Appendix 3 The assumptions used for the 1998 NAEI base projections and some UK emissions data

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APPENDIX 3A THE ASSUMPTIONS USED FOR THE 1998 NAEI BASE PROJECTIONS

Introduction

This appendix considers the assumptions underpinning the calculation of the National Atmospheric Emissions Inventory (NAEI) from road transport emissions, and the assumptions that are used to forecast future emissions. It is important to this project because it embodies the knowledge base already established and used by the DEFRA. It is the model used to generate the inventory data discussed in the report's main text. It also is the basis upon which the effectiveness of various in-service testing scenarios are quantified, to give the reduction in emissions in units of mass/year, and their context in terms of the overall emissions inventory.

The UK NAEI is compiled by the National Environmental Technology Centre (NETCen) on behalf of the DEFRAs' Air and Environmental Quality Research Programme. The NAEI is the standard reference air emissions inventory for the UK and includes emission estimates for a wide range of important pollutants. In the context of this project, the NAEI provides an inventory from road transport, and from all other sources, for seven of the eight pollutants listed in the AQS, and for all the species specified in the type approval regulations (assuming road vehicle PM is equivalent to PM_{10}, and "hydrocarbons" are equivalent to non-methane volatile organic compounds).

The objective of the NAEI with regard to road transport is to quantify:

$$\sum_{\text{all vehicles}} \sum_{\text{all journeys}} \text{mass of pollutant emitted, } \textit{in a year}.$$

In practice this has to be achieved using a model. The fundamental methodology involves the combining of vehicle emission factors with traffic activity and fleet composition data as depicted in Figure 1.

Basic methodology used

The fleet composition is subdivided into six broad classifications: cars, LGVs, rigid HGVs, articulated HGVs, buses and motor cycles. The first two of these are then further subdivided according to the type of fuel its engine runs on; petrol or diesel. Each of the eight resulting classifications is then further subdivided into different emissions standards as defined by successive EC directives, except the motor cycles, for which different regulations apply (directive 97/24/EC). However, they are also outside the scope of the current project and will not be considered further.

The emissions from the vehicle exhaust for the engine at its normal operating temperature (known as hot emissions) for a particular vehicle type are dependent on the journeys' characteristics. These include average speed, accelerations and decelerations, steady speed and idling characteristics as well as other factors affecting the load on the engine such as road gradient and vehicle weight. However, research has shown that for modelling vehicle emissions for an inventory covering a road network on a national scale, it is sufficient to calculate emissions related to the average speed of the vehicle in the drive cycle. Hence traffic activity is grouped into four specified types of road: urban, rural single carriageway, rural dual carriageway and motorway. The average number of miles travelled by each classification of vehicle type is then estimated from traffic statistics for each of these four road types.

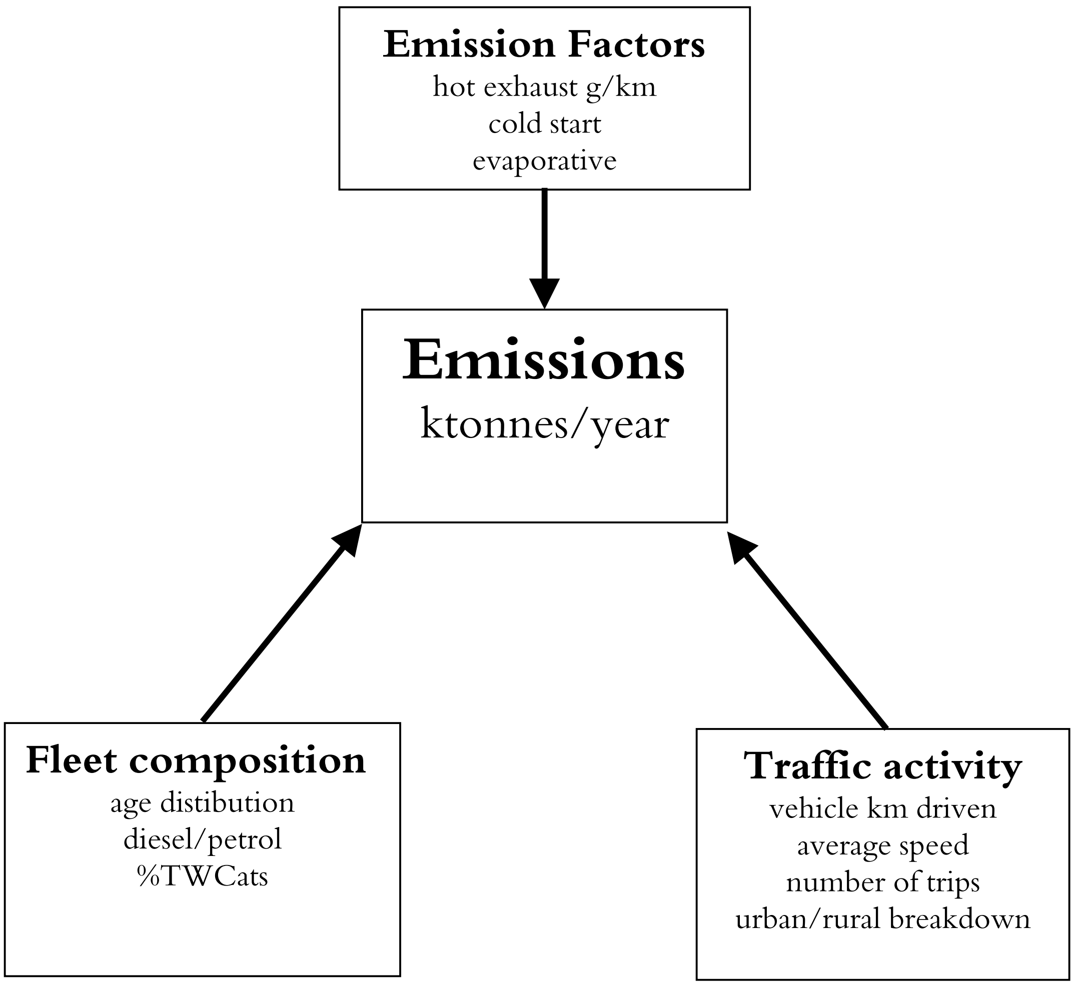

Figure 1 Method for calculating an emissions inventory for road transport

Hot exhaust emissions have been measured for a large number of vehicles. TRL have drawn on the data from a number of European sources and also undertaken some measurements for the DTLR to create a database. From this database polynomial functions expressing the vehicles' emissions as a function of engine capacity, vehicle weight, speed and age can be formulated for the different vehicle types. By undertaking numerical averages of these functions, weighted according to the proportion of the different vehicle sizes in the UK fleet, a **single average emissions factor** (expressed in grams of pollutant per kilometre driven) can be produced for each vehicle type and emissions class at each average speed. Emissions factors are calculated for each type of vehicle when driving along each of the four types of road.

The total emissions for the pollutants NO_X, CO, benzene, 1,3-butadiene, methane, N_2O, PM_{10} and non-methane volatile hydrocarbons (NMVOCs) are then, to a first approximation, calculated by multiplying the emissions factors by the number of vehicle kilometres for each vehicle type and road type and summing.

The basic assumptions and methodology that are pertinent to this study on gasoline fuelled vehicles and were used for the 1998 NAEI road transport emission projections can be summarised[1]:

- Emissions are calculated for current vehicles on urban, rural and motorway roads using emission factor-speed functions for vehicles meeting regulations from 1970 up to 1998. The base emission factors are calculated from speed-emission functions provided by Hickman (reference 1) and taken from the European COPERT II database recommended for CORINAIR emission reporting (reference 2). An illustrative example, for NO_X is summarised in Appendix 1 of this report. PM_{10} emissions from diesel vehicles were based on diesel fuel containing 500 ppm sulphur.
- Emissions factors for new vehicles registered after 2001/2002 and 2006 which must comply with the Euro III and Euro IV emission standards are estimated by applying scaling factors relative to Euro II emission factors.
- The effect of new fuel directives, implemented in 2000 and 2005, on current vehicle emissions are estimated by applying scaling factors to emissions from current fuels.
- The fleet composition in years up to 1997 is based on vehicle licensing statistics from DETR (reference 3).
- The fleet turnover rate defines the fleet composition in future years. This is based on the average survival rate for past years, derived from the number of new registrations in past years and the age distribution in the last few years.
- Data for new car sales are taken from DETRs' Vehicle Market Model.
- The estimates take account of the change in annual mileage with vehicle age using data from the DETR, References 4 and 5.
- The emissions forecasts are based on the central growth rate of the 1997 National Road Traffic Forecasts (reference 6) rescaled to a 1997 base year.

The older in-service vehicles in the test surveys, that were manufactured to a particular emission standard would have covered a range of different ages. Therefore, an emission factor calculated for a specific emissions standard is effectively an average value of vehicles of different ages which inherently takes account of possible degradation in emissions with vehicle age.

The emissions factors, in g/km, for benzene, 1,3 butadiene, CO, NO_X and PM_{10} (and also NMVOCs generically) that were used to generate road transport contribution to the 1998 National Atmospheric Emissions Inventory are given in Appendix 3B.

Vehicle degradation

In addition to the above empirical way of taking account of the change in emissions with vehicle degradation a further methodology is also used in the road transport module of the NAEI model. NO_X, CO and NMVOC emissions from catalyst cars and PM_{10} emissions from

[1] Taken from "UK Road transport emission projections: The assumptions used and results of the 1997 NAEI base projections", (a report to DETR) TP Murrells, NETCEN, Jan 2000, Report reference AEAT-5953.

diesel cars and LGVs are assumed to increase from the "as new, type approved" values by an annual amount.

For NAEI calculations up to and including 1998, the catalyst fleet comprised vehicles complying with either directive 91/441/EEC or 94/12/EC (Euro I and II vehicles). For these the degradation factors used in the NAEI are based on data from the European Auto-Oil study. The factors used are a 60% increase in CO and NO_X emissions over 80,000 km and a 30% increase in NMVOC emissions over the same distance. Based on the average annual mileage of cars, it takes 6.15 years for a passenger car to cover 80,000 km.

The algorithm used to revise the emission factor was

Emission Factor after n years = Initial Emissions Factor + (n × annual increase)

with the upper limit of the pre-91/441/EEC Emission Factor for when n is large.

Projections of emissions inventories require the making of assumptions regarding the fleet composition. For future years this will increasingly be dominated by vehicles complying with directive 98/69/EC Stage A (2000) and Stage B (2005) limit values. For all the vehicles the deterioration factor assumed by the model is for a 10% increase in CO, NO_X and NMVOC emissions over 80,000 km. (Changes like this involves much peer-reviewed discussion between the team generating the data, NETCen, and their customer, DEFRA.) The author's opinion is that whilst this is a much smaller rate than has been used for earlier technologies it is justifiable given the in-use compliance emissions deterioration rates specified in directive 98/69/EC (10%) and experience from the European testing community.

Projections are also based on a catalyst failure rate of 5% per annum with 95% of failed catalysts being repaired after the vehicle is 3 years old. This failure rate is based on old Department of Transport estimates reflecting the performance and maintenance of first generation catalyst cars in the UK, but is currently under review.

Forecasting

The other important aspect of the National Atmospheric Emissions Inventory model is forecasting the emissions for future years. This is achieved in exactly the same way as for the historical data, but using the latest available figures for fleet composition and traffic activity modified by forecasted changes. The emissions factors used are those for the latest current vehicles multiplied by a scalar quantity, known as an **emission scale factor**, reflecting the expected change that will result from the introduction of new legislation on either emissions limits or fuel specification.

Cold start emissions

Cold start emissions are important for modern gasoline fuelled cars, fitted with a three-way catalyst which operate, when warm, at the stiochiometric point. When cold, they run fuel rich in order to obtain stable combustion and the catalyst is not at a sufficiently high temperature to operate efficiently. The net result is that for a short journey, of a few kilometres, the emissions especially of CO and hydrocarbons can be many times (e.g. 10) greater per km than for the warm engine, i.e. cold starting significantly perturbs the emissions inventory. For diesel engines, the basic combustion processes involved, compression ignition of a fundamentally fuel lean mixture, generate much less CO and hydrocarbons even especially when cold and consequently the perturbation to the emissions inventory from cold starting is very much less than for gasoline engines (reference 7).

Emission factors have been derived for cars and LGVs from tests performed with the engine starting cold and warmed up. The difference between the two measurements can be regarded as an additional cold-start penalty paid on each trip a vehicle is started with the engine (and catalyst) cold.

The procedure for estimating cold-start emissions is taken from COPERT II, taking account of the effects of ambient temperature on emission factors for different vehicle technologies and its effect on the distance travelled with the engine cold. A factor, the ratio of cold to hot emissions, is used and applied to the fraction of kilometres driven with cold engines to estimate the cold start emissions from a particular vehicle type using the following 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 II and were used with an annual mean temperature for the UK of 11°C. This is based on historic trends in Met Office data for ambient temperatures over different parts of the UK.

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

$$\beta = 0.698 - 0.051 \,.\, l_{trip} - (0.01051 - 0.000770 \,.\, l_{trip}) \,.\, t_a$$

where: l_{trip} = average trip length

t_a = average temperature.

An average trip length for the UK of 8.4 km was used, taken from Andre et al (1993). This gives a value for β of 0.23.

This methodology was used to estimate annual UK cold start emissions of NO_X, CO, NMVOCs, PM_{10}, benzene and 1,3-butadiene from petrol and diesel cars and LGVs. Emissions were calculated separately for catalyst and non-catalyst petrol vehicles. Cold start emissions data are not available for heavy duty vehicles, but these are thought to be negligible (Boulter, 1996).

For benzene and 1,3-butadiene, the same cold start parameters were used in these equations as for total NMVOCs.

It was estimated that cold-start emissions make up the following percentages of total road transport emissions in the UK in 1998:

- NO_X 6 %
- PM_{10} 6%
- CO 37 %
- NMVOCs 20 %
- Benzene 25%
- 1,3-Butadiene 21%

These are the data in the 1998 NAEI. It should be noted that all the cold start emissions are assume to apply to urban driving. Therefore the percentage of cold start emissions in the urban UK inventory will be higher. Deconvoluting the data, the cold start emissions, expressed as a fraction of the urban inventory were calculated to be:

- NO_X 15.8 %
- PM_{10} 12.8%
- CO 54.1 %
- NMVOCs 26.9 %

(A breakdown of the urban/non-urban emissions for benzene and 1,3-Butadiene was not available, and consequently the fraction of the urban inventory from cold starts was not calculated for these two species.)

Evaporative emissions

Evaporative losses are important for gasoline fuelled vehicles (and gas fuelled vehicles) because of the fuels volatility. Modern gasoline vehicles have systems to reduce this, e.g. to trap the vapour from the fuel tank, and to then feed it into the combustion chamber when the engine is running.

Evaporative emissions of petrol fuel vapour from the tank and fuel delivery system in vehicles constitute a significant fraction of total NMVOC emissions from road transport. The procedure for estimating evaporative emissions of NMVOCs takes account of changes in ambient temperature and fuel volatility.

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.

Evaporative emissions are dependent on ambient temperature and the volatility of the fuel and, in the case of diurnal losses, on the daily *rise* in ambient temperature. Fuel volatility is usually expressed by the empirical fuel parameter known as Reid vapour pressure (RVP). For each of these mechanisms, equations relating evaporative emissions to ambient temperature and RVP were developed by analysis of empirically-based formulae derived in a series of CONCAWE research studies in combination with UK measurements data reported by TRL. Separate equations were developed for vehicles with and without evaporative control systems fitted such as carbon canister devices. The overall methodology is similar to that reported by COPERT II (European Environment Agency, 1997), but the data are considered to be more UK-biased.

Further details, including all the equations for diurnal, hot soak and running loss evaporative emissions from vehicles with and without control systems fitted developed for the inventory are shown in Table A34 of Appendix 1 to the 1998 NAEI (see web site:).

From these it was estimated that evaporative emissions make up 25% of total road transport emissions of NMVOCs in the UK in 1998. Of these, 47% of the emissions were from diurnal losses, 50% were from hot soak losses and 3% from running losses.

Evaporative emissions of benzene were estimated by assuming that benzene makes up 1% of total evaporative NMVOC losses by mass, as recommended by COPERT II. This leads to the conclusion that evaporative emissions make up 6% of total road transport emissions of benzene in the UK in 1998.

The use of this model in this project

When all the contributions to the road transport inventory, discussed above, are combined then either a current inventory, or a projected inventory, can be calculated. The historically computed (1991 – 1997) contribution of road transport to the UK NAEI and the projected inventory (2000 – 2025) for the species of primary importance to this project, namely CO, NO_X, PM_{10} and NMVOCs, are given in Appendix 3B.

It can be assumed when assessing the effectiveness of various in-service emissions testing regimes that these will only affect the emissions factors (the mass of pollutants emitted per km driven). Therefore it is assumed that different in-service testing scenarios will have no impact on the fleet composition, or the traffic activity. Consequently, when quantifying the effectiveness of various in-service emissions testing regimes, the parameter that will be varied is the emission factors, to give a revised inventory, and therefore by subtraction from the base cases tabulated in Appendix 3B nett changes in pollutant mass emitted per year can be computed.

It is also noted that the NAEI model used in this study is the same model that was used by the Cleaner Vehicle Task Force in its analysis.

Bibliography

Reference 1 Hickman, AJ, Transport Research Laboratory, communication February 1998.

Reference 2 COPERT II: Computer Program to Calculate Emissions from Road Transport – Methodology and Emission Factors, P Ahlvik et al., European Topic Centre on Air Emissions, European Environment Agency, April 1997

Reference 3 DETR, Vehicle Licensing Statistics: 1997, Transport Statistics Report, June 1998

Reference 4 DETR (1996) data from "Continuous Survey of Roads Goods Transport" communication June 1996.

Reference 5 DETR (1998) data from "National Travel Survey, Transport Statistics" communication March 1998.

Reference 6 DETR (1997) "National Road Traffic Forecast (Great Britain) 1997).

Reference 7 "Factors affecting cold start emissions: a review" PG Boulter, 1996, Project Report PR/SE/183/96 for DETR Project Record No UG93.

APPENDIX 3B EMISSIONS FACTORS AND CONTRIBUTION OF MOBILE SOURCES TO NAEI

From the preceding discussion on the AQS and the NAEI it is apparent that gasoline vehicles contribute significantly to the inventory of five of the eight species highlighted in the AQS, namely benzene, 1, 3 butadiene, carbon monoxide, oxides of nitrogen and particulates (PM10). The following tables give the emission factors used to calculate the inventory from vehicles for these five species and for NMVOCs generically.

The four tables following these give the UK emissions of CO, NO_X, PM_{10} and NMVOCs from mobile sources broken down according to vehicle type. A selection of historical (1991 – 1997) and projected (2000 – 2025) data is given. These data provide a basis for identifying which type(s) of vehicles contribute the largest share of the inventory, and consequently helps design a targeted, cost effective testing regime.

Appendix 3B Benzene Emissions Factors (mg/km)

	Emission standard	Urban	Rural single c/way	Rural dual c/way	Motorway
Petrol cars	Pre-ECE	113	61.4	42.1	35.6
	ECE 15.00	113	61.4	42.1	35.6
	ECE 15.01	113	61.4	42.1	35.6
	ECE 15.02	113	61.4	42.1	35.6
	ECE 15.03	113	61.4	42.1	35.6
	ECE 15.04	113	61.4	42.1	35.6
	Euro I (91/441/EEC)	5.5	3.42	2.75	5.15
	Euro II	2.42	1.5	1.21	2.27
Diesel cars	Pre-Euro I	2.6	1.8	1.52	1.00
	Euro I	1.38	0.87	0.47	0.29
	Euro II	0.97	0.61	0.33	0.21
Petrol LGV	Pre-Euro I	90.4	52.7	30.9	54.6
	Euro I	3.2	2.5	3.3	6.8
	Euro II	1.4	1.1	1.5	3.0
Diesel LGV	Pre-Euro I	6.93	4.46	2.92	3.88
	Euro I	5.11	3.61	2.45	2.00
	Euro II	3.06	2.17	1.47	1.20
HGV rigid	Old	128	64.2	64.2	64.2
	Pre-Euro I	64.1	37.0	33.7	28.0
	Euro I	37.8	22.4	19.5	12.9
	Euro II	34.9	20.9	18.1	11.7
HGV artic	Old	136	64.2	64.2	64.2
	Pre-Euro I	61.4	33.3	29.1	18.8
	Euro I	29.0	20.5	17.8	12.9
	Euro II	26.1	18.9	16.4	11.2
Buses	Old	116	52.0	52.0	46.0
	Pre-Euro I	27.7	14.0	12.6	10.3
	Euro I	29.9	21.8	18.9	13.6
	Euro II	27.9	18.8	16.3	11.8
Motorcycles	< 50 cc	23.9	13.0	8.9	7.5
	> 50 cc, 2st	37.0	20.2	13.8	11.7
	> 50 cc, 4st	46.3	25.2	17.3	14.6

Appendix 3B 1,3 Butadiene Emissions Factors (mg/km)

	Emission standard	Urban	Rural single c/way	Rural dual c/way	Motorway
Petrol cars	Pre-ECE	37.7	16.5	7.6	8.7
	ECE 15.00	37.7	16.5	7.6	8.7
	ECE 15.01	37.7	16.5	7.6	8.7
	ECE 15.02	37.7	16.5	7.6	8.7
	ECE 15.03	37.7	16.5	7.6	8.7
	ECE 15.04	37.7	16.5	7.6	8.7
	Euro I (91/441/EEC)	1.14	0.00	0.04	0.08
	Euro II	0.50	0.00	0.02	0.03
Diesel cars	Pre-Euro I	4.95	4.38	2.23	2.47
	Euro I	3.75	3.35	1.58	1.44
	Euro II	2.62	2.35	1.10	1.01
Petrol LGV	Pre-Euro I	32.1	19.0	8.8	13.0
	Euro I	1.34	0.00	0.05	0.15
	Euro II	0.59	0.00	0.02	0.06
Diesel LGV	Pre-Euro I	4.61	7.39	3.91	4.74
	Euro I	5.65	8.16	3.83	4.17
	Euro II	3.39	4.90	2.30	2.50
HGV rigid	Old	15.57	23.32	10.56	6.54
	Pre-Euro I	15.57	23.32	10.56	6.54
	Euro I	10.17	16.59	7.52	4.9
	Euro II	9.4	15.42	6.99	4.45
HGV artic	Old	32.27	41.32	18.34	12.73
	Pre-Euro I	32.27	41.32	18.34	12.73
	Euro I	16.14	26.86	11.92	9.55
	Euro II	14.52	24.79	11.00	8.27
Buses	Old	18.80	19.30	8.60	7.46
	Pre-Euro I	18.80	19.30	8.60	7.46
	Euro I	14.10	12.55	5.59	5.59
	Euro II	13.16	10.81	4.82	4.85
Motorcycles	< 50 cc	8.7	6.2	2.8	2.7
	> 50 cc, 2st	14.6	10.3	4.7	4.5
	> 50 cc, 4st	18.5	13.0	5.9	5.7

Appendix 3B CO Emissions Factors (g/km)

	Emission standard	Urban	Rural single c/way	Rural dual c/way	Motorway
Petrol cars	Pre-ECE	26.92	18.70	16.97	16.70
	ECE 15.00	18.43	14.85	22.20	21.32
	ECE 15.01	18.43	14.85	22.20	21.32
	ECE 15.02	15.50	8.03	9.74	9.38
	ECE 15.03	15.94	8.37	9.22	8.84
	ECE 15.04	10.10	6.34	7.97	7.64
	Euro I (91/441/EEC)	1.40	1.22	4.32	3.96
	Euro II	1.26	1.09	3.88	3.56
Diesel cars	Pre-Euro I	0.686	0.456	0.426	0.423
	Euro I	0.394	0.227	0.289	0.276
	Euro II	0.276	0.159	0.203	0.193
Petrol LGV	Pre-Euro I	14.27	8.87	36.13	32.54
	Euro I	2.78	1.42	4.40	4.01
	Euro II	2.50	1.28	3.96	3.61
Diesel LGV	Pre-Euro I	1.09	0.84	1.36	1.29
	Euro I	0.82	0.57	0.80	0.76
	Euro II	0.57	0.40	0.56	0.54
HGV rigid	Old	6.00	2.90	2.90	2.90
	Pre-Euro I	2.64	2.12	1.99	1.97
	Euro I	1.66	1.16	0.97	0.95
	Euro II	1.45	1.07	0.92	0.90
HGV artic	Old	7.30	3.70	3.70	3.10
	Pre-Euro I	3.06	2.48	2.46	2.47
	Euro I	1.67	1.23	1.07	1.05
	Euro II	1.39	1.15	1.07	1.05
Buses	Old	18.80	7.30	7.30	1.76
	Pre-Euro I	9.00	3.29	3.88	4.06
	Euro I	3.77	1.08	0.89	0.86
	Euro II	3.02	0.96	0.78	0.76
Motorcycles	< 50 cc	23.81	36.46	52.13	50.80
	> 50 cc, 2st	23.37	25.80	28.67	28.43
	> 50 cc, 4st	20.81	22.20	31.91	30.83

Appendix 3B NO_x Emissions Factors (g/km)

	Emission standard	Urban	Rural single c/way	Rural dual c/way	Motorway
Petrol cars	Pre-ECE	2.10	2.53	2.84	2.82
	ECE 15.00	2.10	2.53	2.84	2.82
	ECE 15.01	2.10	2.53	2.84	2.82
	ECE 15.02	1.79	2.38	3.61	3.49
	ECE 15.03	1.92	2.61	3.99	3.86
	ECE 15.04	1.64	2.21	3.26	3.16
	Euro I (91/441/EEC)	0.29	0.31	0.60	0.56
	Euro II	1.43	0.157	0.298	0.281
Diesel cars	Pre-Euro I	0.623	0.570	0.739	0.718
	Euro I	0.392	0.223	0.296	0.282
	Euro II	0.274	0.156	0.207	0.197
Petrol LGV	Pre-Euro I	1.83	2.28	3.25	3.16
	Euro I	0.33	0.39	0.63	0.61
	Euro II	0.16	0.20	0.32	0.30
Diesel LGV	Pre-Euro I	1.22	1.15	1.53	1.48
	Euro I	0.54	0.31	0.41	0.39
	Euro II	0.38	0.21	0.28	0.27
HGV rigid	Old	11.80	14.40	14.40	14.40
	Pre-Euro I	6.02	4.96	5.65	5.91
	Euro I	3.94	3.24	3.38	3.47
	Euro II	3.16	2.51	2.59	2.65
HGV artic	Old	18.20	24.10	24.10	19.80
	Pre-Euro I	19.93	12.93	11.69	11.52
	Euro I	9.14	6.82	5.98	5.86
	Euro II	7.48	5.58	4.89	4.79
Buses	Old	16.20	14.80	14.80	13.50
	Pre-Euro I	13.62	5.45	5.88	6.13
	Euro I	14.89	4.39	4.35	4.39
	Euro II	10.63	3.59	3.56	3.59
Motorcycles	< 50 cc	0.03	0.03	0.03	0.03
	> 50 cc, 2st	0.03	0.07	0.13	0.13
	> 50 cc, 4st	0.16	0.23	0.40	0.39

Appendix 3B PM_{10} Emissions Factors (g/km)

	Emission standard	Urban	Rural single c/way	Rural dual c/way	Motorway
Diesel cars	Pre-Euro I	0.174	0.149	0.196	0.190
	Euro I	0.039	0.024	0.060	0.055
	Euro II	0.023	0.014	0.036	0.033
Diesel LGV	Pre-Euro I	0.361	0.304	0.453	0.433
	Euro I	0.109	0.082	0.158	0.148
	Euro II	0.065	0.049	0.095	0.089
HGV rigid	Old	1.831	1.129	1.033	1.033
	Pre-Euro I	0.534	0.415	0.406	0.408
	Euro I	0.352	0.241	0.204	0.199
	Euro II	0.171	0.188	0.099	0.097
HGV artic	Old	1.520	0.910	0.710	0.710
	Pre-Euro I	0.785	0.579	0.517	0.508
	Euro I	0.538	0.372	0.316	0.308
	Euro II	0.207	0.143	0.121	0.118
Buses	Old	1.600	1.400	1.400	0.710
	Pre-Euro I	1.043	0.334	0.290	0.284
	Euro I	0.670	0.263	0.221	0.215
	Euro II	0.412	0.101	0.085	0.083
Motorcycles	< 50 cc	0.04	0.04	0.04	0.04
	> 50 cc, 2st	0.04	0.04	0.04	0.04
	> 50 cc, 4st	0.12	0.12	0.12	0.12

Appendix 3B PM_{10} Emissions Factors for petrol vehicles (g/km)

g/km	Leaded	Unleaded without TWC	Unleaded with TWC
Cars	0.06	0.02	0.01
LGVs	0.08	0.04	0.02
% petrol car km in 1998	21%	24%	55%

Appendix 3B NMVOC Emissions Factors (g/km)

	Emission standard	Urban	Rural single c/way	Rural dual c/way	Motorway
Petrol cars	Pre-ECE	2.30	1.54	1.25	1.25
	ECE 15.00	1.80	1.23	1.08	1.09
	ECE 15.01	1.80	1.23	1.08	1.09
	ECE 15.02	1.81	1.04	0.95	0.95
	ECE 15.03	1.81	1.04	0.95	0.95
	ECE 15.04	1.50	0.93	0.80	0.80
	Euro I (91/441/EEC)	0.14	0.08	0.14	0.13
	Euro II	0.096	0.056	0.097	0.090
Diesel cars	Pre-Euro I	0.153	0.087	0.059	0.061
	Euro I	0.060	0.028	0.014	0.015
	Euro II	0.042	0.019	0.010	0.010
Petrol LGV	Pre-Euro I	1.71	0.77	1.14	1.05
	Euro I	0.09	0.09	0.19	0.18
	Euro II	0.06	0.06	0.13	0.12
Diesel LGV	Pre-Euro I	0.30	0.16	0.19	0.18
	Euro I	0.23	0.13	0.10	0.10
	Euro II	0.16	0.09	0.07	0.07
HGV rigid	Old	6.42	3.21	3.21	3.21
	Pre-Euro I	1.84	1.44	1.39	1.39
	Euro I	1.08	0.71	0.59	0.57
	Euro II	1.00	0.65	0.53	0.52
HGV artic	Old	6.78	3.21	3.21	3.21
	Pre-Euro I	1.63	1.05	0.86	0.83
	Euro I	0.97	0.68	0.59	0.57
	Euro II	0.89	0.61	0.51	0.49
Buses	Old	5.80	2.60	2.60	2.30
	Pre-Euro I	1.93	0.53	0.50	0.50
	Euro I	1.91	0.64	0.52	0.50
	Euro II	1.79	0.56	0.45	0.44
Motorcycles	< 50 cc	12.30	18.50	26.18	25.53
	> 50 cc, 2st	9.52	8.28	8.34	8.29
	> 50 cc, 4st	1.83	1.27	1.28	1.26

Appendix 3B UK EMISSIONS OF CO

UK ktonnes		**1991**	**1993**	**1995**	**1997**	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**
Cars	Petrol (Non-cat)	4842	4098	3142	2220	1150	161	5	0	0	0
	Petrol (Cat)	8	193	613	1046	1428	1645	1354	1159	1163	1206
	DERV	8	13	17	18	20	18	15	14	14	14
	All Cars	4859	4304	3773	3284	2597	1824	1374	1173	1176	1221
LGV	Petrol	546	468	399	307	176	43	21	19	21	23
	DERV	18	22	26	28	27	24	19	18	19	21
	All LGV	564	490	426	336	203	67	40	37	40	44
HGV	Artic	35	33	30	26	22	21	23	26	29	32
HGV	Rigid	74	68	61	54	42	33	33	35	37	39
ALL HGV		109	101	91	80	64	54	56	61	66	71
Buses		60	53	45	35	25	14	11	12	12	13
Motorcycles		104	81	80	77	79	83	87	92	97	102
All DERV		196	189	179	162	136	110	101	104	111	119
All Petrol		5499	4841	4235	3650	2833	1932	1468	1270	1280	1330
All Vehicles		**5695**	**5030**	**4414**	**3812**	**2969**	**2042**	**1569**	**1374**	**1391**	**1450**

Appendix 3B UK EMISSIONS OF NO_x

UK ktonnes		1991	1993	1995	1997	2000	2005	2010	2015	2020	2025
Cars	Petrol (Non-cat)	644.18	565.49	448.48	340.59	180.88	25.71	0.84	0	0	0
	Petrol (Cat)	0.89	22.52	72.43	117.60	150.62	154.48	115.66	98.00	99.53	103.20
	DERV	8.45	11.78	15.50	16.87	19.37	18.28	14.27	12.68	12.62	13.03
	All Cars	653.52	599.78	536.40	475.06	350.86	198.47	130.77	110.68	112.15	116.22
LGV	Petrol	49.75	42.26	35.78	27.73	15.36	3.03	1.02	0.86	0.92	1.02
	DERV	19.00	22.50	24.65	23.34	21.11	15.72	11.29	10.19	10.78	11.86
	All LGV	68.76	64.76	60.43	51.07	36.48	18.75	12.31	11.05	11.70	12.89
HGV	Artic	190.78	182.53	163.40	144.23	111.71	83.61	58.8	41.16	40.01	43.96
HGV	Rigid	241.33	210.91	181.18	154.25	110.88	69.22	45.96	30.10	25.61	26.22
ALL HGV		432.11	393.44	344.59	298.48	222.59	152.83	104.76	71.26	65.62	70.18
Buses		71.63	65.82	63.24	58.91	51.03	39.99	28.28	19.75	15.34	13.78
Motorcycles		0.65	0.50	0.50	0.48	0.49	0.52	0.54	0.57	0.60	0.63
All DERV		531.2	493.53	447.97	397.59	314.10	226.82	158.60	113.88	104.36	108.85
All Petrol		695.47	630.77	557.18	486.4	347.35	183.74	118.06	99.43	101.05	104.85
All Vehicles		**1226.67**	**1124.3**	**1005.15**	**883.99**	**661.45**	**410.56**	**276.66**	**213.31**	**205.41**	**213.70**

Appendix 3B UK EMISSIONS OF PM_{10}

UK ktonnes		**1991**	**1993**	**1995**	**1997**	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**
Cars	Petrol (Non-cat)	14.46	12.02	9.55	7.31	1.77	0.25	0.01	0	0	0
	Petrol (Cat)	0.02	0.37	1.04	1.71	2.70	3.62	3.99	4.28	4.51	4.68
	DERV	2.75	3.38	3.68	3.78	4.03	3.62	2.32	1.55	1.46	1.51
	All Cars	17.22	15.77	14.27	12.80	8.50	7.50	6.32	5.83	5.97	6.19
LGV	Petrol	1.50	1.14	0.85	0.59	0.27	0.13	0.12	0.14	0.15	0.17
	DERV	6.61	7.82	8.39	7.90	7.46	6.41	4.05	2.77	2.68	2.95
	All LGV	8.11	8.95	9.24	8.50	7.73	6.54	4.17	2.90	2.83	3.12
HGV	Artic	8.08	7.88	7.50	5.74	4.04	2.45	1.23	0.64	0.57	0.63
HGV	Rigid	23.14	19.98	16.79	11.94	7.75	4.05	2.08	1.02	0.75	0.77
ALL HGV		31.22	27.86	24.29	17.68	11.79	6.49	3.31	1.66	1.32	1.40
Buses		6.45	5.71	5.04	3.64	2.67	1.27	0.70	0.42	0.30	0.25
Motorcycles		0.48	0.37	0.37	0.35	0.36	0.38	0.40	0.42	0.44	0.47
All DERV		47.03	44.78	41.41	33.01	25.95	17.79	10.38	6.39	5.76	6.11
All Petrol		16.45	13.90	11.81	9.97	5.10	4.39	4.53	4.83	5.11	5.32
All Vehicles		**63.48**	**58.68**	**53.22**	**42.97**	**31.06**	**22.18**	**14.91**	**11.22**	**10.87**	**11.43**

Appendix 3B UK EMISSIONS OF NMVOC

UK ktonnes		1991	1993	1995	1997	2000	2005	2010	2015	2020	2025
Cars	Petrol (Non-cat)	747.1	684.0	531.5	382.8	191.2	26.8	0.9	0	0	0
	Petrol (Cat)	1.0	25.6	79.1	126.7	160.6	182.2	163.8	154.8	158.2	163.8
	DERV	2.1	2.8	3.2	3.2	3.3	2.9	2.3	2.0	2.0	2.1
	All Cars	790.2	712.4	613.8	512.7	355.1	212.0	166.9	156.9	160.2	165.9
LGV	Petrol	60.0	50.7	42.1	30.7	16.1	3.4	1.5	1.4	1.5	1.7
	DERV	5.0	5.9	7.2	7.5	7.4	6.8	5.3	4.9	5.1	5.6
	All LGV	65.0	56.6	49.2	38.2	23.5	10.2	6.8	6.3	6.6	7.3
HGV	Artic	28.7	24.7	20.3	16.8	12.9	11.8	8.3	6.1	6.2	6.9
HGV	Rigid	74.8	65.2	55.9	46.0	33.7	24.8	17.3	11.8	10.4	10.8
ALL HGV		103.5	89.9	75.1	62.8	46.6	36.6	25.6	17.9	16.6	17.7
Buses		18.9	16.4	14.2	11.7	9.4	5.7	4.1	3.3	3.0	2.8
Motorcycles		28.6	22.1	21.6	20.7	21.2	22.1	23.2	24.4	25.6	26.9
All DERV		129.4	114.9	99.7	85.2	66.7	52.0	37.3	28.1	26.7	28.2
All Petrol		876.7	782.5	674.2	560.9	389.1	234.5	189.4	180.6	185.4	192.4
All Vehicles		**1006.1**	**897.4**	**773.9**	**646.1**	**455.8**	**286.5**	**226.6**	**208.7**	**212.0**	**220.6**