.2 In the early months of construction much of the work will be utility works on public highways and early preparation of construction sites (such as erecting hoardings). Utilities infrastructure will be undertaken initially by the early works contractor(s) and final connections will be made by the statutory undertaker (e.g. British Telecom, Thames Water and National Grid). The early works contractors should be required to comply with the HS2 commitment. Many of the statutory undertakers already have significant numbers of Euro VI compliant HGVs and low/ultra-low emission and electric vehicles in their fleet (e.g. British Gas has a fleet of 13,000 vehicles and 13% are currently (2016) electric vehicles).

Proposals

13.1.3 The following proposals are provided for consideration by HS2 Ltd:

13.1.4 *Heavy vehicles (> 3.5 tonnes)*

1. Require contractors (including their sub-contractors) to use HGVs (with a weight greater than 3.5 tonnes) within the London LEZ and relating to the construction of HS2, that are powered by Euro VI (or lower emission) engines, unless it is an exempt vehicle.
2. Require contractors (including their sub-contractors) to determine which vehicles are exempt and to report HGV numbers by Vehicle Registration Number and Euro standard, including any exemptions and non-compliances for all relevant HS2 related works within the London LEZ. The exemptions should be determined in a way that seeks to maximise the use of Euro VI (or lower emission) vehicles.
3. Certain HGVs (with a weight greater than 3.5 tonnes) may be exempted on the grounds of (a) **specialism**, (b) **unforeseen circumstances**, or (c) **triviality**. Section 10 in this report provides further details on the requirements for these exemptions, limitations on what they include, recommendations for their duration and validity, as well as the proposal for setting up a transition period.
4. All contractors, as set out in their Logistics Environment, Sustainability and Safety Management Plans (ESSMPs), should set out their exemptions, management process and report vehicle numbers, exemptions and non-compliances to HS2 Ltd on a monthly basis from start of works, with reducing frequency by agreement as performance is established. Non-compliances are those HGVs (with a weight greater than 3.5 tonnes) which are not Euro VI compliant and have not been exempted under

the agreed grounds for exemption (i.e. exempted vehicles are not considered to be non-compliances with the commitment). Exemptions should account for no more than 8% of unique vehicles on an annual basis, with the exception of a lead in period to be determined by HS2 Ltd, to allow for a baseline to be established.

5. Contractors should prepare and agree an Action Plan with HS2 Ltd:
   a. if there is less than 100% Euro VI compliance; or
   b. if compliance does not show improvement on the previous 3 months; or
   c. if the number of exemptions increases on the previous 3 months.

13.1.5 *Light vehicles (< 3.5 tonnes)*

6. Require all LDVs used by contractors in relation to the construction of HS2 in the London LEZ (with a weight less than or equal to 3.5 tonnes) to be Euro 4 petrol and Euro 6 diesel by 2020.
7. Require contractors (including their sub-contractors), as part of their ESSMPs, to produce a plan to work towards achieving target percentages of ULEVs to be used in the fleet of light vehicles relating to the construction of HS2 for the purposes of their contract entering the London LEZ. This plan should be agreed with HS2 Ltd and progress against it should be measured and reported.
8. The use of cars is expected to be minimal during HS2 construction in London. Contractors should set a target for the supply chain fleet to reach 100% ULEV cars and 75% ULEV vans from 2017 (based on vehicle miles, not unique vehicles), with continuous improvement towards that target. Targets should also be set for fleet average CO_2 emissions. It is proposed that the following aspirational targets are set:
   - fleet average for cars of 75 gCO2/km from 2017 decreasing by 5 gCO2/km every 3 years; and
   - fleet average for vans of 160 gCO2/km from 2017 decreasing by 20 gCO2/km every 3 years).

13.1.6 *Compliance monitoring and reporting*

9. For the metrics for all vehicles referred to above, contractors should be required to establish a baseline of vehicle use, exemptions and compliance percentages within the first 2 months of starting their activities.
10. Data should be reported to HS2 Ltd initially on a monthly basis; once continuous improvement is shown in each of three separate adjacent months, the frequency of reporting may be reduced (with the agreement of HS2 Ltd). Contractors should also provide annual (calendar year) statistics to HS2 Ltd to enable aggregate reports to be compiled.

Recommendations for further work

13.1.7 It is further recommended that HS2 Ltd investigates the charging point provisions for car/van ULEVs at sites outside Euston, if parking is provided.

Appendix A – Air quality standards and legislation

Introduction

Air quality guidelines, limit values and objectives are quality standards for clean air. Some pollutants have standards expressed as annual average (long-term) concentrations, due to the chronic way in which they affect human health or the natural environment (i.e. effects occur after a prolonged period of exposure to elevated concentrations). Others have standards expressed as 24-hour, 1-hour or 15-minute average (short-term) concentrations, due to the acute way in which they affect human health or the natural environment (i.e. after a relatively short period of exposure). Some pollutants have standards expressed in terms of both long-term and short-term concentrations.

The difference between guidelines, limit values and objectives is in the status attributed to them and, in particular how they are enforced, if at all. The WHO guidelines have no legal standing and are aspirational for many countries with levels of pollution much higher than the guidelines. EU limit values are enforceable by European law. UK objectives are not legally enforceable, but their values match the EU limit values and in this way they are indirectly enforced.

WHO Guidelines

The WHO has developed guidelines for ambient levels of air pollutants[55], based on the latest scientific knowledge and epidemiological studies. In relation to particulate matter (PM_{10} and $PM_{2.5}$) there is widespread evidence that prolonged exposure to these pollutants can adversely affect the respiratory and cardiovascular system of people, leading to an increased risk of premature mortality and thus reduced life expectancy for the population. To date, no threshold has been found below which no adverse health effects would occur. Recent studies have also found that particle exhaust emissions from diesel vehicles have a strong association with respiratory mortality[56].

In relation to NO_2, epidemiological studies have shown that long-term exposure to this pollutant can cause symptoms of bronchitis in asthmatic children. High concentrations of NO_2 have also been linked to reduced lung function growth in cities of Europe and North America[57].

The WHO air quality guidelines for PM_{10}, $PM_{2.5}$ and NO_2 are presented in Table 19. The WHO guideline for annual mean NO_2 is the same as the EU limit value and UK air quality objective, but the other standards are all lower and therefore stricter than the EU and UK values:

- The hourly mean NO_2 and 24-hour PM_{10} WHO guidelines are given as maximum values that should not be exceeded whereas the EU and UK values permit a number of exceedances of each value, each year;
- The PM_{10} and $PM_{2.5}$ annual mean WHO guidelines are stricter than the EU and UK values; and
- There is a WHO guideline for 24-hour $PM_{2.5}$ but there is no corresponding EU or UK value.

European Air Quality Management

The EU sets limits on emissions and concentrations of pollutants in air, that is, the limits try to control the output of pollutants and their impact. The controls on emissions of local air quality pollutants include a national emissions ceiling for Member States as well specific limits for emissions from industry and from on-road and off-road vehicles.

In 1996 the European Commission published the Air Quality Framework Directive on ambient air quality assessment and management (96/62/EC)[58]. This Directive defined the policy framework for 12 air pollutants known to have harmful effects on human health and the environment. Limit values (pollutant concentrations not to be exceeded by a certain date) for each specified pollutant were set through a series of Daughter Directives, including Directive 1999/30/EC (the 1st Daughter Directive)[59] which set limit values for NO_2 and PM_{10} amongst other pollutants in ambient air.

In May 2008 the Directive 2008/50/EC[60] on ambient air quality and cleaner air for Europe (CAFE) came into force. This Directive consolidates the above (apart from the 4th Daughter Directive, which will be brought within the new Directive at a later date), provides a new regulatory framework for $PM_{2.5}$ and makes provision for extended compliance deadlines for NO_2 and PM_{10}. The EU limit values for NO_2, PM_{10} and $PM_{2.5}$ are given in Table 19 with the UK objectives.

Air Quality Standards

The CAFE Directive was transposed into national legislation in England by the Air Quality Standards Regulations 2010[61]. The Secretary of State for the Environment has the duty of ensuring compliance with the air quality limit values.

Part IV of the Environment Act 1995[62] places a duty on the Secretary of State for the Environment to develop, implement and maintain an Air Quality Strategy with the aim of reducing atmospheric emissions and improving air quality. The *Air Quality Strategy for England, Scotland, Wales and Northern Ireland*[63] (NAQS) provides the framework for ensuring the air quality limit values are complied with based on a combination of international, national and local measures to reduce emissions and improve air quality. This includes the statutory duty, also under Part IV of the Environment Act 1995, for local authorities to undergo a process of local air quality management. This includes declaring Air Quality Management Areas (AQMA) where air quality objectives are not being met and publishing Action Plans that set out measures directed at meeting the objectives.

The UK air quality objectives have the same numerical value as the limit values for most pollutants, but in some cases the target date for compliance is different (usually later) to the date for the limit value. The key difference is that the Secretary of State for the Environment is required under European law to ensure compliance with the air quality limit values, whereas for the UK air quality objectives local authorities are only obliged under national legislation to undertake best efforts to comply with the air quality objectives.

Table 19: WHO guidelines, EU limit values and UK air quality objectives

Pollutant	Averaging period	WHO guideline	EU limit value	UK objective
Nitrogen dioxide (NO_2)	Annual mean	40µg/m3	40µg/m3	40µg/m3
	1-hour mean	200µg/m3	200µg/m3 [1]	200µg/m3 [1]
Particulate matter (PM_{10})	Annual mean	20µg/m3	40µg/m3	40µg/m3
	24-hour mean	50µg/m3	50µg/m3 [2]	50µg/m3 [2]
Fine particulate matter ($PM_{2.5}$)	Annual mean	10µg/m3	25µg/m3	25µg/m3
	24-hour mean	25µg/m3	n/a	n/a

[1] not to be exceeded more than 18 times a year (99.8th percentile)
[2] not to be exceeded more than 35 times a year (90.4th percentile)

Appendix B – Type of construction vehicles

Concrete (rigid HGV)

Waste (rigid HGV)

Excavated, demolition materials (32t rigid HGV)

Miscellaneous activities:

Transporting NRMM (articulated HGV)

Road cleaning (rigid HGV)

Transporting NRMM or materials (rigid HGV)

Concrete pump (rigid HGV)

3.7t Van (LGV)

7.5t Pick-up truck (rigid HGV)

Appendix C – Vehicle emissions

Euro emission standards

Table 20 and Table 21 show the Euro standards set for NOx and PM10 for the higher class of LGVs (N1-III & N2) and for HGVs. The standards are not "no-exceed" standards, but are the average allowable emissions over the specified test cycle. Hence, in a particular model of driving within the cycle, the emissions can be more or less than the standard, provided the average over the driving cycle is less than the standard.

The limits for LGVs are given in terms of mass of emission per distance travelled by the vehicle (g/km), whereas the limits for HGVs are given in terms of mass of emission per kilowatt-hour of energy generated by the engines. The dates listed in the tables are the year when new models must meet the Euro standard in order to gain type approval. At a later date specified by the Directives, usually one year after the date for new type approval, all vehicles that are first registered must comply with the given Euro standard. It can be observed that the standards get stricter (with lower values) over time (Figure 17 and Figure 18).

Table 20: Euro standards for N1 III & N2 LGVs

Euro standard	Date for new type approval	NOx emissions (g/km)		PM emissions (g/km)	
		Petrol	Diesel	Petrol	Diesel
Euro 1	1994	1.7*	1.7*	n/a	0.25
Euro 2	1998	0.7*	1.2*	n/a	0.17
Euro 3	2000	0.21	0.78	n/a	0.1
Euro 4	2005	0.11	0.39	n/a	0.06
Euro 5	2010	0.082	0.28	0.005	0.005
Euro 6	2015[1]	0.082	0.125	0.005	0.005

** hydrocarbons and NOX combined*
[1] Compliance is from the 1st of September 2015, which corresponds to UK vehicle registration numbers beginning XX65.

Table 21: Euro standards for HDVs

Euro standard	Date for new type approval	NOx emissions (g/kWh)	PM emissions (g/kWh)
Euro I	1992	8.0	0.612 (engines less than 85 kW) 0.36 (engines more than 85 kW)
Euro II	1996	7.0	0.25 0.15 (1998 regulation)
Euro III	2000	5.0	0.10
Euro IV	2005	3.5	0.02
Euro V	2008	2.0	0.02

Euro standard	Date for new type approval	NOx emissions (g/kWh)	PM emissions (g/kWh)
Euro VI	2013[1]	0.4	0.01

[1] Compliance is from the 31st of December 2013, which corresponds to UK vehicle registration numbers beginning XX63 and XX14.

Figure 17: Euro class NOx emission standards (g/km) for N1 III & N2 LGVs

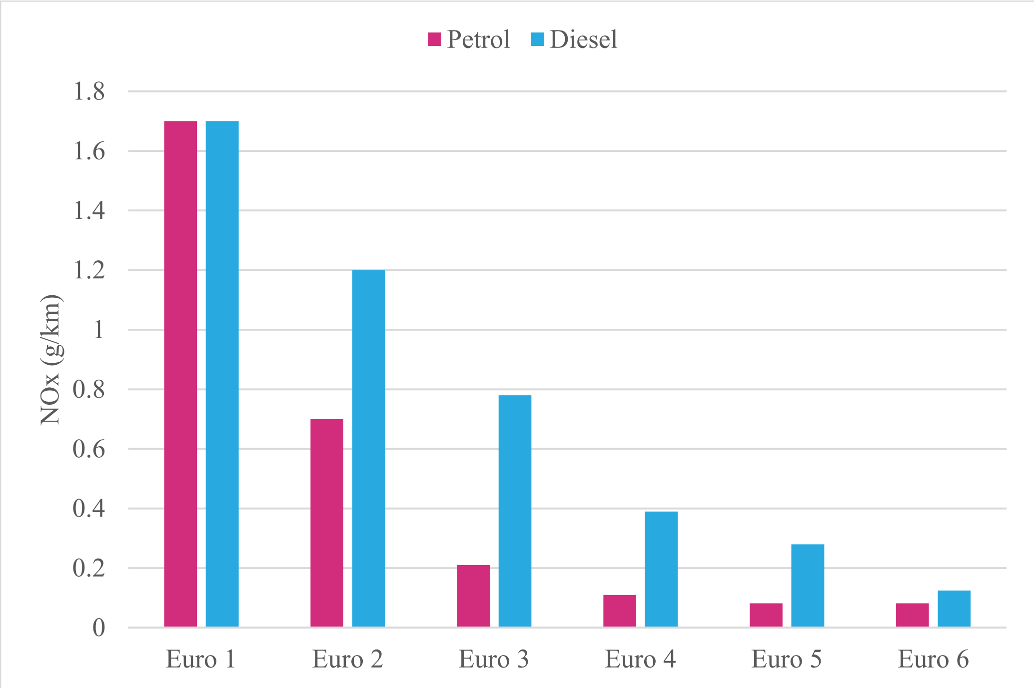
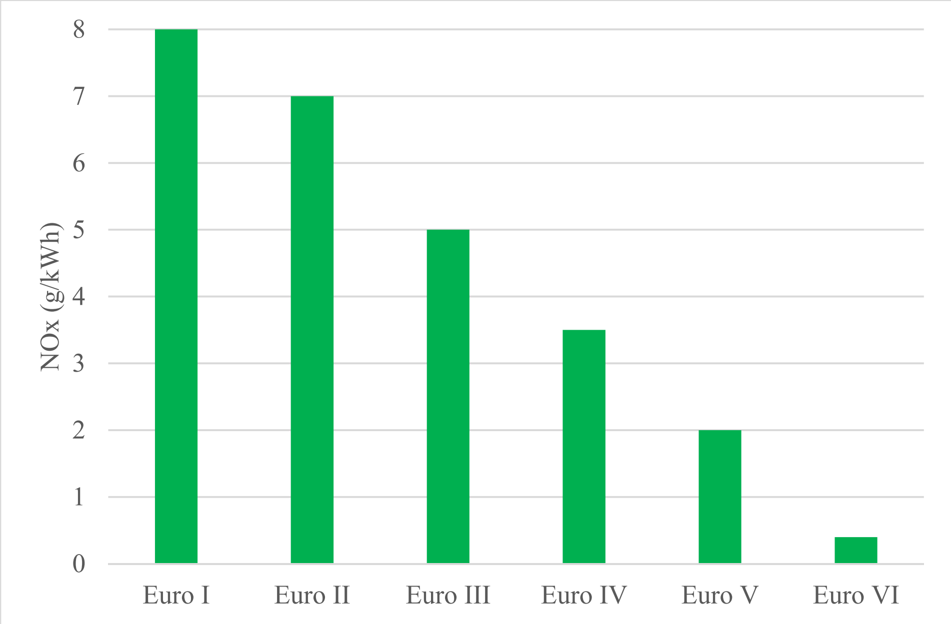


Figure 18: Euro class NOx emission standards (g/kWh) for HDVs



Non-compliance of diesel vehicles in real world driving with Euro standards

The recent Volkswagen and Mitsubishi scandals over vehicle and fuel testing have brought the matter of vehicle tests to public attention, but the impact of manipulating the tests needs to be separated from the other issues which, as they affect more vehicles types, are more important. The impact of cheating will be considered after these other matters.

The "no manipulation" scenario

Vehicle testing for type approval is carried out under laboratory conditions. As long as the vehicle meets the emissions standard in the laboratory, it is granted its type approval and it complies with the Euro standard.

There are respects in which the laboratory conditions are not like on-the-road driving conditions:

- Vehicle manufacturers are allowed to make the vehicle lighter (by removing the back seats), to improve the aerodynamics (by taping over door handles etc.) and to reduce the load on the engine (by switching off headlights or even disconnecting the alternator so that the battery is not (re)charged;

- The drive cycle (the cycle of speed, acceleration and breaking) used for the test is not representative of the type of stop-start driving encountered in urban and congested areas and it is under these conditions that emissions are highest.

There are reasons why the emissions control equipment fitted on the vehicle does not perform to its specification in real world driving conditions:

- The catalytic converters which reduce NOx emissions before the vehicle exhaust, can fail. The failure rate is less than 0.1% for Euro 5 diesel cars;
- Under stop-start driving and short journey distances catalytic converters may not reach the correct operating temperature and therefore underperform on
- Some after-treatment systems are not properly maintained and therefore underperform; and
- Some after-treatment systems perform less well with age (degradation).
- There are further issues in using the Euro standard emission rates for NOx to predict concentrations of NO_2:
- The type approval emission rates, which are averages over a drive cycle, are used as functions of the drive cycle average speed. Average speed alone is not a good indicator of emissions, for instance, travelling at an average speed of 30mph on a motorway would represent stop-start driving, whereas an average speed of 30mph in an urban area might represent smooth driving; and
- The emission standards tested in the type approvals, are for emissions of NO_X whereas the air quality objectives are for NO_2. The proportion of NO_2 in the exhaust emissions has increased with successive Euro classes which is likely to increase roadside NO_2 concentrations (if the NO_X emission is the same).

The "manipulation" scenario

In September 2015 the media reported that Volkswagen Group had fitted software, termed "defeat devices" to their vehicles in order to distort emissions results for NOx during type approval tests in the US. It became apparent that the same practice of using defeat devices had been carried out in European tests[64].

The DfT sought assurances from other vehicle manufacturers that they were not using defeat devices and initiated an Emissions Testing Programme to look for "defeat devices". The Testing Programme would also add to the body of knowledge on the difference between the test performance and the real world emissions performance of a broad selection of the best-selling vehicles in the UK. The testing was managed by the Vehicle Certification Agency and the report of the Programme was recently published[64]. It concluded that there was no evidence of deliberate test cycle manipulation by manufacturers other than the Volkswagen Group.

The deliberate test cycle manipulation was shocking, but in terms of the difference between test cycle and real world emissions, the defeat device is simply another cause of difference; the difference itself had been established and was being tackled by changes to the testing regime.

Performance of vehicles in the real world

The DfT's report on the Vehicle Emissions Testing Programme64, as well as reporting on whether the use of defeat devices was widespread, reported on the performance of LDVs in real world conditions compared with the Euro limit values. The testing included driving each vehicle for 1.5 hours on public roads. The vehicles selected for testing were all passenger cars and accounted for 75% of sales of the top-selling 70 diesel vehicles between the years 2010 – 2015. The vehicles were evenly split between those produced to conform to Euro 5 emissions limits and Euro 6 limits.

The report found:

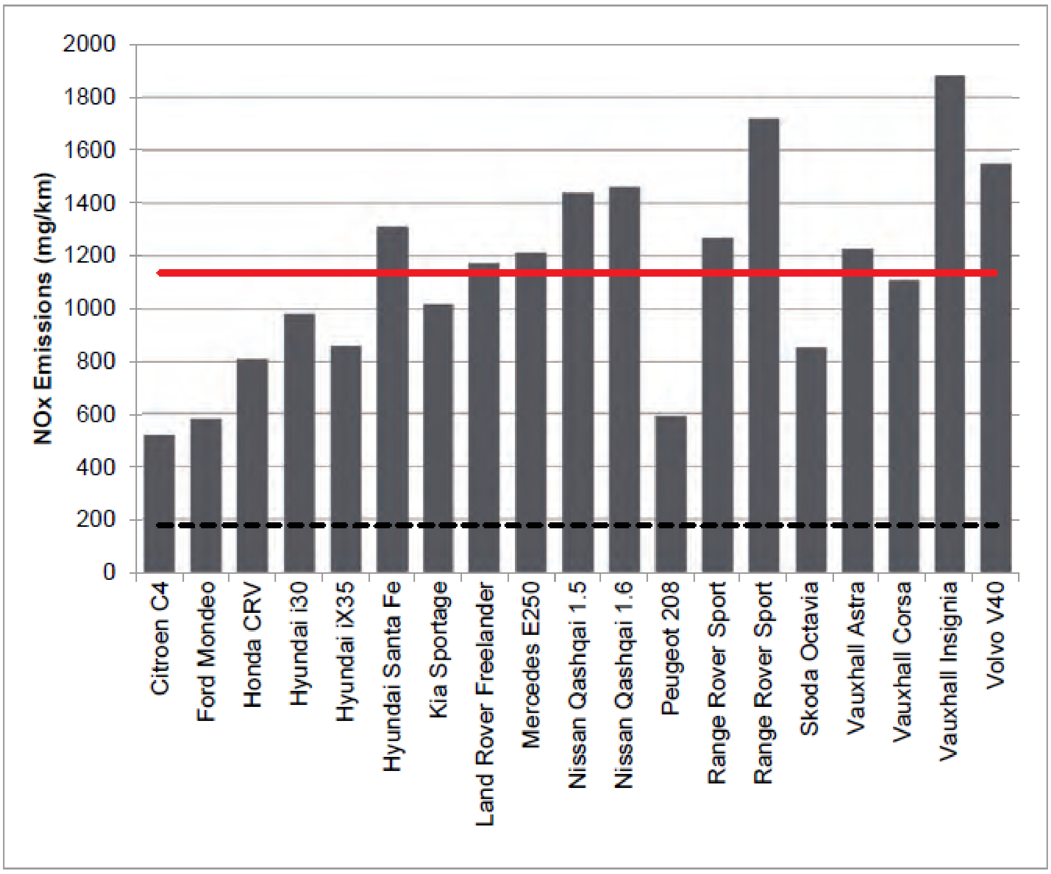
- On average the measured road test NOx emissions from Euro 5 vehicles were over six times higher than the official legislative laboratory test limit;
- On average the measured road test NOx emissions from Euro 6 vehicles were over six times higher than the official legislative laboratory test limit; and
- Euro 6 vehicle emissions were, on average, less than half the average figure for the Euro 5 vehicles as the legislative laboratory test limit is lower.

Figure 19 and Figure 20 show the DfT results for Euro 5 and Euro 6 vehicles respectively. The red lines show the average NOx emissions of all vehicles tested while the black dotted lines shows the type approval limit. For both the Euro 5 and Euro 6 vehicles it can be seen that the average on-the-road performance is indeed six times the type approval limit, with even the best performing vehicles exceeding the type approval limit by a factor of three. The variability in vehicle performance is also quite striking, with a factor of up to five in performance between the best and the worst performers.

DfT notes that these results are not directly comparable to each other as the exact test conditions, being on-the-road, varied from test to test.

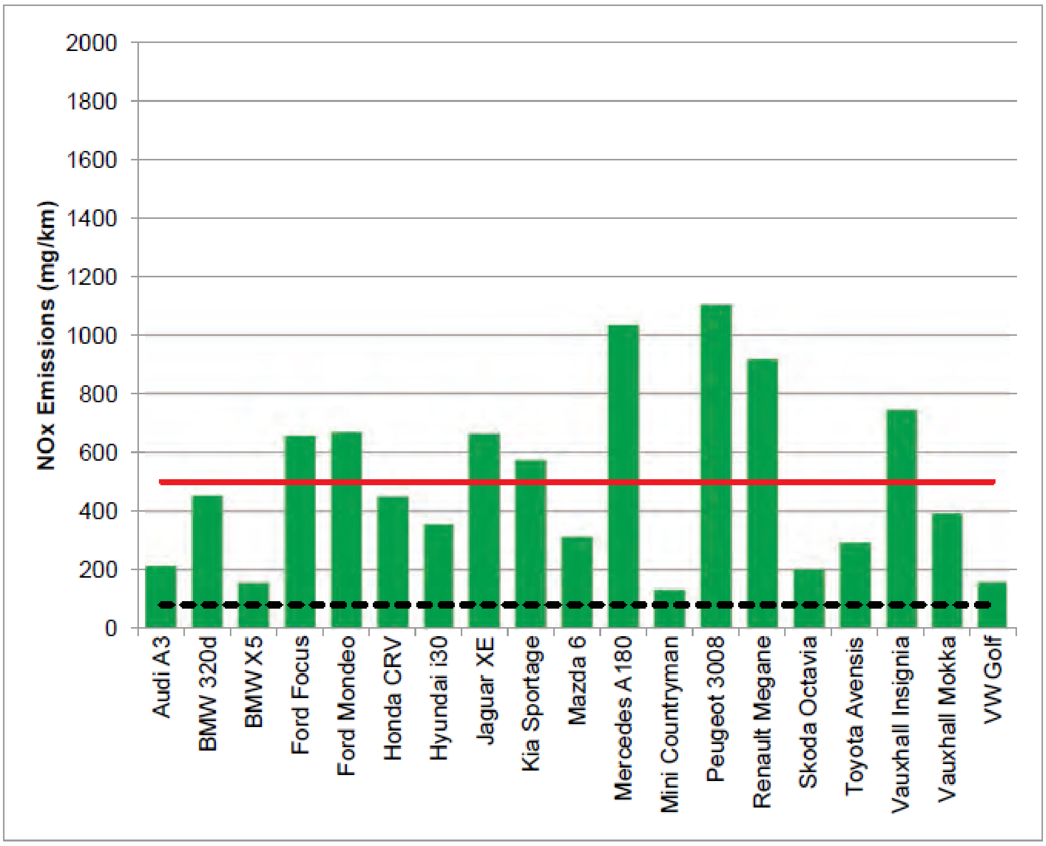
The DfT Vehicle Emissions Testing Programme only covered a sample of passenger cars. Recent work by others testing LGVs in real world conditions show that their emissions in real world conditions also exceed the type approval limit.

Figure 19: Real-driving NOx emissions for Euro 5[F]



[F] Figure 5-5 Real driving NOx emissions – Euro 5 vehicles (note: direct comparisons should not be made between vehicles as test conditions varied). Red line shows the average (1,135mg/km) of the data, the black dashed line is the type approval limit (180mg/km)

Figure 20: Real-driving NOx emissions for Euro 6[F]



EQUA Air Quality Index Technical FAQ

Q. What levels of emissions does each rating equate to?

A. The ratings scale is based on the level of emissions of nitrogen oxides (NO_x) in grams per kilometre – which is the official measure under European regulations. The EQUA Air Quality Index aligns the boundaries between ratings values as much as possible with recognisable points.

Rating	Lower bound (g/km, exclusive)	Upper bound (g/km, exclusive)	External reference point
A	0.00	0.08	Meets Euro 6 limit for diesels, and meets Euro 4 limit for petrols
B	0.08	0.12	Meets 1.5 Conformity Factor under Euro 6 Real Driving Emissions regulation
C	0.12	0.18	Meets Euro 5 limit for diesels (and similar to 2.1 Conformity Factor under Euro 6 Real Driving Emissions regulation)
D	0.18	0.25	Meets Euro 4 limit for diesels
E	0.25	0.50	Meets Euro 3 limit for diesels
F	0.50	0.75	No comparable Euro standard: roughly equal to 6-8 times Euro 6 limit
G	0.75	1.00	No comparable Euro standard: roughly equal to 8-12 times Euro 6 limit
H	1.00	None	No comparable Euro standard: roughly equal to 12+ times Euro 6 limit

Using this scale, a diesel vehicle with an A EQUA Air Quality Index rating can be said to meet the Euro 6 regulatory level even in real-world driving.

Q. What is wrong with the current official emissions test?

A. The current type approval test, required before a car can go on sale, is conducted in a laboratory on the New European Driving Cycle (NEDC). This is a cycle of less than 20 minutes with low average speeds, low rates of acceleration, no gradients and therefore tests the performance of the vehicle with the engine under relatively low load.

Real-world driving typically puts higher loads on the engine, but this remains largely untested. In addition, the test protocol contains a number of leniencies that can be exploited and optimised to achieve low emissions performance on the official test.

From 2017, new regulations will be introduced to address the problems in both CO_2 and NO_x measurement, with the World Harmonised Light Duty Test Protocol (WLTP) for the former and Real Driving Emissions (RDE) for the latter.

Q. What is Real Driving Emissions (RDE)?

A. In order to tighten up the regulation of NO_x emissions, the European Union will introduce an enhanced type approval certification test from September 2017. This will add to a controlled laboratory test an on-road test using Portable Emissions Measurement Systems (PEMS). Vehicles will be required to meet the regulated NO_x limit (0.08 grams per kilometre for diesels) exactly in the laboratory but with a margin of error (called a Conformity Factor) in the on-road test. Initially this Conformity Factor will be set at 2.1, but falling to 1.5 from September 2019 and potentially further thereafter. So, from next year, vehicles will have to emit no more than 0.168 g/km of NO_x in on-road operation (the regulated limit of 0.08 g/km multiplied by the 2.1 Conformity Factor).

Q. Are all vehicles rated on the same scale?

A. Yes. Whether vehicles are diesel or petrol/gasoline, or Euro 5 or 6 regulatory stage, they are rated on the same scale, shown above. This means that, for example, a petrol car can be compared directly to a diesel car for its NO_x emissions.

Q. How many vehicles do you test per year?

A. Emissions Analytics tests between 200 and 400 vehicles each year in the European Union. It's also active in the United States, testing a similar number of vehicles, although these are not included within this ratings programme currently.

Q. Are PEMS suitable for NO_x measurement?

A. PEMS are used for the regulatory testing of nitrogen oxides in Europe for heavy duty vehicles, and are planned to be used similarly for passenger cars from 2017. The equipment is used more widely by the US Environmental Protection Agency for in-service surveillance testing.

The equipment used by Emissions Analytics meets the standards of UN-ECE R-49 and Commission Regulation (EU) No. 582/2011 in the European Union, and 40CFR part 1065 in the United States. Further details of the equipment used can be found at http://www.sensors-inc.com/. The repeatability quoted by the manufacturer for NO_x is typically +/-2%. Emissions Analytics calibrates the equipment to known gas concentrations for each test, according to the equipment manufacturer's recommendation.

Q. What age are the vehicles you test?

A. Vehicles are typically tested within a few months of first registration and have between 1000 and 5000 miles on the clock. This age of vehicle is used because it ensures that the vehicle has been “de-greened” for a period, but has not be exposed to the variables associated with longer-term operation, including service standards and vehicle care more generally.

Q. Do you test used cars?

A. Currently the EQUA Index programme focuses on testing cars when new, where the service history of the vehicle does not affect performance. Having tested for over five years there’s a back catalogue of ratings for vehicles, which are now exclusively available in the second-hand market, although they were tested when new.

Q. How are factors such as driving style, changes in altitude, ambient temperature, ambient humidity and engine temperature taken into account?

A. As many factors as possible are kept constant between tests, including the route, drivers and their driving style. The vehicles are fully warmed up when the test starts. Ambient conditions must fall within parameters that ensure testing is not conducted under extreme high or low temperatures, rain, snow, ice and high winds.

Q. How is the weight added to the vehicle kept constant, as drivers and passengers can vary significantly in weight?

A. The added weight to each vehicle is the same, approximately equal to being half-loaded for an average car. The weights of the driver, passenger, equipment and level of fuel in the tank are taken into account and then additional ballast is used to bring the total weight up to the benchmark level.

Q. What fuel is used in the vehicles and can this affect the results?

A. The fuel used is a standard grade petrol or diesel, conforming to EN590 and EN228 regulations respectively. The only variation from this is if the vehicle manufacturer requires the use of a premium grade. If a premium grade is only “recommended”, then the standard grade is used. The fuel is sourced from a single filling station, which remains the same over time. This enables the best balance of using the same fuel that customers can buy in the real world and consistency over time. With these controls in place, the remaining variability is not material to fuel economy.

Q. To what pressures are tyres inflated?

A. The manufacturer recommended tyre inflation pressures are used for each vehicle, checked before each test.

Q. Do you test every variant of each model?

A. We aim to test each model where the model year, engine size, fuel type, power, number of driven wheels, transmission or Euro regulatory stage are distinct. We consider vehicles materially similar where the difference is only in body style, number of doors or trim level. This is more restrictive than the “families” of vehicle defined under the type approval process.

Q. Is there a validation programme that confirms that test cycle has been completed satisfactorily?

A. Yes, there is a validation programme, which has been designed specifically by Emissions Analytics. This ensures that the cycle overall, and sub-sections of it, meets a number of validity tests, including average speed, acceleration, presence of Diesel Particulate Filter (DPF) regeneration, engine coolant temperature, ambient climatic conditions, and so on. This ensures that there is the greatest consistency possible between different tests of different vehicles on different days.

Q. How are different driving styles factored into the results?

A. The driving style across the test is kept constant by using a small team of drivers who are all trained to drive in the same way. This is verified for each individual test and a more detailed audit of driving styles is conducted annually. Within each test, different rates of acceleration are used at different points in order to assess the vehicle performance, but this approach is applied consistently between tests.

Q. How are the repeatability and reproducibility of results assessed?

A. Repeatability and reproducibility are assessed on a number of levels. First, within each test, repeated identical sub-segments must match each other within certain parameters. Second, a sub-sample of vehicles is retested under the same conditions to ensure consistency. Third, all results are compared to Emissions Analytics’ database to ensure a broader consistency with similar models and technology types. Fourth, a sub-sample of models is selected such that different instances of the same models are tested for inter-model consistency.

EQUA INDEX Aq AIR QUALITY Diesel Euro 6

Manufacturer	Model	Fuel type	Model year	Engine size litres	Power bhp	Driven wheels	Transmision	Regulatory stage	EQUA Aq Index
Audi	A5	Diesel	2014	2.0	161	2	Manual	Euro 6	A
Seat	Alhambra	Diesel	2015	2.0	150	2	Manual	Euro 6	A
Skoda	Superb	Diesel	2016	2.0	148	2	Manual	Euro 6	A
Volkswagen	Golf SV	Diesel	2015	2.0	148	2	Automatic	Euro 6	A
Volkswagen	Passat	Diesel	2016	1.6	118	2	Manual	Euro 6	A
Volkswagen	Scirocco	Diesel	2015	2.0	148	2	Manual	Euro 6	A
Volkswagen	Touran	Diesel	2016	1.6	108	2	Manual	Euro 6	A
Volvo	S60	Diesel	2016	2.0	148	2	Manual	Euro 6	B
Audi	A4	Diesel	2016	2.0	148	2	Manual	Euro 6	C
Audi	A6	Diesel	2014	2.0	187	2	Automatic	Euro 6	C
BMW	3 Series	Diesel	2015	2.0	161	2	Automatic	Euro 6	C
Ford	Fiesta	Diesel	2015	1.5	94	2	Manual	Euro 6	C
Jaguar	XE	Diesel	2016	2.0	178	2	Automatic	Euro 6	C
Jaguar	XF	Diesel	2016	3.0	296	2	Automatic	Euro 6	C
Land Rover	Range Rover Evoque	Diesel	2016	2.0	178	4	Automatic	Euro 6	C
Skoda	Octavia	Diesel	2016	2.0	181	4	Automatic	Euro 6	C
Skoda	Superb	Diesel	2015	1.6	118	2	Manual	Euro 6	C
Volkswagen	CC	Diesel	2016	2.0	180	2	Automatic	Euro 6	C
BMW	1 Series	Diesel	2015	1.5	114	2	Manual	Euro 6	D
BMW	X1	Diesel	2016	2.0	187	4	Automatic	Euro 6	D
BMW	X3	Diesel	2015	2.0	188	4	Manual	Euro 6	D
Citroen	C4 Cactus	Diesel	2014	1.6	99	2	Manual	Euro 6	D
Ford	EcoSport	Diesel	2016	1.5	94	2	Manual	Euro 6	D
Jaguar	XJ	Diesel	2016	3.0	296	2	Automatic	Euro 6	D
Mazda	2	Diesel	2016	1.5	104	2	Manual	Euro 6	D
Mazda	6	Diesel	2013	2.2	148	2	Manual	Euro 6	D
Mazda	6	Diesel	2015	2.2	173	2	Manual	Euro 6	D
Mazda	CX-3	Diesel	2015	1.5	104	2	Manual	Euro 6	D
Mazda	CX-5	Diesel	2015	2.2	148	4	Automatic	Euro 6	D
Peugeot	308	Diesel	2015	2.0	180	2	Automatic	Euro 6	D
Volvo	XC90	Diesel	2016	2.0	222	4	Automatic	Euro 6	D
BMW	4 Series	Diesel	2015	2.0	181	2	Automatic	Euro 6	E
Citroen	C4 Picasso	Diesel	2014	2.0	150	2	Manual	Euro 6	E
Citroen	C4 Picasso	Diesel	2015	1.6	118	2	Manual	Euro 6	E

EQUA INDEX Aq AIR QUALITY — Diesel Euro 6

Manufacturer	Model	Fuel type	Model year	Engine size litres	Power bhp	Driven wheels	Transmision	Regulatory stage	EQUA Aq Index
DS	4	Diesel	2015	1.6	120	2	Manual	Euro 6	E
Ford	S-Max	Diesel	2015	2.0	178	2	Manual	Euro 6	E
Hyundai	i20	Diesel	2015	1.4	89	2	Manual	Euro 6	E
Jaguar	F-Pace	Diesel	2016	2.0	180	4	Automatic	Euro 6	E
Jaguar	XE	Diesel	2015	2.0	163	2	Manual	Euro 6	E
Jaguar	XF	Diesel	2015	2.0	178	2	Automatic	Euro 6	E
Kia	Optima	Diesel	2016	1.7	139	2	Manual	Euro 6	E
Kia	Optima	Diesel	2016	1.7	139	2	Automatic	Euro 6	E
Kia	Sportage	Diesel	2016	1.7	114	2	Manual	Euro 6	E
Mazda	6	Diesel	2013	2.2	173	2	Automatic	Euro 6	E
Mercedes-Benz	C-Class	Diesel	2016	2.1	168	2	Automatic	Euro 6	E
Mercedes-Benz	C-Class	Diesel	2016	2.1	201	2	Automatic	Euro 6	E
Mercedes-Benz	E-Class	Diesel	2015	3.0	255	2	Automatic	Euro 6	E
Mercedes-Benz	E-Class	Diesel	2016	3.0	254	2	Automatic	Euro 6	E
Mercedes-Benz	GLC	Diesel	2016	2.1	168	4	Automatic	Euro 6	E
Mercedes-Benz	GLS	Diesel	2016	3.0	254	4	Automatic	Euro 6	E
Subaru	XV	Diesel	2016	2.0	147	4	Manual	Euro 6	E
Toyota	RAV4	Diesel	2016	2.0	141	2	Manual	Euro 6	E
Vauxhall	Astra	Diesel	2016	1.6	134	2	Manual	Euro 6	E
Vauxhall	Astra	Diesel	2016	1.6	158	2	Manual	Euro 6	E
Volvo	S60	Diesel	2014	2.0	178	2	Manual	Euro 6	E
Volvo	V40	Diesel	2015	2.0	187	2	Manual	Euro 6	E
BMW	X3	Diesel	2014	2.0	187	4	Automatic	Euro 6	F
Ssangyong	Turismo	Diesel	2016	2.2	176	2	Automatic	Euro 6	F
Volkswagen	Polo	Diesel	2015	1.4	89	2	Manual	Euro 6	F
Volvo	XC60	Diesel	2016	2.4	217	4	Automatic	Euro 6	F
BMW	4 Series	Diesel	2014	2.0	184	4	Manual	Euro 6	G
Infiniti	Q30	Diesel	2016	1.5	108	2	Manual	Euro 6	G
Subaru	Forester	Diesel	2015	2.0	145	4	Automatic	Euro 6	G
Vauxhall	Zafira Tourer	Diesel	2014	1.6	134	2	Manual	Euro 6	G
Fiat	500X	Diesel	2015	1.6	118	2	Manual	Euro 6	H
Porsche	Panamera	Diesel	2015	3.0	300	2	Automatic	Euro 6	H
Ssangyong	Korando	Diesel	2016	2.2	176	2	Manual	Euro 6	H

EQUA INDEX Aq AIR QUALITY

Petrol and Hybrid Euro 6

Manufacturer	Model	Fuel type	Model year	Engine size litres	Power bhp	Driven wheels	Transmision	Regulatory stage	EQUA Aq Index
Audi	A1	Petrol	2015	1.4	123	2	Manual	Euro 6	A
Audi	A3	Petrol	2015	1.4	148	2	Automatic	Euro 6	A
Audi	A3	Petrol	2015	1.4	150	2	Manual	Euro 6	A
Audi	A4	Petrol	2016	2.0	187	2	Automatic	Euro 6	A
Audi	RS3	Petrol	2016	2.5	362	4	Automatic	Euro 6	A
Audi	TT	Petrol	2016	1.8	180	2	Manual	Euro 6	A
Bentley	Bentayga	Petrol	2016	6.0	600	4	Automatic	Euro 6	A
BMW	1 Series	Petrol	2015	1.5	134	2	Manual	Euro 6	A
BMW	1 Series	Petrol	2016	3.0	322	2	Manual	Euro 6	A
BMW	2 Series	Petrol	2016	3.0	370	2	Automatic	Euro 6	A
BMW	X5	Petrol	2015	4.4	575	4	Automatic	Euro 6	A
Ford	Focus	Petrol	2016	1.0	125	2	Manual	Euro 6	A
Ford	Focus	Petrol	2016	2.3	350	4	Manual	Euro 6	A
Ford	Kuga	Petrol	2016	1.5	147	2	Manual	Euro 6	A
Hyundai	i20	Petrol	2015	1.4	99	2	Manual	Euro 6	A
Hyundai	i20	Petrol	2016	1.0	118	2	Manual	Euro 6	A
Hyundai	i30	Petrol	2015	1.6	183	2	Manual	Euro 6	A
Infiniti	Q30	Petrol	2016	1.6	120	2	Manual	Euro 6	A
Kia	Sportage	Petrol	2016	1.6	174	4	Manual	Euro 6	A
Mercedes-Benz	CLA	Petrol	2014	1.6	120	2	Manual	Euro 6	A
Mini	Convertible	Petrol	2016	1.5	134	2	Manual	Euro 6	A
Mini	Hatch	Petrol	2014	2.0	189	2	Manual	Euro 6	A
Peugeot	208	Petrol	2015	1.2	110	2	Automatic	Euro 6	A
Porsche	718 Boxster	Petrol	2016	2.5	350	2	Manual	Euro 6	A
Porsche	911	Petrol	2015	3.0	420	2	Automatic	Euro 6	A
Porsche	Cayenne	Petrol Plug-in Hybrid	2016	3.0	410	4	Automatic	Euro 6	A
Rolls-Royce	Dawn	Petrol	2016	6.6	563	2	Automatic	Euro 6	A
Seat	Ibiza	Petrol	2016	1.2	108	2	Manual	Euro 6	A
Seat	Ibiza	Petrol	2016	1.4	148	2	Manual	Euro 6	A
Seat	Ibiza	Petrol	2016	1.8	192	2	Manual	Euro 6	A
Seat	Leon	Petrol	2016	1.4	148	2	Manual	Euro 6	A
Seat	Leon	Petrol	2016	2.0	286	2	Manual	Euro 6	A
Smart	ForFour	Petrol	2015	0.9	89	2	Manual	Euro 6	A
Suzuki	Celerio	Petrol	2015	1.0	67	2	Manual	Euro 6	A
Toyota	Prius	Petrol Hybrid	2016	1.8	134	2	CVT	Euro 6	A
Toyota	Yaris	Petrol Hybrid	2015	1.5	100	2	CVT	Euro 6	A
Toyota	Yaris	Petrol Hybrid	2016	1.5	100	2	CVT	Euro 6	A
Vauxhall	Astra	Petrol	2016	1.4	148	2	Manual	Euro 6	A
Vauxhall	Astra	Petrol	2016	1.6	197	2	Manual	Euro 6	A
Vauxhall	Corsa	Petrol	2015	1.2	69	2	Manual	Euro 6	A
Vauxhall	Corsa	Petrol	2015	1.6	202	2	Manual	Euro 6	A
Vauxhall	Corsa	Petrol	2016	1.4	148	2	Manual	Euro 6	A
Vauxhall	Viva	Petrol	2015	1.0	75	2	Manual	Euro 6	A
Volkswagen	Beetle	Petrol	2016	1.4	148	2	Manual	Euro 6	A
Volkswagen	Caddy	Petrol	2016	1.4	123	2	Automatic	Euro 6	A
Volkswagen	Golf	Petrol	2013	1.4	138	2	Manual	Euro 6	A
Volkswagen	Golf	Petrol Plug-in Hybrid	2015	1.4	201	2	Automatic	Euro 6	A
Volkswagen	Golf	Petrol	2015	2.0	296	4	Manual	Euro 6	A
Volkswagen	Golf	Petrol	2015	2.0	296	4	Automatic	Euro 6	A
Volkswagen	Golf	Petrol	2016	1.0	115	2	Manual	Euro 6	A
Volkswagen	Polo	Petrol	2015	1.2	89	2	Manual	Euro 6	A
Volvo	V40	Petrol	2015	2.0	242	2	Automatic	Euro 6	A
DS	3	Petrol	2015	1.2	128	2	Manual	Euro 6	B
Mercedes-Benz	S-Class	Petrol	2014	4.7	449	2	Automatic	Euro 6	B
Mini	Hatch	Petrol	2014	1.5	134	2	Manual	Euro 6	C
BMW	Alpina	Petrol	2013	3.0	404	2	Automatic	Euro 6	D

EMISSIONS ANALYTICS

EMIS hearing, 20 June 2016

Questions to Emissions Analytics

Nick Molden

10 June 2016

Q1. You have been stating in the press that you have been testing a wide range of vehicles present on the UK market. What and how many vehicles have you tested? What were the results and what is in your view the explanation for those exceedances? Did you alert the UK authorities of the exceedance of NOx emission from diesel vehicles, and when? If yes, what was their response?

A1. We have tested over 800 European vehicles since 2011, evenly split between diesel and gasoline and across a wide range of makes and models. All vehicles tested are either Euro 5 or Euro 6. On average CO_2 emissions are 30% above the combined results from the New European Driving Cycle-based official test, and this excess is similar for gasoline and diesel. For NO_x emissions, on average gasoline vehicles are 42% below the regulated level, while diesels are 4.8 times the limit on average.

The explanation of the differences falls broadly into three areas. First, the NEDC test is a cycle of low speeds and acceleration, which is inherently more gentle than typical real-world driving, which has higher emissions and fuel consumption. Second, the wider protocol of the official test has other elements which in our view flatter the results compared to reality, e.g. the benefit of stop-start engine technology is bigger on NEDC than in real-world. Third, the protocol is drafted in such a way that leaves some discretion and undefined areas that create loopholes which can be exploited to achieve better official results than would be achieved in normal driving.

It is important to qualify this by pointing out that our background is not in laboratory type approval testing or vehicle engineering for car manufacturers, and so we have not been party to this "optimisation" activity and therefore we rely upon research and reports from third party organisations which have studied the various initiatives in more detail. However, we can be certain from our data that the first point, the gentle nature of the NEDC, is a significant contributor to the emissions gap.

We have been publishing this data into the public domain since 2012. Initially, we published real-world fuel economy data via consumer media in the UK, thereby putting it into public hands for free. Since 2014 we have published NO_x data, culminating in the launch of the EQUA Air Quality Index in April 2016, which publishes ratings of over 500 vehicles, again free into the public domain. The primary aim of these services is to allow consumers to choose on an informed basis.

In parallel with this, we have developed discussions with UK government departments and manufacturers, including explaining our methodology and findings in order to show the problems with the existing type approval and compliance process. We have never reported a vehicle for apparent non-compliance to the certification agency.

Q2. Did you ever simulate a NEDC test on the road using PEMS? If so, what were the results? Did you ever notice NOx emissions exceeding the norms by a factor 3 of more? Who exactly has access to the data?

A2. No, we have never simulated a NEDC test on the road. We have focused on creating real-world driving cycles to show the more realistic performance of vehicles.

Q3. Research by EA (the EQUA Air Quality Index) on more than 250 Euro 5 and Euro 6 vehicles, found that just one of 201 Euro 5 diesels did not exceed the limit, while only seven of 62 Euro 6 diesels did so. Do these results show that it is technically possible for car manufacturers to meet EU legal limits for NOx but that most are refusing to do so? What, in your opinion, would be the reasons for cars

not meeting the legal limit and are any of these reasons justifiable from a technical or engineering perspective?

A3. It is technically possible for diesel vehicles to meet the EU legal limits in real-world driving. As the technical solutions involve some combination of added capital cost and increased operating cost of the vehicle, in a highly competitive market it would not be surprising if manufacturers seek to abate NO_x as little as possible consistent with achieving legal compliance. Similar diesel vehicles achieve compliance on an even lower official NO_x limit in the USA – but at a cost, and on a different cycle.

So, it is an optimisation problem in the dimension of purchase price, operating cost and emissions level. There are of course limits to how much NO_x and CO_2 can be reduced on diesel cars without making their cost completely uncompetitive in the market, but the current EU regulations do not push this limit.

Q4. Your research (the EQUA Air Quality Index) claims that no other car manufacturers had fitted their cars with a similar defeat device as used by VW, which recognises when the car is being driven on a test cycle. Can you be sure that none of the cars you tested used a different variety of defeat device? Such as a thermo-window device which senses when the ambient temperature is beyond the conditions specified in the test procedure? Or a hot-restart defeat device based either upon a timer or on the temperature of the engine when it is restarted? Could these devices have been used but not yet detected? Is it possible to detect such devices?

A4. We haven't claimed that no other manufacturer has installed a VW-type defeat device. Our test method has been designed to show what real-world performance is rather than specifically finding such defeat activity.

Our testing does happen to be suitable for identifying some strategies, such as the thermal windows. We test at a range of ambient temperatures, typically in the 5 to 25 degrees Celsius range, and so can look at the average NO_x emissions above and below certain temperature thresholds. While the majority of manufacturers show no material difference in emissions between high and low ambient temperatures, a small number have higher emissions at lower temperatures. This is circumstantial rather than categorical evidence of reducing exhaust-gas recirculation or after-treatment system activity at lower temperatures.

Q5. Some car manufacturers justify switching off the EGR system at certain temperatures in order to protect the engine. Is this justified? If so, what might happen to the engine if the EGR is not switched off and under what conditions/temperatures is this relevant?

A5. Unfortunately, this is not our area of expertise.

Q6. The NOx emission control techniques available at the time of adoption of the Euro5/6 legislation (in 2006) were EGR, LNT and SCR. Is it technically possible to meet the NOx limit value that was set to apply for all new vehicles sold in 2015, i.e. 80 mg/km "in normal use" with one or a combination of those technologies? Is it possible to meet the Euro6 NOx limit value "in normal use" with LNT technology alone? Is it technically possible to meet the US Federal or Californian NOx limit values with a combination of those technologies?

A6. See answer A3 above. The Euro 6 limit can be met in real-world driving generally by combinations of EGT and LNT, or EGR and SCR. It is possible to meet Euro 6 in normal use with EGR and LNT, which has been demonstrated by the Volkswagen Group vehicles that have achieved A ratings on our EQUA Air Quality Index. An A rating means that the 80 mg/km is met on our real-world test. Of the eight diesel vehicles that have received A ratings so far, four of those used LNT systems.

Although we have only recently started NO_x measurements in the USA, we believe it is possible to meet the Federal and Californian standards for diesels vehicles by using SCR but not LNT. However, the use of SCR alone has risks, for example it does not function well when the exhaust is cold. As a result, there is a move towards installing LNT and SCR together, which is a lower risk but higher cost option.

Q7. Your organization is specialized in RDE testing using PEMS. According to several experts, the use of PEMS might lead to different results that need to be taken into account by applying a conformity factor, in addition to the legal limits set in the regulation 715/2007. According to your experience, what is the uncertainty margin linked to the use of portable measurement devices? How can these uncertainties be reduced and by when?

A7. For NO_x measurement, the test-to-test variability for on-road measurement using PEMS under the Emissions Analytics' method is up to +/- 25%. If the test is conducted on a track, thereby eliminating the effect of unpredictable traffic flow, that variability falls to approximately 10%. Therefore, for Real Driving Emissions, if the principle is that a margin of error should be given to reflect measurement variability, a Conformity Factor of 1.25 might be justifiable. However, the RDE protocol differs in certain ways from the Emissions Analytics' method, which will lead to higher variability.

For CO_2 and fuel economy measurement, the test-to-test variability for on-road measurement is up to 5% in our experience. With the test conducted on the track that variability falls to +/- 3%. Therefore, PEMS has proven to be a robust tool for real-world fuel economy measurement.

Q8. When did you start to use PEMS? How does PEMS differ from other systems used by Emissions Analytics?

A8. We started PEMS testing in 2011, and we have only ever used PEMS. The reason for this is that our belief is that PEMS has the best combination of accuracy, authenticity and cost. The accuracy is not far short of the laboratory. It is ultimately authentic as you can test actual customer cars on the real highway with normal drivers. While still requiring significant investment, PEMS does not require the same order of magnitude as for setting up a laboratory with dynamometers.

Q9. Is PEMS the same kind of equipment that will be used by the testing authorities? According to your tests, have the PEMS proved to be reliable and the results accurate? In your opinion, is it necessary to set conformity factors in the new RDE test procedure at all? If so, are the conformity factors of 2.1 (from 2017 to 2020) and 1.5 (from 2021) justifiable?

A9. The PEMS we use is the same as will be used by testing authorities. Our main equipment is the SEMTECH-LDV from Sensors, Inc of Michigan. Although we typically are not conducting type approval activity, the equipment we use conforms to those standards in both EU and the USA.

The reliability of PEMS equipment has been quite impressive. We use our analysers intensively: typically, each analyser is used every working day of the year and still the durability has been good. As a guide, about one in five tests ends in failure. However, only about one in ten fails due to equipment problems, and the majority of those problems are relatively minor and can be fixed by us. The remainder require some intervention from the PEMS manufacturer. Of the non-equipment reasons for failure, the main causes are bad weather and malfunction of the test vehicle itself.

For information on the accuracy of the PEMS systems, please see the answer A7 above.

There is clearly a test-to-test variability using PEMS – as there is with a laboratory, although the levels are slightly higher with PEMS. Whether that variability should be borne by the vehicle manufacturer or a margin of error given in the regulation is a political choice, not a technical one.

If the choice is to give a margin of error, then a Conformity Factor as low as 1.25 could be justified as mentioned in the answer A7. The initial Conformity Factor of 2.1 has been chosen – as far as we understand – such that it can be achieved with only software changes by the manufacturers. The later Conformity Factor of 1.5 is at the very cautious end of estimates of the variability of PEMS measurement. However, even that will come at some cost to manufacturers in order to comply, which will be passed on in part to consumers via some combination of higher diesel car prices and higher operating costs.

As a comparison, the US regulation has had an effective Conformity Factor of 0.4 for many years, although the test cycle of which this is based is fundamentally different from RDE.

Q10. The UK government testing has found no evidence of other car manufacturers using defeat device software, as found in the VW case. However, it is clear that real driving emissions are far above the level of those conducted under the type approval testing mechanisms. Hopefully the new type approval proposal currently going through the co-decision process will improve testing and thus lowering emissions. Member States (via TCMV) have repeatedly said there is a limit to reducing CFs below a certain level, that there is an inherent uncertainty that means there must be a margin of error built in (as seen with the October vote). As we move away from a pass/fail system of Type Approval and head towards better testing and closing the gap to a CF of 1, can you explain/elaborate the wide variation in vehicle performance in this regard?

A10. It is true there is a wide variation in the real-world NO_x performance of Euro 6 diesel vehicles currently. Of the around 70 such vehicles tested so far by Emissions Analytics, eight have met the 80 mg/km limit in real-world driving (equivalent to a Conformity Factor on RDE of 1). The worst performing vehicle has a Conformity Factor of 14.4. These vehicles would have all been certified to the same standard.

The mechanisms for creating the exceedances are set out in the answer A1 above. The size of the exceedances for any individual model then depends on the manufacturers' use of these mechanisms. In other words, how far is the manufacturer willing to use the loopholes and grey areas to achieve NO_x compliance at the smallest cost in terms of the price of the vehicle and the operating cost?

It is perhaps worth noting that – notwithstanding the clearly illegal defeat device in the USA – of the major manufacturers, Volkswagen appears to have acted most closely to the spirit of the regulation in

Europe, as it accounts for seven out of the eight vehicles with A ratings on the EQUA Air Quality Index, suggesting a Conformity Factor of 1 on its existing models.

Q11. Under what conditions do you conduct emission tests? Are they in line with what the European Commission had in mind when setting emission targets?

A11. Emissions Analytics established its test protocol in 2011, long before RDE was fully defined. Our philosophy was to embody the range of typical, rather than extreme, driving in a real on-road test using PEMS. This is similar to the basis of RDE. While I have no knowledge of what was in the European Commission's mind when it set the targets, it would seem reasonable to conclude that our test broadly reflects RDE and that the emissions targets should be achievable on our test.

Areas of agreement between the two methods are many, including the use of PEMS on the public highway, a mix of urban, rural and motorway driving, use of market fuel, real-world payload and so on. The main area of difference between the two methods is in the standardisation of the route and the use of normalisation tools. Emissions Analytics uses a fixed route each time, for all cars, in order to minimise the role of statistical normalisation, and the normalisation itself relies neither on CO_2 windows nor power bins as a proxy for work done by the engine, but rather on real driving characteristics.

Q12. How and by whom is Emissions Analytics financed? What are your links to the car manufacturers?

A12. Emissions Analytics is a private, commercial UK company owned by three private shareholders including me. It has been financed by these individuals. The company operates across Europe and has a wholly-owned subsidiary in the USA.

Revenues are generated by subscription access to our database of over 1200 vehicle tests and from custom testing activity. The tests that form the database are conducted by Emissions Analytics as the principal, financed from its resources, and therefore are completely independent of regulators and manufacturers.

Emissions Analytics' revenue base is highly diversified, and so does not come disproportionately from one source. Over half of European car manufacturers by sales are subscribers to our database or employ Emissions Analytics for custom testing.

None of the shareholders or directors of the company have been personally employed by regulators or manufacturers in the past.

Appendix D – Air quality appraisal (WebTAG)

Methodology

WebTAG (Web-based Transport Analysis Guidance) is a toolkit and guidance from the Department for Transport (DfT) on transport appraisals. It is used for all projects that require government approval through the planning system, such as motorway schemes. For other projects, WebTAG can be used as a best practice guide. Air quality is included within TAG unit A3[65] 'Environmental Impact Appraisal'. The impact on air quality is quantified as money, based on the evidence of the harm to human health and the environment of two pollutants arising as a consequence of road vehicle emissions: oxides of nitrogen (NOx) and particulate matter (PM_{10}). A cost is expressed as a negative amount of money and a benefit as a positive amount.

Following the publication of the SES2 and AP3 ES for HS2 Phase One, HS2 instructed ERM-Temple-Motts (ETM) to undertaken further air quality modelling in order to provide the required data for conducting an air quality appraisal using elements of the WebTAG approach. The purpose of this being to enable the net air quality impacts of construction to be compared in economic terms against the costs of avoiding those impacts through vehicle emissions reductions. This work is based on the air quality assessment undertaken for the main ES as amended, it is an additional analysis and it does not change the original conclusions. These conclusions found that there were significant residual effects in the London Metropolitan area during construction, arising from additional construction vehicle emissions, and highway interventions (road closures and diversions). Air quality benefits occur during construction when roads are closed (temporarily or permanently) and traffic and its emissions is diverted away from that road.

The air quality appraisal has been undertaken for construction of the Scheme within CFAs 1 to 6. The extent of the study area is prescribed by the extent of the road network used in the traffic modelling. Traffic flows were screened using the Design Manual for Roads and Bridges (DMRB) criteria, as described in the Scope and Methodology Report (SMR) Addendum 3 (Volume 5: CT-001-000/4 of the SES2 and AP3 ES). Sensitive receptors were then selected within a 200m buffer of the affected road network. For the selection of sensitive receptors, the Ordnance Survey (OS) AddressBase Plus[66] product was used, which includes a point on the map for each postal address. The appraisal has been undertaken for the two pollutants included in the air quality assessment of the main ES as amended: nitrogen dioxide (NO_2) and particulate matter (PM_{10}).

For CFAs 1 to 3 three scenarios were assessed during the Stage A Construction period, following the air quality assessment in the main ES as amended. These were the three years (2017, 2018 and 2023) where the peaks in construction traffic are predicted. For CFAs 4 to 6 two scenarios were assessed for the Construction period, corresponding to a peak in construction traffic in 2021, following the air quality assessment in the main ES as amended. These were scenario T1 assuming that Old Oak Common Lane would remain open during construction, and scenario T2 assuming that Old Oak Common Lane would be closed. For all assessed scenarios, it was assumed that emission factors and background pollutant concentrations remain constant from 2017 into the future.

Since the impacts during construction within CFA 4 were assessed in both the SES and AP2 ES and the SES3 and AP4 ES, the air quality appraisal for CFAs 4 to 6 has been undertaken for the following cases:

- Scheme as reported in the SES and AP2 ES; and
- Scheme as reported in the SES3 and AP4 ES.

For all above scenarios, a reference case 'without the scheme' scenario was also assessed, following the air quality assessment in the main ES as amended.

The following assumptions were made for the air quality appraisal:

- The change in predicted pollutant concentrations has been rounded to one decimal point for the local air quality calculations of the amount of properties deteriorating, improving or having no change.
- An appraisal of local air quality and economic valuation for $PM_{2.5}$ concentrations has not been undertaken.
- An appraisal of the operation of the scheme (beyond 2026) has not been undertaken.
- For the economic valuation, where data was not available for a specific year, it was assumed that the costs would be the same as in the previous year.
- The economic valuation has been undertaken for the same extent as the local air quality appraisal study area.
- For the economic valuation, it was assumed that all locations exceed the annual mean NO_2 standard (40µg/m^3). This provides a conservative assessment.

Local air quality

There was a total of 130,665 sensitive receptors included in the local air quality appraisal: 85,729 within CFAs 1 to 3 and 44,936 within CFAs 4 to 6. Annual mean NO2 and PM10 concentrations were predicted using the atmospheric dispersion model ADMS-Roads67. These were then combined with the number of sensitive receptors to obtain property-weighted pollutant concentrations for certain distance bands from the roads: 50m, 50-100m, 100-150m and 150-200m. Summary tables were then prepared, following the WebTAG approach.

A summary of the assessment scores for NO2 and PM10 is presented in Table 22. It can be observed that the highest scores for both NO2 and PM10 are for the 2023 peak year scenario during Stage A Construction in CFAs 1 to 3. For CFAs 4 to 6, the highest scores are observed within scenario T2 which assumes that Old Oak Common Lane would be closed, for the SES and AP2 ES assessment. This is expected, since the SES3 and AP4 ES assessment predicted improvements in air quality within CFA 6 compared to the SES and AP2 ES.

During Stage A Construction in CFAs 1 to 3, it is predicted that approximately 60% of properties will experience a deterioration, 24% no change and 16% an improvement in NO2 concentrations during the 2023 peak year scenario. During the other peak assessment years (2017 and 2018), approximately 30-40% of properties are predicted to experience a deterioration and 20% an improvement in NO2 concentrations.

In relation to PM10 concentrations, approximately 75-90% of properties are anticipated to experience no change during Stage A Construction across all peak year scenarios. In the 2023 peak year scenario, approximately 16% of properties are anticipated to experience a deterioration in PM10 concentrations.

During Construction in CFAs 4 to 6, it is predicted that approximately 40% of properties will experience a deterioration, 35% no change and 20-25% an improvement in NO2 concentrations in the T2 scenario when Old Oak Common Lane is closed. The results are very similar for both the SES and AP2 ES and the SES3 and AP4 ES assessments. In the T1 scenario when Old Oak Common Lane remains open, approximately 75% of properties are anticipated to experience no change and 15% a deterioration in NO2 concentrations.

In relation to PM10 concentrations, approximately 75-95% of properties are anticipated to experience no change during Construction across all scenarios. In the T2 scenario, approximately 15% of properties are anticipated to experience a deterioration in PM10 concentrations. In the T1 scenario, approximately 5-7% of properties are anticipated to experience a deterioration in PM10 concentrations.

Table 22: Summary of local air quality assessment scores

Scenario	NO2	PM10
CFAs 1 to 3		
Stage A Construction 2017 peak year	290	-476
Stage A Construction 2018 peak year	2,799	232
Stage A Construction 2023 peak year	8,296	1,244
CFAs 4 to 6 (SES and AP2 ES)		
Construction 2021 T1	908	563
Construction 2021 T2	1,845	581
CFAs 4 to 6 (SES3 and AP4 ES)		
Construction 2021 T1	-62	302
Construction 2021 T2	845	319

Economic valuation

An economic valuation was undertaken using the WebTAG air quality valuation workbook[68]. The air quality impacts are valued using a combination of damage costs and marginal abatement costs following the methodologies described in Defra's Supplementary Green Book guidance[69].

The valuation is applied to changes in PM_{10} concentrations and NOx emissions as a result of the scheme.

It should be noted that the WebTAG workbook linearly interpolates and extrapolates the changes in NOx emissions and PM_{10} concentrations over the appraisal period to calculate the costs. The appraisal period is usually from the opening year of a scheme until a forecast year in the future. In this study, a forecast year was not available; the economic valuation has been undertaken for each assessed scenario as described above for local air quality. The costs therefore present a snapshot of each assessed year during the construction period of the scheme. Table 23 presents a summary of the costs for NOx and PM_{10} for all assessed scenarios.

Table 23: Summary of economic valuation

Scenario	NOx emissions	PM10 concentrations	Net present value
CFAs 1 to 3			
Stage A Construction 2017 peak year	-£21,480	£38,608	£17,128
Stage A Construction 2018 peak year	-£75,896	-£18,464	-£94,359
Stage A Construction 2023 peak year	-£167,815	-£89,528	-£257,343
CFAs 4 to 6 (SES and AP2 ES)			
Construction 2021 T1	-£129,414	-£42,052	-£171,466
Construction 2021 T2	-£92,652	-£43,411	-£136,063
CFAs 4 to 6 (SES3 and AP4 ES)			
Construction 2021 T1	£37,701	-£22,602	£15,099
Construction 2021 T2	£84,171	-£23,685	£60,306

To derive an overall cost of the scheme's construction between 2017 and 2026, it was assumed that each year would have the same costs as the previous one. For CFAs 1 to 3 where three construction years were assessed (2017, 2018 and 2023), costs between 2019 and 2022 were assumed to be the same as in 2018 for each year and costs between 2024 and 2026 were assumed to be the same as in 2023. For CFAs 4 to 6 where only one construction year was assessed (2021), costs were assumed to be the same for every year between 2017 and 2026.

Taking the highest costs for CFAs 4 to 6 (i.e. SES and AP2 ES assessment and scenario T1 when Old Oak Common remains open), it is estimated that there will be -£2.37 million costs for NOx emissions and -£0.83 million costs for PM_{10} concentrations, which would account for a net present value of -£3.20 million for air quality.

Appendix E – Market research questionnaire

HS2 Ltd Vehicle Emissions Standards Study – Air Quality

Market Engagement

1. Background & introduction

HS2 Ltd.'s Sustainability Policy makes a commitment on: 'Environmental change – Commit to protection of the environment through seeking to avoid significant adverse effects on communities, businesses and the natural, historic and built environment, including the prevention of pollution'.

HS2 Ltd has adopted a policy, as published in its Information Paper E13 'Management of Traffic During Construction' for heavy goods vehicles (HGVs) carrying excavated material in Low Emission Zones (i.e. in London) to be Euro VI (or lower emission). A link to the Information paper is provided here.

As an exemplar project, HS2 Ltd has set a best practice target in its Air Quality Strategy that all HGVs route wide from London to Birmingham in Phase 1 are EURO VI, from 2017.

HS2 would also like to promote the up-take of EURO 6 cars and vans (less than 3.5 tonnes), and Ultra Low Emission Vehicles (ULEVs) in this size range

HS2 Ltd would like to understand from its supply chain how quickly it can meet the challenge of using EURO VI/6 vehicles on the project. In this context, for avoidance of doubt, by EURO VI we intend the emission standard applying to vehicles over 3.5 tonnes, and EURO 6 as applying to vehicles less than 3.5 tonnes.

2. Questions

Please give approximate answers to these questions, explaining assumptions or ranges as necessary:

1. How many members does your organisation represent?

2. What is the approximate proportion of micro, SME and large operators which make up your membership?

Size of operator	Proportion of members (%)
Micro	
SME	
Large	

3. Please advise approximately how many vehicles your membership represents in the UK?

Nation	Number of vehicles
England	
Northern Ireland	
Scotland	
Wales	
Total	

Please complete the matrix below in responding to questions 4, 5 & 6;

4. For the vehicle types listed below please indicate as a percentage, what proportion of your member's fleets will be EURO VI in 2017 and by 2020?

5. What is the typical age at first resale in your members' vehicle fleets?

6. How many years of service before being scrapped?

Vehicle type	EURO VI 2017 (% of fleet)	EURO VI 2020 (% of fleet)	Typical age at resale	Typical years of service before scrapping
Cars & Car Based Vans				
Light Goods Vehicles (up to 3.5 tonnes)				
Smaller 2-Axle Lorries (3.5-7.5 tonnes)				
Bigger 2-Axle Lorries 7.5-18 tonnes)				
Multi Axle Lorries <32				
Multi Axle Lorries >32				

7. Please advise if there are there any specific types or duties of vehicle for which the uptake of EURO VI engines may make it a challenge for your members to meet HS2 Ltd's best practice target in 2017 or 2020, including those listed below? (Please add further lines if required)

Vehicle type	Target: 2017 or 2020	Challenge
Tipper		
Concrete lorry		
Skip lorry		
Other (please list)		

8. What do you consider would be the challenges in HS2's target for Euro VI in 2017 and are there any measures that you consider could be taken to help achieve it? Please state if you feel that this will this pose a significant challenge for SMEs to adopt etc.?

Challenge	Mitigating Measures

9. Please complete the table below to indicate an approximate percentage of the fleet of cars and vans (<3.5t) that your members operate, that will be ULEVs (> 10 mile zero emission range, < 75 gCO2/km) in 2017 and by 2020?

Year	Approximate % ULEVs
2017	
2020	

10. If your members need to upgrade their fleet to meet contract our requirements, what would be the potential commercial impact E.g. 5 % increase on costs etc.

HS2 Ltd. would like to take this opportunity to thank you for taking the time to respond to this questionnaire.

Appendix F – ULEVs

Report for HS2

By Steve Williams

March 2016

Cons/1516/

Department for Transport

Contents

Section **Page**

Executive Summary

HS2 asked EST to estimate the average percentage of Ultra Low Emissions Vehicles (ULEVs) under 3.5t that HS2 should expect its contractors to use in visiting sites in London on the 1st January 2017.

The minimum targets that HS2 should set their suppliers for the use of ULEVs in London will depend on several factors. Unless these factors can be assessed a precise figure is difficult to deliver. The factors that need to be considered are

- vehicle type,
- ULEVs available,
- supplier procurement cycles,
- manufacturer lead times.

EST believe given the current availability of ULEVs (which we have defined as those vehicles that qualify for the Government's Plug In Car Grant) the target needs to be looked in separate bandings being all cars and then vans split by EU emissions category (see Appendix A.)

Whilst the danger of this approach is that Contractors may purchase large vans that are not ULEVs and claim that this is the size of van they need for the job to avoid ULEVS, the reverse is that imposing a target on vans when only one class is currently available as a ULEV may have the unintended consequence of having the Contractors buy a number of vans to meet the target that are not suitable to the role required.

Given these parameters we have modelled a number of potential targets based on Vehicle type, Procurement cycles, funding options and manufacturer lead time that may be found in section 5.

1 ULEV Vehicles

1.1 ULEV Cars

Finding a suitable replacement plug in model for Internal Combustion Engine (ICE) car is reasonably straight forward with alternative 4x4's, 5 seat hatches, saloons and estate cars as well as people carriers all being readily available and further models arriving all the time. Given the varied choice of model type targets set by HS_2 this should not be seen as restrictive by its contractors.

The Plug in Grant available has recently changed so it is worth understanding what these changes mean as shown below. We have also listed examples of currently qualifying models in both categories 1 and 2.

Category	CO2 emissions	Zero emission range	Grant	Maximum grant
1	Under 50g/km	At least 70 miles	35% of cost	£4,500
2	Under 50g/km	10 to 69 miles	35% of cost	£2,500
3	50 to 70g/km	At least 20 miles	35% of cost	£2,500

Notes –

Grants are not available for vehicles in category 2 or 3 with a recommended price over £60,000

The 'zero emission range' is the distance the vehicle can travel without producing any CO2 emissions.

Eligible Category 1 vehicles

- BMW i3
- BYD e6
- Citroen CZero
- Ford Focus Electric
- Kia Soul EV
- Mercedes-Benz B-Class Electric Drive

- Mitsubishi iMiEV
- Nissan e-NV200 (5-seater and 7-seater)
- Nissan LEAF
- Peugeot iON
- Renault Fluence
- Renault ZOE
- Smart fortwo electric drive
- Tesla Model S
- Toyota Mirai
- Volkswagen e-up!
- Volkswagen e-Golf

Eligible Category 2 vehicles

- Audi A3 e-tron
- BMW 225xe
- BMW 330e
- Mercedes-Benz C350 e
- Mitsubishi Outlander (except GX3h 4Work)
- Toyota Prius Plug-in
- Vauxhall Ampera
- Volkswagen Golf GTE
- Volvo V60 D6 Twin Engine
- [1]Volvo XC90 T8 Twin Engine

1The Volvo XC90 T8 Twin Engine is only eligible if the cost and the recommended retail price of the variant you buy are both less than £60,000. We have omitted the BMW i8 (category 2),Mercedes-Benz S500 Hybrid (category 3),Porsche Panamera S E-Hybrid (category 3) as they are all over £60,000 and are therefore ineligible for the grant.

It is worth noting that many of the vehicles above cannot be factory ordered as the manufacturers have stopped making them although there may be some stock vehicles available. These include the Renault Fluence, Mitsubishi iMiev and Vauxhall Ampera.

Further details (including the up to date car list) is available at the OLEV website: https://www.gov.uk/plug-in-car-van-grants/what-youll-get

1.2 ULEV Vans

The plug in grant for vans has not changed and remains as detailed in the table below.

Category	CO2 emissions	Zero emission range	Grant	Maximum grant
Van	Under 75g/km	At least 10 miles	25% of cost	£8,000

Vans are more difficult to identify not least because the majority of vans that currently qualify for the plug-in van grant are smaller models, up to around 2.4t gross vehicle weight (e.g. Ford Transit Connect size). The exceptions are the Mercedes Vito E-CELL, but this is only available on very specific terms from Mercedes and BD Auto's conversions of a Renault Trafic and a Ducato. BD do not yet have a track record in the UK and so cost, performance and after sales backup are highly uncertain. The Smith Electric is we understand, not currently available. Therefore, when it comes to considering replacing a van with an electric model there are two broad options to consider:

- Direct, like-for-like replacement of a small to medium sized van
- Whether a larger van can be downsized and replaced with a smaller electric option.

The range of plug in vans that currently qualify for the UK Government's electric van grant are:

- BD Otomotiv eTraffic
- BD Otomotiv eDucato
- Citroen Berlingo
- Daimler Mercedes-Benz Vito E-CELL
- Mitsubishi Outlander GX3h 4Work
- Nissan e-NV200 cargo van
- Peugeot ePartner
- Renault Kangoo ZE
- Smith Electric Smith Edison

Of this list all are pure electric vehicles (EV) with the exception of the Outlander which is a Petrol Hybrid Electric Vehicle (PHEV.)

This list will be revised as more electric vans come to market and it is advisable to check the web site. The current market leaders, in terms of sales, are the Renault Kangoo ZE and the Nissan e-NV200.

Similar to the cars list there are a number of vehicles listed that are no longer available (Smith Edison) or which current availability is unclear (Vito E-Cell).

Thus the number of ULEVs vans that can be targeted is entirely dependent on the Payload required and we would need to understand the operators requirements in detail to be sure.

1.3 Potential EV Alternatives to Company Cars

For the roles usually fulfilled by the Company Cars there are currently several plug in options available. Both fully electric vehicles such as Nissan Leaf, Kia Soul or Renault Zoe or plug in hybrids which include the VW Golf GTE, the Toyota Prius, BMW i3 with a range extender and the Mitsubishi Outlander PHEV can all be considered.

We have chosen to compare 2 EVs and one PHEV to the Typical ICE vehicles identified on fleets.

Nissan Leaf

The Leaf is the fully electric car most visible on the UK roads having sold reasonable numbers particularly in the last 2 years. A 30kW version is now available offering 155 miles of range.

Renault Zoe

The Renault Zoe is a very practical fully electric car which can be fast charged in around an hour which gives it a huge amount of flexibility where trips which are longer are needed.

Mitsubishi Phev

The Mitsubishi Outlander has an OEM range in EV mode of 32 miles after which it drops back to hybrid mode. There is no OEM published data regarding the fuel efficiency in hybrid mode but a range of reviews in the trade press suggest an average of 42 mpg can be achieved (one reviewer reported only 32 mpg).

1.4 Potential Light Van Alternatives

The table below compares three similar EV alternatives.

We have compared the Nissan e-NV200, Peugeot Partner Electric and the Kangoo ZE, using data from the respective manufacturer websites to allow HS2 to be able to forecast the operational viability and business case.

Model	e-NV200 Acenta Rapid	Peugeot Partner Electric	Renault Kangoo ZE ML20
Engine	Electric	Electric	Electric
Overall Length (mm)	4,729	4,380	4,282
Overall Height (mm)	1,867	1,812	1,805
Overall Width (mm)	1,730	1,810	1,829
Wheelbase (mm)	2,926	2728	2,697
Max Range (NEDC less 21%)	83	83	83
Gross Vehicle Weight (kg)	2,220	1,960	2,126
Maximum Payload (kg)	770	695	650
Tailpipe NEDC CO_2 (g/km)	N/A	N/A	N/A

Nissan e-NV200

This is Nissan's electric version of its NV200 van. The Nissan is taller than the Renault and Peugeot alternatives with a load volume of 4.2m^3 and may be an option in applications where a larger payload is needed. Range per charge is realistically 80 miles on the combined cycle and can also be rapid charged which charges the battery to 80% capacity in half an hour.

The Renault Kangoo Z.E. and Kangoo Maxi Z.E.

The electric Kangoo Z.E. meets the payload requirements of the light vans. The Kangoo Z.E. model may have potential to replace the light vans in the fleet. The lithium-ion battery pack of the Kangoo Z.E. provides a range of up to 106 miles based on the New European Drive Cycle, the same test used to derive ICE vehicles' MPG and CO_2 g/km results although a range of up to 80 miles is more realistic.

Citroen Berlingo Electric

The Berlingo Electric uses dual lithium-ion battery packs with a total capacity of 22.5kw/h, providing a quoted 100-mile range. The L1 variant has a load volume of 3.3m^3 while the longer L2 has a load volume of 3.7m^3. The batteries can be fast-charged up to 80-percent capacity in 35 minutes and a standard recharge takes six to nine hours.

2 Lead Times

It is a myth that manufacturers have fields of unsold vehicles that stretch as far as the eye can see. Over the last 20 years the vehicle manufacturers have been taking capacity out of the industry in order not to be left with vast number stock vehicles which tie up their capital resources.

Whilst it's true that some Far East produce vehicles that are standardised (except for colour) and fit any "manufacturers extras" at their distribution centres nearly all models produced in Europe are built to order.

Lead times are subject to variations in the lead times that can be affected by the allocation of build slots for the model and the planned proportion of right hand drive allocated in the factory, demand, availability of components. This varies widely between different manufacturers. It is not unknown for a vehicles lead time to be over 12 months

As a minimum a vehicle will take 6 to 8 weeks from the point its ordered to the point it arrives at the supplying dealer.

We have taken some of the more popular ULEVs and given their current lead times

Vehicle Make & Model	Vehicle Type / Size	Propulsion	ULEV Catergory	Lead Time
Mitsubishi Outlander	Medium Sports Utility	Petrol Hybrid	2	3 weeks
Ford Focus Electric	MediumFamily Saloon	Electric	1	16 to 18 Weeks
Peugeot iON	Compact Hatch	Electric	1	4 to 5 Months
Citroen CZero	Compact Hatch	Electric	1	4 to 5 Months
Kia Soul	Compact Sports Utility	Electric	1	16 Weeks
Nissan Leaf	Medium Family Hatch	Electric	1	6 Weeks
Renault Zoe	Compact Hatch	Electric	1	6 to 8 Weeks
Citroen Berlingo Electric	Medium Van	Electric	Van	4 to 5 Months
Peugeot Partner Electric	Medium Van	Electric	Van	4 to 5 Months
Nissan NV200	Medium Van	Electric	Van	6 Weeks
Renault Kangoo ZE	Medium Van	Electric	Van	12 to 16 Weeks

3 Vehicle Procurement

3.1 Funding Types

EST's work within the Construction Industry has allowed it to understand that there is no one template that we can model as each company has different arrangements for the provision of the vehicles.

There are three general methods of provision of a vehicle. These are

- outright purchase,
- leasing,
- cash allowance.

We will not go into the advantages of the one over the other here but would merely point out that for the purposes of this paper that the first requires large amounts of capital but allows for flexibility in terms of the timing of vehicle replacement and the second option requires far less capital but is usually less flexible in terms of replacement as the parties are bound to a contractual term. The third option (which is generally used for cars only) has usually been accompanied with an abdication of authority over the replacement cycle allowing individual drivers to manage this themselves. As a result of the financial incentives there is evidence that some drivers will retain vehicles for a longer time.

3.2 Procurement Cycles

The timescales in which vehicles are replaced differs between not only individual businesses but also between funding types and also between vehicle types. For example it usual for a commercial vehicle to be kept for far longer than a company car and for vehicle that has been purchased outright to be retained longer

If leased, contracts are usually written for 3 or 4 years for Cars and 4 or 5 years for commercial vehicles. However some business will link the vehicle contract to a length of a commercial contract if the vehicles are procured solely for that contract. (In my experience these are usually for a maximum of 5 years)

It is not unusual for a vehicle that has been purchased outright to be retained for at least 7 years as businesses generally "sweat" the asset far more if they have expended the capital.

With Cash Allowance fleets, as a result of the financial incentives inherent in the model there is evidence that some drivers will retain vehicles for a longer time. We have seen a recent example in the construction industry of a cash allowance vehicles above 28 years old, and the average age of the cash allowance fleet being 5 years and 9 months. 38% of the vehicles were over 7 years old.

3.3 Current Levels of ULEVs

We believe it is reasonable to assume that current level of ULEV vehicles in a typical fleet will be just 1% in Cars and Vans in line with ULEV take-up in the UK general vehicle parc.

4 Modelling the Potential Compliance

Taking the above sections into account we have felt it appropriate to split the compliance by vehicle category.

Model 1 – Cars and Category 2 Vans

Procurement Method	Replacement Cycle	Percentage % as at 1st January 2017	Percentage as at 31st December 2017
Lease	3 Years	8%	42%
Lease	4 Years	6%	31%
Out Right Purchase	7 Years	4%	18%
Cash Allowance	Unknown	1%	1%

Assumptions

1. We have assumed that vehicles are ordered evenly over the year with an equal number placed every month as old vehicles replaced.
2. We have assumed that contactors began placing orders on 1st July 2016.
3. We have based this on a recent survey of a construction companies cash allowance fleet. Whilst they already incentive ULEVs the percentage of ULEVs in the cash allowance fleet remains at 1%.
4. We have assumed a 12 week average lead time.

Model 2 – Vans Category 3 and 1

Procurement Method	Replacement Cycle[1,2]	Percentage % as at 1st January 2017	Percentage as at 31st December 2017
Lease	3 Years	0%	0%
Lease	4 Years	0%	0%
Out Right Purchase	7 Years	0%	0%
Cash Allowance[3]	Unknown	0%	0%

Currently no ULEV vans of this size are available. There are indications that a vehicle may become available during the coming year and so would suggest that this category is kept under constant review.

Appendix A –Van Catergories

Class as Defined for EU Emissions standards	Reference Mass (Kilos)	Payload Mass	Comments
Class I	≤1,305	600	Car Derived vans e.g. Ford Fiesta Van or Vauxhall Corsavan
Class II	1,305	<1000kg	Medium sized van e.g Ford Transit Connect or Vauxhall Combo
Class III	> 1740	Up to 1,800	Large Vans such as Ford Transit or Vauxhall Movano

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