Methodology for the UK’s Road Transport Emissions Inventory

Version for the 2016 National Atmospheric Emissions Inventory

Report for the Department for Business, Energy & Industrial Strategy

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Executive summary

Road transport is one of the largest sources of many key pollutants and greenhouse gases (GHGs) in the UK, including carbon dioxide (CO_2), nitrogen oxides (NO_x), fine particulate matter (PM_{10} and $PM_{2.5}$), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOCs). The UK has a wealth of road transport activity data which enables a detailed bottom-up estimation of emissions to be made, consistent across all years from 1990 to the latest year. The level of detail enables the inventory to be constructed using the highest Tier 3 methodologies compliant with the 2006 IPCC Guidelines for reporting National Greenhouse Gas Inventories to the UNFCCC and the EMEP/EEA air pollutant emission inventory guidebook 2016 for reporting air pollutant emissions under the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (CLRTAP) and the EU Directive 2016/2284/EU on National Emissions Ceilings (NECD).

The methodology used for road transport emission estimations is both complex and tailored towards the vehicle activity data available in the UK. It is also constructed to a level of detail and in a manner that enables future emission projections and scenarios to be calculated in support of air quality and climate policy. It provides outputs for spatially resolving emissions and for use as inputs in air quality concentration models.

The activity data includes vehicle kilometres travelled by different types of vehicles on different types of roads and detailed fleet composition data informed by both vehicle registration data and Automatic Number Plate Recognition data allowing a breakdown of vehicle activity on the road according to vehicle age, fuel type, technology and Euro emission standard the vehicle was manufactured to. The activity data are compatible with the Tier 3 methodology emission factors provided for road transport in the 2006 IPCC Guidelines and the EMEP/EEA air pollutant emission inventory guidebook 2016.

Results from the UK's road transport inventory for GHGs and air pollutant emissions are provided in the annual inventory reports and associated reporting templates submitted to the UNFCCC, UNECE/CLRTAP and EU/NECD. These reports have traditionally provided details of the methodologies used. Although the input data on road transport activities and emission factors may be updated each year, the underlying methodologies used are largely static. Therefore, in order to avoid having to repeat the description of the road transport methodology in the National Inventory Reports (NIR for GHGs) and Informative Inventory Reports (IIR for air pollutants) each year, this stand-alone report provides details of the underlying methodologies used in the calculation of emissions from road transport.

The methods described in this report cover all pollutants and vehicle types and all the main sources of emissions from road transport: hot exhaust emissions, excess cold start emissions, evaporative emissions of NMVOCs from petrol used in vehicles and non-exhaust sources of particulate matter emissions. The methods reflect the specific requirements for reporting GHG emissions to the UNFCCC and the air pollutant emissions to UNECE/NECD, including the need to reconcile with national fuel sales statistics.

The activity data used in the compilation of the road transport inventory in a particular year, including any updates to previous years' values are provided in the NIR and IIR each year. This report provides the detailed emission factors currently used in the inventory which are mostly static. This report will be updated when there is a need to change the underlying methodology and/or emission factors, for example because of new versions of the Guidebooks or because new sources of activity data become available that enable a different approach or assumptions to be used. This may be the case if there is a domestic policy need to provide emission outputs in more detail or to reflect more localised data influenced by national or local policies and measures which BEIS or Defra want to be included in the national inventory.

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1. Introduction

The National Atmospheric Emissions Inventory (NAEI, http://naei.beis.gov.uk/) provides the inventory of emissions to air from sources of greenhouse gases (GHGs) and air pollutants in the UK across a time series from 1970 to the latest year that data are available. The emissions inventory is constructed according to the 2006 IPCC Guidelines for reporting National Greenhouse Gas Inventories to the UNFCCC and the EMEP/EEA air pollutant emission inventory guidebook 2016 for reporting air pollutant emissions under the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (CLRTAP) and the EU Directive 2016/2284/EU on National Emissions Ceilings (NECD).

Road transport is one of the largest sources of many key pollutants and GHGs in the UK, including carbon dioxide (CO_2), nitrogen oxides (NO_x), fine particulate matter (PM_{10} and $PM_{2.5}$), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOCs). The UK has a wealth of statistical road transport data which permits detailed bottom-up estimates of emissions from different types of road vehicles to be made. The methodologies used are consistent with the most detailed Tier 3 approaches described in the IPCC 2006 and EMEP/EEA inventory guidebooks. The available data enables a consistent time-series of emission estimates to be made from 1970 to the latest inventory year. The time-series reflects real changes in emissions between years due to the introduction of new technologies and fuels driven by regulations and trends in activity data over time, rather than because of changes in emission calculation methodologies.

The latest activity data and emission factors used in the NAEI's road transport inventory are presented each year in the UK's National Inventory Report (NIR) for GHGs and Informative Inventory Report (IIR) on air pollutants submitted annually to the UNFCCC and UNECE/NECD, respectively. However, the underlying methodologies used remain generally static and therefore do not require repeating in each version of the NIR and IIR. The purpose of this report is to describe details of the methodologies used for the road transport inventories which can be referred to in the annual reports. This methodology report will be updated periodically when major changes are made to the methods used, e.g. due to changes in the Guidebooks or when UK road transport data availability changes, requiring different approaches to be updated.

The methodology covers:

- All main vehicle types: passenger cars, light goods vehicles (LGVs), heavy goods vehicles (HGVs), buses and coaches, motorcycles and mopeds:
- The main fuel types used: petrol, diesel, liquefied petroleum gas (LPG)
- Different types of vehicle technologies that affect emissions, largely driven by the EU vehicle emission regulations (the Euro standards) and therefore the composition of the vehicle fleet in a given year.
- Different types of vehicle operations, whether on high speed motorways or slower urban speed situations
- All pollutants that must be reported by the inventory, including those that are regulated by vehicle emission standards (NO_x, CO, NMVOCs, PM) and those which are not regulated (CH_4, N_2O, NH_3, PAHs and POPs) and the chemical speciation of certain pollutants
- Emissions occurring from different processes, including hot exhaust emissions, excess cold start emissions, evaporative emissions (of NMVOCs), non-exhaust sources of PM.

The methodology itself is based on activity data expressed in terms of amount of fuel consumed or distances travelled by each vehicle and fuel type under different operations and vehicle- and pollutant-specific emission factors.

As the focus of this report is on the methodology used for the UK's road transport inventory in the NAEI, no results are presented here; these would be given in the annual inventory reports (NIR and

IIR) and associated reporting templates. These results will reflect the latest set of activity data for the year, including any minor revisions to estimates for previous years, and current emission factors.

The information given in this report is consistent with the version of the UK's inventory submitted to the UNFCCC and UNECE/NECD in 2018 covering emissions between the years 1970-2016.

2. Overview

This section gives an overview of the methodology used and the sources of activity data and emission factors used in the inventory calculations. Further details of these are given in the following sections.

2.1 Summary of methodology

A Tier 3 methodology is used for calculating exhaust emissions from passenger cars (NFR/CRF[1] code 1A3bi), light goods vehicles (NFR/CRF code 1A3bii), heavy duty vehicles including buses and coaches (NFR/CRF code 1A3biii), and motorcycles (NFR/CRF code 1A3biv). The methodology makes use of the most detailed information available in the UK on vehicle activities at a national level in a consistent manner for each year.

A Tier 2 methodology is used for calculating evaporative emissions (NFR code 1A3bv, CRF code 1A3b) from petrol vehicles. Non-exhaust emissions of particulate matter (PM) from tyre and brake wear (NFR code 1A3bvi, not applicable for GHG reporting) and road abrasion (NFR code 1A3bvii, not applicable for GHG reporting) are also calculated based on a Tier 2 methodology. A separate Tier 1 methodology is used for estimating carbon dioxide (CO_2) emissions from biofuel use in road transport.

Note that the methodology for estimating CO_2 emissions from the unintended burning of lubricants in 4-stroke vehicle engines and the use of urea in exhaust aftertreatment catalysts (for controlling pollutant emissions) are reported under CRF sector 2D and methodological information can be found in the NIR. While emissions from the burning of lubricants in 2-stroke engines is reported separately in the 1A3b road transport sector, the estimate is made using the same methodology as for unintended burning of lubricants, so similarly the methodology can be found in the section for sector 2D in the NIR.

2.2 Summary of emission factors

The distance-based emission factors in grammes per kilometre for each vehicle type are taken from the COPERT 4v11.4 and COPERT 5 source (Emisia, 2016) and the EMEP/EEA Guidebook (2016). Fuel based emission factors expressed in grammes per kg fuel consumed are based on data from the United Kingdom Petroleum Industry Association (UKPIA) for CO_2 and SO_2 and EMEP/EEA Guidebook (2013) for metals.

2.3 Summary of activity data

Vehicle activity data in billion vehicle km travelled by vehicle type and road type are provided by the Department for Transport (DfT) for Great Britain and from the Department for Regional Development (DRDNI) for Northern Ireland.[2] Total sales of petrol, diesel and LPG fuels are provided in the Digest of UK Energy Statistics (DUKES).

2.4 Summary of other supporting data

Vehicle licensing statistics and on-road Automatic Number Plate Recognition data provided by DfT are used to further break down the vehicle km travelled by fuel type and vehicle year of first registration. Several other datasets provided by DfT and the Driver and Vehicle Licencing Agency (DVLA) are used to disaggregate vehicle activities, e.g. into HGV weight categories.

Transport for London (TfL) provides specific fleet composition data for London that account for a Low Emission Zone. The Society of Motor Manufacturers & Traders (SMMT) provides sales weighted data

[1] NFR stands for Nomenclature For Reporting and is the nomenclature used for air quality emissions inventory reporting to United Nations Economic Commission for Europe's (UNECE) and European Monitoring and Evaluation Programme (EMEP). CRF stands for Common Reporting Format which is a standardised reporting format for reporting Greenhouse Gas (GHG) emissions inventories to the United Nations Framework Convention on Climate Change (UNFCCC) and EU Monitoring Mechanism Regulation (MMR).

[2] Now known as the Department for Infrastructure. Northern Ireland Government bodies are currently being restructured and the data that they used to provide may be discontinued.

on manufacturers' type approval CO_2 factors and on average vehicle weight for new cars sold each year in different engine-size categories.

3. Fuel sold *vs* fuel used

3.1 CLRTAP and NECD Reporting

The UK inventory for road transport emissions of key air pollutants as submitted to CLRTAP and NECD is currently based on fuel consumption derived from kilometres driven rather than fuel sales. The UK's interpretation of paragraph 26 of the revised Guidelines on Reporting (ECE/EB.AIR/125)[3] is that it does allow the UK to report emissions on the basis of fuel used or kilometres driven. The UK's inventory based on fuel consumption by road transport will be used to assess compliance with emission reduction commitments under the NECD and CLRTAP. However, an inventory must also be submitted based on fuel sold, although this will not be used for assessing compliance with emission reduction commitments.

The UK has a number of reasons for deciding to report emissions on a fuel used basis. Information on total fuel sales is available on a national scale, but is not broken down by vehicle type or road and area type. Emissions of air pollutants are not directly related to amounts of fuel consumed as they depend on vehicle characteristics, exhaust after treatment technology and vehicle speed or drive cycle in a manner different to the way fuel consumption responds to these factors. The availability of high quality traffic data for different vehicle types on different roads covering the whole road network, combined with fleet composition data and other vehicle behaviour and usage trends makes the use of COPERT-type methodologies a logical choice for estimating emissions in the UK. That methodology is one based on kilometres driven.

This approach also makes it possible to develop a robust inventory, which transport and air quality policy makers can relate to national statistics on transport and measures to control traffic and emissions. This direct link to transport statistics and policies would be lost with the adjustments that would be necessary on a vehicle by vehicle basis to bring consistency with national fuel sales.

The UK's projections on emissions from road transport are based on the UK's forecasts on traffic levels on an area-type basis, not on fuel sales and the inventory projections are a benchmark against which different transport and technical measures can be assessed. This has been crucial for UK air quality policy development and would not be feasible from an inventory based on fuel sales. Using a kilometres driven approach also allows the UK to produce spatially resolved inventories for road transport at 1x1 km resolution, which are widely used for national and local air quality assessments.

The UK does estimate fuel consumption from kilometres driven using g fuel/km factors and compares these each year with national fuel sales figures, as discussed in the following sections. The agreement is within 16% for both petrol and diesel consumption across the 1990-2016 time-series, but the agreement tends to be better in the more recent part of the time-series.

3.2 UNFCCC Reporting

For UNFCCC reporting of GHG emissions, the inventories must be based on fuel sold. Total fuel sales data for petrol, diesel and LPG are available in DUKES, but not split by vehicle type. Bottom-up estimates of fuel consumption by each vehicle type can be made using the vehicle activity data used in the estimation of air pollutant emissions, then normalised to total fuel sales as described further in Section 4.

This procedure is used to estimate CO_2, methane (CH_4) and nitrous oxide (N_2O) emissions by vehicle type. The inventory for CO_2 is derived directly from the amount of fuel sales assigned to each vehicle type and the carbon content of the fuel. Methane and N_2O emissions are, like other pollutants, dependent on vehicle type and technology and so are initially estimated using g/km based emission factors, vehicle km and fleet composition data, but are then normalised to the estimates of fuel sold assigned to each vehicle type. The same normalisation approach is used to estimate air pollutant emissions on the basis of fuel sales for submission to the NECD and CLRTAP.

[3] http://www.ceip.at/fileadmin/inhalte/emep/2014_Guidelines/ece.eb.air.125_ADVANCE_VERSION_reporting_guidelines_2013.pdf

4. Fuel consumption

4.1 Fuel consumption by road transport

Data on petrol and diesel fuels consumed by road transport in the UK are taken from DUKES (BEIS, Annual) and corrected for consumption by off-road vehicles and the very small amount of fuel consumed by the Crown Dependencies included in DUKES. This dataset is provided annually and a discussion of trends and recent data is given in the latest Informative Inventory Report (IIR) and National Inventory Report (NIR).

Since 2005, there has been a growth in consumption of biofuels in the UK. These are not included in the totals presented above for petrol and diesel, which according to BEIS refer only to mineral-based fuels (fossil fuels). Up until 2016, these fuels have made up to 5% of total road fuel use in a given year.

Other fuels known to be used for road transport include LPG and Compressed Natural Gas (CNG). To distribute fuel consumption, and hence emissions, between different vehicle types, a combination of data sources and approaches was used making best use of all available information.

4.2 Fuel consumption factors for petrol and diesel vehicles

Fuel consumption factors for each detailed vehicle category are derived from the fuel consumption-speed relationships given in the EMEP/EEA Emissions Inventory Guidebook (2016). This includes a method for passenger cars which applies a year-dependent 'real-world' correction to the average type-approval CO_2 factor weighted by new car sales in the UK from 2005 onwards. The new car sales weighted type-approval CO_2 factors for cars in different engine size bands are provided by the Society of Motor Manufacturers and Traders (SMMT) on an annual basis. The real-world uplift uses empirically-derived equations in the Guidebook that take account of average engine capacity and vehicle mass. The fleet-averaged fuel consumption factors derived from these sources and the fleet information described in Section 6 for each vehicle and fuel type for each year are provided in the NIR.

4.3 Fuel reconciliation and normalisation

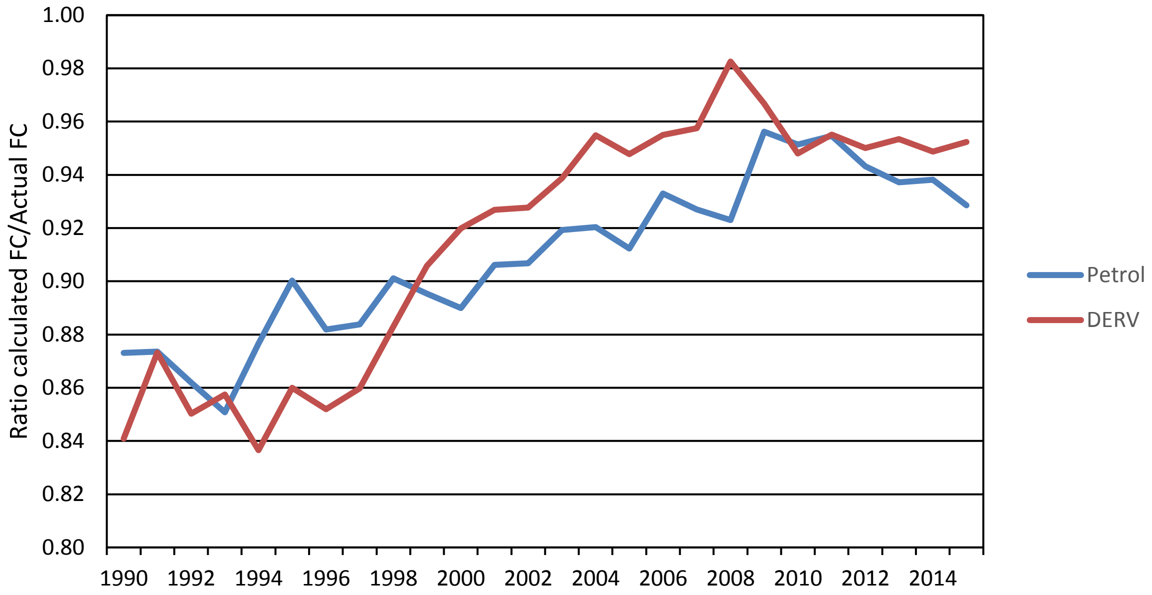
A model is used to calculate total petrol and diesel consumption by combining these factors with relevant traffic and fleet composition data described in Section 6. The bottom-up calculated estimates of petrol and diesel consumption are then compared with DUKES figures for total fuel consumption in the UK, adjusted for the small amount of consumption by inland waterways, off-road machinery and consumption in the Crown Dependencies.

The bottom-up estimated fuel consumption differs from the DUKES based figures and so it is necessary to adjust the calculated estimates for individual vehicle types by using a normalisation process to ensure the total consumption of petrol and diesel equals the DUKES based figures. This is to comply with the UNFCCC reporting system, which requires emissions of GHGs to be based on fuel sales.

Figure 4.1 shows the ratio of model calculated fuel consumption to the figures in DUKES based on total fuel sales of petrol and diesel in the UK, allowing for off-road consumption calculated for the submissions of the NAEI in 2017. For a valid comparison with DUKES, the amount of petrol and diesel displaced by biofuel consumption has been used to correct the calculated consumption of petrol and diesel. In all years, the bottom-up method tends to underestimate fuel consumption. The maximum deviation from DUKES was 16% (for DERV, in 1990). However, the ratio tends towards 1 up to 2009, indicating better agreement with fuel sales data in recent years than in the earlier part of the time series.

The normalisation process introduces uncertainties into the fuel consumption estimates for individual vehicle classes even though the totals for road transport are known with high accuracy. Petrol fuel consumption calculated for each vehicle type is scaled up by the same proportions to make the total consumption align with DUKES. The same procedure is used to scale up diesel consumption by each vehicle type. Passenger cars consume the vast majority of petrol, so one would expect that DUKES provides a relatively accurate description of the trends in fuel consumption by petrol cars. This suggests the gap in the early part of the inventory time series between DUKES and bottom-up estimates is due to inaccuracies in the estimation of fuel consumption by passenger cars during the 1990s.

Figure 4.1 Ratio of calculated consumption of petrol and diesel fuel based on traffic movement and fuel consumption factors summed for different vehicle types to the DUKES figures for these fuels based on fuel sales in the UK (based on submission of the NAEI in 2017)



5. Fuel-based emissions

Carbon dioxide and sulphur oxide (SO_x) emissions are estimated directly from the carbon and sulphur contents of the fuels and the amount of fuel consumed. This is based on the assumption that all the carbon and all the sulphur contained in the fuel is ultimately released as CO_2 and SO_x, respectively, even though a small proportion will be released initially in the form of other pollutants (e.g. CO and CH_4). The IPCC consider it good practice to assume that all the carbon in fuel is emitted as carbon dioxide. The inventory for SO_x is expressed as SO_2 equivalent emissions. Road transport is a relatively small source of SO_x emissions and no account is taken of the small amount of sulphur that may be embedded in the particulate matter emissions.

Exhaust emissions of metals from road transport occur as a result of the trace amounts of metals present in the fuels and in the case of lead pre-2000 from the amount of lead additives in petrol. Sales of leaded petrol have been banned since 2000. The metal emissions are also estimated from the metal contents of fuels.

Emissions of CO_2, SO_x and metals are broken down by vehicle type based on the allocation of fuel consumption to vehicle types calculated by vehicle activity data, normalised to fuel sales as described in Section 4.

5.1 CO_2

Values for the carbon content of petrol and diesel used in the UK were provided by the UK Petroleum Industry Association (UKPIA) from a review carried out in 2004 and are assumed to remain constant. The values are 855 gC/kg fuel for petrol and 863 gC/kg fuel for diesel. This leads to CO_2 factors of 3.135 kgCO_2/kg fuel for petrol and 3.164 kgCO_2/kg fuel for diesel.

5.2 SO_2

Emission factors for SO_2 are based on the weighted average sulphur-content of fuels delivered in the UK. Values of the fuel-based emission factors for SO_2 vary annually as the sulphur-content of fuels change. Data on the sulphur content of fuels is received from the United Kingdom Petroleum Industry Association (UKPIA) annually.

In January 2000, European Council Directive 98/70/EC came into effect relating to the quality of petrol and diesel fuels. During 2000-2004, virtually all the diesel sold in the UK was of ultra-low sulphur grade (<50 ppmS), even though this low level sulphur content was not required by the Directive until 2005. Similarly, ultra-low sulphur petrol (ULSP) became on-line in filling stations in 2000, with around one-third of sales being of ULSP quality during 2000, the remainder being of the quality specified by the Directive. In 2001-2004, virtually all unleaded petrol sold was of ULSP grade (UKPIA, 2004). These factors and their effect on emissions were taken into account in the inventory. It is assumed that prior to 2000, only buses had made a significant switch to ULSD, as this fuel was not widely available in UK filling stations.

The introduction of road fuels with sulphur content less than 10 ppm from January 2009 is taken into account according to Directive 2009/30/EC.

5.3 Metals

Emission factors for metals are based on the EMEP/EEA emissions inventory guidebook for road transport (EMEP, 2013). The guidebook factors cover the combined effect of the trace amounts of metals in the fuel itself and in lubricating oil and from engine wear. The exception is for lead emissions from petrol where UK-specific factors are used. The factors used are given in **Table 5.1**.

Table 5.1 Emission factors used in the UK inventory for road transport

Metal	Fuel	Emission Factor (t/Mt)
Cr	DERV	0.03
Cr	Petrol	0.016
As	DERV	0.0001
As	Petrol	0.0003
Cd	DERV	0.0087
Cd	Petrol	0.0108
Cu	DERV	0.0212
Cu	Petrol	0.042
Hg	DERV	0.0053
Hg	Petrol	0.0087
Ni	DERV	0.0088
Ni	Petrol	0.013
Pb	DERV	0.05
Se	DERV	0.0001
Se	Petrol	0.0002
Zn	DERV	1.74
Zn	Petrol	2.16
V	DERV	12.7
Mn	DERV	0.04
Be	DERV	0.144
Sn	DERV	0.304

The Guidebook does not provide factors for the metals V, Mn, Be and Sn, so for these metals UK specific factors are used.

In order to retain a consistent time series in lead emissions from petrol consumption, UK-specific emission factors are used based on the lead content of leaded petrol (used up until 2000) and unleaded petrol. These figures were provided by the UK petroleum industry. The factor for unleaded petrol is 54 µg/kg fuel, which is higher than the value of 33 µg/kg fuel given by the EMEP/EEA Guidebook. The factors for leaded petrol up until 2000 are year-dependent. Following the Guidebook, the lead emission factors are used in conjunction with a scaling factor of 0.75 to account for the fact that only 75% of the lead in the fuel is emitted to air.

6. Traffic-based emissions

Emissions of the pollutants CH_4, N_2O, NMVOCs, NO_X (as NO_2), CO, PM, NH_3 and other pollutants are calculated from measured emission factors expressed in g/km and road traffic statistics from DfT. The emission factors are based on experimental measurements of emissions from in-service vehicles of different types, driven under 'real-world' test cycles with different average speeds. The road traffic data used are vehicle kilometre estimates for the different vehicle types and different road classifications on the UK road network. These data have to be further broken down by composition of each vehicle fleet in terms of the fraction of diesel and petrol-fuelled vehicles on the road and in terms of the fraction of vehicles on the road made to the different emission regulations, which applied when the vehicle was first registered. These are related to the age profile of the vehicle fleet in each year.

Emissions from motor vehicles fall into several different categories, which are each calculated in a different manner. These are hot exhaust emissions, cold-start emissions, evaporative emissions of NMVOCs, and tyre wear, brake wear and road abrasion emissions of PM_{10} and $PM_{2.5}$.

The emissions calculated in this manner are associated with fuel consumed rather than fuel sold. In the case of CH_4 and N_2O, in order to comply with the requirements of UNFCCC reporting of GHG emissions, the emissions calculated based on traffic data are normalised to fuel sales as described in Sections 4 and 7. A version of the inventory for air pollutants also reported to CLRTAP and NECD is normalised to fuel sales in the same way.

6.1 Hot exhaust emissions

Hot exhaust emissions are emissions from the vehicle exhaust when the engine has warmed up to its normal operating temperature. Emissions depend on the type of vehicle, the type of fuel, the driving style or traffic situation of the vehicle on a journey and the emission regulations which applied when the vehicle was first registered, as this defines the type of technology the vehicle is equipped with that affects emissions.

For a particular vehicle, the driving style or traffic situation over a journey is the key factor that determines the amount of pollutant emitted over a given distance. Key parameters affecting emissions are the acceleration, deceleration, steady speed and idling characteristics of the journey, as well as other factors affecting load on the engine, such as road gradient and vehicle weight. However, work has shown that for modelling vehicle emissions for an inventory covering a road network on a national scale, it is sufficient to calculate emissions from emission factors in g/km related to the average speed of the vehicle in the drive cycle (Zachariadis and Samaras, 1997). A similar conclusion was reached in the review of emission modelling methodology carried out by TRL on behalf of DfT (Barlow and Boulter, 2009, see TRL Report PPR355 at https://www.gov.uk/government/publications/road-vehicle-emission-factors-2009). Emission factors for average speeds on the road network are then combined with the national road traffic data.

6.1.1 Vehicle and fuel type

Emissions are calculated for vehicles of the following types:

- Petrol cars;
- Diesel cars;
- Petrol Light Goods Vehicles (Gross Vehicle Weight (GVW) ≤ 3.5 tonnes);
- Diesel Light Goods Vehicles (Gross Vehicle Weight (GVW) ≤ 3.5 tonnes);
- Rigid-axle Heavy Goods Vehicles (GVW ≥ 3.5 tonnes);
- Articulated Heavy Goods Vehicles (GVW ≥ 3.5 tonnes);
- Buses and coaches; and
- Motorcycles and mopeds.

Total emission rates are calculated by multiplying emission factors in g/km with annual vehicle kilometre figures for each of these vehicle types on different types of roads.

6.1.2 Vehicle kilometres by road type

Hot exhaust emission factors are dependent on average vehicle speed, and therefore the type of road the vehicle is travelling on. Average emission factors are combined with the number of vehicle kilometres travelled by each type of vehicle on rural roads and higher speed motorways/dual carriageways and many different types of urban roads with different average speeds. The emission results are combined to yield emissions on each of these main road types:

- Urban;
- Rural single carriageway; and
- Motorway/dual carriageway.

DfT estimates annual vehicle kilometres (vkm) for the road network in Great Britain by vehicle type on roads classified as trunk, principal and minor roads in built-up areas (urban) and non-built-up areas (rural) and motorways (DfT, Annual A). DfT provides a consistent time series of vehicle km data by vehicle and road types going back to 1993. The vkm data are derived by DfT from analysis of national traffic census data involving automatic and manual traffic counts. Additional information, discussed in **Section 6.1.4**, is used to provide the breakdown in vkm for cars by fuel type.

Vehicle kilometre data for Northern Ireland by vehicle type and road class were provided by the Department for Regional Development (DRDNI) for Northern Ireland[4], Road Services (DRDNI, 2016). This gave a time series of vehicle km data from 2008 to 2014. To create a time series of vehicle km data for 1990 to 2007, the previous vehicle km data from DRDNI (2013) was used. The data was scaled up or down based on the ratio of the data for 2008 between DRDNI (2016) and DRDNI (2013) for the given vehicle type and road type considered. Data for 2015 onwards are not available as the dataset has been discontinued, and thus values are extrapolated from 2014 vehicle km data for Northern Ireland based on the traffic growth rates since 2014 in Great Britain. Motorcycle vehicle km data are not available from the DRDNI data and so they are derived based on the ratio of motorcycles registered in Northern Ireland relative to Great Britain each year. The ratios were then applied to the motorcycle vehicle km activity data for Great Britain. Additional information is provided by Northern Ireland Department for Infrastructure about the split between cars and LGVs and the petrol/diesel car split for cars and LGVs in the traffic flow based on further interrogation by Northern Ireland Department for Infrastructure of licensing data (Northern Ireland Department for Infrastructure, Annual).

The Northern Ireland data have been combined with DfT data for Great Britain to produce a time series of total UK vehicle kilometres by vehicle and road type from 1970 to the most recent inventory year. Tables showing the latest set of vehicle km data by vehicle and road type from 1990 to the latest inventory year are provided in the latest version of the NIR and IIR.

6.1.3 Vehicle speeds by road type

Vehicle speed data are used to calculate emission factors from the emission factor-speed relationships available for different pollutants. Average speed data for traffic in a number of different areas were taken from the following main sources: Transport Statistics Great Britain (DfT, 2009a) provided averages of speeds in Central, Inner and Outer London surveyed at different times of day during 1990 to 2008. Speeds data from other DfT's publications such as 'Road Statistics 2006: Traffic, Speeds and Congestion' (DfT, 2007a) and 2008 national road traffic and speed forecasts (DfT, 2008) were used to define speeds in other urban areas, rural roads and motorways. Where information is not available, road speed limits are used for the vehicles expected to observe these on the type of road concerned. **Table 6.1** shows the speeds used in the inventory for light duty vehicles, HGVs and buses. Speeds on individual roads and at specific times of day/week will vary from the values shown in this table. These average speeds are not updated annually, but should be regarded as typical for these types of roads and areas and are appropriate for the types of average speed related emission factors used in the national inventory.

[4] Now known as the Department for Infrastructure. Northern Ireland.

Table 6.1 Average Traffic Speeds in Great Britain

Road Type		Cars & LGV (km/h)	HGV (km/h)	Buses (km/h)
Urban Roads				
Central London	Major principal roads	16	16	16
	Major trunk roads	24	24	16
	Minor roads	16	16	16
Inner London	Major principal roads	21	21	24
	Major trunk roads	32	32	24
	Minor roads	20	20	20
Outer London	Major principal roads	31	31	32
	Major trunk roads	46	46	32
	Minor roads	29	29	29
	Motorways	108	87	87
Conurbation	Major principal roads	31	31	24
	Major trunk roads	38	37	24
	Minor roads	30	30	30
	Motorways	97	82	82
Urban	Major principal roads	36	36	32
	Major trunk roads	53	52	32
	Minor roads	35	34	29
	Motorways	97	82	82
Rural Roads				
Rural single carriageway	Major roads	77	72	71
	Minor roads	61	62	62
Rural dual carriageway		111	90	93
Rural motorway		113	90	95

6.1.4 Vehicle fleet composition: by age, size, technology and fuel type

Vehicle kilometre data based on traffic surveys do not distinguish between the type of fuels the vehicles are being run on (petrol and diesel) nor on their age. The NAEI applies Automatic Number Plate Recognition (ANPR) data provided by DfT biennially (on even years, e.g. 2012, 2014 etc.) (DfT, Biennial) to define the UK's vehicle fleet composition on the road. The ANPR data has been collected annually (since 2007) at over 256 sites in the UK on different road types (urban and rural major/minor roads, and motorways) and regions. Measurements are made at each site on one weekday (8am-2pm and 3pm-9pm) and one half weekend day (either 8am-2pm or 3pm-9pm) each year in June and are available for some years, including 2007 to 2011, 2013 and 2015. Since 2011, measurements have been made biennially. There are approximately 1.4-1.7 million observations recorded from all the sites each year. They cover various vehicle and road characteristics such as fuel type, age of vehicle (which can be associated with its Euro standard), engine sizes, vehicle weight and road types.

The ANPR data are primarily used to define the fleet composition on different road types for the whole of Great Britain (GB), rather than in specific regions. However, Devolved Administration (DA) (country specific) vehicle licensing data (hereafter referred to as DVLA data) are used to define the variation in some aspects of the vehicle fleet composition between DAs (DfT, Biennial). The ANPR data are used in two aspects to define:

- Petrol and diesel mix in the car fleet on different road types (urban, rural and motorway); and
- Variations in age and Euro standard mix on different road types.

As mentioned above, the ANPR data have only been available since 2007, so it is necessary to estimate the road-type variations in the fleet for years before the ANPR became available, otherwise a step-change would be introduced in the emissions time series. For the petrol/diesel mix of the GB car fleet as a whole, this was done by extrapolating the 2007 ANPR data back to 1990 based on the rate of change in the proportion of diesel cars registered in the national fleet as indicated by DfT Vehicle Licensing Statistics. The ANPR data confirmed that there is a higher share and hence a preferential use of diesel cars on motorways relative to petrol car usage when compared with the diesel share according to registrations, but that preferential usage of diesel cars extends to urban roads as well, although not to the extent seen on motorways. For Northern Ireland, where the share of diesel cars in the registered fleet is higher than in the rest of the UK, ANPR data are available for 2010, and biennially from 2011, with a reasonable number of observations having been recorded. However, this data did not show a consistent trend or major difference in the proportion of diesel cars observed on different road types. It also showed that the proportions were similar to those given by the licensing data. As a result, it is assumed that there is no preferential use of diesel cars in Northern Ireland and the petrol/diesel mix in passenger car km should follow the proportions indicated by the licensing statistics provided by Northern Ireland Department for Infrastructure.

Tables showing the latest set of vehicle km data by vehicle, fuel and road type from 1990 to the latest inventory year are provided in the latest version of the NIR and IIR.

The age of a vehicle determines the year–of-first registration and hence the type of emission regulation that applied when it was first registered. These have entailed the successive introduction of tighter emission control technologies, for example three-way catalysts, diesel particulate filters and better fuel injection and engine management systems. Details on the regulations that have come into force up to the latest inventory year are given in the latest IIR and NIR. The date into service is taken to be roughly the mid-point of the European Vehicle Emission Directive's implementation dates for Type-Approval and New Registrations.

In previous years, the inventory was developed using licensing data to define the age mix of the national fleet and data from travel surveys that showed how annual mileage changes with vehicle age. This was used to split the vehicle km figures by age and Euro classification. The ANPR data now provides direct evidence on the age mix of vehicles on the road and how this varies on different road types and thus obviated the need to rely on licensing data and assumptions about changing mileage with age. The ANPR information tended to show that the diesel car, LGV and HGV fleet observed on the road was rather newer than inferred from the licensing records and mileage surveys. However, this information is only available for a handful of more recent years and it has been important to consider how the trends observed in these limited years of ANPR data availability could be applied to earlier years. This was done by developing a pollutant and vehicle specific scaling factor for each road type reflecting the relative difference in the fleet mix on each road type defined by the ANPR data compared with that obtained from the licensing and older mileage with age data. The fleet-adjustment scaling factors were averaged over the 2007-2011 period and were extrapolated to a value of 1 in 1990 because in this year all vehicles meet pre-Euro 1 standard, and hence differences in the age of the fleet on different road types have no effect on emissions. An overall year-, vehicle-, road- and pollutant-specific factor is then applied to GB average emission factors calculated from the vehicle fleet turnover model, across the whole time series, to account for the variations in fleet profiles according to vehicle usage as evidenced from the ANPR data.

For years since 2007 in which no ANPR data were available, the average of the fleet-adjustment scaling factors for the adjacent years was applied to the emission factors derived for the fleet in the relevant year according to licensing data.

For some pollutants, the emission factors cover three engine size ranges for cars: <1400cc, 1400-2000cc and >2000cc. The inventory uses the proportion of cars by engine size varying each year from 2000 onwards based on the vehicle licensing data (DfT, Annual C). In addition, the relative mileage done by different sizes of vehicles was factored into the ratios, to take account of the fact that larger cars do more annual mileage than smaller cars (DfT, Annual B). The emissions impact of alternative vehicle technologies (e.g. hybrid and electric cars) has been taken into account based on emission factors provided in Murrells and Pang (2013). Uptake rates of these alternative vehicles technologies are based on information provided by DfT.

For other vehicle categories, additional investigation had to be made in terms of the vehicle sizes in the fleet as the emission factors cover eight different size classes of rigid HGVs, six different weight classes of artic HGVs, five different weight classes of buses and coaches and six different engine types (2-stroke and 4-stroke) and size classes of mopeds and motorcycles. Information on the size fractions of these different vehicle types is obtained annually from vehicle licensing statistics (DfT, Annual C), or else provided by direct communication with officials in DfT, and used to break down the vehicle km data. Some data were not available and assumptions were necessary in the case of buses, coaches and motorcycles.

DfT provide annual road freight statistics (DfT, Annual D) on the time series of vehicle km (2000 onwards) travelled by different HGV weight classes based on the Continuing Survey of Road Goods Transport (CSRGT). This information is used to allocate HGV vehicle km between different weight classes, although further assumptions have to be made as the inventory uses a more detailed breakdown of weight classes than those defined in the Road Freight Statistics. Discussions of the trends in this data, in particular for the most recent years, are discussed in the latest NIR/IIR.

Only limited information on the sizes of buses and coaches by weight exists; based on analysis of local bus operator information, it is assumed that 72% of all bus and coach km on urban and rural roads are done by buses, the remaining 28% by coaches, while on motorways all the bus and coach km are done by coaches.

Assumptions on the split in vehicle km for buses outside London by vehicle weight class are based on licensing information and correlations between vehicle weight class and number of seats and whether it is single- or double-decker. It is assumed that 31% of buses are <15t and the remaining are 15-18t. For London buses, the split is defined by the fleet composition provided by Transport for London (TfL, 2016).

For motorcycles, the whole time series of vkm for 2-stroke and 4-stroke motorcycles by different engine sizes are based on a detailed review of motorcycle sales, population and lifetime by engine size. It is also assumed that mopeds (<50cc) operate only in urban areas, while only larger >750cc, 4-stroke motorcycles are used on motorways. For all other cases, the number of vehicle kilometres driven on each road type was disaggregated by motorcycle type according to the proportions estimated to be in the fleet. Discussions with motorcycle enthusiasts (unpublished information) indicate that 2-stroke motorcycles are confined to the <150cc class.

6.1.5 Assumptions made about the proportion of failing catalysts in the petrol car fleet

A sensitive parameter in the emission calculations for petrol cars is the assumption made about the proportion of the fleet with catalyst systems that have failed, for example due to mechanical damage or failure of the lambda sensor. Following discussions with DfT (DfT, 2009b), it is assumed that the failure rate is 5% per annum for all Euro standards and that up to 2008, only 20% of failed catalysts were rectified properly, but those that were rectified were done so within a year of failing. The revisions are based on evidence on fitting of replacement catalysts. According to DfT, there is evidence that a high proportion of replacement catalysts before 2009 were not Type Approved and did not restore the emission performance of the vehicle to its original level (DfT, 2009b). This is being addressed through the Regulations Controlling Sale and Installation of Replacement Catalytic Converters and Particle Filters for Light Vehicles for Euro 3 (or above) LDVs after June 2009. Therefore, a change in the successful repair rate is taken into account for petrol LDVs adhering to Euro 3 standards from 20% prior to mid-2009 to 100% after 2009.

6.1.6 Voluntary measures and retrofits to reduce emissions

The inventory also takes account of the early introduction of certain emission standards and additional voluntary measures, such as incentives for HGVs to upgrade engines and retrofit with particle traps to reduce emissions from road vehicles in the UK fleet. This was based on advice from officials in DfT (DfT, 2004)[5].

6.1.7 Emissions from HGVs, buses, LGVs and black cabs (taxis) in London

The inventory pays particular attention to the unique features of the HGV, LGV and bus fleets in London. This is primarily so as to be able to account for measures taken to reduce emissions and improve air quality in London.

[5] There are a number of references to information, data and advice provided by experts in the Department for Transport in personal communications by telephone and e-mail. These were largely based on expert judgement, sometimes in consultation with industry, and cannot be referenced to any particular documentation. The source of most of the information came from within Cleaner Fuels and Vehicles Division of DfT.

The effect of the Low Emission Zone (LEZ) on PM emissions from HGVs and buses from 2008 is taken into account by using a different Euro standard mix for HGVs within the LEZ area. To be compliant, vehicles must meet Euro III standards or above from 2008, but this is only in respect of PM emissions. With respect to other pollutant emissions, the London fleet of HGVs and buses (except TfL's buses) are assumed to be the same as the national fleet.

The specific features of the fleet of buses operated by Transport for London (TfL) were taken into account. Information from TfL on the Euro standard mix of their fleet of buses was used and it is assumed that approximately 78-87% of all bus km in London are done by TfL buses, the remainder being done by non-TfL buses having the composition of the national bus fleet, except from 2008 onwards where the fleet is modified to be compliant with the LEZ. The split is estimated by analysis of DfT (Annuala) statistics on vehicle kilometres travelled in London by buses and coaches compared to DfT (Annuale) statistics on local bus services in London.

The inventory takes into account the introduction of the next phase of the London LEZ in January 2012, which requires the minimum of Euro 3 PM standards for larger vans and minibuses.

Information from TfL was also used to disaggregate the car vkm data between passenger cars and black cab taxis. This was important to take into account the high share of diesel powered light duty vehicles in areas of inner and central London, where black cabs make up a high proportion of the traffic flow, and the consequences this has on NO_X and PM emissions. Emission factors for London black cabs were assumed to be the same as a diesel LGVs. The measures introduced by TfL requiring a minimum of Euro 3 PM standards for black cabs in London are included.

6.1.8 Hot Emission Factors

The emission factors in grammes per kilometre for each vehicle type are taken from the COPERT 5 source (Emisia, 2016) and the EMEP/EEA Guidebook (2016).

6.1.8.1 Regulated pollutants NO_X, CO, NMVOCs, PM_{10} and $PM_{2.5}$

The COPERT sources of emission factors used for these pollutants are expressed as polynomial equations relating emission factor to average speed for each vehicle type, fuel type, vehicle size and Euro standard.

The COPERT 5 source provides factors for NO_x based on the most recent evidence (in 2016) on the real-world performance of Euro 5 and 6 diesel cars and LGVs, with higher emission factors than shown in earlier versions of COPERT.

COPERT provides separate emission functions for Euro V HDVs (HGVs and buses) equipped with Selective Catalytic Reduction (SCR) and Exhaust Gas Recirculation (EGR) systems for NO_X control. According to European Automobile Manufacturers' association (ACEA), around 75% of Euro V HDVs sold in 2008 and 2009 are equipped with SCR systems, and this is recommended to be used if the country has no other information available. These values are applied in the UK case as there is no reason to suspect that the UK situation varies from this European average.

NMVOC emissions are calculated from total hydrocarbon (THC) emission factors given in COPERT. THC emissions include CH_4. Emission factors for CH_4 are given separately (see below) and used to estimate CH_4 emissions for each vehicle type which are then subtracted from the THC emissions to derive NMVOC emissions for each vehicle type.

The COPERT NO_X, THC, CO and PM emission factors correspond to a fleet of average mileage in the range of 30,000 to 60,000 kilometres. For petrol cars and LGVs, COPERT provides additional correction factors (for NO_X, CO and THC) to take account of degradation in emissions with accumulated mileage. The detailed methodology of emission degradation is provided in the 2016 EMEP/EEA Emissions Inventory Guidebook (EMEP, 2016).

Scaling factors are also provided to take into account the effects of fuel quality, since some of the measurements would have been made during times when available fuels were of inferior quality compared to now, particularly in terms of sulphur content. These fuel scaling factors are also applied to the COPERT NO_X, PM, CO and THC emission factors.

The speed-emission factor equations were used to calculate emission factor values for each vehicle type and Euro emission standard at each of the average speeds of the road and area types shown in Table 6.1. The calculated values were averaged to produce single emission factors for the three main road classes described earlier (urban, rural single carriageway and motorway/dual carriageway), weighted by the estimated vehicle kilometres on each of the detailed road types taken from DfT. Factors illustrative of speeds on urban, rural and motorway roads are presented in **Annex A.**

Various other assumptions and adjustments were applied to the emission factors. An additional correction is made to take account of the presence of biofuels blended into conventional fossil fuel. Uptake rates of biofuels are based on annual figures from Her Majesty's Revenue and Customs (HMRC, Annual) and it is assumed that all fuels were consumed as weak (typically 5%) blends with fossil fuel. The effect of biofuel (bioethanol and biodiesel) on exhaust emissions was represented by a set of scaling factors given by Murrells and Li (2008). Biofuel scaling factors for PM were updated with values given in a report by Ricardo Energy & Environment for Defra following a review of the literature in 2017. For 5% biofuel blends, scaling factors of 0.925 and 0.948 are used for older petrol and diesel vehicles respectively. No scaling factors are applied for motorcycles, nor for more recent Euro 5 and 6 light duty vehicles, and Euro IV, V or VI heavy duty vehicles. A combined scaling factor was applied to the emission factors according to both the emission effects of the biofuel and its uptake rates each year. The effects on these pollutants are generally rather small for these weak blends.

Emission factors for alternative vehicle technologies (e.g. hybrid electric cars), which are still a relatively small proportion of the vehicle fleet, are based on scaling factors applied to emission factors for conventional petrol and diesel vehicles. These scaling factors from a review of the literature are provided in Murrells and Pang (2013). Exhaust emission factors for battery electric vehicles are zero at the point of use.

Account was taken of some heavy duty vehicles in the fleet being retrofitted with pollution abatement devices, perhaps to control particulate matter emissions (PM), or that otherwise lead to reductions in NO_X, CO, and NMVOC emissions beyond that required by Directives. Emissions from some Euro II buses and HGVs were scaled down, according to the proportion fitted with oxidation catalysts or diesel particulate filters (DPFs) and the effectiveness of these measures in reducing emissions from the vehicles.

Implied emission factors for each main vehicle category and pollutant for the UK fleet from 1990 to the latest inventory year are given in the latest IIR. These are weighted according to the mix of Euro classes and technologies in the fleet each year as well as the proportion of kilometres travelled at different speeds and, therefore, with different emission factors.

6.1.8.2 Non-regulated pollutants: NH_3, POPs, PAHs, N_2O and CH_4

Ammonia emissions from combustion sources are usually small, but significant levels can be emitted from road vehicles equipped with catalyst devices to control NO_X emissions. Nitrous oxides (N_2O) and ammonia emissions are an unintended by-product of the NO_X reduction process on the catalyst and were more pronounced for early generation petrol cars with catalysts (Euro 1 and 2). Factors for later petrol vehicle Euro standards and diesel light duty vehicles are lower. The NH_3 factors for heavy duty vehicles are also low, but become higher for the later Euro V and VI standards due to ammonia slip from the SCR system.

The emission factors for NH_3 and N_2O for all vehicle types are based on the recommendation of the EMEP/EEA Emissions Inventory Guidebook (EMEP, 2016) and the COPERT 5 source. The effect of NH_3 slippage from Euro 5/V and 6/VI diesel vehicles with SCR is reflected by the higher emission factors for these vehicles when compared with the factors for the earlier Euro standards, as provided by these sources of emission factors and shown in Table A7 in the Annex to this report.

For NH_3 and N_2O emissions from petrol cars and LGVs, emission factors are provided for different Euro standards and driving conditions (urban, rural, highway) with adjustment factors that take into account the vehicle's accumulated mileage and the fuel sulphur content. Factors for light duty diesel vehicles are provided for groups of Euro standard and road type only – the later Euro standards tend to have higher factors than earlier Euro standards. Factors for heavy duty vehicles are also provided by Euro standard and road type and show higher levels for Euro V and VI vehicles than earlier Euro standards. Factors for motorcycles make no distinction between different Euro standards and road types and bulk emission factors are provided.

Road transport is a relatively unimportant emitter of CH_4, only being produced as a consequence of incomplete combustion, but largely controlled by catalysts on petrol vehicles. Emission factors are based on factors given in the EMEP/EEA guidebook (EMEP, 2016) for urban, rural and motorway speeds.

Polyaromatic hydrocarbons (PAHs) are emitted from exhausts as a result of incomplete combustion. The NAEI focuses on 16 PAH compounds that have been designated by the USEPA as compounds of interest, using a suggested procedure for reporting test measurement results (USEPA, 1988). Road transport emission factors for these 16 compounds were developed through a combination of expert judgement and factors from various compilations. A thorough review of the DfT/TRL emission factors, available at https://www.gov.uk/government/publications/road-vehicle-emission-factors-2009, was initially undertaken. Single emission factors were given for a number of PAHs, including the 16 USEPA species, for all driving conditions. Where possible, information from the database of emission measurements was used, however, in the absence of such data, COPERT 4 emission factors were used by DfT/TRL. The factors were provided in g/km, and independent of speed (Boulter et al, 2009). The assessment of the DfT/TRL factors indicated that data from additional sources should be reviewed and, as a result, the NAEI emission factors have been derived from the following data sources or combination of sources:

- DfT/TRL emission factors (Boulter et al, 2009);
- EMEP/EEA emission inventory guidebook 2009, updated June 2010 (EMEP, 2009); and
- Expert judgement.

The expert judgement focused on how PAH emission factors change with Euro standard and technologies, using trends shown by other pollutants as proxy. Consideration was largely based on whether the PAH species was volatile or condensed phase and either trends in NMVOC or PM emissions, respectively, were taken as proxy. The aim was to develop an internally consistent set of factors for each PAH species across the vehicle types and Euro classes.

Emission factors have been specified by vehicle type and Euro standard for all 16 PAHs. As an example, the implied emission factors for benzo[a]pyrene for each main vehicle category and pollutant for the UK fleet from 1990 to the latest inventory year is given in the latest IIR. Factors illustrative of speeds on urban, rural and motorway roads, split by Euro Standard and vehicle type, are also presented in **Annex A.**

Emission factors for Persistent Organic Pollutants (POPs), specifically PCDD/PCDFs and PCBs are based on the EMEP/EEA Emissions Inventory Guidebook. The factors for emissions of these pollutants from petrol vehicles before 2000 are scaled up to take into account the much higher emissions from vehicles using leaded petrol. This assumption is consistent with information in the European dioxin inventory (http://ec.europa.eu/environment/archives/dioxin/pdf/stage1/road_transport.pdf).

6.1.8.3 Pollutant speciation

A number of pollutants covered by the inventory are actually groups of discrete chemical species and emissions are reported as the sum of its components. Of key interest to road transport is the speciation in emissions of the groups of compounds represented as NO_X, NMVOCs and PM.

Nitrogen oxides are emitted in the form of nitric oxide (NO) and nitrogen dioxide (NO_2). The fraction emitted directly as NO_2 (f-NO_2) is of particular interest for air quality modelling and the inventory is required for domestic air quality modelling purposes to provide estimates of the fraction emitted as NO_2 for different vehicle categories. Values of f-NO_2 are taken from the EMEP/EEA Emissions Inventory Guidebook (2014) for different vehicle types and Euro standards and recent studies by Carslaw et al (2016). All the factors are taken from the Guidebook, except those for Euro V and VI HGVs and buses which are based on Carslaw et al from measurements of NO_2/NO_x ratios using roadside remote sensing. Based on these and the turnover in the fleet, the fleet-averaged values of f-NO_2 for each main vehicle class have been calculated and whilst not reported here, factors for the UK fleet are available on the UK's inventory website at http://naei.defra.gov.uk/data/ef-transport. These factors are updated annually with fleet-averaged factors representative of the vehicle fleet in the latest inventory year.

Particulate matter is emitted from vehicles in various mass ranges. PM emissions from vehicle exhausts fall almost entirely in the PM_{10} mass range. Emissions of $PM_{2.5}$ and smaller mass ranges can be estimated from the fractions in the PM_{10} range. Mass fractions of PM_{10} for different PM sizes are given in the IIR for different sources. The NAEI currently uses the fraction of PM_{10} emitted as $PM_{2.5}$ of 1.0 for exhaust emissions, taken from EMEP (2016), in other words all the PM exhaust emissions are in the $PM_{2.5}$ mass range.

NMVOCs are emitted in many different chemical forms. Because of their different chemical reactivity in the atmosphere, the formation of ozone and secondary organic aerosols depends on the mix of NMVOCs emitted and the chemical speciation of emissions differs for different sources. The speciation of NMVOCs emitted from vehicle exhausts is taken from EMEP (2016).

6.2 Cold-Start Emissions

Cold start emissions are the excess emissions that occur when a vehicle is started with its engine below its normal operating temperature. The excess emissions occur from petrol and diesel vehicles because of the lower efficiency of the engine and the additional fuel used when it is cold, but more significantly for petrol cars, because the three-way catalyst does not function properly and reduce emissions from the tailpipe until it has reached its normal operating temperature.

Cold start emissions are calculated following the recommendations made by TRL in a review of alternative methodologies carried out on behalf of DfT (Boulter and Latham, 2009). The main conclusion was that the inventory approach ought to take into account new data and modelling approaches developed in the ARTEMIS programme and COPERT 4 (EMEP, 2007). However, it was also acknowledged that such an update can only be undertaken once the ARTEMIS model and/or COPERT 4 have been finalised and that at the time of their study it was not possible to give definitive emission factors for all vehicle categories.

Boulter and Latham (2009) also stated that it is possible that the incorporation of emission factors from different sources would increase the overall complexity of the UK inventory model, as each set of emission factors relates to a specific methodology. It was, therefore, necessary to check on progress made on completing the ARTEMIS and COPERT 4 methodologies and assess their complexities and input data requirements for national scale modelling.

The conclusion from this assessment of alternative methodologies was that neither ARTEMIS nor a new COPERT 4 was sufficiently well-developed for national scale modelling and that COPERT 4 referred to in the EMEP/EEA Emissions Inventory Guidebooks still utilises the approach in COPERT III (EEA, 2000). COPERT III was developed in 2000 and is quite detailed in terms of vehicle classes and uses up-to-date information, including scaling factors for more recent Euro standards reflecting the faster warm-up times of catalysts on petrol cars. COPERT III is a trip-based methodology, which uses the proportion of distance travelled on each trip with the engine cold and a ratio of cold/hot emission factor. Both of these are dependent on ambient temperature. Different cold/hot emission factor ratios are used for different vehicle types, Euro standards, technologies and pollutants.

Cold start emissions are calculated from the formula:

$$E_{cold} = \beta \,.\, E_{hot} * (e^{cold}/e^{hot} - 1)$$

where

E_{hot} = hot exhaust emissions from the vehicle type

β = fraction of kilometres driven with cold engines

e^{cold}/e^{hot} = ratio of cold to hot emissions for the particular pollutant and vehicle type

The parameters β and e^{cold}/e^{hot} are both dependent on ambient temperature and β is also dependent on driving behaviour, in particular, the average trip length, as this determines the time available for the engine and catalyst to warm up. The equations relating e^{cold}/e^{hot} to ambient temperature for each pollutant and vehicle type were taken from COPERT III and were used with monthly average temperatures for central England based on historic trends in UK Met Office (Annual) data.

The factor β is related to ambient temperature and average trip length by the following equation taken from COPERT III:

$$\beta = 0.6474 - 0.02545 * l_{trip} - (0.00974 - 0.000385 * l_{trip}) * t_a$$

where

l_{trip} = average trip length

t_a = average temperature

The method is sensitive to the choice of average trip length in the calculation. A review of average trip lengths was made, including those from the National Travel Survey, which highlighted the variability in average trip lengths available (DfT, 2007b). A key issue seems to be what the definition of a trip is according to motorist surveys. The mid-point seems to be a value of 10 km given for the UK in the EMEP/EEA Emissions Inventory Guidebook (EMEP, 2016), so this figure was adopted.

The COPERT III method provides pollutant-specific reduction factors for β to take account of the effects of Euro 2 to Euro 4 technologies in reducing cold start emissions relative to Euro 1.

This methodology was used to estimate annual UK cold start emissions of NO_X (as NO_2), PM, CO and NMVOCs from petrol and diesel cars and LGVs. Emissions were calculated separately for each Euro standard of petrol cars. Cold start emissions data are not available for heavy-duty vehicles, but these are thought to be negligible (Boulter, 1996).

Cold start emissions of NH_3 and N_2O were estimated using a method provided by the COPERT 5 methodology for the EMEP/EEA Emissions Inventory Guidebook (EMEP, 2016). The method is simpler in the sense that it uses a mg/km emission factor to be used in combination with the distances travelled with the vehicle not fully warmed up, i.e. under "cold urban" conditions. For petrol cars and LGVs, a correction is made to the cold start factor that takes into account the vehicle's accumulated mileage and the fuel sulphur content, in the same way as for the hot exhaust emission. The cold start factors in mg/km for NH_3 and N_2O emissions from light duty vehicles are shown in **Table 6.2**, calculated for zero cumulative mileage and <30ppm S fuel. There are no cold start factors for HGVs and buses.

Table 6.2 Cold Start Emission Factors for Petrol Cars and LGVs for NH_3 and N_2O

mg/km	NH_3	N_2O
Pre-Euro 1	2.0	10.0
Euro 1	38.3	43.4
Euro 2	43.5	55.0
Euro 3	4.4	16.1
Euro 4	4.4	11.9
Euro 5	12.7	1.6
Euro 6	12.7	1.6

For methane, the EMEP/EEA guidebook (EMEP, 2016) provides a separate mg/km factor for cold start emissions by Euro standard. These are used in conjunction with estimates on the number of urban kilometres travelled with cold engines.

All the cold start emissions are assumed to apply to urban driving.

6.3 Evaporative Emissions of NMVOCs

Evaporative emissions of petrol fuel vapour from the tank and fuel delivery system in vehicles fall under NFR category 1A3bv and constitute a significant fraction of total NMVOC emissions from road transport. The methodology for estimating evaporative emissions is based on the Tier 2 method approach given in the EMEP/EEA Emissions Inventory Guidebook (EMEP, 2016). This is the preferred approach to use for national scale modelling of evaporative emissions for the UK inventory, as concluded from a review by Stewart *et al*. (2009) and recommendations of a review carried out by TRL under contract to DfT (Latham and Boulter 2009).

There are three different mechanisms by which gasoline fuel evaporates from vehicles:

i) Diurnal Loss

This arises from the increase in the volatility of the fuel and expansion of the vapour in the fuel tank due to the diurnal rise in ambient temperature. Evaporation through "tank breathing" will occur each day for all vehicles with gasoline fuel in the tank, even when stationary.

ii) Hot Soak Loss

This represents evaporation from the fuel delivery system when a hot engine is turned off and the vehicle is stationary. It arises from transfer of heat from the engine and hot exhaust to the fuel system where fuel is no longer flowing. Carburettor float bowls contribute significantly to hot soak losses.

iii) Running Loss

These are evaporative losses that occur while the vehicle is in motion.

These emissions depend to varying degrees on ambient temperatures, volatility of the fuel, the size of vehicle, type of fuel system (carburettor or fuel injection and whether it uses a fuel return system) and whether the vehicle is equipped with a carbon canister for evaporative emission control. Since Euro 1 standards were introduced in the early 1990s, evaporative emissions from petrol cars and vans have been controlled by the fitting of carbon canisters to capture the fuel vapours, which are then purged and returned to the engine manifold, thus preventing their release to air. Evaporative emissions were particularly high from vehicles using carburettor fuel intake systems and these have been largely replaced by fuel injection systems on more modern vehicles, which have further reduced evaporative losses.

EMEP (2016) provides a method and emission factors for estimating evaporative emissions for detailed vehicle categories and technologies and also has the benefit of including factors for motorcycles. The vehicle classes are compatible with those available and currently used by the inventory in the calculation of exhaust emissions, although approximations and assumptions have been necessary to further divide vehicles into technology classes according to the type of fuel control systems used on cars (carburettor and fuel return systems) and carbon canisters fitted to motorcycles, given the absence of any statistics or other information available on these technologies relevant to the UK fleet.

It has also not been possible to take into account the failure of VOC-control systems because of lack of data on failure rates and emission levels that occur on failure. The EMEP (2016) method uses temperature and trip dependent emission factors, and it utilises look-up tables to assign emission factors according to summer/winter climate conditions and fuel vapour pressure.

The application of the method for the UK inventory required the following input data and assumptions.

The number of petrol cars in the small, medium and large engine size range was required and was taken from national licensing statistics. All Euro 1+ vehicles are assumed to be equipped with carbon canister controls. However, the method provides different emission factors for different sizes of canisters. The numbers of vehicles in the UK equipped with different sized canisters are not available, but the EMEP/EEA Emissions Inventory Guidebook provides a table that correlates size of carbon canister with Euro emission class. Hence, an assignment of the appropriate EMEP (2016) evaporative emission factor can be made to Euro class in the UK fleet.

The method also requires additional information on the number of cars with carburettor and/or fuel return systems. Both these systems lead to higher emissions, the latter because fuel vapour being returned to the fuel tank is warm and, therefore, heats the fuel in the tank. Data are not available in the UK on the number of cars running with either of these systems, but it was assumed that all pre-Euro 1 cars would be with carburettor and that all Euro 1 onward cars would use fuel injection, but with fuel return systems, hence, having high emission factors. The latter is a conservative assumption as some modern cars with fuel injection might be using returnless fuel systems and, hence, have lower emissions, but it was not possible to know this as there is no association with the car's Euro class.

EMEP (2016) provides different emission factors for six classes of motorcycles associated with engine cc, whether the engine operated as 2-stroke or 4-stroke and for the largest motorcycles, whether they were or were not equipped with a carbon canister. A review of the motorcycle fleet had been undertaken to yield most of the required information, but it was necessary to make a conservative assumption that no motorcycles are currently fitted with carbon canisters.

Trip information was required to estimate hot soak and running loss evaporative emissions. The information required is the number of trips made per vehicle per day and the proportion of trips finishing with a hot engine. The same trip lengths as used in the calculation of cold start emissions were used.

The EMEP (2016) methodology is based on knowledge of fuel vapour pressure (levels most appropriate for the region in the summer and winter seasons) and climatic conditions (ranges of ambient temperatures most applicable to the region in the summer and winter seasons). Based on the information on seasonal fuel volatility received annually from UKPIA (Annual), the EMEP (2016) emission factors adopted for summer days were those associated with 70 kPa vapour pressure petrol and cooler summer temperature conditions and those adopted for winter days were those associated with 90 kPa vapour pressure petrol and milder winter temperature conditions characteristic of the UK climate.

The seasonal emission factors are applied based on the number of summer and winter days in each month. However, as the EMEP (2016) emission factors are also classified by fuel vapour pressure, the number of summer and winter days in each month has been defined by whether the fuel sold in that month is either a winter or summer blend or a mixture of both. The information from UKPIA indicates the average vapour pressure of fuels sold in the UK in the summer, winter and also the transitional spring and autumn months. This information allows identification of summer and winter months for the purpose of assigning EMEP (2016) evaporative emission factor (winter months have an average vapour pressure of 90 kPa or more and summer months have a vapour pressure of 70 kPa or less).

In the transitional months (September, May), the equivalent number of winter and summer days in the month were calculated from the average vapour pressure for the month assuming a winter fuel vapour pressure of 90 kPa and a summer blend vapour pressure of 70 kPa. From this, weighted average evaporative emission factors could be derived for the month.

Further details of the methodology and tables of emission factors are given in the EMEP/EEA Emission Inventory Guidebook (EMEP, 2016).

An implied emission factor based on the population, composition of the fleet and trips made in the latest inventory year is given in the latest IIR.

6.4 Non-exhaust emissions of PM

Particulate matter is emitted from the mechanical wear of material used in vehicle tyres, brake linings and road surface. The non-exhaust sources of PM emissions from road transport fall under NFR categories 1A3bvi (tyre and brake wear) and 1A3bvii (road abrasion).

Methods for calculating emissions from tyre and brake wear are provided in the EMEP/EEA Emissions Inventory Guidebook (EMEP, 2016) derived from a review of measurements by the UNECE Task Force on Emissions Inventories (http://vergina.eng.auth.gr/mech0/lat/PM10/). Emission factors are provided in g/km for different vehicle types with speed correction factors, which imply higher emission factors at lower speeds. For heavy duty vehicles, a load correction factor is provided and tyre wear emissions depend on the number of axles. Further details are given in the AQEG (2005) report on PM.

Table 6. shows the PM_{10} emission factors (in mg/km) for tyre and brake wear for each main vehicle and road type based on the average speed data used in the inventory. There are no controls on emissions from tyre and brake wear, so the emission factors are independent of vehicle technology or Euro standard and are held constant each year. Emissions are calculated by combining emission factors with vehicle km data.

PM emissions from road abrasion are estimated based upon the emission factors and methodology provided by the EMEP/EEA Emissions Inventory Guidebook (EMEP, 2016). The emission factors are given in g/km for each main vehicle type and are constant for all years, with no road type dependence. The factors for PM_{10} (in mg/km) are shown in **Table** . The factors are combined with vehicle-km data to calculate the national emissions of PM from this source.

Table 6.3 Emission factors for PM_{10} from tyre and brake wear

mg PM_{10} /km		Tyre	Brake
Cars	Urban	8.7	11.7
	Rural	6.8	5.5
	Motorway	5.8	1.4

mg PM_{10} /km		Tyre	Brake
LGVs	Urban	13.8	18.2
	Rural	10.7	8.6
	Motorway	9.2	2.1
Rigid HGVs	Urban	20.7	51.0
	Rural	17.4	27.1
	Motorway	14.0	8.4
Artic HGVs	Urban	47.1	51.0
	Rural	38.2	27.1
	Motorway	31.5	8.4
Buses	Urban	21.2	53.6
	Rural	17.4	27.1
	Motorway	14.0	8.4
Motorcycles	Urban	3.7	5.8
	Rural	2.9	2.8
	Motorway	2.5	0.7

Table 6.4 Emission factors for PM_{10} from road abrasion

mg PM_{10}/km	Road abrasion
Cars	7.5
LGVs	7.5
HGVs	38.0
Buses	38.0
Motorcycles	3.0

Emissions of $PM_{2.5}$ and smaller mass ranges are estimated from the fractions in the PM_{10} range. Mass fractions of PM_{10} for different PM sizes are given in the IIR for different sources. Using information from the EMEP/EEA Emissions Inventory Guidebook (EMEP, 2016), the fraction of PM_{10} emitted as $PM_{2.5}$ for tyre wear, brake wear and road abrasion is shown in **Table 6.1**.

Table 6.1 Fraction of PM_{10} emitted as $PM_{2.5}$ for non-exhaust traffic emission sources

	$PM_{2.5}$ /PM_{10}
Tyre wear	0.7
Brake wear	0.4
Road abrasion	0.54

The particulate matter emitted from tyre and brake wear comprise various metal components. Based on information on the metal content of tyre material and brake linings, the metal emissions from tyre and brake wear are included in the inventory and calculated from the mass content of each metal component in the PM.

7. Fuel-normalised traffic-based emissions

As stated earlier, the traffic-based emissions calculated initially using g/km factors and vehicle km data are associated with fuel consumed rather than fuel sold. In the case of CH_4 and N_2O, it is necessary to report emissions according to fuel sold in order to comply with the requirements of UNFCCC reporting of GHG emissions. When normalising the traffic-based emissions to fuel sales, it is necessary to take into account not only the fossil fuel sales figures given in DUKES (as used for the CO_2 emission calculations), but also the sales of biofuels as these also contribute to CH_4 and N_2O emissions.

To do this, year-dependent implied fuel-based emission factors in g/kg fuel are derived by dividing the total traffic-based emissions for CH_4 and N_2O by the total traffic-based fuel consumption estimates for each vehicle type. The implied emission factors thus take into account the mix of vehicle technologies affecting emissions of each of these pollutants each year. The implied emission factors are then multiplied by the fuel sales assigned to the vehicle type (Sections 4 and 5), including estimates of the amount of fossil fuel displaced by the sale of bioethanol and biodiesel each year taking into account the different energy contents of the biofuels. The allocation of biofuels to each vehicle type is done *pro-rata* to the distribution of fossil fuels to vehicle types (Section 5). The implicit assumption is that the emissions of CH_4 and N_2O from bioethanol and biodiesel are the same as emissions from fossil fuel petrol and diesel, respectively, by energy content.

It is also necessary to report a version of the inventory of air pollutants to CLRTAP and the NECD based on fuel sales. The procedure for estimating emissions of these pollutants according to fuel sales is done exactly the same way as for CH_4 and N_2O and therefore also includes the contribution from biofuel consumption.

8. Emissions from liquefied petroleum gas (LPG) consumption

Few vehicles in the UK run on LPG. There are no reliable figures available on the total number of vehicles or types of vehicles running on this fuel. This is unlike vehicles running on petrol and diesel where DfT have statistics on the numbers and types of vehicles registered as running on these fuels. It is believed that many vehicles running on LPG are cars and vans converted by their owners and that these conversions are not necessarily reported to vehicle licensing agencies. Figures from DUKES suggest that the consumption of LPG is around 0.2% of the total amount of petrol and diesel consumed by road transport since the turn of the century, and much less beforehand. Vehicle licensing data suggest 0.2% of all light duty vehicles registered since 2004 run on LPG.

Carbon emissions from LPG consumption are calculated from the total LPG consumption given in DUKES and fuel-based factors given in the NIR.

Emissions of CH_4 and N_2O from consumption of LPG were calculated from vehicle km data and emission factors (expressed as g of pollutant per km) available from COPERT 4 covering all types of light duty vehicles (cars and LGVs). Reliable vkm statistics for LPG vehicles are not readily available. As information on the type of LPG vehicles travelling in the UK is not available, it has been assumed that all vehicles using LPG are LGVs and this assumption then allows the kilometres travelled by LPG LGVs to be calculated from fuel efficiency factors for vehicles using this fuel taken from DfT/TRL (DfT, 2009c) combined with the total LPG consumption given in DUKES. The LPG kilometres were then combined with the g/km emission factors for CH_4 and N_2O provided in COPERT 4 assuming the fleet composition of LPG vehicles in terms of the mix of Euro standards was the same as for diesel LGVs. Although the method for calculating CH_4 and N_2O emissions from LPG consumption is based on g/km emission factors, the use of LPG fuel consumption to estimate km travelled means the emissions are in effect based on LPG sales consistent with the method used for petrol and diesel consumption.

The traffic-based emission estimates of other pollutants do not treat LPG explicitly. All the vehicle km used in the traffic-based emission calculations were assumed to be done by petrol or diesel vehicles. As in reality a very small proportion of these vkm were done by LPG fuelled vehicles (mainly LGVs), the implicit assumption is that a g/km factor for the LPG vehicles is the same as for a petrol/diesel vehicle.

The UK inventory does not currently estimate emissions from vehicles running on natural gas. The number of such vehicles in the UK is extremely small, with most believed to be running in captive fleets on a trial basis in a few areas. Estimates are not made as there are no separate figures from BEIS on the amount of natural gas used by road transport, nor are there useable data on the total numbers and types of vehicles equipped to run on natural gas from vehicle licensing sources. The small amount of gas that is used in the road transport sector would currently be allocated to other sources in DUKES.

9. Overseas Territories and Crown Dependencies

Fuel consumption data for road transport are obtained from national statistics for all Overseas Territories and Crown Dependencies. Fleet composition data are available for some territories and used to break down fuel consumption and calculate emissions. For other regions, the UK fleet composition was assumed. These were used in conjunction with UK-specific emission factors.

Different UK Overseas Territories and Crown Dependencies are included for different submissions; these are explained in the NIR and IIR.

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Annex A. Hot Exhaust Factors

The factors presented in this section are for a typical urban, rural and motorway speed. Some of the assumptions used to derive the factors are approximately in line with assumptions used for the 2016 NAEI submissions for the year 2014. Note that these factors do not account for many of the finer elements (e.g. degradation, fuel effects) of the NAEI methodology and are derived directly from the COPERT speed-emission equations or tables given in EMEP/EEA Emissions Inventory Guidebook without any further adjustment.

Dashes signify that the factor is 0 as emissions are expected to be negligible. The emission factors below are generally given to 3 significant figures, or as many significant figures as are provided, where the source factors are not given to as many as 3 significant figures (e.g. motorcycle emission factors in Table A 6).

Table A 1 PM_{10} Hot Exhaust Emission Factors (mg/km)

Vehicle Type	Fuel	Euro Standard	Urban	Rural	Motorway
Car	Petrol	Pre-Euro 1	3.22	3.22	3.22
		Euro 1	3.22	3.22	3.22
		Euro 2	3.22	3.22	3.22
		Euro 3	1.28	1.28	1.28
		Euro 4	1.28	1.28	1.28
		Euro 5	1.38	1.20	1.85
		Euro 6	1.46	1.24	1.80
Car	Diesel	Pre-Euro 1	170	132	217
		Euro 1	54.0	68.7	138
		Euro 2	42.8	40.2	61.1
		Euro 3	27.9	32.0	55.4
		Euro 4	27.1	24.1	28.4
		Euro 5	2.16	1.70	1.45
		Euro 6	1.49	1.11	0.90
LGV	Petrol	Pre-Euro 1	3.22	3.22	3.22
		Euro 1	3.22	3.22	3.22
		Euro 2	3.22	3.22	3.22
		Euro 3	1.28	1.28	1.28
		Euro 4	1.28	1.28	1.28
		Euro 5	1.30	2.36	4.72
		Euro 6	1.30	2.36	4.72
LGV	Diesel	Pre-Euro 1	289	318	376
		Euro 1	62.3	84.3	200
		Euro 2	62.3	84.3	200
		Euro 3	41.7	56.5	134
		Euro 4	21.8	29.5	70.1
		Euro 5	1.10	0.91	0.84
		Euro 6	1.10	0.91	0.84
HGV - rigid	Diesel	Pre-Euro 1	367	298	290
		Euro 1	243	193	188
		Euro 2	118	128	138
		Euro 3	121	93	90
		Euro 4	28.2	24.3	24.3
		Euro 5	34.0	27.6	27.2
		Euro 6	3.33	2.53	2.52

Vehicle Type	Fuel	Euro Standard	Urban	Rural	Motorway
HGV - articulated	Diesel	Pre-Euro 1	483	423	380
		Euro 1	375	329	293
		Euro 2	203	214	234
		Euro 3	188	145	138
		Euro 4	43.6	34.5	33.3
		Euro 5	51.4	39.8	38.0
		Euro 6	4.90	3.72	3.55
Buses and coaches	Diesel	Pre-Euro 1	453	340	272
		Euro 1	268	214	199
		Euro 2	144	129	124
		Euro 3	139	111	105
		Euro 4	33.5	27.3	29.1
		Euro 5	39.1	34.4	34.6
		Euro 6	3.76	3.17	3.19
Motorcycle (<50cc) - two stroke	Petrol	Pre-Euro 1	0.176		
		Euro 1	0.04		
		Euro 2	0.007		
		Euro 3	0.004		
Motorcycle (>50cc) - two stroke	Petrol	Pre-Euro 1	0.20	0.20	
		Euro 1	0.08	0.08	
		Euro 2	0.04	0.04	
		Euro 3	0.012	0.012	
Motorcycle (>50cc) - four stroke	Petrol	Pre-Euro 1	0.02	0.02	0.02
		Euro 1	0.02	0.02	0.02
		Euro 2	0.005	0.005	0.005
		Euro 3	0.005	0.005	0.005

Table A 2 CO Hot Exhaust Emission Factors (g/km)

Vehicle Type	Fuel	Euro Standard	Urban	Rural	Motorway
Car	Petrol	Pre-Euro 1	7.66	4.60	4.64
		Euro 1	1.56	1.39	2.39
		Euro 2	0.607	0.589	1.00
		Euro 3	0.551	0.762	1.62
		Euro 4	0.214	0.323	0.799
		Euro 5	0.265	0.280	0.705
		Euro 6	0.233	0.239	0.600
Car	Diesel	Pre-Euro 1	0.584	0.446	0.359
		Euro 1	0.342	0.194	0.261
		Euro 2	0.264	0.079	0.0525
		Euro 3	0.0795	0.0319	0.00805
		Euro 4	0.0631	0.0297	0.0199
		Euro 5	0.0413	0.0205	0.00398
		Euro 6	0.0504	0.0387	0.0560
LGV	Petrol	Pre-Euro 1	10.5	6.77	24.9
		Euro 1	2.58	0.920	7.33
		Euro 2	1.57	0.561	4.47
		Euro 3	1.34	0.479	3.81
		Euro 4	0.721	0.258	2.05
		Euro 5	0.392	0.460	1.69
		Euro 6	0.392	0.460	1.69
LGV	Diesel	Pre-Euro 1	1.06	1.04	1.43
		Euro 1	0.341	0.398	0.914
		Euro 2	0.341	0.398	0.914
		Euro 3	0.279	0.326	0.750
		Euro 4	0.221	0.259	0.594
		Euro 5	0.000297	0.000167	0.0000788
		Euro 6	0.000297	0.000167	0.0000788
HGV - rigid	Diesel	Pre-Euro 1	2.12	1.77	1.70
		Euro 1	1.34	1.20	1.17
		Euro 2	1.09	1.08	1.10
		Euro 3	1.28	1.13	1.11
		Euro 4	0.660	0.522	0.498
		Euro 5	1.04	0.870	0.845
		Euro 6	0.123	0.0895	0.0941

Vehicle Type	Fuel	Euro Standard	Urban	Rural	Motorway
HGV - articulated	Diesel	Pre-Euro 1	2.57	2.24	2.22
		Euro 1	2.22	2.01	2.00
		Euro 2	1.80	1.78	1.79
		Euro 3	2.07	1.90	1.90
		Euro 4	0.990	0.754	0.711
		Euro 5	1.63	1.31	1.26
		Euro 6	0.155	0.119	0.115
Buses and coaches	Diesel	Pre-Euro 1	2.99	2.29	1.39
		Euro 1	1.59	1.22	1.18
		Euro 2	1.29	1.05	1.16
		Euro 3	1.44	1.21	1.29
		Euro 4	0.761	0.549	0.660
		Euro 5	1.26	0.904	0.960
		Euro 6	0.167	0.126	0.128
Motorcycle (<50cc) - two stroke	Petrol	Pre-Euro 1	14.7		
		Euro 1	6.7		
		Euro 2	4.2		
		Euro 3	2.7		
Motorcycle (>50cc) - two stroke	Petrol	Pre-Euro 1	15.9	21.2	
		Euro 1	10.5	14.0	
		Euro 2	8.32	11.1	
		Euro 3	4.60	6.11	
Motorcycle (>50cc) - four stroke	Petrol	Pre-Euro 1	18.1	19.6	22.3
		Euro 1	10.4	11.0	9.84
		Euro 2	2.59	4.00	5.41
		Euro 3	1.43	2.21	2.98

Table A 3 NO_X Hot Exhaust Emission Factors (g/km)

Vehicle Type	Fuel	Euro Standard	Urban	Rural	Motorway
Car	Petrol	Pre-Euro 1	2.05	2.58	3.47
		Euro 1	0.260	0.311	0.586
		Euro 2	0.144	0.159	0.188
		Euro 3	0.0720	0.0571	0.0615
		Euro 4	0.0466	0.0266	0.0184
		Euro 5	0.0252	0.0175	0.0118
		Euro 6	0.0286	0.0190	0.0115
Car	Diesel	Pre-Euro 1	0.563	0.524	0.729
		Euro 1	0.569	0.577	0.737
		Euro 2	0.599	0.563	0.793
		Euro 3	0.687	0.671	0.864
		Euro 4	0.481	0.436	0.720
		Euro 5	0.545	0.479	0.638
		Euro 6	0.449	0.395	0.525
LGV	Petrol	Pre-Euro 1	2.82	3.34	3.92
		Euro 1	0.407	0.421	0.610
		Euro 2	0.139	0.143	0.207
		Euro 3	0.0856	0.0885	0.1281
		Euro 4	0.0407	0.0421	0.0610
		Euro 5	0.0176	0.0138	0.0114
		Euro 6	0.0176	0.0138	0.0114
LGV	Diesel	Pre-Euro 1	1.29	0.81	1.92
		Euro 1	1.05	1.01	1.44
		Euro 2	1.05	1.01	1.44
		Euro 3	0.883	0.845	1.21
		Euro 4	0.715	0.684	0.980
		Euro 5	1.12	1.21	2.29
		Euro 6	0.905	0.981	1.848
HGV - rigid	Diesel	Pre-Euro 1	9.04	8.17	8.12
		Euro 1	6.21	5.66	5.64
		Euro 2	6.71	6.00	5.95
		Euro 3	5.26	4.64	4.59
		Euro 4	3.65	3.33	3.20
		Euro 5	2.97	1.48	1.30
		Euro 6	0.233	0.111	0.0917

Vehicle Type	Fuel	Euro Standard	Urban	Rural	Motorway
HGV - articulated	Diesel	Pre-Euro 1	14.4	11.5	10.9
		Euro 1	10.1	8.08	7.69
		Euro 2	10.7	8.57	8.17
		Euro 3	8.58	6.89	6.58
		Euro 4	5.87	4.94	4.43
		Euro 5	3.90	2.03	1.74
		Euro 6	0.268	0.135	0.115
Buses and coaches	Diesel	Pre-Euro 1	10.8	9.3	8.6
		Euro 1	7.3	6.00	6.42
		Euro 2	7.8	6.46	7.00
		Euro 3	6.14	4.66	5.33
		Euro 4	4.21	3.35	3.85
		Euro 5	3.51	2.18	1.78
		Euro 6	0.264	0.112	0.0807
Motorcycle (<50cc) - two stroke	Petrol	Pre-Euro 1	0.056		
		Euro 1	0.22		
		Euro 2	0.17		
		Euro 3	0.17		
Motorcycle (>50cc) - two stroke	Petrol	Pre-Euro 1	0.0308	0.0335	
		Euro 1	0.0417	0.0528	
		Euro 2	0.0508	0.0606	
		Euro 3	0.0255	0.0303	
Motorcycle (>50cc) - four stroke	Petrol	Pre-Euro 1	0.242	0.372	0.543
		Euro 1	0.259	0.397	0.575
		Euro 2	0.146	0.264	0.676
		Euro 3	0.105	0.174	0.343

Table A 4 NMVOC Hot Exhaust Emission Factors (mg/km)

Vehicle Type	Fuel	Euro Standard	Urban	Rural	Motorway
Car	Petrol	Pre-Euro 1	1170	732	670
		Euro 1	128	99.4	105
		Euro 2	43.6	31.6	32.7
		Euro 3	10.6	14.8	29.1
		Euro 4	9.31	11.7	14.0
		Euro 5	2.91	2.62	3.81
		Euro 6	3.53	3.12	4.66
Car	Diesel	Pre-Euro 1	93.9	66.5	47.1
		Euro 1	40.4	23.2	26.3
		Euro 2	37.8	25.4	17.2
		Euro 3	16.9	11.7	10.2
		Euro 4	7.63	6.15	5.73
		Euro 5	7.16	5.61	3.99
		Euro 6	7.16	5.61	3.99
LGV	Petrol	Pre-Euro 1	1270	389	754
		Euro 1	149	65.7	84.9
		Euro 2	25.1	6.62	12.74
		Euro 3	21.5	9.44	9.85
		Euro 4	8.52	2.90	5.94
		Euro 5	3.83	3.74	14.7
		Euro 6	3.83	3.74	14.7
LGV	Diesel	Pre-Euro 1	91.9	89.2	108
		Euro 1	109	92.2	113
		Euro 2	113	98.2	114
		Euro 3	71.3	62.8	71.6
		Euro 4	26.5	23.3	26.6
		Euro 5	24.9	21.2	18.5
		Euro 6	24.9	21.2	18.5
HGV - rigid	Diesel	Pre-Euro 1	668	472	428
		Euro 1	300	249	232
		Euro 2	204	151	138
		Euro 3	193	130	122
		Euro 4	35.0	26.3	26.1
		Euro 5	31.0	22.0	21.7
		Euro 6	20.8	14.3	14.3

Vehicle Type	Fuel	Euro Standard	Urban	Rural	Motorway
HGV - articulated	Diesel	Pre-Euro 1	508	383	354
		Euro 1	463	358	332
		Euro 2	308	216	196
		Euro 3	283	182	170
		Euro 4	53.9	38.9	38.2
		Euro 5	46.8	32.7	32.0
		Euro 6	30.9	20.7	20.6
Buses and coaches	Diesel	Pre-Euro 1	924	732	293
		Euro 1	313	278	293
		Euro 2	221	196	197
		Euro 3	207	190	195
		Euro 4	41.3	36.0	34.0
		Euro 5	34.6	30.1	31.9
		Euro 6	23.1	20.1	22.0
Motorcycle (<50cc) - two stroke	Petrol	Pre-Euro 1	8180		
		Euro 1	736		
		Euro 2	766		
		Euro 3	520		
Motorcycle (>50cc) - two stroke	Petrol	Pre-Euro 1	7370	7290	
		Euro 1	2260	2760	
		Euro 2	1220	1490	
		Euro 3	772	934	
Motorcycle (>50cc) - four stroke	Petrol	Pre-Euro 1	1600	1090	1530
		Euro 1	889	652	653
		Euro 2	320	336	475
		Euro 3	203	236	332

Table A 5 CH_4 Hot Exhaust Emission factors (mg/km)

Vehicle Type	Fuel	Euro Standard	Urban	Rural	Motorway
Car	Petrol	Pre-Euro 1	131	86	41
		Euro 1	26	16	14
		Euro 2	17	13	11
		Euro 3	3	2	4
		Euro 4	2.87	2.69	5.08
		Euro 5	2.87	2.69	5.08
		Euro 6	2.87	2.69	5.08
Car	Diesel	Pre-Euro 1	28	12	8
		Euro 1	11	9	3
		Euro 2	7	3	2
		Euro 3	3	-	-
		Euro 4	1.1	-	-
		Euro 5	1.1	-	-
		Euro 6	1.1	-	-
LGV	Petrol	Pre-Euro 1	131	86	41
		Euro 1	26	16	14
		Euro 2	17	13	11
		Euro 3	3	2	4
		Euro 4	2	2	-
		Euro 5	2	2	-
		Euro 6	2	2	-
LGV	Diesel	Pre-Euro 1	28	12	8.0
		Euro 1	11	9.0	3.0
		Euro 2	7.0	3.0	2.0
		Euro 3	3.0	-	-
		Euro 4	1.1	-	-
		Euro 5	1.1	-	-
		Euro 6	1.1	-	-
HGV - rigid	Diesel	Pre-Euro 1	143	59.5	52.0
		Euro 1	143	59.5	52.0
		Euro 2	91.3	51.8	48.4
		Euro 3	79.9	55.3	47.3
		Euro 4	4.28	4.16	3.12
		Euro 5	4.28	4.16	3.12
		Euro 6	4.28	4.16	3.12

Vehicle Type	Fuel	Euro Standard	Urban	Rural	Motorway
HGV - articulated	Diesel	Pre-Euro 1	175	80	70
		Euro 1	175	80	70
		Euro 2	112	69.6	65.1
		Euro 3	98	74.4	63.7
		Euro 4	5.25	5.6	4.2
		Euro 5	5.25	5.6	4.2
		Euro 6	5.25	5.6	4.2
Buses and coaches	Diesel	Pre-Euro 1	175	80	70
		Euro 1	175	80	70
		Euro 2	114	52	45.5
		Euro 3	103	47.2	41.3
		Euro 4	5.25	2.4	2.1
		Euro 5	5.25	2.4	2.1
		Euro 6	5.25	2.4	2.1
Motorcycle (<50cc) - two stroke	Petrol	Pre-Euro 1	219		
		Euro 1	44		
		Euro 2	24		
		Euro 3	20		
Motorcycle (>50cc) - two stroke	Petrol	Pre-Euro 1	150	150	
		Euro 1	99	107	
		Euro 2	30	31.5	
		Euro 3	12	13.5	
Motorcycle (>50cc) - four stroke	Petrol	Pre-Euro 1	200	200	200
		Euro 1	128	139	154
		Euro 2	127	93.2	102
		Euro 3	76.4	32.7	30

Table A 6 N_2O Hot Exhaust Emission factors (mg/km). These are given for zero accumulated mileage

Vehicle Type	Fuel	Euro Standard	Urban	Rural	Motorway
Car	Petrol	Pre-Euro 1	10	6.5	6.5
		Euro 1	21.3	7.8	4.0
		Euro 2	10.7	3.78	2.08
		Euro 3	1.08	0.263	0.184
		Euro 4	1.77	0.218	0.156
		Euro 5	2.07	0.145	0.918
		Euro 6	2.07	0.145	0.918
Car	Diesel	Pre-Euro 1	-	-	-
		Euro 1	2	4	4
		Euro 2	4	6	6
		Euro 3	9	4	4
		Euro 4	9	4	4
		Euro 5	9	4	4
		Euro 6	11	4	4
LGV	Petrol	Pre-Euro 1	10	6.5	6.5
		Euro 1	22.0	13.8	6.9
		Euro 2	16.3	9.27	5.78
		Euro 3	4.74	1.17	1.17
		Euro 4	1.11	0.0834	0.0834
		Euro 5	2.07	0.145	0.918
		Euro 6	2.07	0.145	0.918
LGV	Diesel	Pre-Euro 1	-	-	-
		Euro 1	2	4	4
		Euro 2	4	6	6
		Euro 3	9	4	4
		Euro 4	9	4	4
		Euro 5	9	4	4
		Euro 6	11	4	4
HGV - rigid	Diesel	Pre-Euro 1	30	30	30
		Euro 1	10.8	8.87	6.38
		Euro 2	10.4	8.87	5.96
		Euro 3	5.06	5.06	3.81
		Euro 4	11.0	13.4	11.0
		Euro 5	28.7	38.5	32.5
		Euro 6	35.5	37.2	28.1

Vehicle Type	Fuel	Euro Standard	Urban	Rural	Motorway
HGV - articulated	Diesel	Pre-Euro 1	30	30	30
		Euro 1	14.7	10.8	17.7
		Euro 2	14.7	9.8	17.7
		Euro 3	8.80	6.85	8.80
		Euro 4	22.9	18.8	18.6
		Euro 5	65.3	54.7	48.1
		Euro 6	62.8	47.1	59.8
Buses and coaches	Diesel	Pre-Euro 1	30	30	30
		Euro 1	11.2	10.6	11
		Euro 2	11.2	10.3	11
		Euro 3	5.72	5.44	5
		Euro 4	13.1	12.4	11.2
		Euro 5	35.2	33.3	29.8
		Euro 6	40.8	38.0	37
Motorcycle (<50cc) - two stroke	Petrol	Pre-Euro 1	1		
		Euro 1	1		
		Euro 2	1		
		Euro 3	1		
Motorcycle (>50cc) - two stroke	Petrol	Pre-Euro 1	2	2	
		Euro 1	2	2	
		Euro 2	2	2	
		Euro 3	2	2	
Motorcycle (>50cc) - four stroke	Petrol	Pre-Euro 1	2	2	2
		Euro 1	2	2	2
		Euro 2	2	2	2
		Euro 3	2	2	2

Table A 7 NH_3 Hot Exhaust Emission factors (mg/km). These are given for zero accumulated mileage.

Vehicle Type	Fuel	Euro Standard	Urban	Rural	Motorway
Car	Petrol	Pre-Euro 1	2	2	2
		Euro 1	70	131	73.3
		Euro 2	143	148	83.3
		Euro 3	1.9	29.5	64.6
		Euro 4	1.9	29.5	64.6
		Euro 5	4.1	8	21.8
		Euro 6	4.1	8	21.8
Car	Diesel	Pre-Euro 1	1	1	1
		Euro 1	1	1	1
		Euro 2	1	1	1
		Euro 3	1	1	1
		Euro 4	1	1	1
		Euro 5	1.9	1.9	1.9
		Euro 6	1.9	1.9	1.9
LGV	Petrol	Pre-Euro 1	2	2	2
		Euro 1	70.0	131	73.3
		Euro 2	143	148	83.3
		Euro 3	1.9	29.5	64.6
		Euro 4	1.9	29.5	64.6
		Euro 5	4.1	8	21.8
		Euro 6	4.1	8	21.8
LGV	Diesel	Pre-Euro 1	1	1	1
		Euro 1	1	1	1
		Euro 2	1	1	1
		Euro 3	1	1	1
		Euro 4	1	1	1
		Euro 5	1.9	1.9	1.9
		Euro 6	1.9	1.9	1.9
HGV - rigid	Diesel	Pre-Euro 1	3	3	3
		Euro 1	3	3	3
		Euro 2	3	3	3
		Euro 3	3	3	3
		Euro 4	3	3	3
		Euro 5	11	11	11
		Euro 6	9	9	9

Vehicle Type	Fuel	Euro Standard	Urban	Rural	Motorway
HGV - articulated	Diesel	Pre-Euro 1	3	3	3
		Euro 1	3	3	3
		Euro 2	3	3	3
		Euro 3	3	3	3
		Euro 4	3	3	3
		Euro 5	11	11	11
		Euro 6	9	9	9
Buses and coaches	Diesel	Pre-Euro 1	3	3	3
		Euro 1	3	3	3
		Euro 2	3	3	3
		Euro 3	3	3	3
		Euro 4	3	3	3
		Euro 5	3	3	3
		Euro 6	3	3	3
Motorcycle (<50cc) - two stroke	Petrol	Pre-Euro 1	1		
		Euro 1	1		
		Euro 2	1		
		Euro 3	1		
Motorcycle (>50cc) - two stroke	Petrol	Pre-Euro 1	2	2	
		Euro 1	2	2	
		Euro 2	2	2	
		Euro 3	2	2	
Motorcycle (>50cc) - four stroke	Petrol	Pre-Euro 1	2	2	2
		Euro 1	2	2	2
		Euro 2	2	2	2
		Euro 3	2	2	2

Table A 7 Benzo[a]pyrene Hot Exhaust Emission factors (µg/km)

Vehicle Type	Fuel	Euro Standard	Urban	Rural	Motorway
Car	Petrol	Pre-Euro 1	0.48	0.48	0.48
		Euro 1	0.32	0.32	0.32
		Euro 2	0.201	0.201	0.201
		Euro 3	0.166	0.166	0.166
		Euro 4	0.130	0.130	0.130
		Euro 5	0.130	0.130	0.130
		Euro 6	0.130	0.130	0.130
Car	Diesel	Pre-Euro 1	2.85	2.85	2.85
		Euro 1	0.63	0.63	0.63
		Euro 2	0.425	0.425	0.425
		Euro 3	0.284	0.284	0.284
		Euro 4	0.189	0.189	0.189
		Euro 5	0.134	0.134	0.134
		Euro 6	0.134	0.134	0.134
LGV	Petrol	Pre-Euro 1	0.48	0.48	0.48
		Euro 1	0.32	0.32	0.32
		Euro 2	0.201	0.201	0.201
		Euro 3	0.166	0.166	0.166
		Euro 4	0.130	0.130	0.130
		Euro 5	0.130	0.130	0.130
		Euro 6	0.130	0.130	0.130
LGV	Diesel	Pre-Euro 1	4.28	4.28	4.28
		Euro 1	0.945	0.945	0.945
		Euro 2	0.638	0.638	0.638
		Euro 3	0.425	0.425	0.425
		Euro 4	0.284	0.284	0.284
		Euro 5	0.201	0.201	0.201
		Euro 6	0.201	0.201	0.201
HGV - rigid	Diesel	Pre-Euro 1	1.35	1.35	1.35
		Euro 1	0.675	0.675	0.675
		Euro 2	0.359	0.359	0.359
		Euro 3	0.331	0.331	0.331
		Euro 4	0.153	0.153	0.153
		Euro 5	0.153	0.153	0.153
		Euro 6	0.0551	0.0551	0.0551

Vehicle Type	Fuel	Euro Standard	Urban	Rural	Motorway
HGV - articulated	Diesel	Pre-Euro 1	1.8	1.8	1.8
		Euro 1	0.9	0.9	0.9
		Euro 2	0.479	0.479	0.479
		Euro 3	0.441	0.441	0.441
		Euro 4	0.204	0.204	0.204
		Euro 5	0.204	0.204	0.204
		Euro 6	0.0734	0.0734	0.0734
Buses and coaches	Diesel	Pre-Euro 1	2.63	2.63	2.63
		Euro 1	1.31	1.31	1.31
		Euro 2	0.699	0.699	0.699
		Euro 3	0.644	0.644	0.644
		Euro 4	0.297	0.297	0.297
		Euro 5	0.297	0.297	0.297
		Euro 6	0.107	0.107	0.107
Motorcycle (<50cc) - two stroke	Petrol	Pre-Euro 1	1.01		
		Euro 1	1.01		
		Euro 2	1.01		
		Euro 3	1.01		
Motorcycle (>50cc) - two stroke	Petrol	Pre-Euro 1	1.01	1.01	
		Euro 1	1.01	1.01	
		Euro 2	1.01	1.01	
		Euro 3	1.01	1.01	
Motorcycle (>50cc) - four stroke	Petrol	Pre-Euro 1	3.02	3.02	3.02
		Euro 1	3.02	3.02	3.02
		Euro 2	3.02	3.02	3.02
		Euro 3	3.02	3.02	3.02

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