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METHODOLOGY FOR CALCULATING TRANSPORT EMISSIONS AND ENERGY CONSUMPTION

Edited by A J Hickman

Deliverable 22 for the project MEET
(Methodologies for estimating air pollutant emissions from transport)

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13. **Summary**

This report is a summary of all the individual methodologies and corresponding emission factors and functions produced in the MEET project, for use in estimating pollutant emissions and energy consumption from transport. It covers all current vehicle technologies for all different types or classes of road vehicles, as well as rail, shipping and air transport. For road transport, cold start extra emissions, evaporative losses, road gradient and vehicle load effects are addressed. In addition, guidance is given regarding the emissions behaviour of future vehicles and fuels. The methodologies and emission data are complemented with statistical input as regards the necessary transport activity data. Data are also provided on the pollutant emissions associated with energy production. Examples of the use of the methodologies are included in two ways: for road and rail transport, a variety of aggregated emission factors have been calculated, and comparisons have been made for passenger and freight journeys using different modes of transport.

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Contents **Page**

Figures **Page**

Tables **Page**

Page

Page

Page

Page

Page

INTRODUCTION

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1. INTRODUCTION

In the European Union, almost one third of all energy is used for transport (285 Mtoe[1] from a total of 992 Mtoe in 1995 [1][2]). Moreover, the use of energy for transport is increasing while other uses are relatively stable; between 1980 and 1995, transport energy usage increased by about 45%, while that used for industry and other purposes declined very slightly (about 0.5%). The demand for transport is closely linked with economic development. It is both a contributor to prosperity since it provides opportunities to participate in international trade, and a consequence of prosperity, allowing people more choice of recreation and leisure activities and access to a wider range of goods and services.

Transport is a very valuable and necessary part of modern society but, increasingly, its widespread and escalating existence is recognised as a major contributor to an extensive range of undesirable side-effects. Traffic congestion makes cities less pleasant and reduces the efficiency of the transport system by increasing journey time, fuel consumption and driver stress. The infrastructure used for transport activity must sometimes be built on agriculturally useful land or in locations that are sensitive for ecological, historic, aesthetic or other reasons. Thus, environmentally, economically and politically, it is important that the transport system is designed and used in the most effective way so that it satisfies the needs for personal and freight transport without creating unacceptable conditions. Its costs must be kept in check and its adverse effects on the natural and anthropological environment should be minimised.

One important detrimental environmental effect of transport is its contribution to atmospheric pollution. Each litre of fuel that is burnt produces, in very approximate terms, 100 grams of carbon monoxide, 20 grams of volatile organic compounds, 30 grams of oxides of nitrogen, 2.5 kilograms of carbon dioxide and a variety of other emissions including lead compounds, sulphur compounds and fine particles. All of these compounds are associated to some degree with air pollution problems ranging from local direct health effects to global concerns such as the greenhouse effect.

This project, MEET - 'Methodologies for estimating air pollutant emissions from transport', has been undertaken in order to provide a basic, Europe-wide procedure for evaluating the impact of transport on air pollution. It has been carried out in conjunction with the activities of COST Action 319 - ‘Estimation of pollutant emissions from transport’, and readers may refer to the final report of that Action [2] for a more comprehensive discussion of some of the scientific aspects of the research. The project brings together the most comprehensive and up-to-date information on transport vehicle emission rates and activity statistics which, together, make it possible to estimate the emissions resulting from almost any transport operation. There are, of course, many reasons other than air pollution impacts that determine any particular transport choice, but the results of this work give policy and decision makers the information necessary to test alternative transport options and ensure that their actions are, in this respect, well-informed.

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1 Mtoe = megatonnes of oil equivalent energy.

2 Numbers in square brackets [ ] refer to references that can be found at the end of each part of the report.

1.1 International activities on reporting of national air emission inventories

1.1.1 European Environment Agency and European Topic Centre on Air Emissions

The European Environment Agency (EEA) was established in 1995 in Copenhagen (Denmark) and has been fully operational since 1996.

The main tasks of the EEA are to:

- Establish, in co-operation with the Member States, and co-ordinate the European Environment Information and Observation Network (EIONET). In this context the EEA is responsible for the collection, processing and analysis of data and information.

- Provide the Community, Member States, policy makers and the public with timely, targeted, relevant and objective information necessary for framing and implementing sound and effective environmental policies that help to achieve significant and measurable improvements in Europe's environment.

- Record, collate and assess data on the state of the environment, to draw up expert reports on the quality, sensitivity and pressures on the environment.

To assist the EEA, European Topic Centres have been established for a number of topics. In 1995 the European Topic Centre on Air Emissions (ETC/AE) started its activities. The main objective of ETC/AE is to provide EEA and its clients with all necessary information on air emissions in order to support the main tasks of the EEA. The main clients of EEA and ETC/AE are the European Commission and the national governments of the EU Member States. An important product of the EEA is its regular State of the Environment report, for example the report 'Europe's Environment : The Second Assessment', published in June 1998 as an update of 'Europe's Environment : the Dobris Assessment' (1995).

The main aim of the work programme of ETC/AE is to set up an annual European air emission inventory from the year 1990 onwards (CORINAIR : CORe INventory of AIR emissions), based on official national inventories, including total emissions and emissions by source sector. ETC/AE also assists participating countries to report their national emission inventories according to the various international obligations in a consistent, transparent, complete and timely way. The main relevant reporting obligations are:

- UNECE Convention on Long Range Transboundary Air Pollution (CLRTAP)

- UN Framework Convention on Climate Change (UNFCCC)

- EC Monitoring Mechanism of Community CO_2 and other Greenhouse Gas Emissions (93/389/EEC).

ETC/AE makes available to participating countries a software package (CollectER, Collect Emission Register, June 1998) to enable the countries to report according to all these international obligations. In addition a software package (with a report and manual) to estimate national emissions from road transport was made available (COPERT2, Computer Programme for estimating Emissions from Road Transport[3]) to participating countries at the end of 1997. EEA proposes that participating countries use COPERT2 for the compilation of internationally required emission inventories. However it should be noted that for the international reporting obligations countries can report using their own more detailed methods and models, provided that background information and documentation are made available.

The COPERT2 methodology can be applied for the calculation of traffic emission estimates at a relatively high aggregation level, both temporally and spatially, for example national totals on a yearly basis. COPERT2 is based on preliminary results available at the end of 1997, from COST 319 and MEET. In the work programme of 1998 for ETC/AE, EEA has included the updating of COPERT2 to include the main results of MEET and COST319 for road transport. The software will most likely be finalised in 1999.

1.1.2 UNECE/CLRTAP/EMEP

Parties to CLRTAP (almost all European countries) are requested to report annual emissions of the following pollutants: SO_2, NO_X, CO_2, CH_4, NMVOC, CO, NH_3, various heavy metals (HMs) and persistent organic pollutants (POPs), as national totals and at least in the 11 source sectors as identified in SNAP (Selected Nomenclature for Sources of Air Pollution). For transport this means a distinction between road transport (SNAP 07) and other mobile sources (SNAP 08). However parties are encouraged to report more detailed data, on SNAP level 2 or more detailed. SNAP level 2 means for transport a source sector split as follows:

- road transport

  passenger cars
  light duty vehicles (< 3.5 t)
  heavy duty vehicles (> 3.5 t)
  mopeds and motorcycles (< 50 cm3)
  mopeds and motorcycles (> 50 cm3)
  gasoline evaporation from vehicles
  automobile tyre and brake wear

- other mobile sources and machinery

  military
  railways
  inland waterways
  maritime activities
  air traffic
  agriculture
  forestry
  industry
  households and gardening

3 COPERT2 is available through the internet: http://vergina.eng.auth.gr/mech/lat/copert/copert.htm

Methodologies for estimating emissions are described by SNAP source sector in the joint EMEP/CORINAIR Atmospheric Emission Inventory Guidebook [3], prepared by emission inventory experts working within the expert panels of the EMEP Task Force on Emission Inventories[4].

During 1997 and 1998 the first experiences from COST319 and MEET were incorporated into the Guidebook chapters on transport emissions [4][5]. In the subsequent version of the Guidebook it is intended to include the latest MEET and COST319 results.

1.1.3 UNFCCC/IPCC and EC Monitoring Mechanism

Parties to UNFCCC are requested to report annual emissions of the following pollutants : CO_2, CH_4, N_2O, NO_X, NMVOC, CO, HFCs, PFCs and SF_6. Parties are encouraged to use the Revised IPCC Guidelines for National Greenhouse Gas Inventories [5] [6] for estimating and reporting national inventories. However other national methods can be used, provided that background information and documentation are made available.

EU Member States are required to report to the Commission under the EC Monitoring Mechanism the official national emission estimates of the same pollutants, but currently not yet including HFCs, PFCs and SF_6. However in March 1998 the Commission adopted a proposal for the inclusion of all gases for which reporting is required under UNFCCC from 2000.

In the IPCC Guidelines experiences from several experts and organisations have been included, for example from expert panels under the CLRTAP/EMEP Task Force on Emission Inventories. Reporting in the following source categories for transport is required:

- civil aviation - international (bunkers), domestic
- road transport - cars, light duty trucks, heavy duty trucks, motorcycles, evaporative emissions
- railways
- navigation - international marine (bunkers), international navigation
- other transportation - pipeline transport, off-road

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4 The first version of the Guidebook (1996) was published by EEA on paper and CD-ROM and is also available on the EEA internet site (http://www.eea.eu.int).

5 The revised draft Guidebook was available in 1998 (http://www.aeat.co.uk/netcen/airqual/TFEI/unece.htm).

6 IPCC Guidelines are also available at http:/www.oecd.org/env/cc/tocinv.htm.

1.2 Trends in transport activity and emissions

As stated above, transport movements have increased continuously for many years. However, the growth has not been uniform across different transport modes and sectors, and has varied from country to country. A number of trends are presented below.

Figure 1 demonstrates changes in some forms of passenger transport within the EU. In each case, an average for the Union is shown as a bold line, which is bounded by lighter lines illustrating the variation between different Member States (the highest and lowest growth trends). While this Figure and those that follow have been compiled from the best available data (taken principally from [1] and [6]), it is often incomplete or inconsistent; nevertheless, the general observations that are made are well established even though some discontinuities may be produced artificially[7].

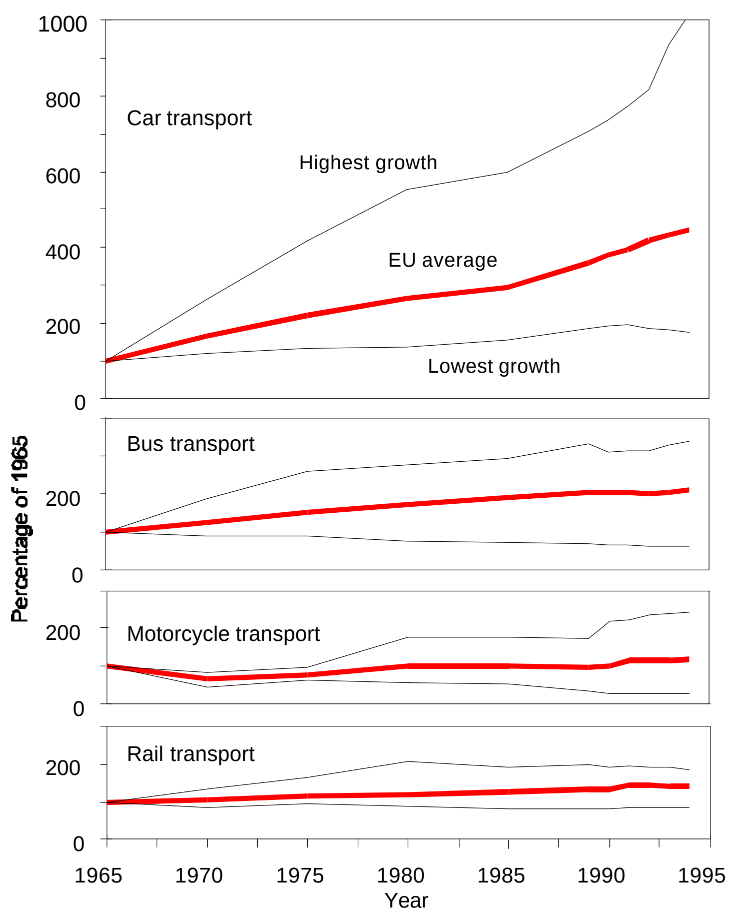

Figure 1. Trends in passenger transport in the EU

[7] One example of this is that statistics for Germany until 1990/91 usually exclude the Eastern part; its inclusion in later years gives higher values.

All forms of passenger transport have seen an increase during the period from 1965, but travel by private car has grown most. On average, car travel in 1994 was more than 4 times that in 1965; bus and train travel show smaller increases and travel on motorcycles remained more or less constant. The dominance of cars as a means of passenger transport is also shown in Figure 2, which shows that travel by road provides more than 90% of passenger transport (excluding air travel), and that more than 80% of road transport is by car. During the 30 year period shown, the proportion of travel by bus has declined, on average, from 23% to 13% of road passenger transport, and rail travel reduced from 13% to 6% of the total.

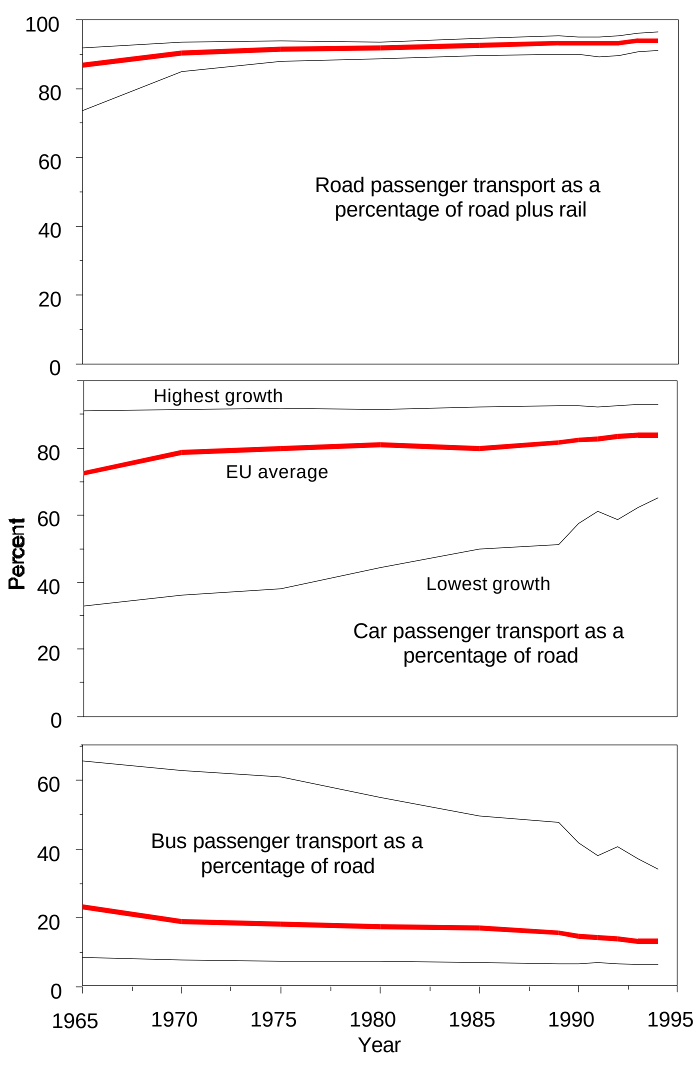

Figure 2. Trends in groundborne passenger transport in the EU

Air travel in the EU (and, indeed, from Europe to the rest of the world and *vice versa*) has shown the largest growth rate of all transport modes since 1970, when it was estimated that 43 billion passenger kilometres were flown [7], compared with 274 billion in 1995. The amount of air travel is now comparable with that on railways, at about 6% of all passenger transport.

Similar statistics for goods transport by road and rail are shown in Figure 3. In 1970, approximately 30% of freight transport was by railway, and this proportion reduced by about half in the period to 1994. The total amount of goods transport by road vehicles (expressed in tonne.kilometres) increased by a factor of around 2.5, while rail goods transport remained almost the same (a 3% reduction on average). Considering only the quantity of goods transported by road (tonnes) shows an increase over the same period of about 30%, indicating that much of the growth in road goods transport is a consequence of longer journeys, rather than the movement of more goods. Tonnes of freight transported by rail fell by about 20%, which is significantly more than the reduction in tonne.kilometres, and again indicates an increase in average journey lengths.

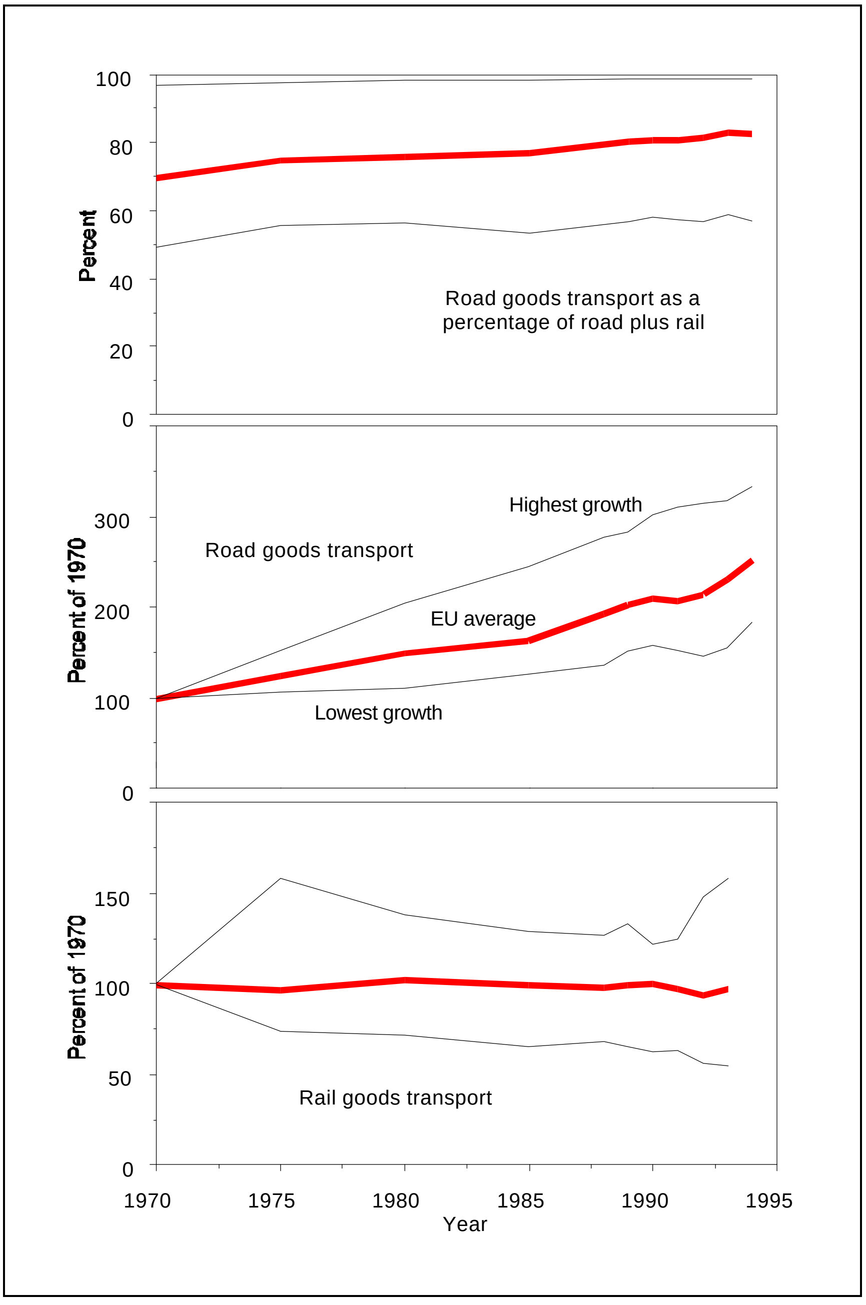

Figure 3. Trends in goods transport in the EU

The final mode of transport considered is by water, and an indication of trends in waterborne freight transport is shown in Figure 4. In some countries, particularly Germany and the Netherlands, where the proportions of freight moved in this way are 16% and 53% of the national totals respectively, inland waterways are an important means of goods transport, while they play only a minor role in other national transport systems. Overall, the amount of transport has remained fairly constant since 1965, at around 110 billion tonne.kilometres, but the modal share has declined from 12% in 1970 to a little less than 8% in 1995. Seaborne freight transport, measured as the total tonnage of goods loaded and unloaded at seaports in the EU, has increased steadily.

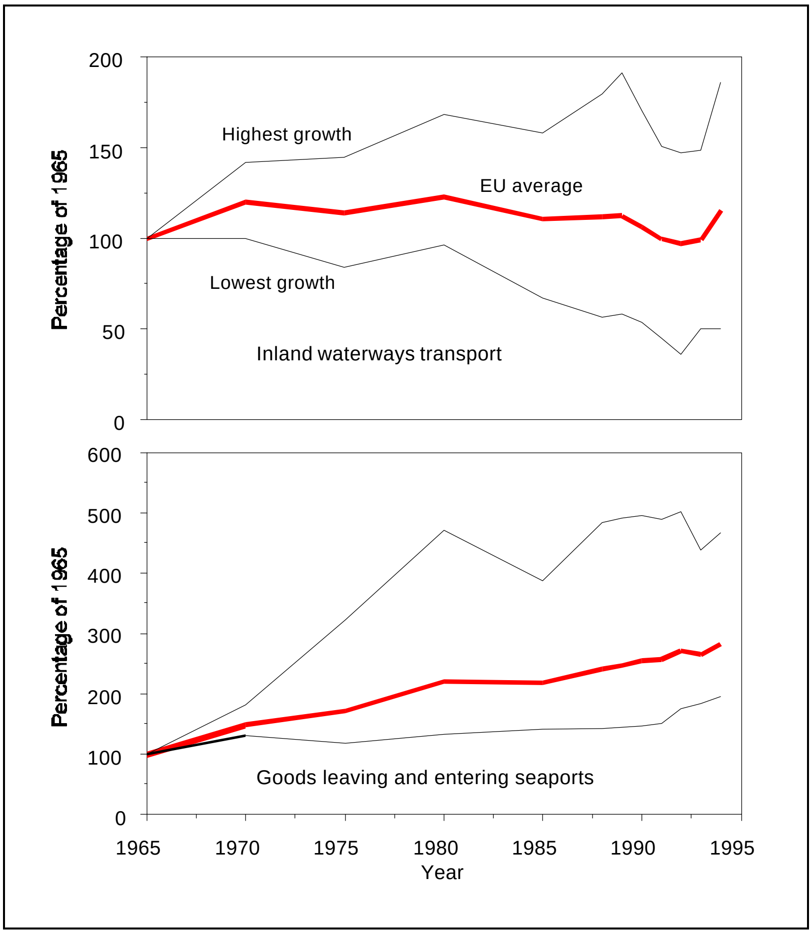

Figure 4. Trends in waterborne goods transport in the EU

Naturally, the general increase in transport activity has been accompanied by an increase in the amount of energy used to provide transport services. Figure 5 shows how transport's share of energy consumption has evolved between 1980 and 1995, increasing from a little less than 21% to almost 28%. The largest transport use is for travel by road (goods and passengers), whose proportion has increased by a third since 1980. Since the total energy usage has also risen, this represents an increase of almost a half in absolute terms. While air transport uses a relatively modest amount of total energy (about 3.5%), it is the most rapidly growing sector. The change in the proportion of energy used for air transport is about 50%, and the absolute increase approximately 70%. These data exclude the use of energy for waterborne transport, but it may be inferred from the trends in shipping activity (Figure 4) that energy use on inland waterways is likely to have remained fairly constant, while that used by sea-going vessels will have increased, perhaps by about a third since 1980.

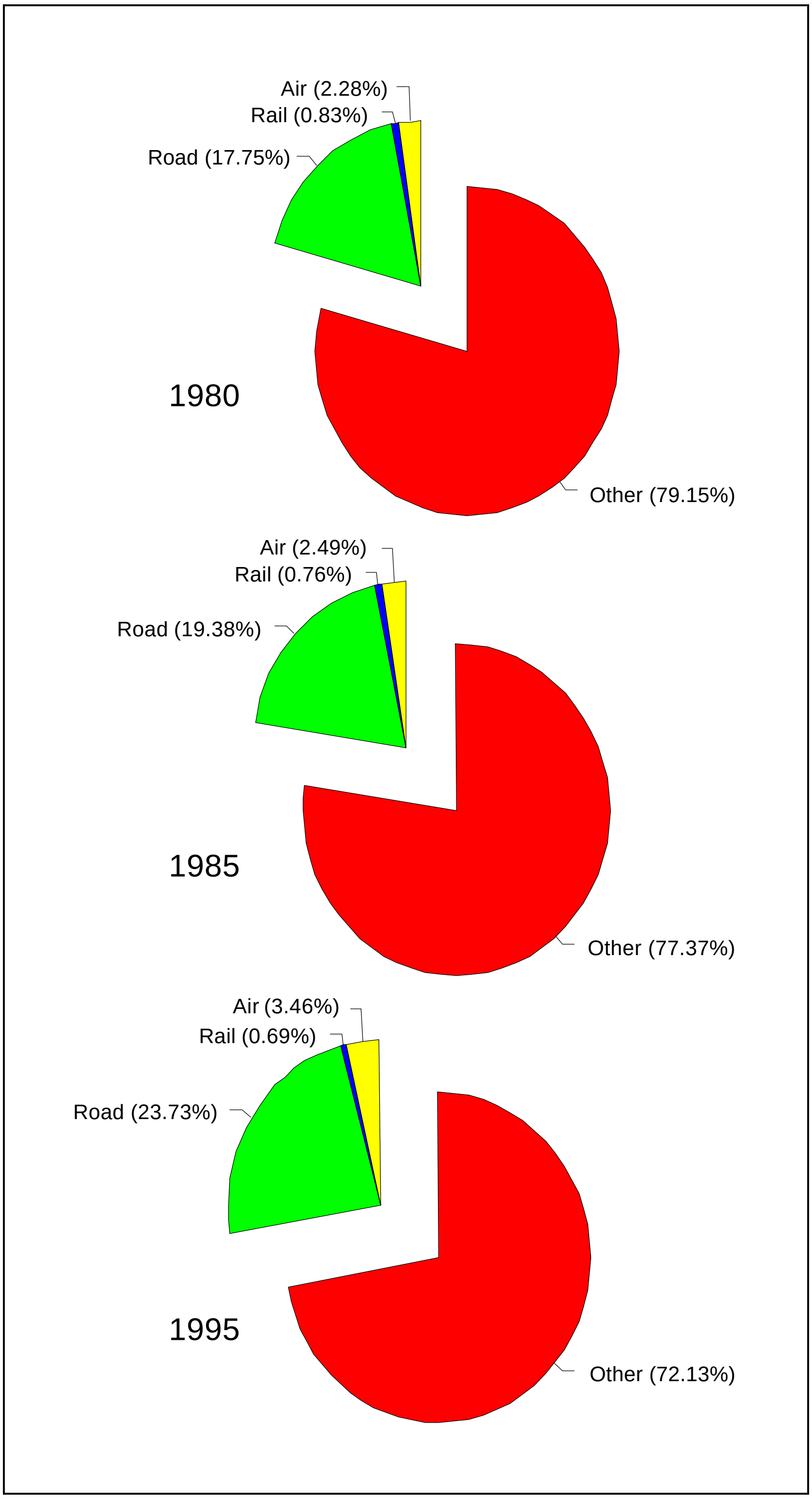

Figure 5. Changes in the use of energy for transport in the EU, 1980 to 1995

Intuitively, it might be assumed that the trends in transport activity and energy consumption would be paralleled by similar increases in pollutant emissions, but that is not the case. Very significant improvements have been made to the emission characteristics of vehicles, especially in the road transport sector since the early 1970s when the EU first introduced emission limits for light duty vehicles. The regulations have peen periodically amended to make them more stringent and to extend their application to other vehicle types. The progress to less polluting vehicles has also been assisted by improved fuel standards restricting, for example, the lead content of petrol and the sulphur content of diesel. Thus, Figures 6 and 7, which show trends in emissions of carbon monoxide and oxides of nitrogen for a selection of EU Member States between 1980 and 1995, do not reflect the strong growth trends in transport, but in many cases show an overall decline.

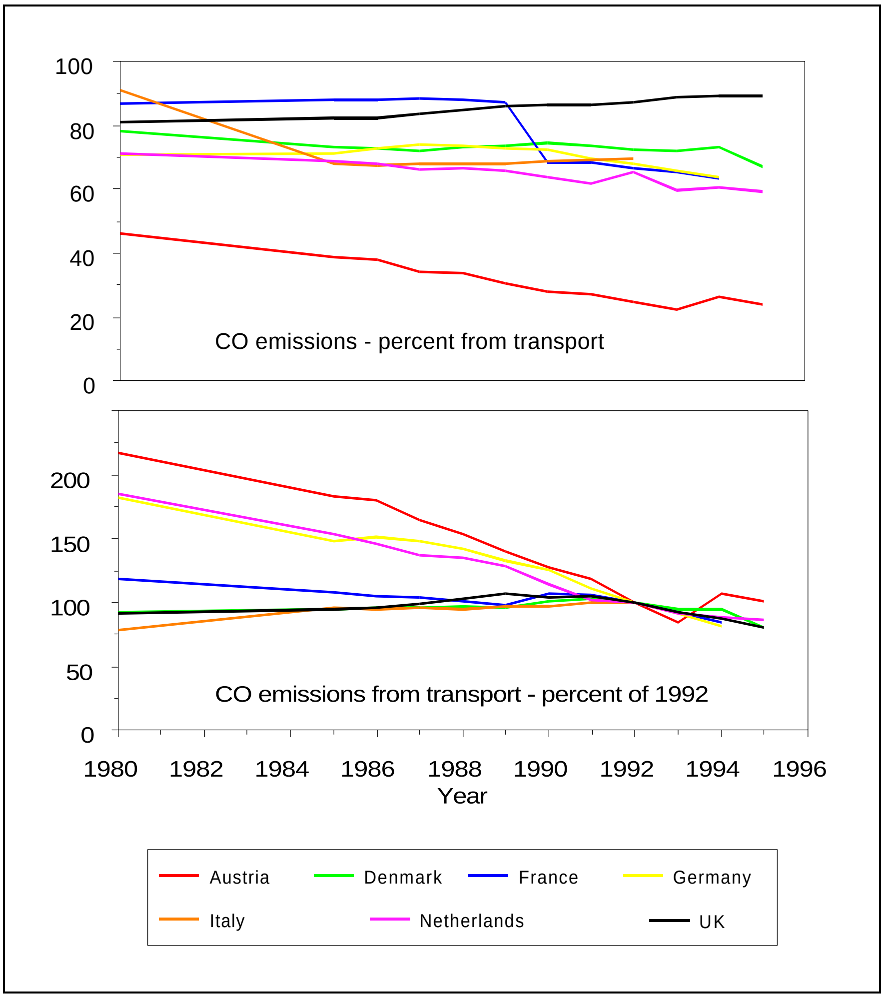

Figure 6. Trends in carbon monoxide emissions for selected EU Member States

Concerning carbon monoxide, there is a close correspondence between the trends shown and the composition of the passenger car fleets in the different countries. Uncontrolled petrol vehicles produce considerably more carbon monoxide than diesels or petrol vehicles with catalysts. Thus, there is a clear difference in the proportion of carbon monoxide from transport between, for example, the United Kingdom and Austria. Local regulations ensured the introduction of catalyst controlled vehicles in Austria well before they were introduced in the

UK, and the proportion of diesels in Austria is higher, so that in 1990, the Austrian fleet contained around 30% of 'low-emission' cars (diesel and catalyst combined). In the UK in 1990, there were virtually no catalyst equipped cars and only about 3% of diesels. Consequently, the relatively high emissions from UK cars caused the transport contribution to be greater than in Austria.

The same feature is apparent in the lower graph in Figure 6, which shows changes in carbon monoxide emissions from transport since 1980. In Austria, the Netherlands and Germany, low-emission cars were encouraged or required before the EU Directive made it obligatory, and therefore those countries show a strong downward trend over the whole time period. In Italy and the UK, there was no significant uptake of improved technology vehicles until 1992/3, so in those countries there was a tendency for emissions to increase (because of increased traffic) until that time. France shows a somewhat intermediate pattern, with an overall downward trend that is less marked than in Austria, the Netherlands and Germany. This is because of the increasing popularity of diesel cars in France, and their gradual introduction into the fleet in larger numbers.

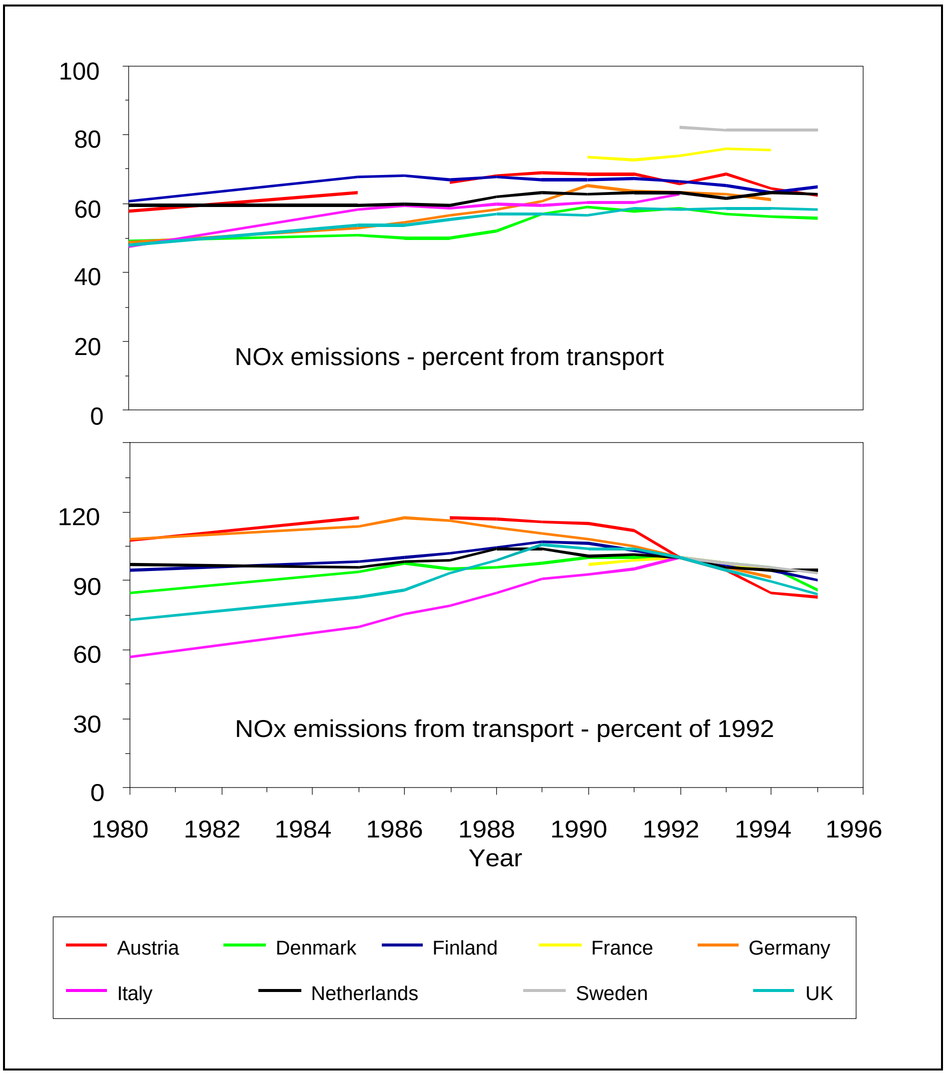

Figure 7. Trends in oxides of nitrogen emissions for selected EU Member States

The proportions of oxides of nitrogen emitted by transport sources also depend, of course, on the composition of the vehicle fleets, but are strongly influenced by the principal methods of power generation in the different countries. Power generation by combustion processes produces significant quantities of oxides of nitrogen, whereas nuclear generation and the use of renewable sources (solar, hydro, etc.) does not. In France, approximately 40% of electricity is produced by nuclear power stations, and in Sweden, a combination of nuclear and renewable energy makes up almost 50% of their total production. Not surprisingly, therefore, transport emissions of oxides of nitrogen are a higher proportion of the total than in the other countries shown. Conversely, in Denmark there is almost no non-combustion production of energy, and that country shows the lowest proportion of transport related oxides of nitrogen. Changes in the amount of oxides of nitrogen emissions from transport do not show reductions as large as for carbon monoxide because the effects of early introduction of catalyst cars and growth in the diesel share would be less effective in reducing oxides of nitrogen. Many of the early catalyst vehicles were of the open-loop type, and therefore less efficient in oxides of nitrogen control than the modern closed-loop systems and, while diesels produce less oxides of nitrogen than uncontrolled petrol cars, it is only by a factor of two to three (for carbon monoxide, the difference is a factor of ten or more). Even so, there is some evidence that the countries in which these vehicles were introduced earliest have seen greater reductions than elsewhere. Over the time period considered, emissions in Austria and Germany fell by around 20%, while those in Denmark and the UK show an overall increase (although they are now declining).

The objective behind the strenuous efforts that have been (and are continuing to be) made to control pollutant emissions from transport is to achieve improvements in air quality, and their success might best be evaluated in terms of effects on air pollution concentrations. This link is briefly examined by reference to pollution measurements made in a number of major European cities. Firstly, Figure 8 shows recorded levels of nitrogen dioxide from 1980 to 1995.

In the upper graph, annual average concentrations are plotted for each year when data are available. However, concentrations fluctuate markedly from year to year, mainly because of variations in the weather conditions, and it is difficult to discern any trends that might be attributable to changes in emissions over the period. Therefore, the lower graph has been produced showing trends produced by linear fits to the data. Once again, however, no clear pattern emerges: downward trends are seen for three cities, upward trends for two and little change for the remaining two. Nor do these general trends appear to be related to emission changes in individual countries as the two cities showing the steepest increase in concentrations are in Germany and the Netherlands where, as discussed above, low emission cars were introduced earlier than in most of Europe. It should be stated, though, that the correspondence between nitrogen dioxide concentrations and oxides of nitrogen emissions would not be expected to be simple. A large majority of the emissions is in the form of nitric oxide, which is oxidised to nitrogen dioxide in the atmosphere. Thus, the nitrogen dioxide concentration depends not only on the quantity of oxides of nitrogen emitted, but also on the quantities of oxidising agents (mainly ozone) present in the air. Near to a significant source of emissions, it is often the ozone concentration that is the limiting factor on nitrogen dioxide formation, and in those circumstances the impact of reduced emissions may be negligible.

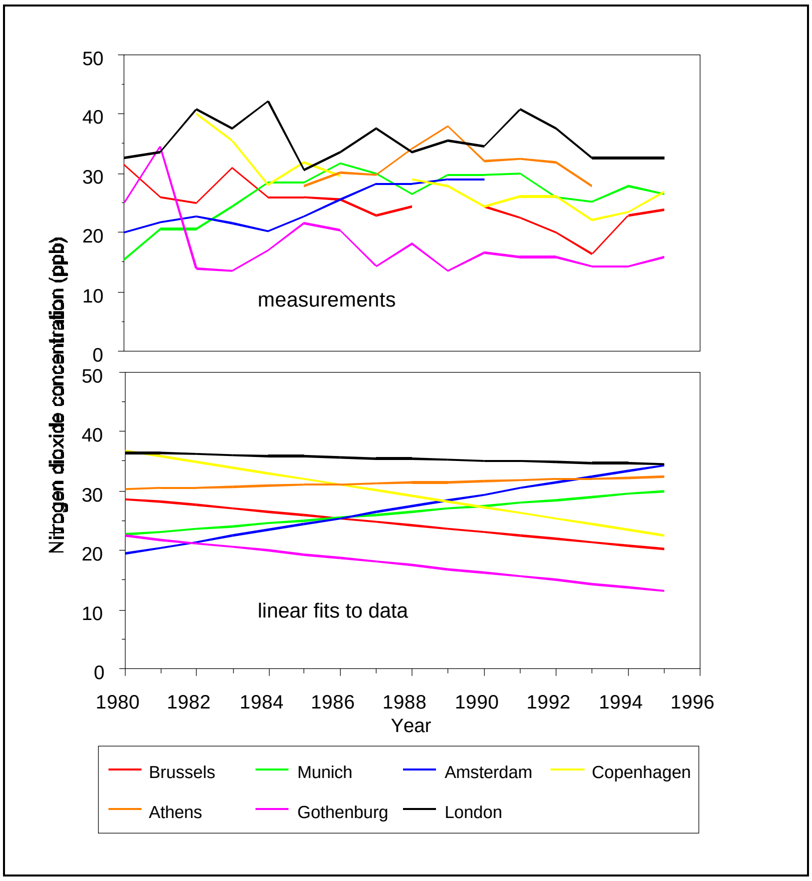

Figure 8. Annual average nitrogen dioxide concentrations measured in European cities

A second example, shown in Figure 9, presents measurements of airborne particles from another group of European cities. Because these data were measured using a range of techniques, and because the method of measurement influences its result, concentrations are not given in absolute units, but as a percentage of the level in 1985. Unlike nitrogen dioxide concentrations, those of particles show a consistent downward trend in all the cities examined, with levels in 1995 about two thirds of those in 1980. However, the extent to which reduced emissions from transport has contributed to these improvements is probably insignificant.

Diesel engined vehicles emit significantly higher levels of particles than other fuel types, and, during the period considered, diesel fuel sales increased significantly. As a total over all the countries whose cities are shown, diesel sales almost doubled, while sales of petrol increased by about 15%. This increased the average diesel share of road transport fuel from about 30% in 1980 to 45% in 1995. During the same period, as noted earlier, vehicle technologies were improving to give lower rates of emission per vehicle.kilometre. The combination of these two effects was that road transport emissions of particles showed little overall change. An example is shown in Figure 10 of estimated trends in emissions in the UK[8][8].

[8] Diesel consumption in the UK increased from 23% of road transport fuel to 35% between 1980 and 1995. Of the countries considered, the diesel share in the UK in 1995 was second lowest; in France, as a second example, the share increased from 25% to 55%.

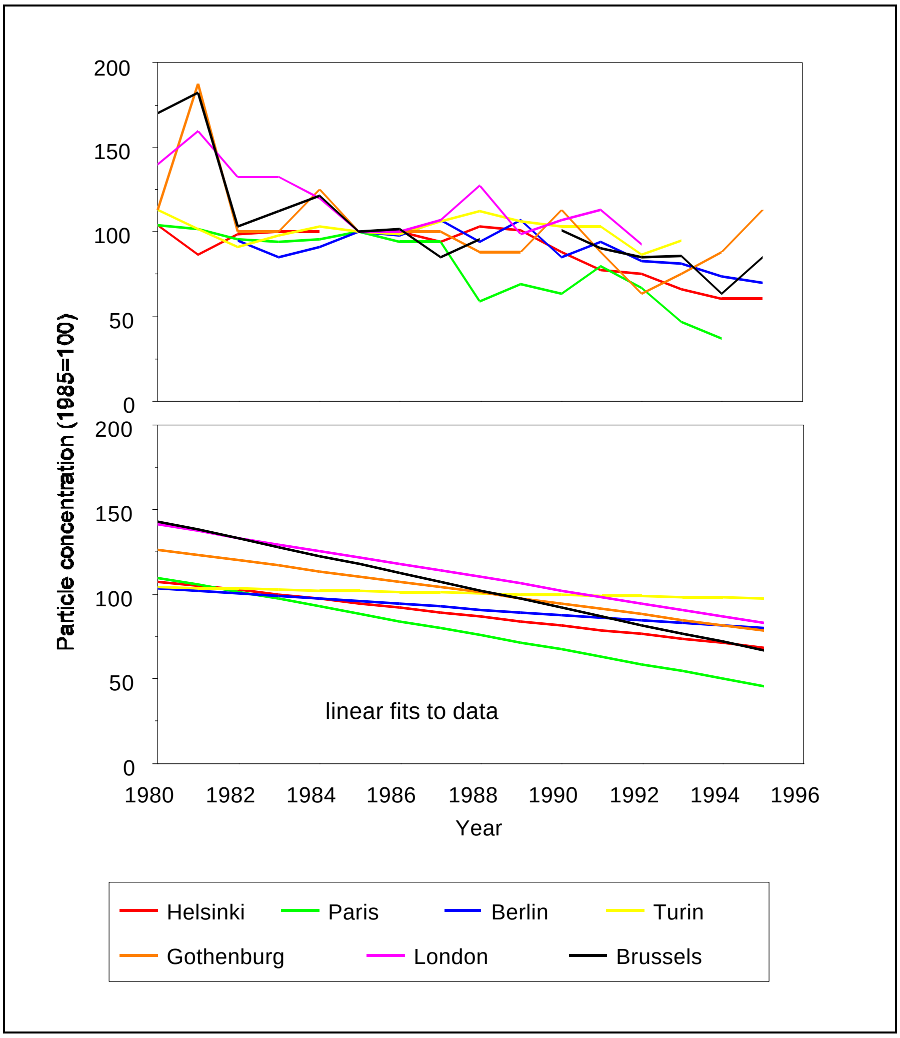

Figure 9. Annual average concentrations of airborne particles measured in European cities

The emissions from road transport are seen to rise because of increases in traffic activity and in the use of diesel, until 1990 and to fall thereafter. The net effect is that emissions in 1995 were slightly higher (ఠ2%) than in 1980. On the other hand, the lower graph in Figure 10, showing the evolution of emissions from all sources, indicates a significant fall in non-transport emissions, and that non-transport sources make a large contribution to the total production of particles. This observation is consistent with the air pollution measurements recorded in Figure 9.

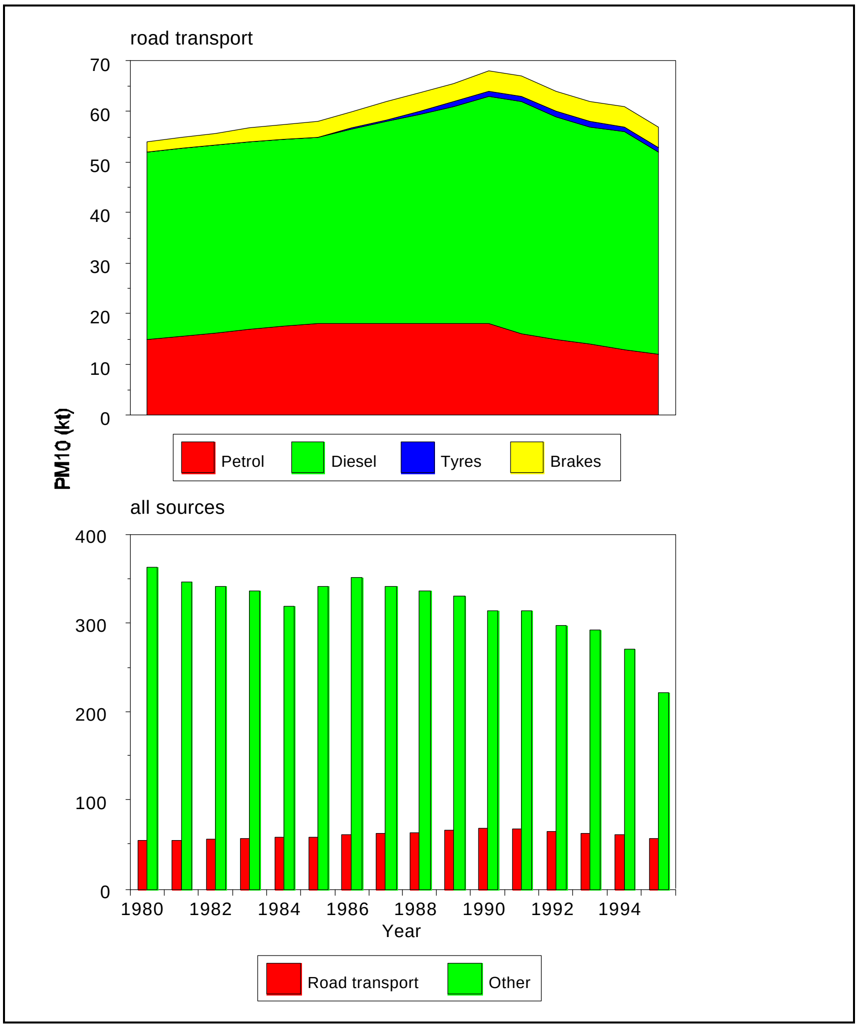

Figure 10. Emissions of particles (PM_{10}) in the UK, 1980 to 1995

It is not known to what extent the UK situation represents those of the other countries of Europe, but the general correspondence of the trends measured in the different cities suggests that it is not untypical. As regards the influence of diesel vehicles, it is of interest to compare the data from Helsinki with those from Brussels or Paris. In Finland there was virtually no change in the proportional sales of petrol and diesel between 1980 and 1995, while in France and Belgium, diesel sales more than doubled and petrol sales fell by a few percent. Consequently, it would be expected that road transport emissions of particles in Finland would show a smaller increase (or a larger reduction, depending on the balance between traffic growth and improvements in emission control) than in France or Belgium. Conversely, though, the rate of decrease in atmospheric concentrations in Helsinki was lower than Paris or Brussels. This again strongly suggests that other factors were important in achieving the improvements in air quality.

MEET does not consider the eventual translation of changes in transport emissions to changes in air pollution concentrations, but it is vital to remember that there is not a direct link. The examples discussed, concerning nitrogen dioxide and airborne particles were selected with that in mind. Not only are they perhaps the pollutants currently of most concern (in relation to human health impacts), but they also demonstrate the non-linearity between emission changes and pollution levels. In each case there is an important influence from atmospheric chemistry, and each is also produced in significant quantities by non-transport sources. Atmospheric conditions, pollution control in other sectors and contributions from the natural environment can be equally, or more important than changes in transport emissions.

The main reasons for presenting this brief summary of trends in European transport operations and emissions are to give some background information on the context of the MEET project and to try to show some of the important features necessary in evaluating transport's impacts on emissions and air quality. In its simplest form, an estimate of emissions can be seen as the product of an amount of traffic activity and an emission factor (i.e. the amount of emissions per unit of activity). Thus, consideration must be given to transport operational statistics, and trends such as those shown in Figures 1 - 4 are important. But also, since emission factors show great variation depending on features such as the mode of transport, the type of fuel used, the technological development of the vehicle and the conditions under which it is operated, it is necessary to develop a classification system whereby appropriate, disaggregated transport statistics can be matched with suitable emission factors. In the following sections, the basic principles of the MEET methodology are considered in more detail. Further parts of the report then focus on each of the main transport modes separately - road, rail, air and water -, and on the emissions produced during the production of fuels and energy used for transport. In the final part, the MEET methodology is used for a number of illustrative calculations, providing aggregated emission factors for some transport modes and in an intercomparison of transport by different modes.

1.3 Transport modes included

The mobile sources that produce air pollution, are classified by CORINAIR [3] as:

- road transport
- other mobile sources and machinery
- military
- railways
- inland waterways
- maritime activities
- air traffic
- agriculture
- forestry
- industrial
- household and gardening

In the context of this project, mobility is not the criterion used for the inclusion of a particular activity, but whether the activity is involved in goods or passenger transportation. Therefore only road transport, air traffic, railways and water transport will be considered. Water transport combines inland waterways and a part of maritime activities, since the latter includes not only transportation by sea but also non-transport activities such as fishing, water sports etc.

1.4 Pollutants covered

A large number of different species produced by transport activities are generally considered as pollutants. The production rates (i.e. the emission factors) for some of them have been investigated in detail, and are therefore well known, while for others only limited data exist, which are frequently insufficient to be representative of the relevant activities. Consequently, it is possible currently to provide soundly based emission factors for some of the pollutants and some of the vehicle categories; for others it is possible to provide only order of magnitude estimates of the emission factors, while for the rest the available information is so little that it can not be presented.

For this reason, it was decided to classify the pollutants in three levels, according to the reliability of the available data on emission factors:

- Level 1: includes the pollutants for which the existing data allow for the definition of representative emission factors with a high degree of certainty[9]**.**

- Level 2[10]: this level includes the pollutants for which the existing emission factors cannot be considered representative: emission factors given for level 2 pollutants are to be considered only as an indication of the order of magnitude.

- Level 3: includes the pollutants for which there are only very few data, and no emission factors will be given.

The general list of pollutants includes:

- carbon dioxide - CO_2 (not defined as a pollutant yet by the legislation, considered here because of its contribution to the greenhouse effect)
- carbon monoxide - CO
- volatile organic compounds (also referred to as hydrocarbons) - VOC (HC)
- oxides of nitrogen - NO_X
- particulate matter - PM
- sulphur dioxide - SO_2
- lead compounds - Pb
- nitrogen dioxide - NO_2
- ammonia - NH_3
- nitrous oxide - N_2O
- other heavy metals - HM (cadmium - Cd, zinc - Zn, copper - Cu, chromium - Cr, nickel - Ni, selenium - Se)
- hydrogen sulphide - H_2S.

9 The term certainty as used here is relative to the quality of data for levels 2 and 3. No emission factors are known with absolute certainty.

10 The distinction between levels 2 and 3 is not clearly defined as there is no definite point at which the degree of uncertainty in the data precludes the specification of an approximate emission factor.

The VOCs include a large number of different organic compounds, with varying impacts on the environment and on human health, therefore it is of interest to further subdivide this pollutant into two categories:

- methane - CH_4
- non-methane hydrocarbons (NMVOC).

Some of the non-methane hydrocarbons are well known mutagenic compounds. A known sub-category of VOC in this context is polycyclic aromatic hydrocarbons (PAH), and the individual compounds benzene (C_6H_6) and 1,3-butadiene (C_4H_6).

The particulate matter also has different effects depending on the size of the particles. It is therefore of interest to know the size distribution of PM.

In addition, energy consumption is also considered; either by calculation from carbon containing pollutants in the case of road transport, or for non-road modes, as the primary parameter from which other emissions are estimated.

Considering the above sub-categories to be different pollutants, Table 1 presents them using the three level classification defined for the project. The importance of the pollutants classified in levels 2 and 3 should be stressed. Table 2 lists the compounds for which the EU has proposed or intends to propose air quality standards, and it is noteworthy that many of them fall into levels 2 and 3. It is therefore strongly recommended that research be carried out in order to collect sufficient data to allow for the future definition of soundly-based emission factors for these pollutants.

Table 1. Pollutant categories according to the present knowledge of emission factors

Pollutant	Level 1	Level 2	Level 3
Energy consumption	❄		
CO_2	❄		
CO	❄		
VOC	❄		
NO_X	❄		
PM	❄		
SO_2	❄		
Pb	❄		
N_2O		❄	
CH_4		❄	
NMVOC		❄	
VOC speciation (PAH, benzene etc.)		❄	
PM size distribution			❄
NH_3			❄
H_2S			❄
NO_2			❄
HM			❄

Table 2. Pollutants for which EU air quality standards are proposed

Pollutant	Limit value	Target date
Benzene	Annual average 0.5 $\mu g/m^3$	2010
Carbon monoxide	8-hour rolling mean 10 mg/m^3	2010
Lead	Annual average 0.5 $\mu g/m^3$	2005
Nitrogen dioxide	1-hour average 200 $\mu g/m^3$ not exceeded more than 18 times a year Annual average 40 $\mu g/m^3$	2010
PM_{10}	24-hour average 50 $\mu g/m^3$ not exceeded more than 35 times a year Annual average 40 $\mu g/m^3$	2005
Sulphur dioxide	1-hour average 350 $\mu g/m^3$ not exceeded more than 24 times a year Daily average 125 $\mu g/m^3$ not exceeded more than 3 times a year	2005
PAH	No proposal yet	
Cadmium	No proposal yet	
Arsenic	No proposal yet	
Nickel	No proposal yet	
Mercury	No proposal yet	

1.5 Spatial and temporal resolution

The effects of air pollution cover the whole range of spatial sizes, from local to global. On a local scale (single streets, urban areas, railway stations etc.) pollution affects public health and the quality of life. Regionally, pollution affects plants and the built environment, through the dispersion, deposition and chemical transformation of the pollutants (photochemical reactions, acid rain), and continues to impact on human health as many products of photochemical reactions (secondary sulphate and nitrate particles, ozone etc.) cause adverse health effects and may be transported over long distances. Globally, pollution is related to climate changes and the depletion of the stratospheric ozone layer. Figure 11 schematically presents the extent of these various pollutant effects. It is clear that there is no general optimum spatial resolution for the calculation of emissions, this optimum depending each time on the specific application. The same is also true for temporal resolution, as some effects depend on the incidence of short term peak concentrations while others act over periods of many years.

Effect	Pollutant									
	PM	HM	NH_3	SO_2	NO_X	NMVOC	CO	CH_4	CO_2	N_2O
LOCAL (health + quality of life)										
REGIONAL										
acidification										
photochemical										
GLOBAL										
greenhouse effect (indirectly)										
greenhouse effect (directly)										

stratospheric ozone layer										

Figure 11. Effects of transport related pollutants (adapted from [9]).

Table 3 presents possible spatial and temporal resolutions. At least in theory, every combination shown in Table 3 is possible. Naturally, the finer the resolution, the greater becomes the amount of detail of the data required for the calculation, with increasing accuracy requirements as well. Therefore the selection has to take into account the purpose of the calculation, keeping in mind the extent of the effects, as shown in Figure 11, in order to keep the data collection effort to a reasonable level. It is, for example, necessary to know the CO, NMVOC and NO_X emissions on an hourly basis and for major emission sources within a study area, in order to have sufficient input data for pollutant dispersion modelling, to allow the estimation of ambient pollutant concentrations or in order to develop anti-pollution strategies for the area. On the other hand the calculation of N_2O emissions hourly from each source is not needed, since it is known that this pollutant has a cumulative, long-term effect, related to climate change. Therefore, in this case, the average emission over the year for the whole area is sufficient for the basic needs of scientific research.

Table 3. Possibilities for temporal and spatial resolution for emission calculation

TEMPORAL	SPATIAL
Hour	Local (urban street, highway, etc.)
Day	City
Week	Region of Country
Month	Country
Season	Region of continent
Year	Global

Figure 12 schematically shows the limits of the spatial and temporal resolutions for emission calculation in terms of the different pollutants. Where the effects of a certain compound are only important on a large geographical scale and long time scale, it is superfluous to attempt to estimate with greater detail. Thus, the greenhouse gases (CO_2, CH_4 etc.) are shown in the top right of the graph, representing annual average calculations on a global scale. Of course, an estimate of emissions on a global scale will probably be derived as the sum of more local calculations, but they need not provide fine detail. Pollutants which cause short term, local impacts must be treated with greater resolution, and some of these (CO, NO_X etc.) are shown in the lower left, indicating local estimates on an hourly time base. However, in this case, this shows only the maximum resolution as many of these compounds also contribute to large-scale problems. CO, for example, is eventually oxidised to CO_2, and so contributes to global warming; NO_X and VOC are important ozone precursors on a regional scale. Where the objective of a calculation is to address these types of issue, it is unnecessary for emission estimates to be made with the maximum resolution.

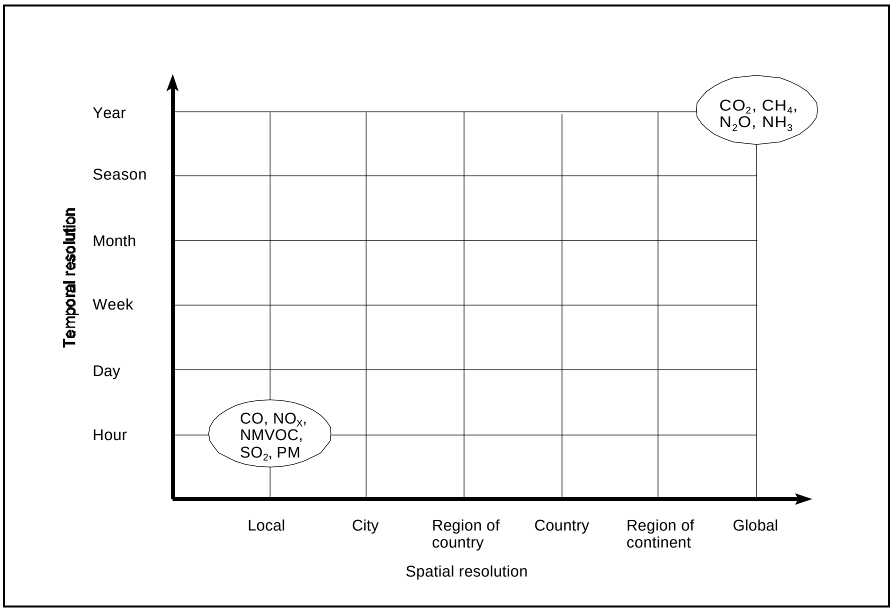

Figure 12. Usually required spatial and temporal resolution combinations

Table 4 lists typical combinations of spatial and time scales used in practice. These cover most known applications, but there may be some unusual circumstances requiring other combinations, and in some cases it may be necessary to take a finer resolution into account in order to produce an aggregated estimate. For example, Table 4 suggests that global estimates are not usually required with a greater time resolution than an annual average, and that is indeed so. However, many emissions depend strongly on ambient conditions, and they may vary widely during the year, so the annual mean may have to be derived from the aggregation of monthly or seasonal estimates.

Table 4. Typical combinations of spatial and temporal resolution

	HOUR	DAY	WEEK	MONTH	SEASON	YEAR
LOCAL	◆	❖	❖	❖	❖	❖
CITY		◆	❖	❖	❖	❖
REGION OF COUNTRY					◆	❖
COUNTRY					◆	❖
REGION OF CONTINENT						◆
GLOBAL						◆

◆ primary estimation of maximum resolution
❖ secondary estimation (aggregation)

The following conclusions are based on Table 4:

- the simulation of air pollution over an urban area requires the knowledge of emissions at a rather fine grid (of the order of 500 x 500 m), on an hourly basis. Such an approach allows for the development of different emission profiles for the time periods with known different behaviour (e.g. day and night, working days and weekends, summer and winter, etc.).

- the knowledge of the seasonal variation of emissions over a country is usually sufficient, even though it is possible to increase the temporal resolution using adequate disaggregation profiles, if such resolution is needed. The production and storage of information required for very high temporal resolutions is not recommended in this case, because of the amount of data required and the nature of pollution effects on such a scale.

1.6 Calculation methods for energy consumption and emissions

A variety of methods are used to calculate energy consumption and emissions, as detailed in the following parts of the report. They depend on the pollutant, the transport mode and the vehicle type, and are inevitable because of the varying amounts and quality of data in each case. The methods may be grouped into four classes:

- *calculation based on transport activity* - this is the basic method for the more common emissions from road vehicles and for the energy consumption for non-road modes; the emissions calculated in this way may include hot emissions, trip start emissions when the engine is not fully warmed up, and evaporative emissions

- *calculation based on energy consumption* - this is the standard method for emissions from non-road modes, and also for SO_2 and Pb emissions from road vehicles; the types of emission included (hot, start, evaporative) depend on those included in the energy consumption estimate

- *carbon balance calculations* - calculations of fuel consumption or carbon dioxide emissions may be based on the equation representing the mass balance of carbon in the fuel and its combustion products; for road vehicles (with combustion engines), the method is applied to calculate fuel consumption, while for other modes it is used to calculate CO_2; it may take into account hot, start and evaporative emissions (see section A1.2 for details of the calculation[11]**)**

- *pollutant specific calculations* - some pollutants are sub-categories of others (e.g. VOC species are part of total VOC, particle size fractions are part of total PM); estimates may be made from the main pollutant and details on speciation and size distribution; hot, start and evaporative emissions may be included.

Table 5 gives a more detailed indication of the methods appropriate in different cases.

[11] While details of the carbon balance method are given in the road transport part of the report, it may be used for any combustion engine using a carbon containing fuel.

Table 5. Methods of calculating different pollutant emissions according to the transport mode and engine type

		Combustion engines				Electric motors
		Road	Rail	Water	Air	(road, rail)
Energy consumption		1	2	2	2	2
Exhaust and evaporative emissions	CO_2	2, 3	5	5	5	
	CO	2, 3	4	4	4	
	VOC	2, 9	4	4	4	
	NO_X	2, 3	4	4	4	
	PM	2, 3				
	SO_2	4				
	Pb	4				
	N_2O	2, 3				
	CH_4	2, 6				
	NMVOC	2, 6				
	VOC spec.	7				
	PM size	8				
	NH_3	2				
	H_2S	2				
	NO_2	2				
	HM	2				
Energy production emissions	CO_2	4	4	4	4	4
	CO	4	4	4	4	4
	VOC	4	4	4	4	4
	NO_X	4	4	4	4	4
	PM	4	4	4	4	4
	SO_2	4	4	4	4	4
	CH_4	4	4	4	4	4
	NMVOC	4	4	4	4	4

Key:
1 Fuel consumption = f(CO, CO_2, VOC, PM) [carbon balance]
2 Calculation according to the activity
3 Emission = hot emission + start emission
4 Emission = f(energy consumption) [energy specific emission factors]
5 Emission = f(fuel consumption, CO, VOC, PM) [carbon balance]
6 NMVOC + CH_4 = VOC
7 VOC species = f($VOC_{exhaust}$, $VOC_{evaporative}$, $VOC_{composition}$)
8 PM size = f(PM, $PM_{size\ distribution}$)
9 Emission = hot emission + start emission + evaporative emission

1.7 References

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Part A. ROAD TRANSPORT

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A1. INTRODUCTION

Road vehicle emissions have justifiably received the greatest attention of all transport modes because of their dominance as a means of transporting both passengers and goods. Not only does road transport have the biggest share of transport activity, but its decentralised and groundborne nature bring it into close proximity with more people than the other modes. Because a large amount of information on road transport emissions is available[12], it has been possible to propose a relatively detailed methodology. In later parts of the report it will be seen that this has not been possible for the non-road transport modes. An outline of the methodology is given below, and that is followed by a detailed description of the procedure and the data required for its application.

A1.1. Basic principles

The main sources of emission from road vehicles are the exhaust gases and hydrocarbons produced by evaporation of the fuel. When an engine is started below its normal operating temperature, it uses fuel inefficiently, and the amount of pollution produced is higher than when it is hot. These observations lead to the first basic relationship used in the calculation method, i.e:

$$E = E_{hot} + E_{start} + E_{evaporative} \qquad \text{(A1)}$$

where:

E	is the total emission
E_{hot}	is the emission produced when the engine is hot
E_{start}	is the emission when the engine is cold
$E_{evaporative}$	is the emission by evaporation (only for VOC)

Each of these contributions to the total emission depends on an emission factor and one or more parameters relating to the operation of the vehicle, so that in general:

$$E_x = e_x \times a \qquad \text{(A2)}$$

where:

E_x	is one of the contributions to total emissions
e_x	is an activity related emission factor
a	is the amount of traffic activity relevant to this type of emission

The parameters e_x and a are themselves functions of other variables.

For hot emissions, the activity related emission factor, e_{hot}, is expressed primarily as a function of the average speed of the vehicle. Modification factors (which may themselves be functions of other variables) allow corrections to be made for features such as the road gradient or the load carried by a vehicle. The activity, a, is then the amount of operation (vehicle.kilometres)

[12] This statement does not imply that there are no lacks or uncertainties in the data. The term 'large amount' is used relative to information available for other modes.

carried at a particular average speed, on roads with a certain gradient, for vehicles with a certain load[13].

Start emissions, because they only occur during the early part of a journey, are expressed as an amount produced per trip, and not over the total distance travelled. The emission factor, e_{start}, is calculated as a function of the average vehicle speed, the engine temperature, the length of the trip and the length of the cold part of the trip. The activity, *a*, is the number of trips. This procedure is used only for light duty vehicles. Because data for other types is very limited, such detail cannot be used, and cold start emissions are proposed simply as constants (excess emissions per cold start).

Evaporative emissions occur in a number of different ways. Fuel vapour is expelled from the tank each time it is refilled, the daily increase in temperature (compared with overnight temperatures) causes fuel vapour to expand and be released from the fuel tank, and vapour is created wherever fuel may be released to the air, especially when the vehicle is hot during or after use. There are therefore a number of different emission factors, $e_{evaporative}$, depending on the type of evaporative emission. Generally, these factors are a function of the ambient temperature and the fuel volatility. Similarly, a number of activity data are also needed, including total distance travelled and numbers of trips according to the temperature of the engine at the end of the trip.

These principles apply, with some exceptions, to all pollutants and vehicle types, but different classes of vehicle behave differently and relationships between emissions and operating characteristics vary for each pollutant. For that reason, an estimate of emissions from mixed traffic must be made as a summation of emissions from each homogeneous vehicle class in the traffic, and where the area studied contains roads with different traffic behaviour, this must also be taken into account. And, of course, this must be done separately for each pollutant.

A1.2. Fuel consumption, lead and sulphur dioxide emissions

The combustion of a hydrocarbon fuel (such as petrol, diesel, CNG) in air, in ideal conditions follows a simple chemical reaction:

$$C_x H_y + \left(x + \frac{y}{4} \right) O_2 = x\, CO_2 + \frac{y}{2} H_2O \qquad \text{(A3)}$$

where:

C_xH_y is the fuel (a compound of carbon and hydrogen)
O_2 is oxygen from the air
CO_2 is carbon dioxide
H_2O is water

[13] Other factors may also be taken into account, as will be described in the detailed methodology. Here, only a limited set of parameters is mentioned for the sake of clarity.

Because the masses of reactants and products are related in accordance with their molecular weights, it is possible to determine the amount of CO_2 and water that would be produced from a certain weight of fuel or *vice versa*. For example, the mass of carbon in the fuel is given by:

$$[C]=[C_xH_y]\times\frac{12}{(12x+1y)} \tag{A4}$$

where:

$[C]$	is the mass of carbon
$[C_xH_y]$	is the mass of fuel
12 and *1*	are the approximate atomic weights of carbon and hydrogen respectively[14]

this amount of carbon would combine with oxygen as follows:

$$[C]+\left([C]\times\frac{32}{12}\right)O_2=[CO_2] \tag{A5}$$

where:

$[CO_2]$	is the mass of carbon dioxide produced
32	is the approximate molecular weight of oxygen

In practice, the fuel combustion does not proceed according to the ideal equation; some of the carbon is incompletely oxidised and is emitted as CO or carbon particles (PM), some fuel escapes combustion and is emitted as VOC, and NO_X are produced because of the oxidation of nitrogen in the air and traces in the fuel itself. Nevertheless the same principle may be used to calculate the amount of fuel that would produce a certain combination of CO_2, CO, VOC and PM since there must be a balance between the total carbon in the fuel and the total carbon in all of the combustion products. Alternatively, the mass of any one of the carbon containing pollutants may be calculated from the mass of fuel and the amounts of the others. However, this would be imprecise except for CO_2 because the other compounds are produced in relatively small amounts.

Emission tests usually include the measurement of CO_2 as well as the other pollutants, and it is less frequent that fuel consumption is measured directly. For that reason, road transport emission factors are presented for the exhaust components, including CO_2, and fuel consumption may be derived using the 'carbon balance' method outlined above, using the following equation:

$$[FUEL]=(12+r_1)\times\left\{\frac{[CO_2]}{44}+\frac{[CO]}{28}+\frac{[HC]}{(12+r_2)}+\frac{a[PM]}{12}\right\} \tag{A6}$$

where:

[14] The exact atomic weights of the elements vary by very small amounts from these whole numbers, but uncertainties in other variables are far greater, and it serves no useful purpose to be more precise.

[*FUEL*] is the mass of fuel
[CO_2], [*CO*], [*HC*] and [*PM*] are the masses of exhaust pollutants
r_1 and r_2 are the hydrogen to carbon ratios of the fuel and HC emissions respectively[15]
✂ is the proportion of carbon in the PM emission[16]

It is also uncommon to find directly measured data on the emissions of lead and sulphur dioxide, but this is unimportant as they may be estimated with reasonable accuracy from the fuel consumption and the amounts of lead and sulphur in the fuel. Some lead compounds are retained in the exhaust system, the engine and the lubricating oil, and it is customary to assume that 75% of the lead in the fuel is released to the atmosphere. All of the sulphur in the fuel is assumed to be emitted, and the amount may be expressed directly as sulphur, or as sulphur dioxide by simply doubling the amount of sulphur (because the molecular weight of SO_2 is twice the atomic weight of sulphur).

A1.3. Other non-standard emissions

It was noted earlier that the amounts of information available for some pollutants were insufficient to allow detailed emission factors to be specified, and Table 1 gave a classification of pollutants according to the certainty or uncertainty of the emissions data. For some of these compounds it is possible to make order of magnitude estimates using the limited data or by inference using data for other pollutants. Table A1 lists the pollutants again, with the confidence level that was assigned, and gives an indication of the method recommended for their calculation[17,18].

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[15] It may be assumed that r_1 and r_2 are equal, and typical values are 1.8 for petrol and 2.0 for diesel

[16] Where this is not known, a value of 1 may be used for ✂. While it is not in fact the case that all of the PM is emitted as carbon, the assumption will make little difference to the calculated fuel consumption as the mass of PM is very small compared with those of the other emissions.

[17] If sufficient data exist, it is always possible to use the standard methods. The other methods may be used as alternatives in the absence of adequate direct data

[18] Although methods are indicated for all pollutants, it should be remembered that data limitations, especially for those in level 3 and for cold and evaporative emissions, may make their estimation with reasonable accuracy impossible.

Table A1. Pollutants, confidence classes and calculation methods

Pollutant	Level	Calculation method	Contributions
CO_2	1	Standard methods	hot, cold
CO	1	Standard methods	hot, cold
VOC	1	Standard methods	hot, cold, evap
NO_X	1	Standard methods	hot, cold
PM	1	Standard methods	hot, cold
Fuel consumption	1	From CO_2, CO, VOC, PM	hot, cold,(evap)
SO_2	1	From fuel consumption and sulphur content	hot, cold,(evap)
Pb	1	From fuel consumption and lead content	hot, cold,(evap)
N_2O	2	Standard methods	hot, cold
CH_4	2	From the relationship VOC = NMVOC + CH_4, if either NMVOC or CH_4 is known	hot, cold
NMVOC	2		hot, cold, evap
VOC species	2	From VOC emissions and fuel composition	hot, cold, evap
PM by size	3	From PM emissions and size distributions	hot, cold
NH_3	3	Standard methods	hot, cold
H_2S	3	Standard methods	hot, cold
NO_2	3	Standard methods	hot, cold
HM	3	Standard methods	hot, cold

A2. ROAD TRANSPORT EMISSION MODELS

A2.1 Types of emission model

Estimates of road transport emissions on a national basis, and more locally as part of pollution impact studies, have been made in some European countries since the 1970s. The methods used have been improved and developed since then, mainly depending on the amount, type and quality of data available. Currently, there are three principal methods in use, which vary mainly in the way that they treat the interaction between vehicle operation and the corresponding emissions.

The longest established of these methods exploits the fact that average emissions over a trip vary according to the average speed of the trip. The characteristic shapes of the speed-emission curves are well known (see, for example, Figure A1), and though they vary somewhat depending on the type of vehicle and the pollutant, they generally show high emissions at slow average speeds when the vehicle operation is inefficient because of stops, starts and delays, a tendency to high emissions at high speeds because of the high power demand on the engine, and minimum emissions in the middle speed range.

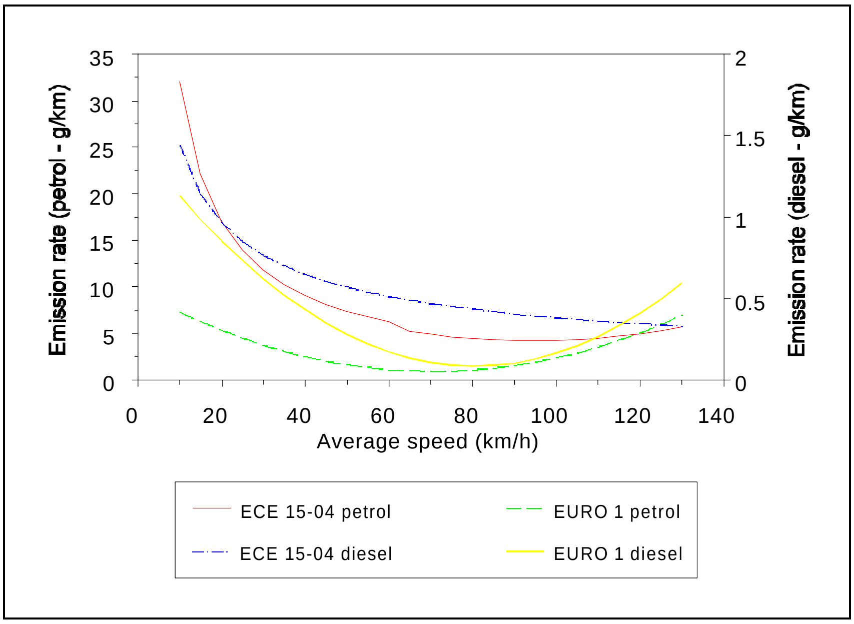

Figure A1. Carbon monoxide emissions from passenger cars as a function of average speed

The measurements from which speed-emission curves are derived are nearly always performed on a chassis dynamometer, where the test vehicle is operated over a certain drive cycle while its emissions are collected and analysed. The relationship with average speed is determined by combining results from tests using cycles with different average speeds. The accuracy of the relationships can depend strongly on the extent to which both the vehicle sample tested and the driving cycles are representative of the in-use fleet and its operation. For the MEET project, the latter of these issues was addressed by using only data from measurements using cycles based on real world operation. These contrast significantly with the other commonly used cycles on which the type approval tests are based. In the second case, the driving cycles are often very stylised, and bear little relationship to real driving patterns on the road. Figure A2 gives an example of a typical urban driving cycle together with the urban part of the EU type approval cycle for cars. Clearly, the amount and frequency of transient operation is far greater in the realistic example. The cycles and vehicle samples that formed the MEET database for passenger cars and light duty trucks are described in detail in Deliverable 7 [A20].

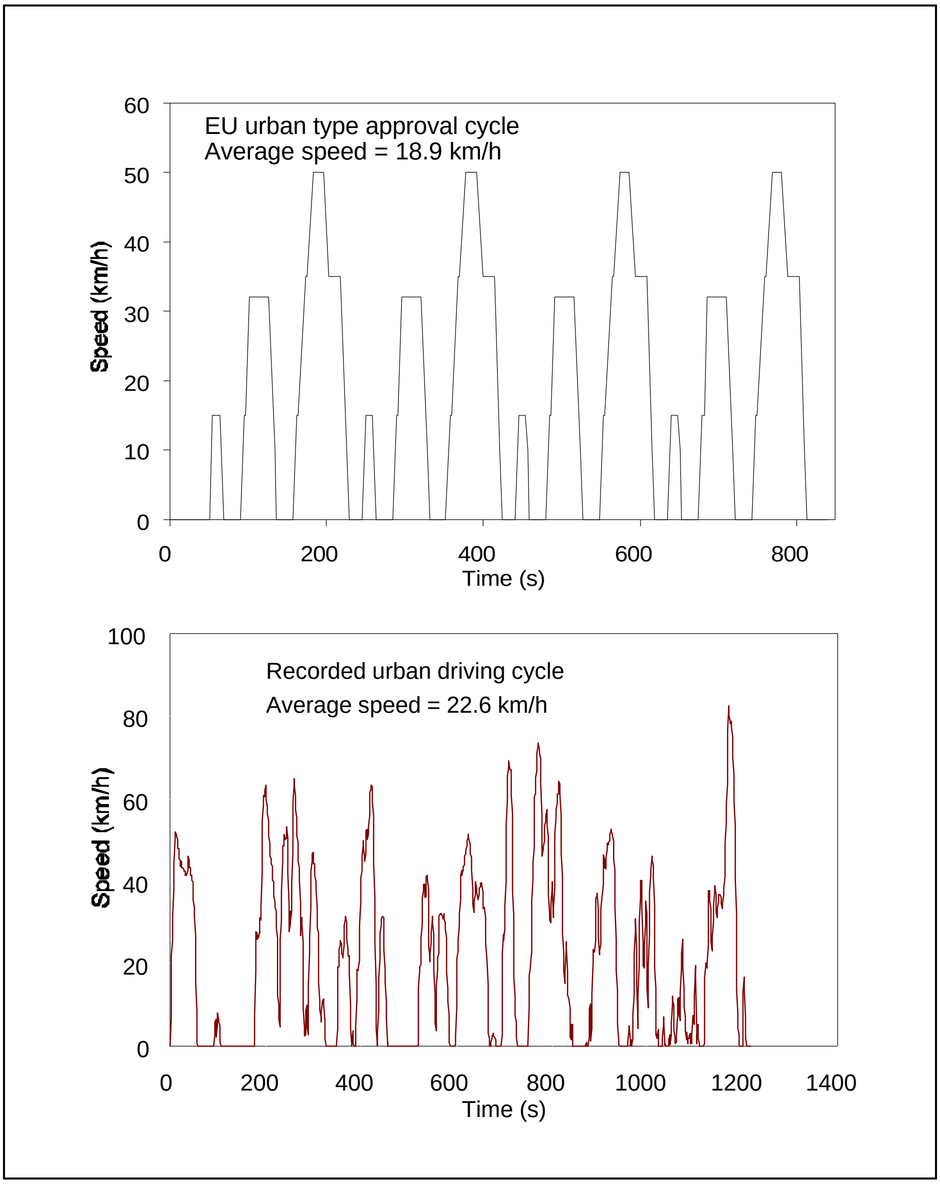

Figure A2. Examples of driving cycles for passenger car emission tests

It is clear, though, that a certain average speed may be achieved in a number of different ways: a ten minute trip at an average of 40 km/h could be driven constantly at 40 km/h, for 5 minutes at 80 km/h with a 5 minute delay or any way between these extremes. Because of the possible differences in operation at the same average speed, other methods have attempted to classify the vehicle operation to take this into account. Trips are specified by the vehicle speed, but also by another variable that defines the amount of speed variation.

In the Swiss/German 'Handbuch der Emissionsfaktoren des Strassenverkehrs', the second variable is not a quantified parameter, but is a verbal description of the type of traffic situation for which an emission factor is applicable. For each traffic situation, pollutant and vehicle type (a classification similar to that shown in Table A5 is used), a unique emission factor is given. Because each traffic situation is associated with a certain average speed, it is possible to show the Handbuch data in terms of the average speed for comparison with the more conventional speed-emission curves (Figure A3). The emission factors from the Handbuch show a similar general pattern to those produced from the speed-emission curve, but do not conform to such a regular function. This is because each individual factor represents a defined type of vehicle operation rather than the average operation at a certain average speed. Thus, for example, in the speed range from 60 to 80 km/h the speed-emission curve generates emission rates in a relatively narrow range (about 0.95 to 1.1 g/km) while those from the Handbuch vary from 0.9 to 2 g/km because of the greater variation of operating conditions they cover.

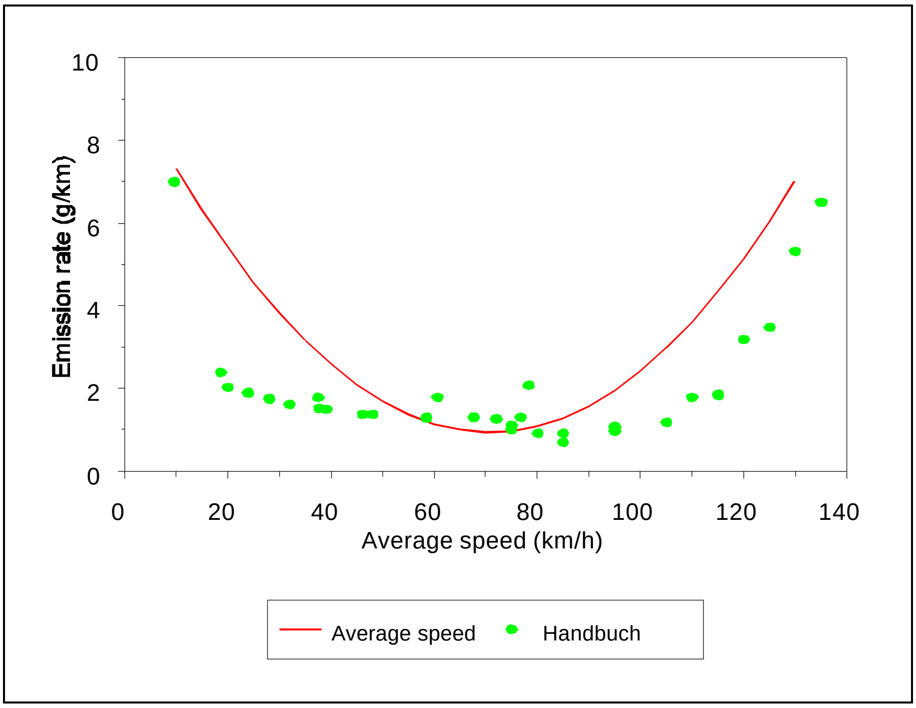

Figure A3. Comparison between emission rates from the Swiss/German Handbuch and a speed-emission curve - CO emissions, medium sized EURO I petrol cars

The third type of present generation emission model uses a second numerical variable, with the vehicle speed, in order to describe the vehicle's operation in more detail. The second variable is usually the acceleration rate, or the product of the speed and acceleration[19]. This type of model no longer attempts to calculate average emissions for a trip, but assigns an emission rate to each instantaneous combination of the two chosen variables (the timescale is usually every second).

[19] The product of speed and acceleration gives a better indication of the power demand on the engine than acceleration alone.

Data for these instantaneous models are derived from continuous measurements of speed (from which the second operational variable can be calculated) and emissions. Emission rates corresponding with operating conditions in certain bands are combined to provide a two-dimensional matrix of emission factors, classified by the two operational variables. Table A2 shows one example of an emission matrix, specified in terms of speed and speed times acceleration [A1].

Table A2. Instantaneous emission matrix - CO emissions (g/h), medium sized EURO I petrol cars

Speed x acceleration (m^2/s^3)	**Speed (km/h)**									
	0	5	15	25	35	45	55	65	75	85
-15	-	-	66	56	63	69	59	76	92	115
-10	-	-	57	61	63	84	94	141	129	134
-5	-	53	53	73	85	102	130	204	194	325
0	33	59	74	116	123	131	196	193	274	152
5	-	142	163	192	192	207	275	263	350	211
10	-	-	274	301	295	357	330	454	403	275
15	-	-	-	469	568	603	779	706	1041	308

Application of this type of model requires the specification of the speed profile of a journey, and the integration of the emission factors corresponding with each of the second by second pairs of speed and speed times acceleration. More generalised results can be obtained using a distribution of speed and acceleration pairs based on a wider selection of operation than a single journey.

In recent years, it is this third type of emission model that has probably received most attention by the research community, and it could be regarded as the state-of-the-art methodology. For a number of reasons, though, it has not been selected as the basis for the MEET emission calculations, and the more established average speed-related emission functions are recommended. However, because there has been widespread interest in instantaneous models, the following section reviews some recent developments. A more detailed account can be found in MEET Deliverable 6 [A2].

A2.2. Instantaneous emission data and their use in estimating passenger car emissions

A2.2.1. Existing models

One of the first instantaneous models to be developed was the Graz model (DGV) [A3]. This model is a method to estimate road traffic emissions in direct combination with recordings of driving patterns, and has been used to evaluate traffic calming measures [A4]. A similar approach was based on measurements using the United States FTP 75 and Highway driving cycles [A5]. Another model was created within the Drive/Modem project [A6]. In that work, 14 urban driving cycles were developed from driving patterns recorded in several European cities. These cycles were then used as the basis for chassis dynamometer tests performed on 150 vehicles. The emission data were recorded continuously, and emission matrices with the parameters speed and speed times acceleration were derived. A joint emission factor programme conducted in Germany [A7] and Switzerland [A8] used instantaneous emission data to create emission factors for passenger cars. The basis for the emission matrices were chassis dynamometer tests on around 300 vehicles using the FTP 75, NEDC, US-Highway and German Autobahn cycles as driving patterns.

A2.2.2. Current research

The aims of current research are to define the application range of available instantaneous emission data and to improve the models. On-going investigations in Switzerland [A9, A10] are aimed at defining the application range of the methodology, and the requirements for emission matrices. The Technical University of Graz is studying the conditions in the measurement programme that are required to obtain reliable emission matrices. INRETS are examining the reliability of current instantaneous emissions models [A11], and TRL are investigating the use of these models to assess traffic calming and other traffic management schemes.

There are some general uncertainties associated with the collection of emission data that influence the quality of emission estimates for standard (average-speed) and instantaneous models, and other factors that are of importance only in the second case. General factors include:

- Selecting a small vehicle sample to represent vehicle fleets comprising millions of vehicles

- Defining representative driving cycles

- A large number of measurements are performed under identical, and perhaps unrealistic, conditions. The wide variety of actual environment conditions have not been taken into account

Additional uncertainties related mainly to the use of instantaneous emission models include:

- The need to align emissions exactly in time with vehicle operating conditions means that attention must be given to the response time of the analysers and the delay time in the measurement chain.

- In general, when creating the emission matrices, data have been used from measurements using legislative cycles such as FTP 75, NEDC, etc. in addition to tests with real-world driving cycles. The application of legislative driving cycles ensures comparability of data from differing origins. But driving cycles such as the NEDC have little to do with real driving on roads.

- Some models have used speed and acceleration, whilst other models use the parameters speed and speed times acceleration to specify the emission matrix. These differences in method may be relevant to the calculation of emissions. Similarly, the method of calculating the acceleration from the speed-time curve may influence the result of the emissions calculation.

- The emission rates are stored as average values over particular time intervals (usually 1 second) in a matrix. The parameters for storage are the speed and the acceleration, or the product of speed and acceleration. Smaller increments mean that a driving cycle can be represented more precisely, but limit the amount of emission data available to populate each cell.

Influences from the measurement set-up

One means of assessing the accuracy of data from continuous emission measurements is to compare the average of the instantaneous data with the average emissions over a test cycle determined by collecting the gas over the whole cycle and measuring the average concentration. If the response time and accuracy of the continuous measurement system is satisfactory, there should be close agreement between them. A number of studies [A9, A10, A12, A13] have shown a variation depending on the pollutant and the vehicle type (petrol or diesel). Differences of up to 30% have been observed, though agreement within about 10% is more typical. Another recent investigation has shown the repeatability of emission measurements to be in the range 25 to 40% (standard deviation / mean) for CO, HC and NO_X, though much lower (< 3%) for CO_2. Partly, these differences result from the inevitable variation in the driving pattern between tests (it is not possible to follow a speed cycle precisely, and gear changes are never repeated exactly in the same way). However, provided that the driving cycle actually driven during each test is used in the data analysis (rather than the notional cycle), this should not adversely affect the results.

Emission matrix

The overall robustness of a particular emission matrix depends on the degree to which the cells in the matrix contain data, while the quality of data within a particular cell depends on the number of observations upon which it is based. These depend in turn on the number and types of test cycles used (more varied cycles give a greater coverage of possible operating conditions so that more cells in the matrix contain data) and on the number of vehicles tested (more vehicles give more values per cell). Figure A4 shows the cells of an emission matrix - defined by speed and speed times acceleration - that are covered by the NEDC cycle, and also the cells of the matrix necessary to calculate the emissions of a real urban driving pattern. It is evident that many of the cells that appear for real urban driving behaviour are not occupied in the matrix of the NEDC test.

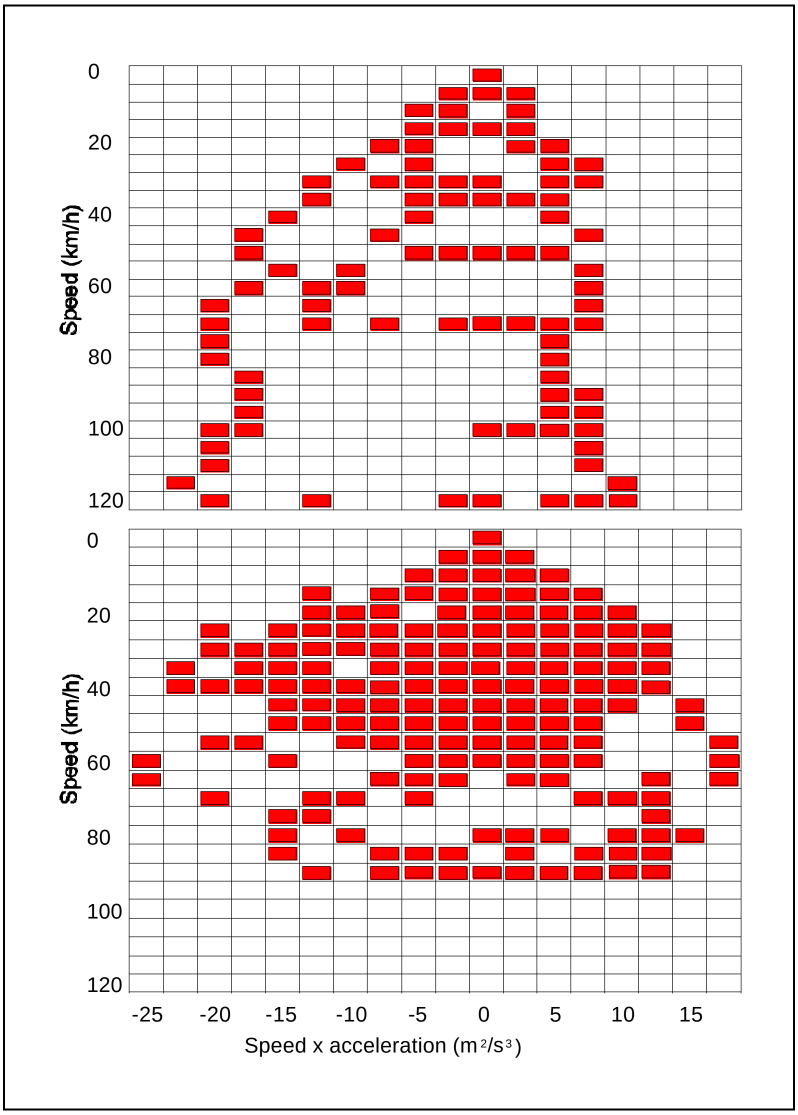

Figure A4. Emission matrices for NEDC cycle (top) and a typical urban driving pattern

Influence of driving cycles

The influence of the driving cycles used to construct the emission matrix has also been examined by comparing measured emissions with those estimated from matrices based on various combinations of data. The following cycles were used to provide data for the emission matrices:

- Legislative driving cycles: FTP-75 bag 3 and 2 (LA4), US Highway and NEDC.

- Real-world-driving-pattern: city main street (CMS) with high dynamics, city secondary street (CSS) with low dynamics [A15]; BUWAL T30 and BUWAL T50 [A13].

Table A3 specifies the test cases, indicating the driving cycles used for generation of the emission matrix and the driving cycle for which the calculation and comparison with measurement data were performed.

Table A3. Inventory of the calculation cases

Case	Emission matrix from driving cycles	Calculated driving cycle
Diesel cars		
A	FTP-75	FTP-75
B1	FTP-75, NEDC	FTP-75
B2	FTP-75, NEDC	NEDC
C1	FTP-75, NEDC	CMS
C2	FTP-75, NEDC	CSS
D	FTP-75, NEDC, CMS	CSS
E	FTP-75, NEDC, CSS	CMS
F1	FTP-75, NEDC, CMS, CSS	CMS
F2	FTP-75, NEDC, CMS, CSS	CSS
Petrol cars		
G	FTP-75	FTP-75
H1	FTP-75, NEDC	FTP-75
H2	FTP-75, NEDC	NEDC
I1	FTP-75, Highway, NEDC	BUWAL T50
I2	FTP-75, Highway, NEDC	BUWAL T30
J1	FTP-75, Highway, NEDC, BUWAL T30	BUWAL T50
J2	FTP-75, Highway, NEDC, BUWAL T50	BUWAL T30
K1	FTP-75, Highway, NEDC, BUWAL T30, BUWAL T50	BUWAL T50
K2	FTP-75, Highway, NEDC, BUWAL T30, BUWAL T50	BUWAL T30

Figure A5 shows the results of the comparison for diesel vehicles, as the percentage differences from the value measured (the sum of the continuously recorded emission values).

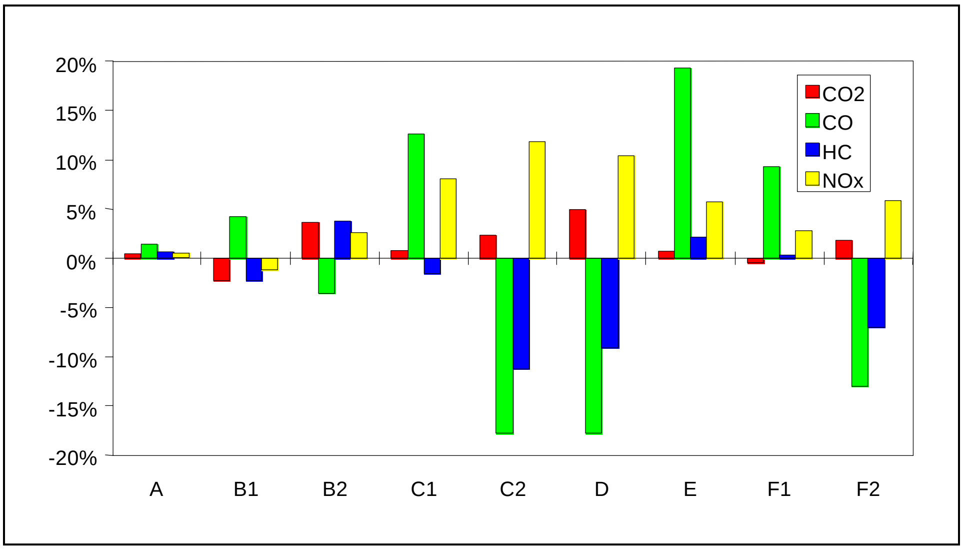

Figure A5. Differences between calculations and measurements, diesel cars

As expected, on re-calculating the FTP-cycle using data measured over the same cycle (case A), the differences for all pollutants were very small. But there is a tendency for errors to increase as the emission matrix deviates in content from the cycle for which the calculation is made. Thus, for example, cases C1 and C2, where calculations of real-world cycles are made using only data from legislative cycles, show larger percentage errors. Results for the petrol cars (Figure A6) were similar, though absolute differences were larger than for the diesels. Again, calculations of legislative cycles using data measured over legislative cycles (cases G, H1 and H2) showed small differences, whereas the use of legislative-cycle data to estimate real-world emissions produced significant errors (cases I1 and I2). Intermediate results were found when real-world emissions were estimated from mixed matrices (real and legislative combined, cases J and K).

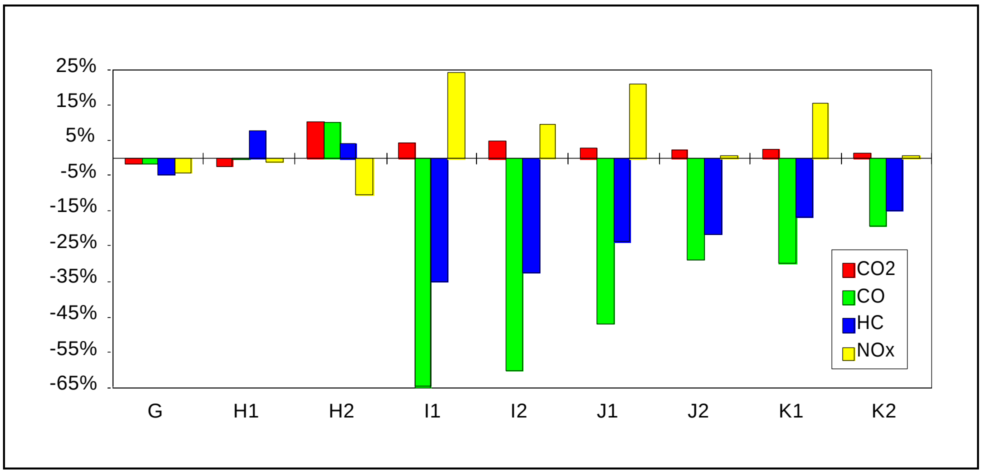

Figure A6. Difference between the calculation and measurements, medium size petrol cars

The following general conclusions were drawn:

- The sole use of emission values from legislative driving cycles is insufficient. It is necessary to include emission information from real world driving patterns in the emission matrices.

- Calculation results improve if the proper emission information is incorporated in the matrix. This means that if highly dynamic driving behaviour occurs, an emission matrix with information from highly dynamic cycles has to be used, and *vice versa*.

More or less the same findings have resulted from recent work by EMPA/BUWAL[A9, A10], INRETS [A11] and TRL [A16].

Similar investigations were undertaken by EMPA, but more emphasis was put on the use of real-world driving cycles. Measurements and calculations of CO emissions were made for petrol vehicles over driving cycles with similar average speeds, but significantly different levels of acceleration and deceleration. The measured emissions differed by a factor of 8; an average speed model would suggest a difference of about 15%, and the instantaneous model showed a difference by a factor of around 2.5 (varying slightly depending on the emission matrix used for the inter-comparison). The modal model therefore gave a better result than a simple average speed estimate, but still underestimated the effects of different driving cycle dynamics. Calculations for the 'high-dynamic' cycle were low, and *vice versa*, again showing the importance of using an emission matrix based on driving behaviour similar to that for which the calculation is made.

INRETS re-evaluated data from the Modem study to show how well the model replicated measurements for each of the 14 modem cycles. On average over all the cycles considered, the error equalled zero (because the model was designed using all the data). But when single cycles were considered the relative error of the model with respect to the measurement value ranged from –51% to +57% (varying with the cycle and the pollutant). Once again, it was shown that the similarity between the emission matrix and the cycle to be calculated was important.

TRL has developed driving cycles to represent the situation before and after the introduction of traffic calming measures (road humps). The cycles were reproduced on a chassis dynamometer so that emission measurements could be made. Emissions were found to be higher in the 'calmed' situation, with increases in CO of between 64% and 259%, for HC between 75% and 207%, and for NO_X between 12% and 62%. The Modem model was used to predict emissions, again using the before- and after-calming cycles. In contrast to the measurements, the model predicted relatively small changes in emissions (ranging from a 13% decrease in NO_X to a 36% increase in HC). Emissions of NO_X were predicted to decrease, whereas the measurements showed increases. These results support previous observations concerning the discrepancies between the magnitude (and in the case of NO_X the direction) of measured changes in emissions from individual vehicles and specific cycles, and those predicted by a generalised model.

Further analysis was carried out to examine whether any of the individual vehicles used to construct the Modem database would demonstrate changes similar to those observed. Matrices of emission factors, identical in construction to the original average Modem matrix, were determined for each vehicle and each pollutant. For each vehicle this usually yielded emission rates for the 6 composite Modem cycles that were similar (i.e. within ±10%) to the rates originally measured. However, the changes in emissions for all individual vehicles, comparing again the before- and after-calming cycles were again considerably lower than the observed changes. It is suggested that the cycles on which the Modem model is based cannot be used to reproduce the emission behaviour of vehicles driven over unusual cycles, such as those used to represent roads with traffic calming.

Influence of model parameters

A number of tests have been carried out to investigate the influence of different methodologies (the use of acceleration alone or its product with speed) and increments used to define the grid of the matrix. Calculations combining these options in different ways, with the number of matrix cells ranging from 90 in the coarsest grid to 1125 in the finest, and using both acceleration and speed times acceleration showed virtually no difference between the results obtained by any approach.

Similar results were found in a study by INRETS [A17, A11] where an attempt was made to improve the Modem model. The speed and speed times acceleration classes were refined, and the effects of increasing the total number of matrix cells from 70 to 928 was considered. In a second step, acceleration was calculated differently, either over an interval of one second or over an interval of 3 seconds. Neither change resulted in a significant change in the emission estimates.

Because of their frequency of occurrence in the different driving patterns used to construct the matrices, the number of events in each cell differs. Some have a high occupancy, some a very low one, and the standard deviation of the emission values in each matrix cell may be large. The number of emission events sampled within each cell is obviously related to the distance between two cells: the finer the grid, the fewer the events counted for each cell. It is possible to reduce the standard deviation if, for example, cells with only a few readings are eliminated.

INFRAS [A10] showed that a minimum number of 10 readings per cell was necessary to minimise the standard deviation. However, if cells with fewer than 10 readings were eliminated from the matrix, emission estimates became poorer. Often, the emissions from an infrequent event (such as a very high rate of acceleration) are disproportionately high, and make a significant contribution to the total, and the elimination of cells with few readings means that these are excluded from the database.

In their study INRETS aggregated cells until each contained sufficient readings to minimise the variation coefficient (standard deviation divided by the mean). Figure A7 shows that this did not decrease greatly when the number of data per cell was over 30. They first chose a very detailed matrix in which each cell contained a maximum of 30 readings and secondly merged adjacent cells that were poorly populated to get the minimum number of data per cell. This resulted in an emission matrix whose intervals depended on the local density of data. There was, however, little effect on the accuracy of the calculation.

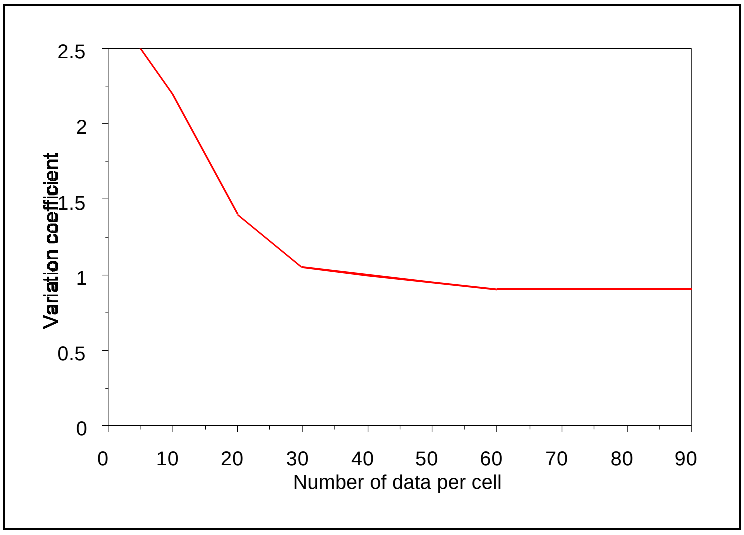

Figure A7. Variation coefficient in one cell as a function of the number of data per cell

A2.2.3. Reliability of instantaneous models

The main concern when applying any model is reliability. All the calculations reviewed here show that the quality of the emission data used (in terms of driving dynamics) plays an important role. For many applications the uncertainty can be reduced to a range of ±10 to 15%. But it has also been shown that for single applications (certain single driving cycles) the uncertainty is much higher and the models sometimes even predict wrong trends when evaluating measures which result in alterations in driving behaviour.

A2.2.4. Improvement of instantaneous emission models

Emissions during certain high-emission events have been shown to have a large impact [A10, A11]. Such high-emission events occur during phases of high acceleration in general, and during gear changes in particular. The duration of such events is usually only a few seconds, but the emission level might reach many times the level of the emissions during more normal operation. This is especially true for modern petrol vehicles with closed-loop catalytic converters. They generally have a low basic emission level, but show episodes of high emissions during open-loop operation. If it is possible to allocate these open-loop operation periods, and combine them with operation of the vehicle, the accuracy of emission estimations would increase.

The relative importance of specific high-emission events was shown by recent work at INRETS [A18, A11]. Instantaneous emission measurements were performed on a three-way catalyst vehicle, and expressed as a function of the engine speed and the engine load (real power/maximum power at each speed).The results showed that CO emissions were 200 to 20000 times higher for loads greater than 75 %, and NO_X emissions were 10 times higher (Figures A8 and A9). Over the whole cycle about 90 % of the total CO emission occurred during only 15 % of the time. It was proposed that modelling effort should be concentrated much more on extreme engine operating conditions, at least for catalyst vehicles.

The introduction of enrichment functions for the open-loop operation of TWC petrol cars is one step to improve the accuracy of modal modelling. Another might be to introduce one or more additional parameters to describe the dynamics of a driving pattern better. Gear changing has been shown to be one main key to a better understanding of the influence of the level of dynamics on the total emission level [A10]. First estimates indicate that the total level of variance, defined as the mean relative standard deviation of the emission data within the cells of the emission matrix, can be lowered by 30% by the introduction of such a new parameter.

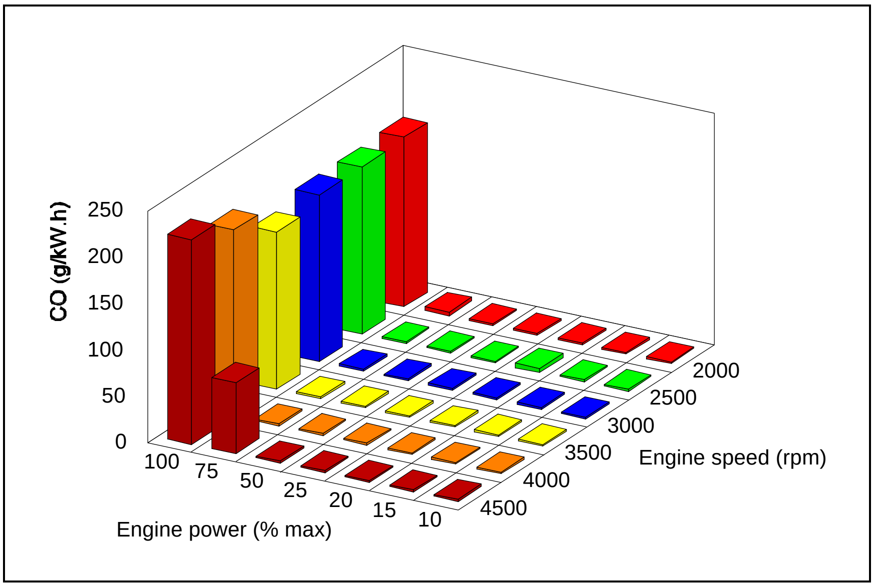

Figure A8. CO instantaneous emissions as a function of engine speed and load over a motorway cycle for a catalyst vehicle

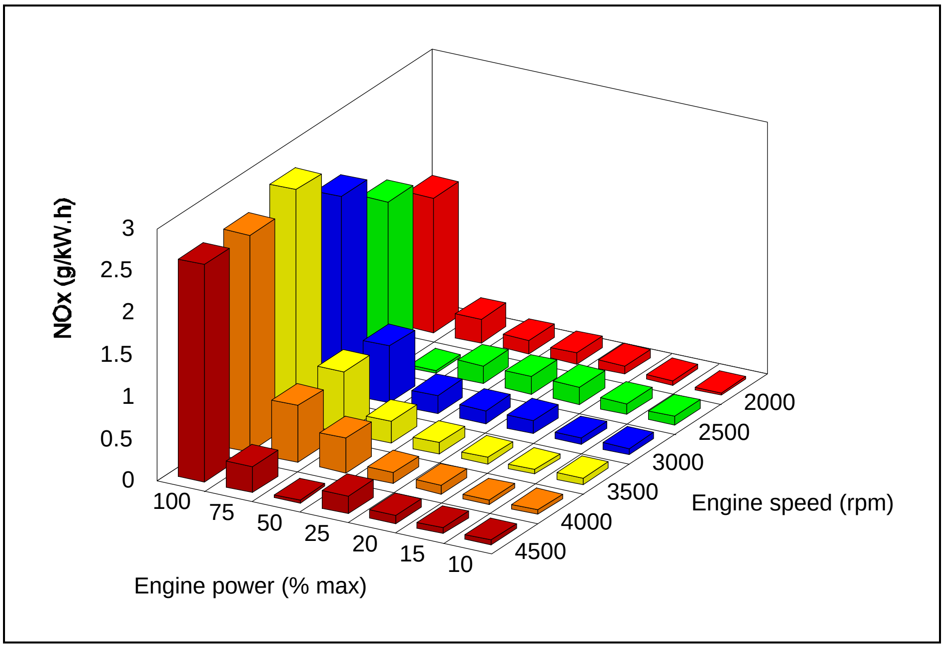

Figure A9. NO_X instantaneous emission as a function of engine speed and load over a motorway cycle for a catalyst vehicle

Improvements such as these will not show benefits in the area of average emission predictions. For such matters, measurements on vehicles truly representative of the fleet are of far greater importance. For the assessment of traffic-related measures (lowering speed limits, introduction of traffic control systems, etc.), however, the main focus is on the relative changes in emissions rather than on absolute values. For such questions, where the only parameter changing significantly might be the level of dynamics of the driving patterns, improved emission functions may allow the instantaneous emission approach to be used with greater confidence.

A2.2.5. Summary

The investigations described in this section generated the following conclusions:

- The quality of the emission matrix used (i.e. which driving patterns are used to generate the emission data) plays an important role.
- The use of instantaneous emission approaches is recommended where driving behaviour and dynamics is of major interest. Average speed models are not appropriate for such tasks.
- However, it has also been shown that for single applications (certain single driving cycles) the uncertainty is high, and instantaneous models sometimes predict wrong trends when evaluating certain measures which result in alterations to driving behaviour.

A2.3 Conclusions

The most appropriate calculation methodology depends on the application. For most applications emission factors based on average speed or for a set of typical traffic situations (as in the Swiss/German Handbuch) will allow emission estimates to be made with sufficient accuracy. But there are certain areas were emission changes due to changes in driving dynamics have to be estimated (e.g. traffic calming). In such cases the use of instantaneous emission models will lead to more reliable results.

Because the purpose of MEET is to provide methods to be used for more general purposes than the assessment of changes in driving behaviour, and primarily for application on a strategic scale, it was decided to focus on the average-speed dependent emission factors and functions.

A3. VEHICLE CLASSIFICATION AND EMISSION STANDARDS

A3.1. Vehicle categories

The emissions performances of different types of vehicle vary considerably, so it is necessary to establish a classification in which the vehicles in each class display sufficient homogeneity to be treated as a single group. Emission factors must be combined with traffic activity data to provide emission estimates, and so the emission classification must be compatible with those used in traffic statistics.

A3.1.1. Categories according to international statistics

In order to help in identifying the vehicle categories, Table A4 gives the classification according to the UN-ECE, based on the physical properties of different vehicle types.

Table A4. Classification of vehicles according to UN-ECE [A19]

Category	Description
L	Motor vehicles with less than four wheels
L1	Two-wheeled vehicles with an engine cylinder capacity not exceeding 50 cc and a maximum design speed not exceeding 40 km/h
L2	Three-wheeled vehicles with an engine cylinder capacity not exceeding 50 cc and a maximum design speed not exceeding 40 km/h
L3	Two-wheeled vehicles with an engine cylinder capacity exceeding 50 cc or a maximum design speed exceeding 40 km/h
L4	Vehicles with three wheels asymmetrically arranged in relation to the longitudinal median axis, with an engine cylinder capacity exceeding 50 cc or a design speed exceeding 40 km/h (motorcycles with sidecar)
L5	Vehicles with three wheels symmetrically arranged in relation to the longitudinal median axis with a maximum weight not exceeding 1000 kg and either an engine cylinder capacity exceeding 50 cc or a design speed exceeding 40 km/h (motorcycles with sidecar)
M	Power driven vehicles having at least four wheels or having three wheels when the maximum weight exceeds 1 tonne, and used for the carriage of passengers.
M1	Vehicles used for the carriage of passengers and comprising not more than eight seats in addition to the driver's seat
M2	Vehicles used for the carriage of passengers and comprising more than eight seats in addition to the driver's seat, and having a maximum weight not exceeding 5 tonnes
M3	Vehicles used for the carriage of passengers and comprising more than eight seats in addition to the driver's seat, and having a maximum weight exceeding 5 tonnes
N	Power driven vehicles having at least four wheels or having three wheels when the maximum weight exceeds 1 tonne, and used for the carriage of goods
N1	Vehicles used for the carriage of goods and having a maximum weight not exceeding 3.5 tonnes
N2	Vehicles used for the carriage of goods and having a maximum weight exceeding 3.5 tonnes but not exceeding 12 tonnes
N3	Vehicles used for the carriage of goods and having a maximum weight exceeding 12 tonnes

In this project, a somewhat different categorisation is proposed, in order to match more closely with traffic statistics that are routinely compiled. Four main categories will be used, corresponding with those of UN-ECE as follows:

- Passenger Cars (PC) M1
- Light Duty Vehicles (LDV) N1
- Heavy Duty Vehicles (HDV) M2, M3, N2, N3
- Two Wheel Vehicles (2-W) L1, L2, L3, L4, L5

A3.1.2. Categories for emissions calculations

Within each of these four main categories there is still a diversity of vehicle types, as regards both their emissions and operational characteristics. Cars, for example, use both petrol and diesel fuel, have different types of emission control system, and their size range is large enough for the distinction of emissions by engine capacity. Similarly, although heavy duty vehicles are almost exclusively driven by diesel engines, they include lorries, buses and coaches, whose operations are quite different, and cover a large range of sizes from 3.5 to 60 tonnes in maximum weight. Therefore, for the calculation of emissions, it is necessary to define a further sub-classification of the vehicles so that each group displays a reasonably uniform emissions performance. Table A5 lists the categories finally defined in this way. The main criteria involved in the classification are:

- The vehicle type (PC, LDV, HDV, 2-W)
- The vehicle size (engine capacity or gross weight)
- The level of emission control (according to stages of EU emission control legislation)
- The fuel (petrol, diesel, LPG or, for the future, alternatives such as CNG and electricity)
- The engine (for PC and 2-W, 4-stroke or 2-stroke)
- The operational purpose (for HDVs, whether goods vehicle, urban bus or coach)

In order to identify the level of emission control, the years of introduction of the various amendments to EU legislation may be linked with the model years of vehicles within the fleet. Table A5 therefore also indicates the model years appropriate for each vehicle category. This association should be regarded only as indicative as there have been some slight differences in procedures in different Member States. Some of the classes refer to future vehicle types - either standard vehicles that will be introduced after future proposed changes in emission control legislation or vehicles using new fuels and engine technologies. These future types are indicated by italics.

Table A5. Vehicle categories

Category	Engine/fuel	Size	Model year	Control level
Passenger car	Petrol	<1.4 l	until 1971	Pre-regulation
			1972 - 1977	70/220 & 74/290/EEC
			1978 - 1980	77/102/EEC
			1981 - 1984	78/665/EEC
			1985 - 1992	83/351/EEC
			1986 - 1991	Improved Conventional
			1986 - 1991	Open loop catalyst
			1991 - 1996	91/441/EEC (EURO I)
			1996 - today	94/12/EEC (EURO II)
			2001-2005	*EURO III*
			2005 -	*EURO IV*
		1.4-2.0 l	until 1971	Pre-regulation
			1972 - 1977	70/220 & 74/290/EEC
			1978 - 1980	77/102/EEC
			1981 - 1984	78/665/EEC
			1985 - 1992	83/351/EEC
			1986 - 1991	Improved Conventional
			1986 - 1991	Open loop catalyst
			1991 - 1996	91/441/EEC (EURO I)
			1996 - today	94/12/EEC (EURO II)
			2001-2005	*EURO III*
			2005 -	*EURO IV*
		>2.0	until 1971	Pre-regulation
			1972 - 1977	70/220 & 74/290/EEC
			1978 - 1980	77/102/EEC
			1981 - 1984	78/665/EEC
			1985 - 1992	83/351/EEC
			1986 - 1991	Improved Conventional
			1986 - 1991	Open loop catalyst
			1991 - 1996	91/441/EEC (EURO I)
			1996 - today	94/12/EEC (EURO II)
			2001-2005	*EURO III*
			2005 -	*EURO IV*
Passenger car	Diesel	< 2.0 l	until 1986	Uncontrolled
			1986 - 1996	88/436 & 91/441/EEC (EURO I)
			1996 - today	94/12/EEC (EURO II)
			2001-2005	*EURO III*
			2005 -	*EURO IV*
		> 2.0 l	until 1986	Uncontrolled
			1986 - 1996	88/436 & 91/441/EEC (EURO I)
			1996 - today	94/12/EEC (EURO II)
			2001-2005	*EURO III*
			2005 -	*EURO IV*

Table A5 (continued). Vehicle categories

Category	Engine/fuel	Size	Model year	Control level
Passenger car	LPG	All	until 1986	Conventional
			1986 - 1996	88/436 & 91/441/EEC (EURO I)
			1996 - today	94/12/EEC (EURO II)
			2001-2005	*EURO III*
			2005 -	*EURO IV*
	CNG	*All*		
	Alcohols	*All*		
	Bio diesel	*All*		
	Electric	*All*		
	Hybrid[20]	*All*		
	2 stroke	*All*		*Uncontrolled*
				Future categories
Light duty vehicles	Petrol	<3.5 t	until 1995	Uncontrolled
			1995 - 1998	93/59/EEC (EURO I)
			1998 -	96/69/EEC (EURO II)
				EURO III
				EURO IV
	Diesel		until 1995	Uncontrolled
			1995 - 1998	93/59/EEC (EURO I)
			1998 -	96/69/EEC (EURO II)
				EURO III
				EURO IV
	LPG			
	CNG			
	Alcohols			
	Bio diesel			
	Electric			
	Hybrid			
Heavy duty vehicles	Diesel	HGV 3.5 - 7.5 t	until 1993	ECE R49 & 88/77/EEC
			1993 - 1997	91/542/EEC stage I (EURO I)
			1997 - today	91/542/EEC stage II (EURO II)
				EURO III
				EURO IV
		HGV 7.5 - 16 t	until 1993	ECE R49 & 88/77/EEC
			1993 - 1997	91/542/EEC stage I
			1997 - today	91/542/EEC stage II
				EURO III
				EURO IV

[20] In principle this class refers to gasoline/electric and diesel/electric vehicles

Table A5 (continued). Vehicle categories

Category	Engine/fuel	Size	Model year	Control level
Heavy duty vehicles		HGV 16 - 32 t	until 1993	ECE R49 & 88/77/EEC
			1993 - 1997	91/542/EEC stage I
			1997 - today	91/542/EEC stage II
				EURO III
				EURO IV
		HGV 32 - 40 t	until 1993	ECE R49 & 88/77/EEC
			1993 - 1997	91/542/EEC stage I
			1997 - today	91/542/EEC stage II
				EURO III
				EURO IV
		HGV > 40 t	until 1993	ECE R49 & 88/77/EEC
			1993 - 1997	91/542/EEC stage I
			1997 - today	91/542/EEC stage II
				EURO III
				EURO IV
		Urban buses	until 1993	ECE R49 & 88/77/EEC
			1993 - 1997	91/542/EEC stage I
			1997 - today	91/542/EEC stage II
				EURO III
				EURO IV
	Diesel	Coaches	until 1993	ECE R49 & 88/77/EEC
			1993 - 1997	91/542/EEC stage I (EURO I)
			1997 - today	91/542/EEC stage II (EURO II)
				EURO III
				EURO IV
	LPG	All		
	CNG	All		
	Bio diesel	All		
	Electric	All		
	Hybrid	All		
2-wheeled vehicles	Petrol	< 50 cm^3	until 1996	ECE R 47
			1997-1998	COM(93)449 Stage 1
			after 1999	COM(93)449 Stage 2
		> 50 cm^3 4 stroke	until 1996	ECE R 40.01
			after 1997	COM(93)449
		> 50 cm^3 2 stroke	until 1996	ECE R 40.01
			after 1997	COM(93)449

A3.1.3 Vehicle emission legislation and technology

One of the most important of the criteria used to define the vehicle categories in Table A5 is the ‘control level’. This is defined as the emission control standard to which the vehicle was type approved. But another way of classifying vehicles would be according to the technology of their engines and emission control systems. For petrol engined passenger cars, for example, such a classification might be ‘uncontrolled’, ‘open loop catalyst’, and ‘closed loop catalyst’. There is, though, a reasonably close correspondence between the two alternative classification systems: the limit values set by legislation usually dictate the types of technologies needed to meet them, even though the technologies themselves are not legally specified. In this section, the history of emission standards in the EU is briefly examined with reference to their effects on vehicle technology and rates of emission.

Light duty vehicles

The first emission standard adopted in the EU set limit values for carbon monoxide and hydrocarbon emissions from petrol engined vehicles (Directive 70/220/EEC). At this stage, the legislation was principally intended to prevent individual national requirements from creating barriers to trade: Member States were not obliged to adopt the standards, but could not set standards that were more stringent. The Directive itself was based on regulations developed by the United Nations Economic Commission for Europe (ECE Regulation 15)[21]. No special emission control equipment was needed to meet the early standards and the limit values were easily achievable. Successive amendments to the Directive were introduced with a number of purposes:

- Directive 74/290 reduced the emission limits
- Directive 77/102 added a limit value for oxides of nitrogen
- Directive 78/665 again reduced the emission limits
- Directive 83/351 further reduced the emission limits, gave a combined limit for oxides of nitrogen and hydrocarbons and made them also applicable to diesel cars. Changes were also made to the methods of sampling and analysis used in the test procedure.

Under this series of standards, the emission limits were specified as grams of pollutant per test, and varied depending on the weight of the vehicle. The test cycle was a low-speed, urban driving simulation (approximately 4 km at an average speed of 19 km/h). In approximate terms, the emission limits of Directive 83/351/EEC were around a half of those originally

[21] The first 5 stages of EU legislation were adopted from ECE Regulations, and for that reason, vehicles are frequently referred to in those terms rather than by the equivalent EC Directives. Equivalences are as follows:

Directive 70/220/EEC: ECE Regulation 15.00
Directive 74/290/EEC: ECE Regulation 15.01
Directive 77/102/EEC: ECE Regulation 15.02
Directive 78/665/EEC: ECE Regulation 15.03
Directive 83/351/EEC: ECE Regulation 15.04

required by 70/220/EEC, but it was still possible for them to be achieved by cars without any special emission control systems. As an example, Figure A10 shows the changes in limit values for carbon monoxide through this sequence of amendments (as stated, limits varied depending on the weight of the vehicle, those shown are for vehicles in the range 1250 to 1470 kg).

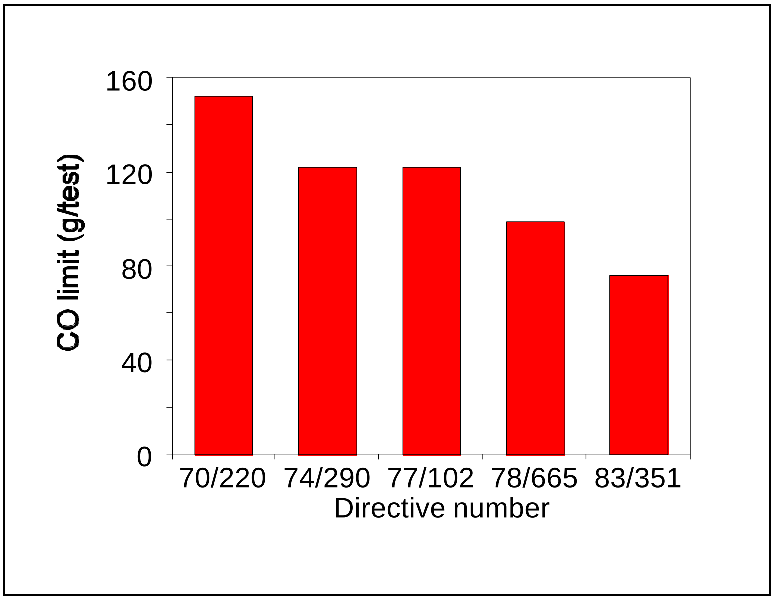

Figure A10. Reductions in CO emission limits for cars in early stages of the EU legislation

The success of the legislation changes in reducing in-use emission rates was examined in the 1980s with reference to two surveys of car emissions carried out in the UK [A14]. The emissions measured in tests on about 400 cars were grouped according to the weight and emission standard of the vehicle, and differences were examined with respect to the type approval limits. Figure A11 presents some of the results from that study. For carbon monoxide and hydrocarbons, the trends in measured emissions follow those of the standards quite closely: average rates of emission showed a steady reduction with successive stages of the legislation. It is also notable, though, that the measured emissions were systematically higher than the standards, and for carbon monoxide, significantly higher. Because the tests were carried out on in-use cars, it is likely that this was the result of maladjustments of the engines, a view which was confirmed by retesting a sub-sample of the vehicles after tuning. The oxides of nitrogen results did not, however, reflect the changes made in the legislation, but showed an increase for cars approved to 78/665/EEC, whereas the limit value reduced. These rates of emission were well below the limit values, although the tuned and retested subsample showed higher average emissions. On vehicles without emission control systems, there is a relatively simple trade-off between CO and HC emissions with those of NO_X, and the relative emissions depend mainly on the air:fuel ratio. It is probable that this is the explanation for the observations outlined above. Firstly, in meeting the increasingly severe standards for CO and HC, manufacturers increased NO_X emissions (as they were significantly below the limits, they could still meet the standards despite this increase), and secondly, deterioration in use tended to reduce the air:fuel ratio, producing higher CO and HC emission and lower NO_X; tuning, which was usually done on the basis of the CO emission, reversed this.

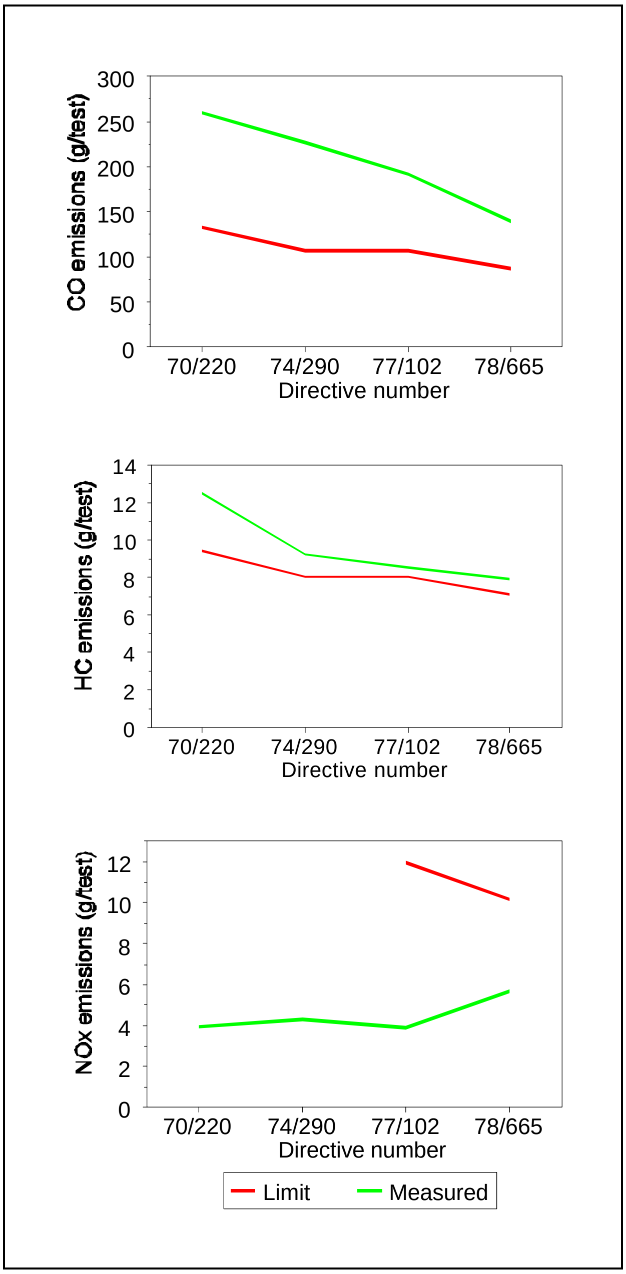

Figure A11. Changes in average petrol car emissions and corresponding changes in standards

The 1980s saw a period of intense activity on emission standards in the EU. Environmental concerns in Germany resulted in proposals from their government to introduce unilateral standards. They announced their intention to require all petrol cars to use three way catalysts from 1986, and to offer tax incentives for clean vehicles. They were supported by Denmark and the Netherlands, but opposed by France, Italy and the UK. In response, the European Commission made a proposal in 1984 for further reductions in emission limits, and after much debate, Directive 88/76/EEC was adopted at the end of 1987. This was followed by Directive 89/458/EEC, which introduced stricter limits for small cars (<1.4 l); these were extended to all cars by Directive 91/441/EEC - the so-called EURO I standards. Because there was overlap between the dates when these Directives became effective, it was only the last of them that was universally applied. As well as significantly reducing allowable emission rates, this series of amendments resulted in several other fundamental changes to the emission standards:

- The Directive was now compulsory to all Member States
- A new driving cycle incorporating a high speed 'extra-urban driving cycle' was used
- Emission limits were expressed in g/km and the same limits applied to all sizes of car
- A requirement was introduced to demonstrate the durability of emission control systems
- A limit on evaporative emissions of hydrocarbons was introduced
- There was a commitment to introduce further more stringent limits by 1996

As a consequence of these changes in the legislation, it was necessary for all new petrol cars to be equipped with closed-loop three way catalysts and with carbon canisters for evaporative emission control, and thus these technologies first entered widespread use in the EU from the beginning of 1993. Several member states, though, anticipated this through the use of fiscal incentives and other means to encourage cleaner vehicles. As a result, a number of intermediate technologies were in use in some countries from 1986, and they are referred to as 'improved conventional' and 'open loop' in Table A5[22].

Because of the numerous changes to the type approval procedure accompanying Directive 91/441/EEC, it is difficult to make comparisons with earlier limit values. However, the effect on emission rates can be seen by comparing the in-use emission functions for these vehicle classes with those of the earlier types (see Tables A14 to A17). A comparison is also shown graphically in Figure A12, for an arbitrary average speed of 40 km/h.

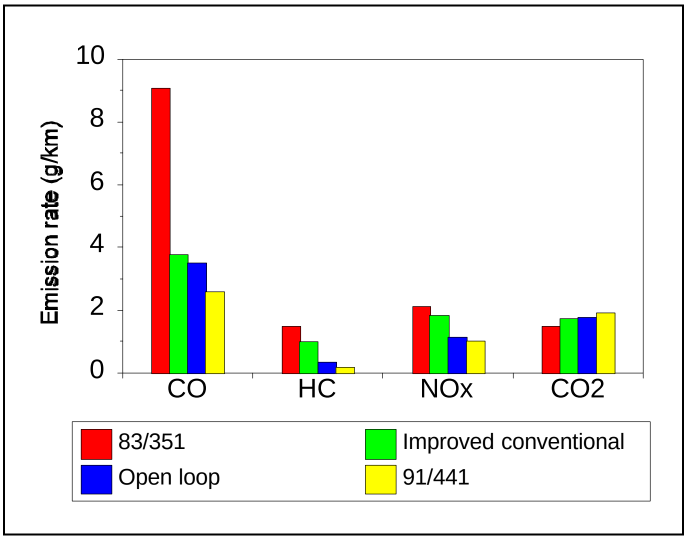

Figure A12. Relative emission rates from medium size petrol cars with different technologies

[22] Vehicles in these classes are found in the vehicle fleets of Germany, Greece, Ireland and the Netherlands.

Limits on light commercial vehicles, of equivalent stringency to those in 91/441/EEC for cars, were introduced by Directive 93/59/EC. The obligation further to restrict car emissions from 1996 was formalised in Directive 94/12/EC. In this Directive, a distinction was made between permissible emissions from diesel and petrol cars: the limit for CO from diesels was significantly lower, and that for HC + NO_X significantly higher than the corresponding petrol car limits. In addition, production cars selected at random were required to meet the same standards (earlier Directives had allowed for production tolerances by including slightly less stringent conformity of production standards). Again, this level of stringency was also applied to light commercial vehicles under Directive 96/69/EC.

In order for future emission control policies to be optimised to provide the necessary air quality improvements without placing an undue burden on any individual sector, the European Commission initiated the Auto-Oil Programme in 1992. This was a tripartite initiative involving the Commission, the vehicle manufacturing industry and the oil industry. In contrast with the earlier focus on improving vehicle technologies to reduce emissions, the Auto-Oil programme examined a wide range of options including vehicle technologies, fuel quality, evaporative emission controls, inspection and maintenance programmes, pricing policies and public transport.

In 1996, taking into account the results from the Auto-Oil Programme, the Commission presented its strategy for the further control of emissions from road transport. Its aim was to reduce current levels of carbon monoxide, benzene, nitrogen dioxide and tropospheric ozone by 60 to 70% by 2010. It proposed stricter vehicle emission standards, improvements in fuel quality, and stricter vehicle maintenance and inspection provisions (including on-board diagnostics). Supplementary measures could include road pricing, improved public transport, the scrapping of old vehicles and tax incentives to promote the uptake of vehicles complying with the new emission standards. It was also proposed to establish a second, Auto-Oil II, program, which started in 1997. New Directives on emissions from cars and light commercial vehicles (98/69/EC) and on fuel quality (98/70/EC) were published in December 1998. The key points of these Directives are:

- Mandatory limit values set for emissions and fuels for 2000 and 2005
- Fiscal incentives for 2005 emission limits and fuels can be introduced from 2000
- Durability requirements extended from 80000 km in 2000 to 100000 km in 2005
- On board diagnostics required on petrol vehicles from 2000 and diesels from 2003
- The test procedure is modified to include a cold start at -7^{o}C
- Leaded petrol to be phased out by 2005

The emission limit values for cars are given in Table A6, those for light commercial vehicles in Table A7, and the limits on the sulphur content of fuels are given in Table A8.

Table A6. Emission limits (g/km) for cars in 2000 and 2005 (Directive 98/69/EC)

Year	CO		HC		NO_X		$HC+NO_X$		PM	
	petrol	diesel	petrol	diesel	petrol	diesel	petrol	diesel	petrol	diesel
2000	2.3	0.64	0.20	-	0.15	0.50	-	0.56	-	0.05
2005	1.0	0.50	0.10	-	0.08	0.25	-	0.30	-	0.025

Table A7. Emission limits (g/km) for LCVs in 2000 and 2005 (Directive 98/69/EC)

Year	Ref.	CO		HC		NO_X		$HC+NO_X$		PM	
	mass (kg)	petrol	diesel	petrol	diesel	petrol	diesel	petrol	diesel	petrol	diesel
2000	< 1305	2.30	0.64	0.20	-	0.15	0.50	-	0.56	-	0.05
2001	1305 - 1760	4.17	0.80	0.25	-	0.18	0.65	-	0.72	-	0.07
2001	> 1760	5.22	0.95	0.29	-	0.21	0.78	-	0.86	-	0.10
2005	< 1305	1.00	0.50	0.10	-	0.08	0.25	-	0.30	-	0.025
2006	1305 - 1760	1.81	0.63	0.13	-	0.10	0.33	-	0.39	-	0.04
2006	> 1760	2.27	0.74	0.16	-	0.11	0.39	-	0.46	-	0.06

Table A8. Maximum sulphur content of fuels in 2000 and 2005 (Directive 98/70/EC)

Year	Petrol	Diesel
2000	150 ppm	350 ppm
2005	50 ppm	50 ppm

Heavy duty vehicles

With the exception of an early Directive restricting visible smoke (72/306/EEC), the history of emission control in the heavy duty sector is much shorter than for light duty vehicles. The first limits on mass emissions of gaseous pollutants were introduced by Directive 88/77/EEC. This set standards for emissions of CO, HC and NO_X, based on a 13 mode steady state engine test. Emissions are measured in each of the 13 modes of the test[23], weighting factors are used to calculate a composite emission rate in g/kW.h, which must not exceed the limit value. The limits were amended by Directive 91/542/EEC, which set successively stringent standards to be applied in 1993 and 1996. Limits for particulate emissions were also introduced by these amendments and Directive 96/1/EC relaxed the 1996 particulate standard for smaller engines for an interim period. The limits specified by these Directives are given in Table A9.

Table A9. Emission standards for diesel engines used in heavy duty vehicles

Directive	CO (g/kW.h)	HC (g/kW.h)	NO_X (g/kW.h)	PM (g/kW.h)
88/77/EEC	11.2	2.45	14.4	-
91/542/EEC stage I	4.5	1.10	8.0	0.36
91/542/EEC stage II	4.0	1.10	7.0	0.15
96/1/EC (for engines under 85 kW, until 1997/98)				0.25

[23] In fact, the test covers only 11 discreet engine operating conditions; it has 13 modes because one condition (idle) is used three times.

Again taking into account the results of the Auto-Oil Programmes, considerable progress has now been made towards the development of future standards for heavy duty engines. The common position on limit values reached by the Environment Council in December 1998 is summarised in Tables A10 and A11.

Table A10. Limit values for heavy duty diesel engines - ESC and ELR test cycles

Implementation date	CO (g/kW.h)	HC (g/kW.h)	NO_X (g/kW.h)	PM (g/kW.h)	Smoke (m^{-1})
2000	2.1	0.66	5.0	0.10	0.8
2005	1.5	0.46	3.5	0.02	0.5
2008	1.5	0.46	2.0	0.02	0.5
EEV (1999)	1.5	0.25	2.0	0.02	0.15

Table A11. Limit values for heavy duty diesel and gas engines - ETC test cycle

Implementation date	CO (g/kW.h)	NMHC (g/kW.h)	Methane* (g/kW.h)	NO_X (g/kW.h)	PM (g/kW.h)
2000	5.45	0.78	1.6	5.0	0.16**
2005	4.0	0.55	1.1	3.5	0.03**
2008	4.0	0.55	1.1	2.0	0.03
EEV (1999)	3.0	0.4	0.65	2.0	0.02

* Not applicable to diesel engines
** Not applicable to gas engines

Several features of this proposal represent significant departures from the earlier legislation:

- New test cycles are to be used, depending on the engine technology. The ESC (European Steady State Cycle) and the ELR (European Load Response Cycle) are to be used for conventional and advanced diesel engines[24], while the ETC (European Transient Cycle) will be used for advanced diesel engines[25] and gas engines.

- The limits apply to gas engines, as well as diesels, and because of their relatively high methane emissions, a methane limit is also included.

- A new class of vehicle is introduced - the EEV (Environmentally Enhanced Vehicle). These must be approved on all three cycles and achieve lower emission levels. These vehicles would be the subject of fiscal incentives.

In terms of diesel engine technology, it is anticipated that limits for 2000 will be achievable without the use of advanced emission control systems. However, to meet the 2005 requirements it is likely that particulate traps will be necessary, and for 2008 and EEVs, both particulate traps and $deNO_X$ catalysts will probably be necessary.

[24] Mass emissions are determined using the ESC, and visible smoke using the ELR.
[25] This includes engines fitted with $deNO_X$ catalysts and/or particulate traps.

There are not sufficient data available to be able to demonstrate how the imposition and tightening of standards has affected the in-use emissions from heavy duty vehicles. Their potential impacts may be shown, though, by comparing the past, present and future limit values. This is done in Figure A13, with reference to the limits proposed for the ESC and ELR cycles, chosen because of the similarity between the ESC and the earlier 13 mode cycle.

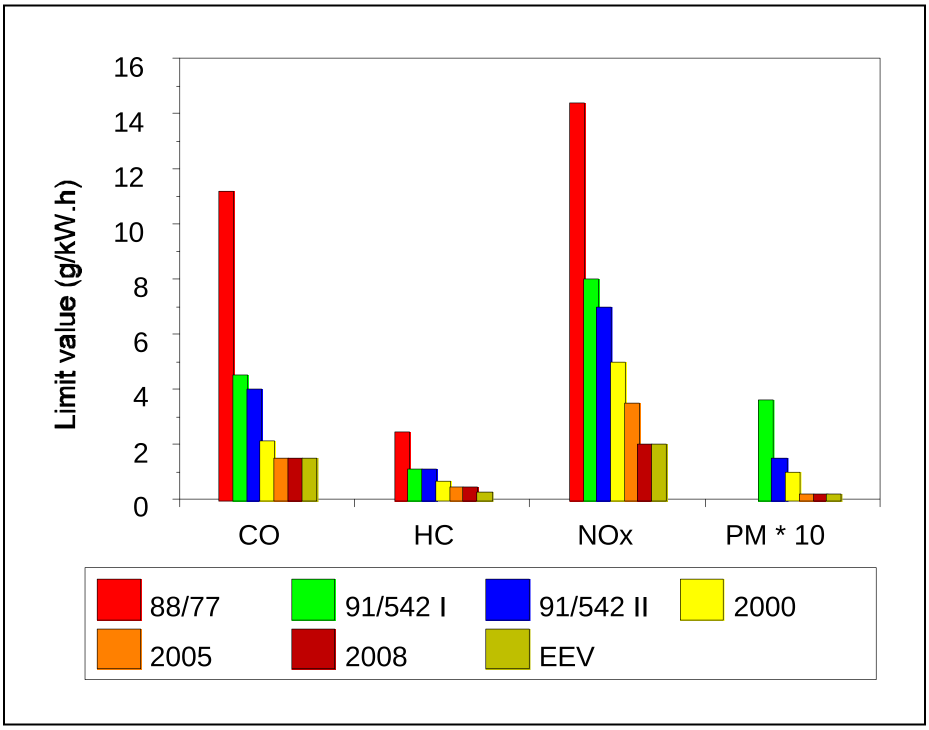

Figure A13. Changes in emission limits for heavy duty engines

Motorcycles

As yet, there are no limits on the emissions from motorcycles, but Directive 97/24/EC includes a two stage procedure for their introduction. Standards are included for CO and HC+NO_X, as shown in Table A12.

Table A12. Emission limits for motorcycles

Implementation date	CO (g/km)	HC+NO_X (g/km)
June 1999	6.0	3.0
June 2000	1.0	1.2

A4. HOT EMISSIONS

A4.1. Basic equations

Hot emissions are the emissions produced when the engine and the pollution control systems of the vehicle (e.g. catalyst) have reached their normal operating temperature. They can be calculated if the emission per unit of activity and the total activity over the time scale of the calculation are known, using the formula:

$$E_{hot} = e \times m \tag{A7}$$

where:

E_{hot} is the emission, in units of mass per unit of time (usually in t/a)
e is the hot emission factor in g/km
m is the activity, in distance travelled per time unit (usually in km/a)

The activity *m* required for the emission calculation according to Equation (A7) is defined as:

$$m = n \times l \tag{A8}$$

where:

n is the number of vehicles in each of the categories defined in Table A5.
l is the average distance travelled by the average vehicle of the category over the time unit, in km/a

It is obvious that Equation (A7) has to be applied for each vehicle category, since the emission factors and the activity are different. It is also stressed that the vehicle average annual distance is different from one country to another, and in any case, this distance is distributed over different types of roads. A part of the distance is travelled in urban areas, a part in rural areas and the rest on highways, each type of road having a different average speed and affecting the emission factors.

Therefore, in order to apply Equation (A7), the data needed are:

- the number of vehicles in each vehicle category
- the total annual distance travelled by each vehicle category
- the percentage of this distance driven on urban and rural roads and on highways
- the average speed on each type of road
- the emission factor - average speed correlation

Combining Equation (A7) and Equation (A8), and taking into account the different vehicle categories, the final equation for hot emission estimation can be derived:

$$E_k = \sum_{i=1}^{i=categories} n_i \times l_i \times \sum_{j=1}^{j=roadtypes} p_{i,j} \times e_{i,j,k} \tag{A9}$$

where:

- k identifies the pollutant
- i is the number of the vehicle categories
- j is the number of the types of road
- n_i is the number of vehicles in category i
- l_i is the average annual distance travelled by the vehicles of category i
- $p_{i,j}$ is the percentage of the annual distance travelled on road type j by vehicle type i
- $e_{i,j,k}$ is the emission factor of pollutant k corresponding to the average speed on road type j, for vehicle category i.

Table A13 presents the form of the data for a limited number of categories. There will be one data set of this form with lines for every vehicle category, as listed in Table A5, for each country and reference year.

Table A13. Form of the data required for the calculation of the hot emissions from road transport

Code	Fleet	Miles (km)	Urban Miles (%)	Urban Speed (km/h)	Rural Miles (%)	Rural Speed (km/h)	Highway Miles (%)	Highway Speed (km/h)	CO_2 (g/km)	NO_X (g/km)	PM (g/km)	••• (g/km)	FC (g/km)
1													
1.1													
1.1.1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	•••	(12)
1.1.2	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	•••	(12)
•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••
1.1.9													
1.1.9.1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	•••	(12)
1.1.9.2	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	•••	(12)
•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••
3.8.1	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	•••	(12)
3.8.2	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	•••	(12)
•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••
4.3.2	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	•••	(12)

Key to Table A13

- (1) Number of vehicles in the specific category.
- (2) Annual distance driven by the average vehicle of the category, in km.
- (3) Percentage of the annual distance, driven in urban areas, in %.
- (4) Average speed of urban areas, in km/h.
- (5) Percentage of the annual distance, driven in rural areas, in %.
- (6) Average speed of rural areas, in km/h.
- (7) Percentage of the annual distance, driven on highways, in %.
- (8) Average speed of highways, in km/h.
- (9) - (11) Formulae to calculate emission factors of the relevant pollutant as a function of the average speed, in g/km. One such column is needed for each pollutant.
- (12) Formula to calculate fuel consumption from the carbon containing pollutant emissions, in g/km.

A4.1.1. Passenger cars and light duty trucks

In COST Action 319 a great number of measured data on in-use cars have been made available from many countries and laboratories. These data were analysed and a consistent set of emission factors and functions was produced for all the important technological classes of PCs and LDVs, by adopting the average speed dependency approach [A20]. It should be stressed that the raw data did not cover all vehicle technologies (in particular older ones). Therefore some emission functions developed earlier for COPERT I [A21] have been adopted in order to have a full coverage of all the possible combinations of technologies and fuels[26].

On the basis of the data made available by all partners, the following categories were treated:

- Gasoline cars complying with EURO I (91/441/EEC) emission standards
- Diesel cars complying with EURO I (91/441/EEC, 88/436/EEC and US83) emission standards
- Conventional Gasoline LDVs
- Conventional Diesel LDVs
- Gasoline LDVs complying with EURO I (93/59/EEC) emission standards
- Diesel LDVs complying with EURO I (93/59/EEC) emission standards

All other older technology categories have been covered by the equations of CORINAIR/ COPERT approach.

- Only the so called conventional (CO, VOC, NO_X and PM from diesel vehicles) pollutants were treated, as well as CO_2 emissions.

- Only real world cycles were used for these correlations. Therefore the FTP and the EUDC were excluded from the correlations. Nevertheless some additional attempts to take on board either the FTP or the EUDC or both showed that either there was no noticeable effect on the final correlations or the emission functions shifted to smaller values.

- A first investigation to differentiate between early catalyst cars and those complying with EURO I (91/441/EEC) emission standards gave no result. Therefore it was decided not to split these emission control technologies and to adopt only one category under EURO I.

- Cars with more than 100000 km and less than 3000 km of accumulated mileage were not taken into account in the correlations of catalyst equipped vehicles, in order, in principle, to avoid discrepancies introduced either by failed catalysts or by cars in the their run-in phase.

- The split between the three different engine capacity classes (i.e. <1.4l, 1.4 to 2.0l and >2.0l) was kept for EURO I cars, with different equations for each of the three capacity classes.

[26] This section deals only with the emission functions for existing vehicle types and conventional fuels. For other types, covering future standards and alternative fuels, emission functions cannot be derived in the same way as there are insufficient experimental data. They are considered separately in a later section of the report.

- It was not possible to make any distinction between engine capacity classes for the diesel passenger cars.

- It was not possible to differentiate more than one weight class of LDVs. Therefore it was decided to provide equations for all LDVs with a weight less than 3.5 tonnes.

The full set of emission equations for all vehicle categories and pollutants produced on the basis of the above is presented in Tables A14 to A21 (passenger cars) and A22 to A23 (light duty trucks). In these Tables the equations are given as functions of the average speed of the vehicle (denoted as V); in addition the correlation coefficients (R^2) of the best fit curves are presented.

In many cases, it will be noted that the correlation coefficients are low, implying a low statistical probability that the functions represent a genuine relationship between the rates of emission and average speed. However, one of the main reasons for the poor correlation is the very large scatter that is observed in the data sets. All measurement programmes demonstrate this variability, and it must be acknowledged that there can be large differences between the emissions from different vehicles within the same category, and even from the same vehicle when measurements are made at different times. Provided that the samples of vehicles for which measurements are available are fairly representative, then the average rates of emission generated by these functions can be reasonably accurate in spite of the low correlations.

It is also notable that the correlation between average speed and emissions is poorer for EURO I cars than for earlier types (correlation coefficients for non catalyst cars are generally higher than 0.5, while those for EURO I petrol cars are typically around 0.1, see Tables A14 to A16). This greater variability of emissions is probably attributable to effects of the emission control system. The engines of catalyst equipped cars are likely to produce rates of emission with a variability comparable to those of non-catalyst vehicles[27], but the emissions are then treated by the catalyst, and there is the potential for almost complete removal of the pollutants, virtually no effect or anything between these extremes. This variation occurs on an individual car, depending on its operating condition (see Figures A7 and A8), and also between cars, depending on their state of tune, their different engine management regimes, the extent to which their catalysts have degraded and so on. Overall, therefore, there is a possibility for emissions from catalyst equipped cars to vary more than those from non-catalyst cars, and this is indeed reflected in the data.

As part of the development of these emission functions, a number of statistical analyses were performed to determine whether there were systematic variations in the data. Three main parameters were examined: the laboratory at which the measurement was performed, the mileage that the vehicle had covered at the time of the test and the vehicle's engine capacity. Dependencies on the engine size and vehicle mileage were found, and they were incorporated into the calculation method by providing individual emission functions for small, medium and large engines and by providing a mileage correction function (see A4.2.4).

[27] They may, in fact be less variable because of the improved fuel delivery and engine management systems.

From the analysis of results measured at different laboratories, it was shown that there were significant differences between them. Figure A14 shows a few examples of the comparisons that were made, and demonstrates that the highest average results were invariably measured by LAT, generally followed by TγV, INRETS and TNO. The reasons for the differences are not known. They may include the test conditions in each institute (the equipment used, its set-up and the ambient conditions), the way in which the vehicle samples are selected (some of the measurements are from national programmes whose objectives dictate a non-random sample selection) or they may simply reflect the overall conditions of different national vehicle populations. Further studies should be carried out to resolve these questions.

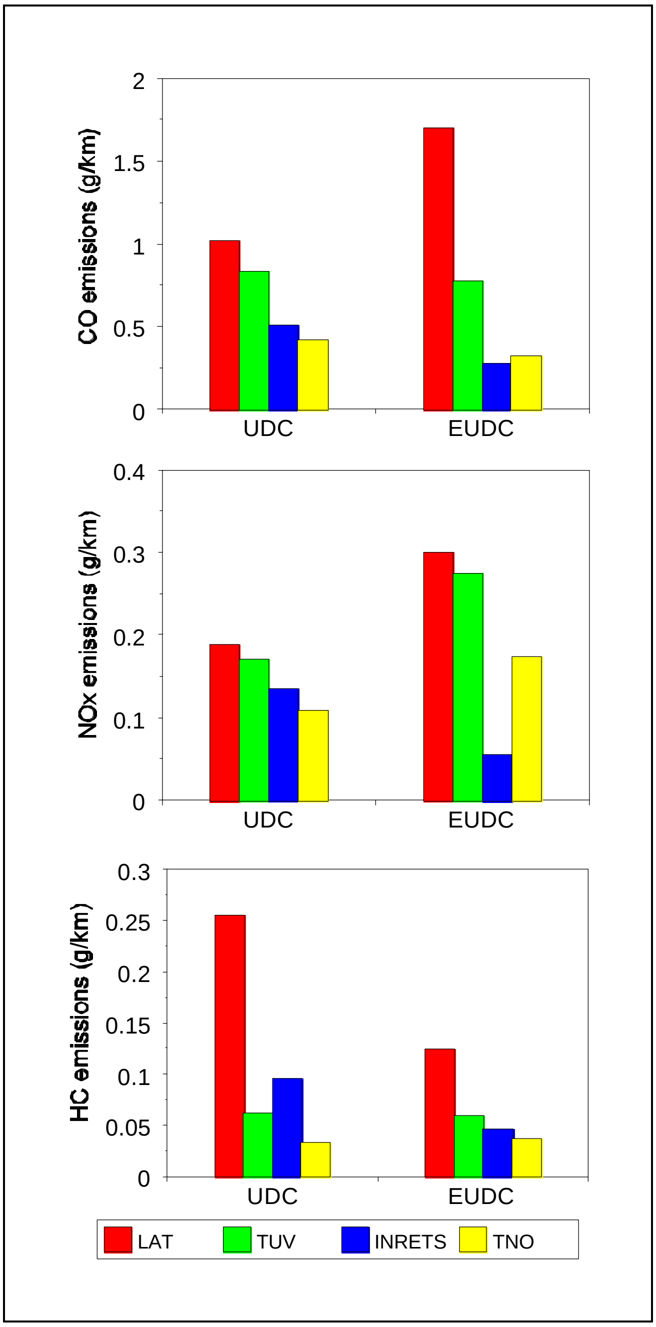

Figure A14. Comparison of average emission rates measured at four laboratories

Table A14. Speed dependency of CO emission factors for gasoline passenger cars

Vehicle class	**Cylinder capacity**	**Speed range**	**CO emission factor (g/km)**	**R^2**
PRE ECE	All categories	10-100	$281V^{-0.630}$	0.924
	All categories	100-130	$0.112V + 4.32$	-
ECE 15-00/01	All categories	10-50	$313V^{-0.760}$	0.898
	All categories	50-130	$27.22 - 0.406V + 0.0032V^2$	0.158
ECE 15-02	All categories	10-60	$300V^{-0.797}$	0.747
	All categories	60-130	$26.260 - 0.440V + 0.0026V^2$	0.102
ECE 15-03	All categories	10-20	$161.36 - 45.62 \ln(V)$	0.790
	All categories	20-130	$37.92 - 0.680V + 0.00377V^2$	0.247
ECE 15-04	All categories	10-60	$260.788V^{-0.910}$	0.825
	All categories	60-130	$14.653 - 0.220V + 0.001163V^2$	0.613
Improved conventional	CC < 1.4 l	10-130	$14.577 - 0.294V + 0.002478V^2$	0.781
	1.4 l < CC < 2.0 l	10-130	$8.273 - 0.151V + 0.000957V^2$	0.767
Open loop	CC < 1.4 l	10-130	$17.882 - 0.377V + 0.002825V^2$	0.656
	1.4 l < CC < 2.0 l	10-130	$9.446 - 0.230V + 0.002029V^2$	0.719
EURO I	CC < 1.4 l	10-130	$9.846 - 0.2867V + 0.0022V^2$	0.133
	1.4 l < CC < 2.0 l	10-130	$9.617 - 0.245V + 0.001729V^2$	0.145
	CC > 2.0 l	10-130	$12.826 - 0.2955V + 0.00177V^2$	0.109

Table A15. Speed dependency of VOC emission factors for gasoline passenger cars

Vehicle class	**Cylinder capacity**	**Speed range**	**VOC emission factor (g/km)**	**R^2**
PRE ECE	All categories	10-100	$30.34V^{-0.693}$	0.980
	All categories	100-130	1.247	-
ECE 15-00/01	All categories	10-50	$24.99V^{-0.704}$	0.901
	All categories	50-130	$4.85V^{-0.318}$	0.095
ECE 15-02/03	All categories	10-60	$25.75V^{-0.714}$	0.895
	All categories	60-130	$1.95 - 0.019V + 0.00009V^2$	0.198
ECE 15-04	All categories	10-60	$19.079V^{-0.693}$	0.838
	All categories	60-130	$2.608 - 0.037V + 0.000179V^2$	0.341
Improved conventional	CC < 1.4 l	10-130	$2.189 - 0.034V + 0.000201V^2$	0.766
	1.4 l < CC < 2.0 l	10-130	$1.999 - 0.034V + 0.000214V^2$	0.447
Open Loop	CC < 1.4 l	10-130	$2.185 - 0.0423V + 0.000256V^2$	0.636
	1.4 l < CC < 2.0 l	10-130	$0.808 - 0.016V + 0.000099V^2$	0.49
EURO I	CC < 1.4 l	10-130	$0.628 - 0.01377V + 8.52E\text{-}05V^2$	0.207
	1.4 l < CC < 2.0 l	10-130	$0.4494 - 0.00888V + 5.21E\text{-}05V^2$	0.197
	CC > 2.0 l	10-130	$0.5086 - 0.00723V + 3.3E\text{-}05V^2$	0.043

Table A16. Speed dependency of NO_X emission factors for gasoline passenger cars

Vehicle class	**Cylinder capacity**	**Speed range**	**NO_X emission factor (g/km)**	**R^2**
PRE ECE ECE 15-00/01	CC < 1.4 l	10-130	$1.173 + 0.0225V - 0.00014V^2$	0.916
	1.4 l < CC < 2.0 l	10-130	$1.360 + 0.0217V - 0.00004V^2$	0.960
	CC > 2.0 l	10-130	$1.5 + 0.03V + 0.0001V^2$	0.972
ECE 15-02	CC < 1.4 l	10-130	$1.479 - 0.0037V + 0.00018V^2$	0.711
	1.4 l < CC < 2.0 l	10-130	$1.663 - 0.0038V + 0.00020V^2$	0.839
	CC > 2.0 l	10-130	$1.87 - 0.0039V + 0.00022V^2$	-
ECE 15-03	CC < 1.4 l	10-130	$1.616 - 0.0084V + 0.00025V^2$	0.844
	1.4 l < CC < 2.0 l	10-130	$1.29 e^{0.0099V}$	0.798
	CC > 2.0 l	10-130	$2.784 - 0.0112V + 0.000294V^2$	0.577
ECE 15-04	CC < 1.4 l	10-130	$1.432 + 0.003V + 0.000097V^2$	0.669
	1.4 l < CC < 2.0 l	10-130	$1.484 + 0.013V + 0.000074V^2$	0.722
	CC > 2.0 l	10-130	$2.427 - 0.014V + 0.000266V^2$	0.803
Improved conventional	CC < 1.4 l	10-130	$-0.926 + 0.719 \ln(V)$	0.883
	1.4 l < CC < 2.0 l	10-130	$1.387 + 0.0014V + 0.000247V^2$	0.876
Open Loop	CC < 1.4 l	10-130	$-0.921 + 0.616 \ln(V)$	0.791
	1.4 l < CC < 2.0 l	10-130	$-0.761 + 0.515 \ln(V)$	0.495
EURO I	CC < 1.4 l	10-130	$0.5595 - 0.01047V + 1.08E\text{-}04V^2$	0.122
	1.4 l < CC < 2.0 l	10-130	$0.526 - 0.0085V + 8.54E\text{-}05V^2$	0.077
	CC > 2.0 l	10-130	$0.666 - 0.009V + 7.55E\text{-}05V^2$	0.014

Table A17. Speed dependency of carbon dioxide emission factors for gasoline passenger cars

Vehicle class	**Cylinder capacity**	**Speed range**	**CO_2 emission factor (g/km)**	**R^2**
PRE ECE	CC < 1.4 l	10-130	$768 + 3.13V - 199\ln(V)$	-
	1.4 l < CC < 2.0 l	10-130	$1005 + 4.15V - 263\ln(V)$	-
	CC > 2.0 l	10-130	$1498 + 8.21V - 0.0133V^2 - 421\ln(V)$	-
ECE 15-00/01	CC < 1.4 l	10-130	$173 - 2.52V + 0.0182V^2 + 1930/V$	-
	1.4 l < CC < 2.0 l	10-130	$1065 + 4.00V - 284 \ln(V)$	-
	CC > 2.0 l	10-130	$835 + 3.71V + 2297/V - 229\ln(V)$	-
ECE 15-02	CC < 1.4 l	10-130	$345 + 0.0106V^2 + 1275/V - 68.6\ln(V)$	-
	1.4 l < CC < 2.0 l	10-130	$835 + 3.93V + 986/V - 231\ln(V)$	-
	CC > 2.0 l	10-130	$879 + 4.32V + 2298/V - 244\ln(V)$	-
ECE 15-03	CC < 1.4 l	10-130	$664 + 2.09V + 0.00449V^2 - 167\ln(V)$	-
	1.4 l < CC < 2.0 l	10-130	$1074 + 5.49V - 0.00461V^2 - 305\ln(V)$	-
	CC > 2.0 l	10-130	$957 + 4.51V + 1832/V - 264\ln(V)$	-
ECE 15-04	CC < 1.4 l	10-130	$614 + 2.56V - 157\ln(V)$	-
	1.4 l < CC < 2.0 l	10-130	$264 + 0.0103V^2 + 2049/V - 49.8\ln(V)$	-
	CC > 2.0 l	10-130	$1173 + 4.83V - 315\ln(V)$	-
Improved conventional	CC < 1.4 l	10-130	$226 - 3.91V + 0.0368V^2$	-
	1.4 l < CC < 2.0 l	10-130	$333 - 6.11V + 0.0518V^2$	-
Open Loop	CC < 1.4 l	10-130	$238 - 3.67V + 0.0319V^2$	-
	1.4 l < CC < 2.0 l	10-130	$331 - 5.88V + 0.0499V^2$	-
EURO I	CC < 1.4 l	5-130	$157 - 2.07V + 0.0172V^2 + 1835/V$	-
	1.4 l < CC < 2.0 l	5-130	$231 - 3.62V + 0.0263V^2 + 2526/V$	-
	CC > 2.0 l	5-130	$294 - 5.50V + 0.0393V^2 + 3513/V$	-

Table A18. Speed dependency of factors for uncontrolled diesel vehicles <2.5 t

Pollutant	Cylinder capacity	Speed range	Emission factor (g/km)	R^2
CO	All categories	10-130	$5.413V^{-0.574}$	0.745
NO_X	CC < 2.0l	10-130	$0.918 - 0.014V + 0.000101V^2$	0.949
	CC > 2.0l	10-130	$1.331 - 0.018V + 0.000133V^2$	0.927
VOC	All categories	10-130	$4.61V^{-0.937}$	0.794
PM	All categories	10-130	$0.45 - 0.0086V + 0.000058V^2$	0.439
CO_2	All categories	10-130	$374 - 6.58V + 0.0442V^2 - 30.3/V$	-

Table A19. Speed dependency of emission factors for diesel vehicles <2.5 t, complying with the EURO I Directive

Pollutant	Cylinder capacity	Speed range	Emission factor (g/km)	R^2
CO	All categories	10-120	$1.4497 - 0.03385V + 2.1E-04V^2$	0.550
NO_X	All categories	10-120	$1.4335 - 0.026V + 1.785E-04V^2$	0.262
VOC	All categories	10-130	$0.1978 - 0.003925V + 2.24E-05V^2$	0.342
PM	All categories	10-130	$0.1804 - 0.004415V + 3.33E-05V^2$	0.294
CO_2	All categories	10-130	$286 - 4.07V + 0.0271V^2$	-

Table A20. Speed dependency of emission factors for conventional LPG vehicles <2.5 t

Pollutant	Cylinder capacity	Speed range	Emission factor (g/km)	R^2
CO	All categories	10-130	$12.523 - 0.418V + 0.0039V^2$	0.893
NO_X	All categories	10-130	$0.77V^{0.285}$	0.598
VOC	All categories	10-130	$26.3V^{-0.865}$	0.967
CO_2	All categories	10-130	$283 - 4.15V + 0.0291V^2$	-

Table A21. Speed dependency of emission factors for LPG vehicles <2.5 t, complying with EURO I Directive

Pollutant	Cylinder capacity	Speed range	Emission factor (g/km)	R^2
CO	All categories	10-130	$0.00110V^2 - 0.1165V + 4.2098$	n/a
NO_X	All categories	10-130	$0.00004V^2 - 0.0063V + 0.5278$	n/a
VOC	All categories	10-130	$0.00010V^2 - 0.0166V + 0.7431$	n/a
CO_2	All categories	10-130	$0.0208V^2 - 2.70V + 228$	n/a

Table A22. Speed dependency of emission factors for gasoline light duty vehicles <3.5 t

Pollutant	**Vehicle class**	**Speed range**	**Emission factor (g/km)**	**R^2**
CO	Uncontrolled	5-110	$0.01104V^2$ - 1.5132V + 57.789	0.732
	EURO I	5-120	$0.0037V^2$ - 0.5215V + 19.127	0.394
NO_X	Uncontrolled	5-110	0.0179V + 1.9547	0.159
	EURO I	5-120	7.55E-05V^2 - 0.009V + 0.666	0.014
VOC	Uncontrolled	5-110	$0.000677V^2$ - 0.1170V + 5.4734	0.771
	EURO I	5-120	5.77E-05V^2 - 0.01047V + 0.5462	0.358
CO_2	Uncontrolled	5-110	$0.0541V^2$ - 8.4326V + 514.5	0.787
	EURO I	5-120	$0.0621V^2$ - 9.8381V + 601.2	0.723

Notes: Due to limited available data, the functions for the following cases are a mere copy of those applied in passenger cars. In any case, they seem to be in good compliance with both the measured data and the emission standards.

NO_X EURO I Gasoline, the emission factor function for Gasoline PC<1,4l EURO I has been adopted

Table A23. Speed dependency of emission factors for diesel light duty vehicles <3.5 t

Pollutant	**Vehicle class**	**Speed range**	**Emission factor (g/km)**	**R^2**
CO	Uncontrolled	10-110	$0.00020V^2$ - 0.0256V + 1.8281	0.136
	EURO I	10-110	$0.000223V^2$ - 0.026V + 1.076	0.301
NO_X	Uncontrolled	10-110	$0.000816V^2$ - 0.1189V + 5.1234	0.402
	EURO I	10-110	$0.000241V^2$ - 0.03181V + 2.0247	0.072
VOC	Uncontrolled	10-110	$0.000066V^2$ - 0.0113V + 0.6024	0.141
	EURO I	10-110	$0.0000175V^2$ - 0.00284V + 0.2162	0.037
PM	Uncontrolled	10-110	$0.0000125V^2$ - 0.000577V + 0.2880	0.023
	EURO I	10-110	$0.000045V^2$ - 0.004885V + 0.1932	0.224
CO_2	Uncontrolled	10-110	$0.066V^2$ - 8.2756V + 464.4	0.486
	EURO I	10-110	$0.0617V^2$ - 7.8227V + 429.51	0.422

A4.1.2. Heavy duty vehicles

Only relatively few data are available on emissions from heavy duty vehicles. The most recent thorough compilation of emission factors is that presented in the Workbook on Emission Factors for Road Transport [A22]. The Workbook provides emission factors for all types of vehicle, including heavy lorries and buses, for a variety of driving patterns. Other features taken into account are the road gradient and, for heavy goods vehicles, the load state of the vehicle. Both heavy goods vehicles and buses are further subdivided into a number of classes according to their weight.

The emission factors were derived using data from engine test-bed measurements. The types of engines that were tested were identified from an analysis of the vehicle fleet in the Federal Republic of Germany, which showed that 300 types of heavy-duty vehicle were in use. A total of 36 diesel engines were tested, representing the range of engines used in the 300 vehicle types. They included 18 engines of mid-1980s technology, 12 state-of-the-art engines of 1990 technology, and 6 other engines to take account of Swiss fleet composition. Each engine was categorised according to the type of vehicle in which it was used. The four vehicle categories were "truck", "articulated vehicle", "coach", and "bus", and each category was further sub-divided according to mass, body style, and model year band.

In order to produce characteristic emission maps, each engine was run on a test-bed under steady-state and transient conditions (using the 13-mode, US transient, and TÜV-FIGE cycles).

The road speed, engine speed, and torque were recorded as a function of time for 25 commercial vehicles during normal operation on the following types of road:

- Motorways
- Non-motorway dual carriageways
- Urban roads outside built-up areas
- Main urban streets
- Urban streets with a large distance between intersections
- Urban streets with a small distance between intersections

On each type of road, the traffic was categorised according to whether it was free-flowing, slightly congested, moderately congested, or heavily congested. The roads were also sub-divided into seven gradient classes, and two load factors per gradient class (10% and 90%). By combining the data collected, emission factors were calculated for a wide range of heavy-duty vehicles according to the road and traffic classes identified. The principal idea behind the model was the use of the relationship between instantaneous vehicle emissions determined from the engine tests and the instantaneous engine power output derived from the vehicle operation measurements.

The emission factors from the Workbook were compared with data derived from vehicle based measurements performed by TRL in the early 1990s [A23], and with two rather similar emission models, developed by TNO [A24] and the Technical University of Graz [A25]. The comparisons in each case showed an acceptable level of agreement [A26], bearing in mind that each of the data sets is based on limited measurements on different samples of engines and vehicles and following different experimental procedures. Because of their comprehensiveness and because their general level of accuracy was largely confirmed through the comparisons, the factors from the Workbook have been used as the basis for the derivation of average speed related emission functions.

The Workbook provides discreet emission factors for each of a set of pre-defined driving patterns. Continuous functions of emission rates depending on the average speed of the vehicle were derived from statistical curve fits to the data from the Workbook. The functions are of the form:

$$\varepsilon = K + av + bv^2 + cv^3 + \frac{d}{v} + \frac{e}{v^2} + \frac{f}{v^3} \qquad \text{(A10)}$$

where:

e	is the rate of emission in g/km for an unloaded goods vehicle, or for a bus or coach carrying a mean load, on a road with a gradient of 0%
K	is a constant
a - f	are coefficients
v	is the mean velocity of the vehicle in km/h

They were derived for four classes of heavy goods vehicle (3.5 to 7.5 tonnes, 7.5 to 16 tonnes, 16 to 32 tonnes and 32 to 40 tonnes) for urban buses and for coaches. The pollutants considered were carbon monoxide, carbon dioxide, hydrocarbons, oxides of nitrogen and particulates. Coefficients for these equations are presented in Tables A24 to A27 for heavy goods vehicles and A28 to A29 for buses and coaches.

In some EU Member states, HGVs are in use with a gross weight greater than 40 tonnes. It has not been possible to provide emission functions for these because there are no suitable data. However, the emissions of CO and HC do not show a large dependency on gross weight, so the functions for vehicles in the 32 - 40 tonne class may be used for heavier vehicles. NO_X and CO_2 emissions, and to a lesser extent PM emissions are more dependent on the vehicle weight. In order that heavier vehicle classes may be taken into account, one possibility is to extrapolate the data. Using the MEET functions, emissions were calculated over the speed range 10 to 90 km/h, at intervals of 10 km/h, and then an average taken over the speed range. This average result was assumed to represent a typical emission rate for each pollutant and vehicle weight. Then, as shown in Figure A15, the averages were plotted against the mid-point of the appropriate vehicle weight class. This procedure demonstrated a reasonably systematic relationship between gross weight and the average emission rate, and suggested that extrapolation to heavier weights may be acceptable. Linear fits to the data were therefore made, and the functions solved for weights of 45 and 55 tonnes (to represent new weight categories of 40 to 50 tonnes and 50 to 60 tonnes). Finally, the values for these higher weight classes were expressed relative to the value for the 32 to 40 tonne class in order to provide ‘weight correction factors’ given in Table A30. To estimate emissions for vehicles in the high weight classes, it is therefore possible to use the functions for the 32 to 40 tonne HGVs multiplied by the appropriate weight correction factor.

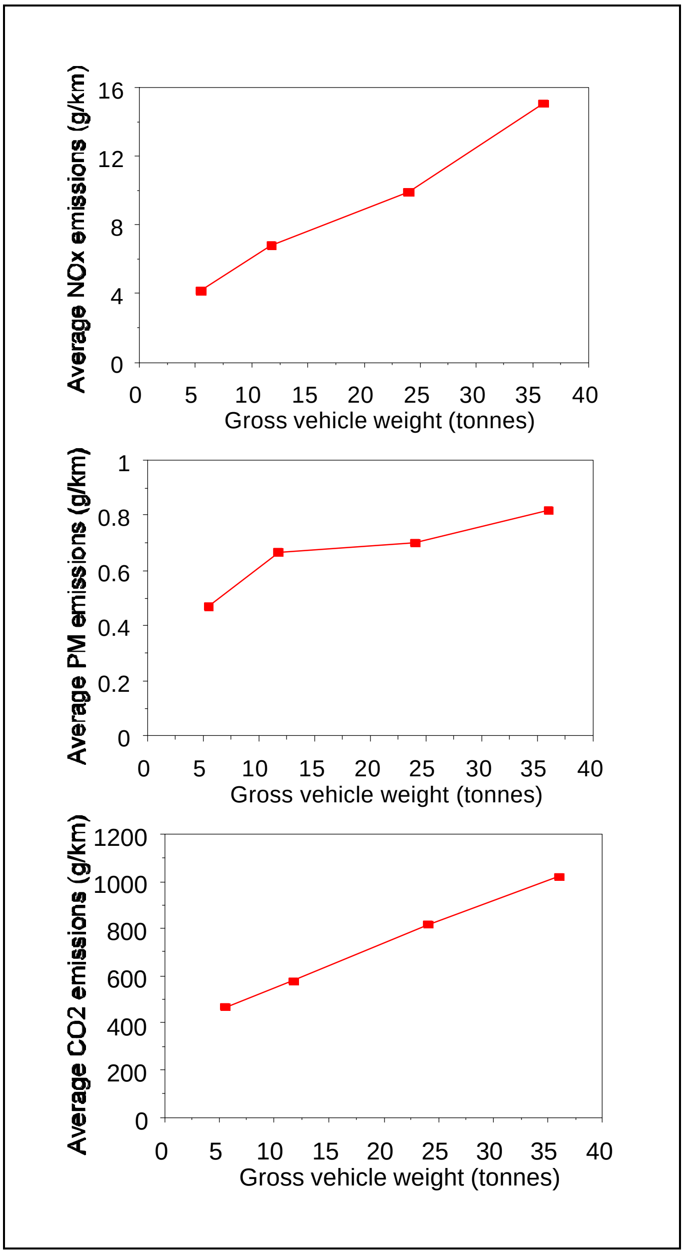

Figure A15. Variation of average HDV emissions with gross vehicle weight

Table A24. Coefficients of emission functions for heavy goods vehicles with gross vehicle weights from 3.5 to 7.5 tonnes

	K	*a*	*b*	*c*	*d*	*e*	*f*
CO	1.50	-0.0595	0.00119	-6.16E-6	58.8	0	0
CO_2	110	0	0	0.000375	8702	0	0
VOC	0.186	0	0	-2.97E-7	61.5	0	0
NO_X	0.508	0	0	3.87E-6	92.5	-77.3	0
PM	0.0506	0	0	1.22E-7	12.5	0	-21.1

Table A25. Coefficients of emission functions for heavy goods vehicles with gross vehicle weights from 7.5 to 16 tonnes

	K	*a*	*b*	*c*	*d*	*e*	*f*
CO	3.08	-0.0135	0	0	-37.7	1560	-5736
CO_2	871	-16.0	0.143	0	0	32031	0
VOC	1.37	0	-8.10E-5	0	0	870	-3282
NO_X	2.59	0	-0.000665	8.56E-6	140	0	0
PM	0.0541	0.00151	0	0	17.1	0	0

Table A26. Coefficients of emission functions for heavy goods vehicles with gross vehicle weights from 16 to 32 tonnes

	K	*a*	*b*	*c*	*d*	*e*	*f*
CO	1.53	0	0	0	60.6	117	0
CO_2	765	-7.04	0	0.000632	8334	0	0
VOC	0.207	0	0	0	58.3	0	0
NO_X	9.45	-0.107	0	7.55E-6	132	0	0
PM	0.184	0	0	1.72E-7	15.2	0	0

Table A27. Coefficients of emission functions for heavy goods vehicles with gross vehicle weights from 32 to 40 tonnes

	K	**a**	**b**	**c**	**d**	**e**	**f**
CO	0.349	0.0101	0	0	79.6	0	0
CO_2	1576	-17.6	0	0.00117	0	36067	0
VOC	0.254	0	0	0	53.9	0	0
NO_X	5.27	0	0	0	343	-552	0
PM	0.246	0	0	0	18.2	0	0

Table A28. Coefficients of emission functions for urban buses

	K	*a*	*b*	*c*	*d*	*e*	*f*
CO	1.64	0	0	0	132	0	0
CO_2	679	0	0	-0.00268	9635	0	0
VOC	0.0778	0	0	0	41.2	0	184
NO_X	16.3	-0.173	0	0	111	0	0
PM	0.0694	0	0.000366	-8.71E-6	13.9	0	0

Table A29. Coefficients of emission functions for coaches

	K	*a*	*b*	*c*	*d*	*e*	*f*
CO	0.930	0	-4.00E-5	0	99.2	0	0
CO_2	523	0	-0.0487	0.000527	12501	0	0
VOC	0.632	-0.00402	0	0	59.3	0	254
NO_X	6.12	0	-0.000651	7.23E-6	181	0	0
PM	0.193	0	0	0	15.6	0	29.6

Table A30. Weight correction factors for goods vehicles over 40 tonnes gross weight

Weight class	Weight correction factor (applicable to functions for HGVs 32 - 40 t)		
	NO_X	PM	CO_2
40 - 50 t	1.18	1.12	1.17
50 - 60 t	1.41	1.24	1.35

A4.1.3. Mopeds and motorcycles

Emissions from two-wheelers have had little attention in the past, certainly less than emissions from passenger cars and trucks. Yet it was demonstrated as early as the 1970s that in countries with a large two-wheeler population their contribution can be significant. This is all the more true since emissions from cars and trucks have been, or will be, severely restricted. Two-stroke engines in particular can emit significant quantities of hydrocarbons, but what measurements there are also show that four-stroke engines are not up to the standards of those in passenger cars. In some national emission inventories two-wheelers may contribute a significant part.

For a good estimate of the general emission behaviour of two-wheelers the problem is that measured data are scarce and usually based on very few vehicles. On the other hand the variation in vehicles is much larger than in passenger cars, in mass and engine power, in engine types and in vehicle types. The shortage of data makes this variation difficult to represent.

The vehicle types considered are:

- *Mopeds*. Small vehicles, usually restricted in their performance. Much variation exists between countries in, for example, top speed (from 25 km/h to 50 km/h) and other properties (such as with or without gears).

- *Motor cycles*. Larger vehicles varying from less than 125 to more than 1200 cc, from 60 to 350 kg, and from 3.5 to 100 kW or more. There are road, off-road and hybrid machines.

The engine types considered are 2-stroke and 4-stroke. Wankel engines have seen a short appearance but are completely off the market now. As far as emissions are concerned there are different legislation steps the vehicles have to comply with. This legislation often has different requirements for 2- and 4-stroke engines, and certainly for different vehicle types.

A recent inventory made by Swiss and German institutes and published by the Swiss Ministry for the Environment [A27] provides more information. In total, emissions from 24 motorcycles were measured over the European UDC, the European EUDC, the American US-FTP, the American Highway Cycle and the German Motorway Cycle. This allowed a speed dependency to be established. The proposed emission factors are presented in Tables A31 to A33 [A28].

Table A31. Emission factors for mopeds

Mopeds	CO (g/km)	NO_X (g/km)	VOC (g/km)	CO_2 (g/km)
Uncontrolled	15.0	0.03	9.00	27.3
Controlled Stage 1	9	0.03	5	49.4
Controlled Stage 2	5	0.01	2	65.2

Table A32. Speed dependency of emission factors for 2 stroke motorcycles of engine capacity over $50cm^3$

Pollutant	**Vehicle class**	**Speed range**	**Emission factor (g/km)**
CO	Uncontrolled	10 - 60	$-0.00100V^2 + 0.1720V + 18.10$
		60 - 110	$0.00010V^2 + 0.0500V + 21.50$
	Controlled	10 - 60	$-0.00630V^2 + 0.7150V - 6.900$
		60 - 110	$-0.00070V^2 + 0.1570V + 6.000$
NO_X	Uncontrolled	10 - 60	$0.00003V^2 - 0.0020V + 0.064$
		60 - 110	$-0.00002V^2 + 0.0049V - 0.157$
	Controlled	10 - 60	$0.00002V^2 - 0.0010V + 0.032$
		60 - 110	$0.00002V^2 + 0.0041V - 0.152$
VOC	Uncontrolled	10 - 60	$0.00350V^2 - 0.4090V + 20.10$
		60 - 110	$0.00030V^2 - 0.0524V + 10.60$
	Controlled	10 - 60	$-0.00100V^2 + 0.0970V + 3.900$
		60 - 110	$-0.00030V^2 + 0.0325V + 5.200$
CO_2	Uncontrolled	10 - 110	$88.2 + 0.616V - 22.3\ln(V)$
	Controlled	10 - 110	$33.3 + 0.00164V^2 + 155/V$

Table A33. Speed dependency of emission factors for 4 stroke motorcycles of engine capacity over $50cm^3$

Pollutant	**Cylinder Capacity**	**Speed**	**Emission Factor [g/km]**
CO	Uncontrolled <$250cm^3$	10 - 60	$0.01930V^2 - 1.9200V + 68.30$
		60 - 110	$0.00170V^2 + 0.1210V + 9.500$
	Uncontrolled 250<cc<$750cm^3$	10 - 60	$0.01390V^2 - 1.4200V + 55.00$
		60 - 110	$0.00090V^2 - 0.0099V + 17.80$
	Uncontrolled >$750cm^3$	10 - 60	$0.01230V^2 - 1.1900V + 42.80$
		60 - 110	$0.00050V^2 + 0.1240V + 6.900$
	Controlled - All Capacities	10 - 60	$0.00760V^2 - 0.7300V + 23.50$
		60 - 110	$0.00100V^2 + 0.0510V + 0.800$
NO_X	Uncontrolled <$250cm^3$	10 - 60	$0.00005V^2 - 0.0010V + 0.090$
		60 - 110	$0.00002V^2 + 0.0006V + 0.102$
	Uncontrolled[3] 250<cc<750cm	10 - 60	$0.00005V^2 - 0.0009V + 0.092$
		60 - 110	$0.00002V^2 + 0.0007V + 0.104$
	Uncontrolled >$750cm^3$	10 - 60	$0.00005V^2 - 0.0008V + 0.100$
		60 - 110	$0.00002V^2 + 0.0008V + 0.112$
	Controlled All Capacities	10 - 60	$0.00005V^2 - 0.0007V + 0.137$
		60 - 110	$0.00002V^2 + 0.001V + 0.143$
VOC	Uncontrolled <$250cm^3$	10 - 60	$0.00190V^2 - 0.2110V + 6.950$
		60 - 110	$0.00090V^2 - 0.1410V + 6.420$
	Uncontrolled 250<cc<$750cm^3$	10 - 60	$0.00150V^2 - 0.1640V + 5.510$
		60 - 110	$0.00001V^2 + 0.0005V + 0.860$
	Uncontrolled >$750cm^3$	10 - 60	$0.00220V^2 - 0.2570V + 9.280$
		60 - 110	$0.00010V^2 - 0.0310V + 3.290$
	Controlled All Capacities	10 - 60	$0.00050V^2 - 0.0755V + 2.630$
		60 - 110	$0.00007V^2 - 0.0152V + 1.190$
CO_2	Uncontrolled <$250cm^3$	10 - 110	$155 + 0.843V - 41.3\ln(V)$
	Uncontrolled 250<cc<$750cm^3$	10 - 140	$397 + 1.78V - 111\ln(V)$
	Uncontrolled >$750cm^3$	10 - 140	$423 + 0.00693V^2 - 92.5\ln(V)$
	Controlled All Capacities	10 - 140	$340 + 1.28V - 85.4\ln(V)$

A4.2. Other parameters affecting hot emissions

Apart from vehicle technology and average speed, other parameters affect emissions either directly (e.g. vehicle mileage, engine temperature, altitude) or by altering the mode of operation of the engine (e.g. road gradient, vehicle load). The vast majority of available experimental data on emissions refer to 'standard' testing conditions, i.e. zero altitude, zero road gradient, empty vehicle, etc. The vehicle mileage is usually recorded prior to testing, while engine temperature is usually either 20°C (cold start - as defined by the legislation) or normal operating temperature (hot start).

A4.2.1. Road gradient

The gradient of a road has the effect of increasing or decreasing the resistance of a vehicle to traction. Increases or decreases in the load on the engine have a corresponding effect on rates of emission and fuel consumption, but even in the case of large-scale applications, it cannot be assumed that the extra emission when travelling uphill is fully compensated by the reduced emission when travelling downhill.

In principle the emissions and fuel consumption of both light and heavy duty vehicles are affected by road gradient. However, because of their higher masses, the gradient influence is much more significant in the case of heavy duty vehicles.

The method adopted to allow for the effect of gradient is based on the results of the German Emission Factor programme [A29]. Special gradient factors have been introduced, considered to be a function of :

- The technology (for light duty vehicles) or the mass (for heavy duty vehicles)
- The road gradient
- The pollutant
- The mean speed of the vehicle

For each vehicle category, gradient and pollutant, the gradient factor can be calculated as a polynomial function of the vehicle's mean speed:

$$as_{i,j,k} = A6_{i,j,k} \cdot V^6 + A5_{i,j,k} \cdot V^5 + A4_{i,j,k} \cdot V^4 + A3_{i,j,k} \cdot V^3 + A2_{i,j,k} \cdot V^2 + A1_{i,j,k} \cdot V + A0 \quad \text{(A11)}$$

where:

$as_{i,j,k}$	is the correction factor
V	is the mean speed
$A0_{i,j,k}$... $A6_{i,j,k}$	are constants for each pollutant, vehicle and gradient class

Hence, it is proposed to correct the emission factor calculated for vehicle's use on a flat road according to the following equation, in order to incorporate the influence of the road gradient:

$$ec_{hot,i,j,k} = as_{i,j,k} \times e_{hot,i,j,k} \quad \text{(A12)}$$

where:

$ec_{hot,i,j,k}$ is the corrected emission factor of the pollutant *i*, in g/km, of the vehicle of category *j* driven on roads of type *k* with hot engines

$e_{hot,i,j,k}$ is the emission factor of the pollutant *i*, in g/km, of the vehicle of category *j* driven with hot engines on roads of type *k* with zero gradient

$as_{i,j,k}$ is the gradient correction factor of the pollutant *i* of the vehicle of category *j* driven on roads of type *k* for the appropriate gradient class, gradient classes are 0%, 2%, 4%, 6%, -2%, -4% and -6%.

The coefficients necessary for the calculation of the gradient correction factor are presented in Tables A34 to A42. Vmin and Vmax give the speed range in which the correction is applicable.

Table A34. Coefficients of gradient factor functions for passenger and light duty vehicles with conventional gasoline engine

A6	**A5**	**A4**	**A3**	**A2**	**A1**	**A0**	**Pollutant**	**Slope (%)**	**Vmin (km/h)**	**Vmax (km/h)**
2.94E-11	-1.41E-08	2.56E-06	-2.21E-04	9.34E-03	-1.66E-01	2.20E+00	VOC	6	18.6	120.0
2.76E-11	-9.63E-09	1.14E-06	-5.00E-05	1.68E-04	2.97E-02	1.33E+00		-6	18.6	127.8
-1.85E-11	8.28E-09	-1.44E-06	1.22E-04	-5.34E-03	1.36E-01	-4.23E-01		4	18.6	120.0
-1.19E-11	7.85E-09	-1.79E-06	1.85E-04	-9.23E-03	2.10E-01	-1.73E-01		-4	18.6	127.8
1.05E-11	-4.37E-09	7.44E-07	-6.75E-05	3.40E-03	-7.90E-02	1.68E+00		2	18.6	130.0
-6.92E-12	3.88E-09	-7.76E-07	6.91E-05	-2.80E-03	5.07E-02	6.63E-01		-2	18.6	130.0
3.46E-10	-1.36E-07	2.04E-05	-1.49E-03	5.56E-02	-9.70E-01	7.57E+00	CO	6	18.6	120.0
1.21E-11	-2.13E-09	-2.09E-07	6.57E-05	-4.74E-03	1.33E-01	-7.58E-01		-6	18.6	127.8
3.43E-10	-1.25E-07	1.71E-05	-1.10E-03	3.48E-02	-4.88E-01	3.40E+00		4	18.6	120.0
-3.89E-11	2.10E-08	-4.29E-06	4.20E-04	-2.05E-02	4.73E-01	-3,04E+00		-4	18.6	127.8
1.22E-10	-4.73E-08	6.91E-06	-4.86E-04	1.77E-02	-3.17E-01	3.27E+00		2	18.6	130.0
3.14E-12	1.51E-10	-2.79E-07	4.13E-05	-2.26E-03	5.08E-02	4.41E-01		-2	18.6	130.0
0.00E+00	1.30E-09	-4.95E-07	7.29E-05	-5.14E-03	1.57E-01	9.33E-01	NO_X	6	18.6	120.0
0.00E+00	0.00E+00	0.00E+00	1.42E-08	2.56E-05	-3.90E-03	2.81E-01		-6	18.6	127.8
0.00E+00	-5.03E-10	1.41E-07	-9.72E-06	-3.18E-04	3.92E-02	1.16E+00		4	18.6	120.0
0.00E+00	0.00E+00	0.00E+00	1.60E-07	2.36E-05	-5.97E-03	5.09E-01		-4	18.6	127.8
0.00E+00	-8.59E-12	-8.39E-09	4.05E-06	-5.55E-04	2.43E-02	1.12E+00		2	18.6	130.0
0.00E+00	0.00E+00	0.00E+00	5.79E-07	-1.15E-04	6.32E-03	5.94E-01		-2	18.6	130.0
0.00E+00	0.00E+00	0.00E+00	0.00E+00	-4.74E-05	1.17E-02	1.40E+00	CO_2	6	18.6	120.0
0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.26E-05	-7.28E-03	6.15E-01		-6	18.6	127.8
0.00E+00	0.00E+00	0.00E+00	0.00E+00	-3.11E-06	4.72E-03	1.23E+00		4	18.6	120.0
0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.34E-05	-1.08E-02	9.52E-01		-4	18.6	127.8
0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.63E-06	2.25E-03	1.09E+00		2	18.6	130.0
0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.04E-05	-3.49E-03	9.06E-01		-2	18.6	130.0

Table A35. Coefficients of gradient factor functions for passenger and light duty vehicles with regulated catalyst

A6	A5	A4	A3	A2	A1	A0	Pollutant	Slope (%)	Vmin (km/h)	Vmax (km/h)
4.99E-10	-1.98E-07	3.01E-05	-2.23E-03	8.55E-02	-1.64E+00	1.42E+01	VOC	6	18.6	120.0
1.51E-10	-5.06E-08	5.78E-06	-2.42E-04	7.16E-04	1.59E-01	-1.27E+00		-6	18.6	127.8
3.82E-10	-1.49E-07	2.23E-05	-1.62E-03	6.07E-02	-1.13E+00	9.59E+00		4	18.6	120.0
-6.61E-11	3.44E-08	-6.81E-06	6.46E-04	-3.04E-02	6.69E-01	-4.32E+00		-4	18.6	127.8
6.71E-11	-2.54E-08	3.55E-06	-2.28E-04	7.30E-03	-1.07E-01	1.54E+00		2	18.6	130.0
-2.86E-11	1.38E-08	-2.55E-06	2.22E-04	-9.37E-03	1.73E-01	1.24E-01		-2	18.6	130.0
7.67E-10	-2.96E-07	4.33E-05	-3.01E-03	1.03E-01	-1.62E+00	1.15E+01	CO	6	18.6	120.0
1.14E-11	-6.25E-11	-9.08E-07	1.57E-04	-1.01E-02	2.69E-01	-1.97E+00		-6	18.6	127.8
2.87E-10	-1.01E-07	1.29E-05	-6.92E-04	1.39E-02	1.10E-02	-2.23E-01		4	18.6	120.0
-7.12E-11	3.55E-08	-6.84E-06	6.44E-04	-3.06E-02	6.80E-01	-4.49E+00		-4	18.6	127.8
9.97E-12	-1.19E-10	-8.36E-07	1.44E-04	-8.55E-03	2.09E-01	-6.10E-01		2	18.6	130.0
-2.70E-11	1.24E-08	-2.20E-06	1.88E-04	-8.00E-03	1.54E-01	8.85E-02		-2	18.6	130.0
8.05E-11	-2.56E-08	2.91E-06	-1.50E-04	4.22E-03	-8.46E-02	3.13E+00	NO_X	6	18.6	120.0
0.00E+00	0.00E+00	0.00E+00	-1.95E-08	-1.31E-05	1.55E-03	2.08E-01		-6	18.6	127.8
1.22E-10	-4.82E-08	7.38E-06	-5.59E-04	2.21E-02	-4.30E-01	4.91E+00		4	18.6	120.0
0.00E+00	0.00E+00	0.00E+00	-9.67E-07	2.77E-04	-2.69E-02	1.31E+00		-4	18.6	127.8
-3.17E-11	1.51E-08	-2.77E-06	2.44E-04	-1.06E-02	2.13E-01	-5.83E-01		2	18.6	130.0
0.00E+00	0.00E+00	0.00E+00	-1.17E-07	1.55E-05	-4.92E-04	7.40E-01		-2	18.6	130.0
0.00E+00	0.00E+00	0.00E+00	0.00E+00	-8.04E-05	1.58E-02	1.36E+00	CO_2	6	18.6	120.0
0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.29E-05	-8.72E-03	6.32E-01		-6	18.6	127.8
0.00E+00	0.00E+00	0.00E+00	0.00E+00	-6.38E-05	1.32E-02	1.05E+00		4	18.6	120.0
0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.36E-05	-8.86E-03	8.28E-01		-4	18.6	127.8
0.00E+00	0.00E+00	0.00E+00	0.00E+00	-3.36E-05	7.17E-03	9.94E-01		2	18.6	130.0
0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.72E-05	-5.14E-03	9.89E-01		-2	18.6	130.0

Table A36. Coefficients of gradient factor functions for passenger and light duty vehicles with diesel engine

A6	A5	A4	A3	A2	A1	A0	Pollutant	Slope (%)	Vmin (km/h)	Vmax (km/h)
-6.00E-12	1.07E-08	-3.14E-06	3.67E-04	-2.00E-02	4.99E-01	-2.68E+00	VOC	6	18.6	120.0
6.40E-11	-2.65E-08	4.28E-06	-3.47E-04	1.54E-02	-3.68E-01	4.75E+00		-6	18.6	127.8
1.26E-10	-4.62E-08	6.47E-06	-4.39E-04	1.51E-02	-2.51E-01	3.17E+00		4	18.6	120.0
2.20E-11	-4.83E-09	-2.43E-08	7.02E-05	-5.30E-03	1.29E-01	3.89E-01		-4	18.6	127.8
-3.58E-12	2.79E-09	-6.43E-07	5.98E-05	-2.26E-03	3.06E-02	1.02E+00		2	18.6	130.0
3.35E-11	-1.36E-08	2.18E-06	-1.77E-04	7.78E-03	-1.73E-01	2.63E+00		-2	18.6	130.0
7.61E-11	-2.48E-08	2.90E-06	-1.51E-04	3.55E-03	-3.33E-02	1.66E+00	CO	6	18.6	120.0
1.11E-11	-4.83E-09	8.50E-07	-7.87E-05	4.10E-03	-1.15E-01	2.25E+00		-6	18.6	127.8
5.65E-11	-2.19E-08	3.25E-06	-2.36E-04	8.79E-03	-1.51E-01	2.11E+00		4	18.6	120.0
2.48E-11	-9.20E-09	1.30E-06	-9.11E-05	3.53E-03	-7.80E-02	1.93E+00		-4	18.6	127.8
1.86E-11	-7.45E-09	1.17E-06	-9.33E-05	4.06E-03	-8.54E-02	1.62E+00		2	18.6	130.0
2.71E-11	-1.16E-08	1.93E-06	-1.62E-04	7.00E-03	-1.45E-01	2.25E+00		-2	18.6	130.0
-6.48E-11	3.16E-08	-5.78E-06	4.99E-04	-2.12E-02	4.23E-01	-9.42E-01	NO_X	6	18.6	120.0
0.00E+00	0.00E+00	0.00E+00	-1.51E-07	6.12E-05	-7.28E-03	5.26E-01		-6	18.6	127.8
-5.06E-11	2.28E-08	-4.05E-06	3.64E-04	-1.77E-02	4.48E-01	-2.74E+00		4	18.6	120.0
0.00E+00	0.00E+00	0.00E+00	-3.34E-08	8.82E-05	-1.47E-02	1.02E+00		-4	18.6	127.8
-1.56E-11	6.73E-09	-1.10E-06	8.69E-05	-3.47E-03	7.30E-02	5.31E-01		2	18.6	130.0
0.00E+00	0.00E+00	0.00E+00	5.91E-07	-1.13E-04	4.59E-03	7.77E-01		-2	18.6	130.0
0.00E+00	0.00E+00	0.00E+00	0.00E+00	-6.42E-05	9.60E-03	1.89E+00	CO_2	6	18.6	120.0
0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.58E-05	-4.81E-03	4.82E-01		-6	18.6	127.8
0.00E+00	0.00E+00	0.00E+00	0.00E+00	-3.56E-05	6.99E-03	1.52E+00		4	18.6	120.0
0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.91E-05	-1.62E-02	1.12E+00		-4	18.6	127.8
0.00E+00	0.00E+00	0.00E+00	0.00E+00	-7.87E-06	3.92E-03	1.11E+00		2	18.6	130.0
0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.48E-05	-3.12E-03	8.85E-01		-2	18.6	130.0
0.00E+00	0.00E+00	0.00E+00	-3.07E-07	-7.24E-05	2.78E-02	1.60E+00	PM	6	18.6	120.0
0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.37E-05	-5.19E-03	9.53E-01		-6	18.6	127.8
0.00E+00	0.00E+00	0.00E+00	-3.77E-07	1.71E-05	1.01E-02	1.35E+00		4	18.6	120.0
0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.40E-05	-2.93E-03	9.84E-01		-4	18.6	127.8
0.00E+00	0.00E+00	0.00E+00	2.33E-07	-6.85E-05	7.71E-03	1.09E+00		2	18.6	130.0
0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.61E-05	-3.51E-03	9.43E-01		-2	18.6	130.0

Table A37. Coefficients of gradient factor functions for heavy duty vehicles <7.5 t

A6	A5	A4	A3	A2	A1	A0	Pollutant	Slope (%)	Vmin (km/h)	Vmax (km/h)
0.00E+00	-4.33E-09	1.40E-06	-1.53E-04	6.22E-03	-1.01E-01	1.63E+00	VOC	4… 6	13.0	39.3
0.00E+00	-5.14E-08	9.90E-06	-7.17E-04	2.39E-02	-3.57E-01	2.95E+00		-6… -4	13.5	49.9
0.00E+00	-2.05E-08	4.25E-06	-3.30E-04	1.18E-02	-1.92E-01	2.16E+00		0… 4	15.1	69.9
0.00E+00	4.02E-09	-9.36E-07	8.39E-05	-3.66E-03	7.99E-02	3.98E-01		-4… 0	15.1	86.2
0.00E+00	1.51E-07	-1.93E-05	9.26E-04	-2.11E-02	2.57E-01	6.58E-02	CO	4… 6	13.0	39.3
0.00E+00	-7.00E-08	1.25E-05	-8.51E-04	2.71E-02	-3.96E-01	2.86E+00		-6… -4	13.5	49.9
0.00E+00	-1.18E-08	2.49E-06	-1.95E-04	6.78E-03	-9.28E-02	1.52E+00		0… 4	15.1	69.9
0.00E+00	-5.54E-10	1.80E-07	-1.82E-05	6.42E-04	-5.54E-03	8.14E-01		-4… 0	15.1	86.2
0.00E+00	1.82E-08	-1.85E-06	3.32E-05	1.28E-03	-4.14E-03	1.43E+00	NO_X	4… 6	13.0	39.3
0.00E+00	-7.94E-08	1.37E-05	-9.08E-04	2.83E-02	-4.13E-01	2.78E+00		-6… -4	13.5	49.9
0.00E+00	-6.87E-09	1.37E-06	-1.06E-04	3.74E-03	-4.19E-02	1.23E+00		0… 4	15.1	69.9
0.00E+00	-3.00E-10	8.69E-08	-7.87E-06	2.26E-04	-2.07E-03	7.03E-01		-4… 0	15.1	86.2
0.00E+00	4.27E-07	-5.74E-05	2.97E-03	-7.43E-02	9.35E-01	-3.03E+00	CO_2	4… 6	13.0	39.3
0.00E+00	-7.74E-08	1.33E-05	-8.78E-04	2.72E-02	-3.93E-01	2.65E+00		-6… -4	13.5	49.9
0.00E+00	-3.01E-09	5.73E-07	-4.13E-05	1.13E-03	8.13E-03	9.14E-01		0… 4	15.1	69.9
0.00E+00	-1.39E-10	5.03E-08	-4.18E-06	1.95E-05	3.68E-03	6.69E-01		-4… 0	15.1	86.2
0.00E+00	-2.54E-07	3.58E-05	-1.99E-03	5.42E-02	-6.89E-01	4.54E+00	PM	4… 6	13.0	39.3
0.00E+00	-5.34E-08	9.97E-06	-7.05E-04	2.32E-02	-3.48E-01	2.71E+00		-6… -4	13.5	49.9
0.00E+00	-1.96E-08	4.11E-06	-3.22E-04	1.16E-02	-1.83E-01	2.08E+00		0… 4	15.1	69.9
0.00E+00	-1.89E-10	8.23E-08	-9.49E-06	3.25E-04	-2.54E-04	8.21E-01		-4… 0	15.1	86.2

Table A38. Coefficients of gradient factor functions for heavy duty vehicles 7.5 - 16 t

A6	A5	A4	A3	A2	A1	A0	Pollutant	Slope (%)	Vmin (km/h)	Vmax (km/h)
0.00E+00	1.28E-07	-1.65E-05	7.96E-04	-1.82E-02	2.04E-01	3.24E-01	VOC	4… 6	13.1	39.5
0.00E+00	-4.01E-08	8.12E-06	-6.01E-04	2.01E-02	-3.01E-01	2.76E+00		-6… -4	13.5	49.9
0.00E+00	-1.82E-08	3.70E-06	-2.78E-04	9.60E-03	-1.51E-01	1.94E+00		0… 4	15.1	70.3
0.00E+00	1.10E-09	-3.38E-07	3.94E-05	-2.13E-03	5.25E-02	6.52E-01		-4… 0	15.1	86.4
0.00E+00	3.28E-07	-4.35E-05	2.21E-03	-5.46E-02	6.73E-01	-1.88E+00	CO	4… 6	13.1	39.5
0.00E+00	-6.79E-08	1.21E-05	-8.24E-04	2.58E-02	-3.67E-01	2.89E+00		-6… -4	13.5	49.9
0.00E+00	-1.09E-08	2.16E-06	-1.56E-04	4.85E-03	-5.79E-02	1.34E+00		0… 4	15.1	70.3
0.00E+00	-1.11E-10	-3.21E-08	1.19E-05	-1.09E-03	3.34E-02	6.97E-01		-4… 0	15.1	86.4
0.00E+00	-2.42E-07	3.49E-05	-1.96E-03	5.28E-02	-6.52E-01	4.60E+00	NO_X	4… 6	13.1	39.5
0.00E+00	-9.71E-08	1.70E-05	-1.14E-03	3.57E-02	-5.30E-01	3.81E+00		-6… -4	13.5	49.9
0.00E+00	-1.21E-08	2.39E-06	-1.77E-04	6.00E-03	-8.29E-02	1.56E+00		0… 4	15.1	70.3
0.00E+00	-8.49E-11	1.17E-08	3.94E-07	-1.38E-04	2.18E-03	9.09E-01		-4… 0	15.1	86.4
0.00E+00	3.21E-07	-4.29E-05	2.23E-03	-5.75E-02	7.62E-01	-1.98E+00	CO_2	4… 6	13.1	39.5
0.00E+00	-1.24E-07	2.08E-05	-1.33E-03	4.00E-02	-5.65E-01	3.57E+00		-6… -4	13.5	49.9
0.00E+00	-9.78E-10	-2.01E-09	1.91E-05	-1.63E-03	5.91E-02	7.70E-01		0… 4	15.1	70.3
0.00E+00	-6.04E-11	-2.36E-08	7.76E-06	-6.83E-04	1.79E-02	6.12E-01		-4… 0	15.1	86.4
0.00E+00	8.06E-09	3.61E-07	-1.27E-04	5.99E-03	-8.25E-02	1.76E+00	PM	4… 6	13.1	39.5
0.00E+00	-5.44E-08	1.01E-05	-7.06E-04	2.28E-02	-3.38E-01	2.86E+00		-6… -4	13.5	49.9
0.00E+00	-1.61E-08	3.27E-06	-2.45E-04	8.30E-03	-1.18E-01	1.72E+00		0… 4	15.1	70.3
0.00E+00	-7.69E-10	1.50E-07	-7.72E-06	-8.94E-05	1.04E-02	8.95E-01		-4… 0	15.1	86.4

Table A39. Coefficients of gradient factor functions for heavy duty vehicles 16 - 32 t

A6	A5	A4	A3	A2	A1	A0	Pollutant	Slope (%)	Vmin (km/h)	Vmax (km/h)
0.00E+00	0.00E+00	6.18E-06	-6.51E-04	2.39E-02	-3.66E-01	3.24E+00	VOC	4… 6	12.5	36.5
0.00E+00	-4.96E-08	9.03E-06	-6.37E-04	2.11E-02	-3.22E-01	3.08E+00		-6… -4	13.5	49.9
0.00E+00	-2.11E-08	4.32E-06	-3.30E-04	1.17E-02	-1.91E-01	2.25E+00		0… 4	14.9	64.7
0.00E+00	3.21E-09	-7.41E-07	6.58E-05	-2.82E-03	5.69E-02	7.55E-01		-4… 0	15.1	86.1
0.00E+00	0.00E+00	-1.50E-05	1.43E-03	-4.92E-02	7.32E-01	-2.31E+00	CO	4… 6	12.5	36.5
0.00E+00	-7.70E-08	1.30E-05	-8.51E-04	2.62E-02	-3.80E-01	3.15E+00		-6… -4	13.5	49.9
0.00E+00	-2.46E-08	4.79E-06	-3.44E-04	1.13E-02	-1.66E-01	2.12E+00		0… 4	14.9	64.7
0.00E+00	1.44E-09	-3.32E-07	3.06E-05	-1.45E-03	2.91E-02	8.76E-01		-4… 0	15.1	86.1
0.00E+00	0.00E+00	2.30E-06	-2.49E-04	9.39E-03	-1.26E-01	2.51E+00	NO_X	4… 6	12.5	36.5
0.00E+00	-1.09E-07	1.84E-05	-1.20E-03	3.70E-02	-5.49E-01	3.83E+00		-6… -4	13.5	49.9
0.00E+00	-2.00E-08	3.87E-06	-2.81E-04	9.57E-03	-1.43E-01	2.08E+00		0… 4	14.9	64.7
0.00E+00	5.72E-11	1.59E-08	-4.09E-06	2.73E-04	-1.18E-02	9.79E-01		-4… 0	15.1	86.1
0.00E+00	0.00E+00	-6.69E-06	6.55E-04	-2.31E-02	3.69E-01	1.07E-01	CO_2	4… 6	12.5	36.5
0.00E+00	-1.22E-07	2.03E-05	-1.30E-03	3.94E-02	-5.70E-01	3.75E+00		-6… -4	13.5	49.9
0.00E+00	-5.25E-09	9.93E-07	-6.74E-05	2.06E-03	-1.96E-02	1.45E+00		0… 4	14.9	64.7
0.00E+00	-8.24E-11	2.91E-08	-2.58E-06	5.76E-05	-4.74E-03	8.55E-01		-4… 0	15.1	86.1
0.00E+00	0.00E+00	-1.05E-05	9.88E-04	-3.35E-02	5.10E-01	-1.09E+00	PM	4… 6	12.5	36.5
0.00E+00	-6.72E-08	1.16E-05	-7.82E-04	2.50E-02	-3.79E-01	3.23E+00		-6… -4	13.5	49.9
0.00E+00	-3.60E-08	7.00E-06	-5.07E-04	1.69E-02	-2.49E-01	2.59E+00		0… 4	14.9	64.7
0.00E+00	2.40E-11	3.95E-08	-6.78E-06	3.25E-04	-9.46E-03	1.12E+00		-4… 0	15.1	86.1

Table A40. Coefficients of gradient factor functions for heavy duty vehicles >32 t

A6	A5	A4	A3	A2	A1	A0	Pollutant	Slope (%)	Vmin (km/h)	Vmax (km/h)
0.00E+00	5.68E-08	-5.40E-06	1.24E-04	1.11E-03	-6.09E-02	1.80E+00	VOC	4… 6	12.4	35.0
0.00E+00	-2.50E-08	5.91E-06	-4.88E-04	1.79E-02	-2.98E-01	3.08E+00		-6… -4	13.5	49.9
0.00E+00	-2.02E-08	4.10E-06	-3.11E-04	1.09E-02	-1.76E-01	2.18E+00		0… 4	14.8	66.3
0.00E+00	1.95E-09	-4.68E-07	4.26E-05	-1.84E-03	3.52E-02	9.32E-01		-4… 0	15.1	86.3
0.00E+00	1.43E-06	-1.75E-04	8.27E-03	-1.89E-01	2.09E+00	-7.12E+00	CO	4… 6	12.4	35.0
0.00E+00	-6.48E-08	1.17E-05	-7.95E-04	2.51E-02	-3.71E-01	3.10E+00		-6… -4	13.5	49.9
0.00E+00	-8.63E-09	1.50E-06	-9.50E-05	2.65E-03	-2.44E-02	1.35E+00		0… 4	14.8	66.3
0.00E+00	1.28E-09	-3.07E-07	2.99E-05	-1.48E-03	3.00E-02	8.54E-01		-4… 0	15.1	86.3
0.00E+00	2.42E-08	3.11E-06	-4.50E-04	1.79E-02	-2.70E-01	3.56E+00	NO_X	4… 6	12.4	35.0
0.00E+00	-9.96E-08	1.73E-05	-1.15E-03	3.63E-02	-5.48E-01	3.85E+00		-6… -4	13.5	49.9
0.00E+00	-1.31E-08	2.49E-06	-1.82E-04	6.46E-03	-1.01E-01	1.94E+00		0… 4	14.8	66.3
0.00E+00	-7.69E-10	2.13E-07	-2.19E-05	1.06E-03	-2.84E-02	1.08E+00		-4… 0	15.1	86.3
0.00E+00	5.88E-07	-7.24E-05	3.45E-03	-7.86E-02	8.63E-01	-9.76E-01	CO_2	4… 6	12.4	35.0
0.00E+00	-1.18E-07	2.00E-05	-1.29E-03	3.96E-02	-5.78E-01	3.72E+00		-6… -4	13.5	49.9
0.00E+00	-2.04E-09	4.35E-07	-3.69E-05	1.69E-03	-3.16E-02	1.77E+00		0… 4	14.8	66.3
0.00E+00	-1.10E-09	2.69E-07	-2.38E-05	9.51E-04	-2.24E-02	9.16E-01		-4… 0	15.1	86.3
0.00E+00	-3.23E-07	3.70E-05	-1.70E-03	3.89E-02	-4.15E-01	3.36E+00	PM	4… 6	12.4	35.0
0.00E+00	-4.37E-08	8.63E-06	-6.36E-04	2.17E-02	-3.46E-01	3.17E+00		-6… -4	13.5	49.9
0.00E+00	-1.83E-08	3.60E-06	-2.65E-04	8.95E-03	-1.30E-01	1.92E+00		0… 4	14.8	66.3
0.00E+00	4.10E-10	-7.06E-08	4.33E-06	-1.28E-04	-1.87E-03	1.11E+00		-4… 0	15.1	86.3

Table A41. Coefficients of gradient factor functions for urban buses

A6	A5	A4	A3	A2	A1	A0	Pollutant	Slope (%)	Vmin (km/h)	Vmax (km/h)
0.00E+00	-2.12E-06	2.15E-04	-8.50E-03	1.62E-01	-1.49E+00	6.19E+00	VOC	4… 6	11.4	31.2
0.00E+00	-3.13E-07	3.32E-05	-1.37E-03	2.70E-02	-2.45E-01	1.72E+00		-6… -4	11.7	35.3
0.00E+00	1.75E-08	-4.51E-06	3.08E-04	-8.79E-03	1.11E-01	5.33E-01		0… 4	13.1	37.5
0.00E+00	4.15E-07	-5.26E-05	2.59E-03	-6.16E-02	7.06E-01	-2.13E+00		-4… 0	13.2	39.5
0.00E+00	-1.59E-06	1.57E-04	-6.04E-03	1.14E-01	-1.03E+00	4.91E+00	CO	4… 6	11.4	31.2
0.00E+00	-3.26E-07	3.80E-05	-1.71E-03	3.64E-02	-3.61E-01	2.05E+00		-6… -4	11.7	35.3
0.00E+00	-3.21E-07	3.94E-05	-1.92E-03	4.65E-02	-5.57E-01	3.78E+00		0… 4	13.1	37.5
0.00E+00	2.75E-07	-3.56E-05	1.79E-03	-4.36E-02	5.09E-01	-1.46E+00		-4… 0	13.2	39.5
0.00E+00	7.96E-07	-9.09E-05	3.83E-03	-7.42E-02	6.63E-01	-2.96E-01	NO_X	4… 6	11.4	31.2
0.00E+00	-3.27E-07	4.10E-05	-2.00E-03	4.65E-02	-5.18E-01	2.99E+00		-6… -4	11.7	35.3
0.00E+00	1.85E-07	-2.28E-05	1.08E-03	-2.47E-02	2.79E-01	9.98E-02		0… 4	13.1	37.5
0.00E+00	4.52E-08	-5.67E-06	2.75E-04	-6.43E-03	6.72E-02	5.15E-01		-4… 0	13.2	39.5
0.00E+00	1.25E-07	-1.82E-05	7.87E-04	-1.32E-02	7.18E-02	2.07E+00	CO_2	4… 6	11.4	31.2
0.00E+00	-3.77E-07	4.59E-05	-2.16E-03	4.83E-02	-5.14E-01	2.76E+00		-6… -4	11.7	35.3
0.00E+00	8.21E-08	-9.61E-06	4.20E-04	-8.55E-03	8.22E-02	1.05E+00		0… 4	13.1	37.5
0.00E+00	2.13E-07	-2.78E-05	1.41E-03	-3.45E-02	4.00E-01	-1.06E+00		-4… 0	13.2	39.5
0.00E+00	-7.39E-07	5.92E-05	-1.83E-03	2.80E-02	-2.18E-01	1.78E+00	PM	4… 6	11.4	31.2
0.00E+00	2.54E-07	-2.61E-05	1.01E-03	-1.81E-02	1.54E-01	3.83E-01		-6… -4	11.7	35.3
0.00E+00	1.39E-07	-1.87E-05	9.46E-04	-2.26E-02	2.60E-01	-1.14E-01		0… 4	13.1	37.5
0.00E+00	2.02E-07	-2.43E-05	1.14E-03	-2.60E-02	2.86E-01	-3.34E-01		-4… 0	13.2	39.5

Table A42. Coefficients of gradient factor functions for coaches

A6	A5	A4	A3	A2	A1	A0	Pollutant	Slope (%)	Vmin (km/h)	Vmax (km/h)
0.00E+00	0.00E+00	4.15E-06	-5.14E-04	2.17E-02	-3.76E-01	3.43E+00	VOC	4… 6	9.7	34.8
0.00E+00	0.00E+00	3.03E-06	-4.09E-04	1.94E-02	-3.75E-01	3.98E+00		-6… -4	11.7	49.9
2.49E-10	-8.50E-08	1.14E-05	-7.66E-04	2.65E-02	-4.41E-01	3.80E+00		0… 4	13.1	95.3
1.42E-10	-5.47E-08	8.20E-06	-6.05E-04	2.27E-02	-4.01E-01	3.89E+00		-4… 0	13.1	102.9
0.00E+00	0.00E+00	5.20E-06	-6.07E-04	2.51E-02	-4.28E-01	3.56E+00	CO	4… 6	9.7	34.8
0.00E+00	0.00E+00	2.24E-06	-3.21E-04	1.61E-02	-3.30E-01	3.25E+00		-6… -4	11.7	49.9
2.22E-10	-7.88E-08	1.10E-05	-7.63E-04	2.73E-02	-4.69E-01	3.99E+00		0… 4	13.1	95.3
1.09E-10	-4.42E-08	6.93E-06	-5.33E-04	2.09E-02	-3.87E-01	3.60E+00		-4… 0	13.1	102.9
0.00E+00	0.00E+00	-1.15E-05	9.84E-04	-3.02E-02	3.89E-01	7.29E-01	NO_X	4… 6	9.7	34.8
1.65E-08	-3.13E-06	2.39E-04	-9.44E-03	2.02E-01	-2.22E+00	1.04E+01		-6… -4	11.7	49.9
2.97E-10	-9.51E-08	1.18E-05	-7.16E-04	2.18E-02	-3.07E-01	3.21E+00		0… 4	13.1	95.3
1.27E-10	-4.61E-08	6.56E-06	-4.66E-04	1.71E-02	-3.00E-01	2.75E+00		-4… 0	13.1	102.9
0.00E+00	0.00E+00	-1.34E-05	1.12E-03	-3.31E-02	4.00E-01	9.84E-01	CO_2	4… 6	9.7	34.8
1.61E-08	-3.07E-06	2.37E-04	-9.43E-03	2.04E-01	-2.25E+00	1.04E+01		-6… -4	11.7	49.9
1.99E-10	-6.52E-08	8.32E-06	-5.20E-04	1.65E-02	-2.43E-01	3.02E+00		0… 4	13.1	95.3
1.15E-10	-4.23E-08	6.16E-06	-4.48E-04	1.69E-02	-3.05E-01	2.70E+00		-4… 0	13.1	102.9
0.00E+00	0.00E+00	4.91E-07	-1.88E-04	1.17E-02	-2.47E-01	3.11E+00	PM	4… 6	9.7	34.8
-3.03E-09	4.76E-07	-2.59E-05	4.46E-04	6.68E-03	-2.90E-01	3.25E+00		-6… -4	11.7	49.9
2.83E-10	-9.69E-08	1.30E-05	-8.68E-04	2.97E-02	-4.88E-01	4.21E+00		0… 4	13.1	95.3
1.40E-10	-5.29E-08	7.85E-06	-5.78E-04	2.18E-02	-3.91E-01	3.54E+00		-4… 0	13.1	102.9

A4.2.2. Vehicle load

The driving resistance of a vehicle is influenced by vehicle mass, i.e. higher vehicle mass requires higher power from the engine during driving, especially in acceleration modes. Because of the well known fact that emissions and fuel consumption are proportional to the engine power, the calculations have to take into account, in principle, vehicle load.

Passenger cars

Emissions from passenger cars are conventionally measured on a chassis dynamometer. The load setting of the dynamometer normally corresponds to the weight of the vehicle in running order, and including the driver, which is quite typical of normal use. In addition the influence of load on emission and consumption is small because the load range of a passenger car is small, in comparison with heavy duty vehicles. So it can be stated that the load influence is sufficiently covered for this vehicle category via the standard hot emission factors [A27].

Heavy duty vehicles

In the case of heavy duty vehicles the vehicle load has an important influence on emissions and fuel consumption as the load can contribute significantly to the total weight of the vehicle.

Functions to correct for load have been determined for goods vehicles [A26] so that:

$$\varepsilon_l = \varepsilon_u \times \Phi(\gamma, v) \qquad \text{(A13)}$$

where:

e_l	is the emission factor when loaded in g/km
e_u	is the emission factor when unloaded in g/km
$F(g, v)$	is the load correction factor function
g	is the gradient in percent
v	is the mean velocity of the vehicle in km/h

Load correction factor functions ($F(g, v)$) are of the form:

$$\Phi(\gamma, v) = \kappa + n\gamma + p\gamma^2 + q\gamma^3 + rv + sv^2 + tv^3 + \frac{u}{v} \qquad \text{(A14)}$$

where:

k	is a constant
n - u	are coefficients

Coefficients for these functions are presented in Tables A43 to A46.

For urban buses and coaches, the basic functions provide estimates of emissions for the vehicle with a mean load, rather than no load. The load correction functions described above are not applicable for these vehicle types.

Table A43. Coefficients of the load correction functions for HGVs from 3.5 to 7.5 tonnes

	k	*n*	*p*	*q*	*r*	*s*	*t*	*u*
CO	1.09	0.0370	0	-5.29E-4	0	0	-1.52E-7	0
CO_2	1.27	0.0614	0	-0.00110	-0.00235	0	0	-1.33
VOC	0.990	-0.0141	0	4.04E-4	0	0	1.16E-7	0
NO_X	1.26	0.0672	0	-0.00117	0	-1.90E-5	0	-1.60
PM	1.14	0.0306	-0.00278	-9.14E-4	0	0	0	-0.988

Table A44. Coefficients of the load correction functions for HGVs from 7.5 to 16 tonnes

	k	*n*	*p*	*q*	*r*	*s*	*t*	*u*
CO	1.03	0.0345	0	-7.55E-4	9.77E-4	0	0	0
CO_2	1.26	0.0790	0	-0.00109	0	0	-2.03E-7	-1.14
VOC	0.985	0.00367	0	0	0.00135	0	0	0.201
NO_X	1.19	0.0594	0	-9.69E-4	0	0	0	-0.977
PM	1.02	0.0437	0	-9.16E-4	0.00234	0	0	0

Table A45. Coefficients of the load correction functions for HGVs from 16 to 32 tonnes

	k	*n*	*p*	*q*	*r*	*s*	*t*	*u*
CO	1.17	0.0563	0	-8.19E-4	0	0	0	-0.755
CO_2	1.27	0.0882	0	-0.00101	0	0	0	-0.483
VOC	1.01	-0.00660	0	2.09E-4	8.89E-4	0	-2.54E-7	0
NO_X	1.28	0.0795	-0.00105	-0.00117	0	0	0	-0.874
PM	1.24	0.0727	0	-0.00113	0	0	0	-1.06

Table A46. Coefficients of the load correction functions for HGVs from 32 to 40 tonnes

	k	*n*	*p*	*q*	*r*	*s*	*t*	*u*
CO	1.20	0.0849	0	-0.00184	0	0	0	-1.19
CO_2	1.43	0.121	0	-0.00125	0	0	0	-0.916
VOC	1.07	0.0150	0	-1.70E-4	0	0	-9.49E-8	-0.220
NO_X	1.42	0.116	0	-0.00160	0	0	0	-1.62
PM	1.22	0.0709	0	-0.00119	0	0	0	-0.968

A4.2.3. Altitude

Very few data exist on the effect of altitude on emissions. Recently, some limited investigations were carried out within the German/Swiss emission factor programme [A27] to study the influence of altitude on exhaust emissions and fuel consumption. The measurements were carried out on the basis of the US Test 72 with the engine operationally warm. Altitudes of 0, 1000 and 2000 m were simulated. The test vehicles included conventional spark-ignition, closed loop catalyst and diesel passenger cars and light commercial vehicles with direct injection diesel engines. It was shown that it is necessary to take account of the influence of altitude when determining pollutant emissions for the vehicle concepts investigated in cases where a major proportion of the mileage is on roads at a high elevation. Because of the relatively small number of vehicles investigated, the test programme did not permit the development of emission and consumption functions to correct for altitude effects.

Nevertheless, it can be stated that there is an unambiguous relationship between emissions and altitude for all the vehicle types studied. Further investigations should be undertaken to secure the altitude factor for regulated catalyst vehicles in a comprehensive manner. In addition to a larger sample, the test programme must have smaller altitude steps. In order to take account of the effects of driving behaviour, the test programme should include other driving cycles beside the US Test 72 so that basic functions can be produced.

A4.2.4. Degradation of pollution controls

In the case of conventional spark-ignition and diesel vehicles, the emission behaviour generally deteriorates within a service interval. The emission level can, however, be restored to approximately that of a new vehicle by adjustment and maintenance or by the correction of defects, whatever the mileage. Because of this, no deterioration of the emission figures as a function of vehicle mileage is quoted in the case of conventional spark-ignition and diesel vehicles. The generally poorer maintenance condition of older vehicles does have the effect of increasing emissions but this is ignored[28].

Closed-loop catalyst vehicles

In the case of catalyst vehicles, however, an unavoidable deterioration in the degree of conversion by the catalyst (due to thermal ageing and contamination) leads to an increase in emission with increasing mileage. Defects, setting errors and lack of maintenance are superimposed, in practical operation, on the physically determined reduction in the degree of conversion. In contrast to conventional spark-ignition vehicles, however, the new condition emission level cannot be restored at higher mileage even after faults have been corrected, unless a replacement catalyst is fitted.

European and American legislation demands evidence that the emission standards will not be exceeded up to a mileage of 80,000 km. The manufacturer has the possibility of demonstrating observance of this regulation, as part of the type testing, by an exactly defined 80,000 km endurance test in which emission measurements are carried out at intervals of 10,000 km. The so-called deterioration factor is determined by using regression analysis. This is defined as the quotient of the emission at 80,000 km and that in the new condition. The deterioration factors determined in this way on individual vehicles in type approval tests are not, however, suitable for estimating the deterioration of the emissions of the closed loop catalyst cars. This is

[28] The omission of a degradation function need not have a significant effect since the test data used to generate the emission functions are taken from samples of in-use vehicles. Provided the samples adequately represent the fleet (and because of their limited size compared with the total fleet, this may not be the case), their average emissions will also be typical of the fleet, including its maintenance condition. There is, however, a tendency for tests to focus on newer types of vehicle, relying on earlier data to represent older classes. Thus, samples may not include the oldest vehicles, and they may be the ones in the poorest condition. This is offset to some extent in that the mileage covered by old vehicles is usually far less than by newer vehicles.

because the type testing procedure does not reflect, or does not representatively reflect, for example, the driving behaviour, state of maintenance and cold starting procedures.

In order to achieve this objective, one possibility is to determine the statistical relationship between emission and mileage by using regression analysis on the basis of a sufficiently large vehicle population. In Europe such an investigation was conducted in the German / Swiss Emission Factor Programme [A27]. It was deduced that a regression analysis on the basis of the US-Test-75 realistically reflects the influence of vehicle mileage on emission behaviour[29].

A further analysis has been conducted using the larger international data set available to the MEET project. Because it was necessary to include as many data as possible, for vehicles in a wide range of mileage classes, results from legislative test cycles (EC Urban and EUDC) were used. For real-world cycles, data for vehicles in some mileage classes are very few. The analysis confirmed a systematic degradation of emissions with increasing mileage for CO, HC and NO_X, but CO_2 emissions (and therefore fuel consumption) remained stable.

Three phases of the degradation process were identified (see Figure A16):

- *The running-in phase (0 - 10,000 km).* Even relatively new vehicles show an emission deterioration, but emission levels during this period remain low.
- *The middle phase (10,000 - 100,000 km).* Degradation continues during this phase, at about the same rate, and emissions eventually reach quite high levels.
- *The final phase (> 100,000 km)* Emissions of very high mileage vehicles seem to stabilise. This may be because of the need to repair or replace the emission control system on high mileage vehicles, though it should be noted that there are very few data for this phase, and the finding is uncertain.

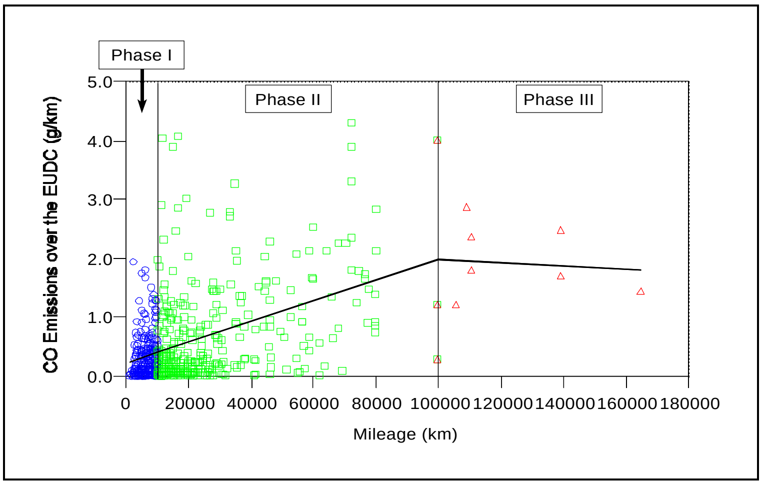

Figure A16. The effect of mileage on CO emissions from EURO I petrol cars

[29] It was also demonstrated that in the case of vehicles with open-loop catalysts no statistical correlation exists between emission and vehicle mileage.

Using this procedure, degradation functions were derived for the three pollutants CO, HC and NO_X, for the three engine size classes used for petrol cars and for the two cycles used in the analysis (EC Urban and EUDC). In order to provide a common basis for both the hot emission functions and the mileage degradation factors, only results from cars included in the production of the hot emission functions were used (additional data were available, from cars tested only using the legislative cycles, and these were used to cross-check the validity of the degradation functions, but not in their production). The degradation functions were normalised so that their value at the average mileage for each pollutant and vehicle class was one. It was thus ensured that they do not modify the basic, average emission factors for the average vehicle, but provide a means of estimating emissions from fleets whose mileage is greater or less than the class average.

Application of the functions is as follows:

$$MCEF = MC(speed,mileage) \times EF(speed) \tag{A15}$$

where:

$MCEF$ is the mileage corrected emission factor
MC is the mileage correction factor
EF is the uncorrected emission factor

The mileage correction factor for low speeds ($\leq$19 km/h) is that determined over the EC Urban cycle, and for high speeds ($\geq$63 km/h) the EUDC correction factor should be used. For intermediate speeds the factor is obtained using the following function:

$$MC_v = MC_{UDC} + \frac{(v-19) \times (MC_{EUDC} - MC_{UDC})}{44} \tag{A16}$$

where:

MC_{UDC} is the urban correction factor
MC_{EUDC} is the extraurban correction factor
MC_v is the correction factor at the intermediate speed
v is the intermediate speed

Coefficients for the urban and extraurban mileage correction functions are given in Table A47. Substituting these expressions in Equation A16 gives a set of equations for the correction factors which have the form:

$$MC_v = a + bv + cm + dvm \tag{A17}$$

where:

m is the mileage of the vehicle
a, b, c & d are coefficients

The coefficients for these equations are also included in Table A47.

Table A47. Mileage correction functions

	Capacity class (l)	**Average mileage (km)**	**a**	**b**	**c**	**d**	**Value at 120000 km**
Urban correction function (v ✁ 19 km/h)							
CO	< 1.4	29057	0.557	0	1.523E-05	0	2.39
	1.4 - 2.0	39837	0.543	0	1.148E-05	0	1.92
	>2.0	47028	0.565	0	9.243E-06	0	1.67
NO_X	< 1.4	29057	0.478	0	1.798E-05	0	2.64
	1.4 - 2.0	39837	0.207	0	1.990E-05	0	2.59
	>2.0	47028	0.839	0	3.416E-06	0	1.25
HC	< 1.4	29057	0.647	0	1.215E-05	0	2.10
	1.4 - 2.0	39837	0.509	0	1.232E-05	0	1.99
	>2.0	47028	0.432	0	1.208E-05	0	1.88
Intermediate correction function (v between 19 and 63 km/h)							
CO	< 1.4	29057	0.578	-1.091E-03	1.451E-05	3.773E-08	
	1.4 - 2.0	39837	0.511	1.682E-03	1.229E-05	-4.257E-08	n/a
	>2.0	47028	0.432	7.000E-03	1.207E-05	-1.486E-07	
NO_X	< 1.4	29057	0.551	-3.841E-03	1.548E-05	1.318E-07	
	1.4 - 2.0	39837	0.116	4.795E-03	2.219E-05	-1.205E-07	n/a
	>2.0	47028	0.941	-5.364E-03	1.246E-06	1.142E-07	
HC	< 1.4	29057	0.577	3.682E-03	1.456E-05	-1.268E-07	
	1.4 - 2.0	39837	0.466	2.273E-03	1.340E-05	-5.693E-08	n/a
	>2.0	47028	0.313	6.250E-03	1.461E-05	-1.331E-07	
Extraurban correction function (v ✍ 63 km/h)							
CO	< 1.4	29057	0.509	0	1.689E-05	0	2.54
	1.4 - 2.0	39837	0.617	0	9.607E-06	0	1.77
	>2.0	47028	0.873	0	2.704E-06	0	1.20
NO_X	< 1.4	29057	0.309	0	2.378E-05	0	3.16
	1.4 - 2.0	39837	0.418	0	1.460E-05	0	2.17
	>2.0	47028	0.603	0	8.442E-06	0	1.62
HC	< 1.4	29057	0.809	0	6.570E-06	0	1.60
	1.4 - 2.0	39837	0.609	0	9.815E-06	0	1.79
	>2.0	47028	0.707	0	6.224E-06	0	1.45

A4.2.5. Ambient temperature

Hot emissions are influenced much less by the ambient temperature than start emissions, but because of the wide range of ambient temperatures found in Europe, from north to south and winter to summer, attention should also be given to this effect.

The main source of information is a report by VTI [A30] summarising measurements by several institutions. The measurements were conducted using the FTP 75 cycle and using results from the second (stabilisation[30]) and third (hot transient) phases of the test.

[30] The stabilisation phase begins after 505 seconds from a cold start. It is possible that the engine is not fully warmed up at the start of this phase when tests are conducted at very low temperatures.

Measurements are available covering the temperature range -20 to +25 ^{o}C. The effect of the temperature may be expressed as the ratio of emissions at any particular temperature with those at a reference temperature, and in this analysis, the reference temperature was taken to be 20 ^{o}C, which is typical for the measurements used to generate the basic emission functions.

Then:

$$TCEF = TC\,(temperature) \times EF\,(speed) \tag{A18}$$

where:

TCEF is the temperature corrected emission factor
TC is the temperature correction factor
EF is the uncorrected emission factor

Table A48 gives coefficients for the determination of the temperature correction factors. There are differences between the correction factors determined using data from the stabilisation and hot transient phases, it must be recognised that the data from which they were derived display considerable variation. In the absence of more complete data, they should be considered only as indications of the effect of ambient temperature on hot emissions. For that reason, it is probably best in practice to use the average of the functions for the two parts of the FTP test: averages are also shown in Table A48.

Table A48. Temperature correction functions (valid from -20 to +22.5^{o}C)

Pollutant	FTP75 phase	A	B	Value at -20^{o}C
CO	s	-0.0249	1.58	2.08
	ht	-0.0155	1.37	1.68
	average	-0.0202	1.48	1.88
NO_X	s	-0.0101	1.26	1.46
	ht	-0.0143	1.28	1.57
	average	-0.0122	1.27	1.51
HC	s	-0.0201	1.47	1.87
	ht	-0.0126	1.31	1.56
	average	-0.0164	1.39	1.72
Temperature correction TC = A × temperature (^{o}C) + B				

A4.2.6. Air conditioning

There is an increasing tendency for passenger cars to be equipped with air conditioning systems. When the air conditioning is in use, it imposes an increased load on the engine, with consequential effects on fuel consumption and emissions. Tests have been conducted by ADEME [A31] and UTAC [A32] to compare emissions and fuel consumption on a range of diesel and three way catalyst cars. The two sets of tests were carried out somewhat differently, but because of the relatively small sample of cars and the variability of the results, no systematic differences were apparent: they have therefore been considered together. Figure A17 shows the average variation in emissions and the 95% confidence intervals for the two types of vehicle over the range of regulated pollutants.

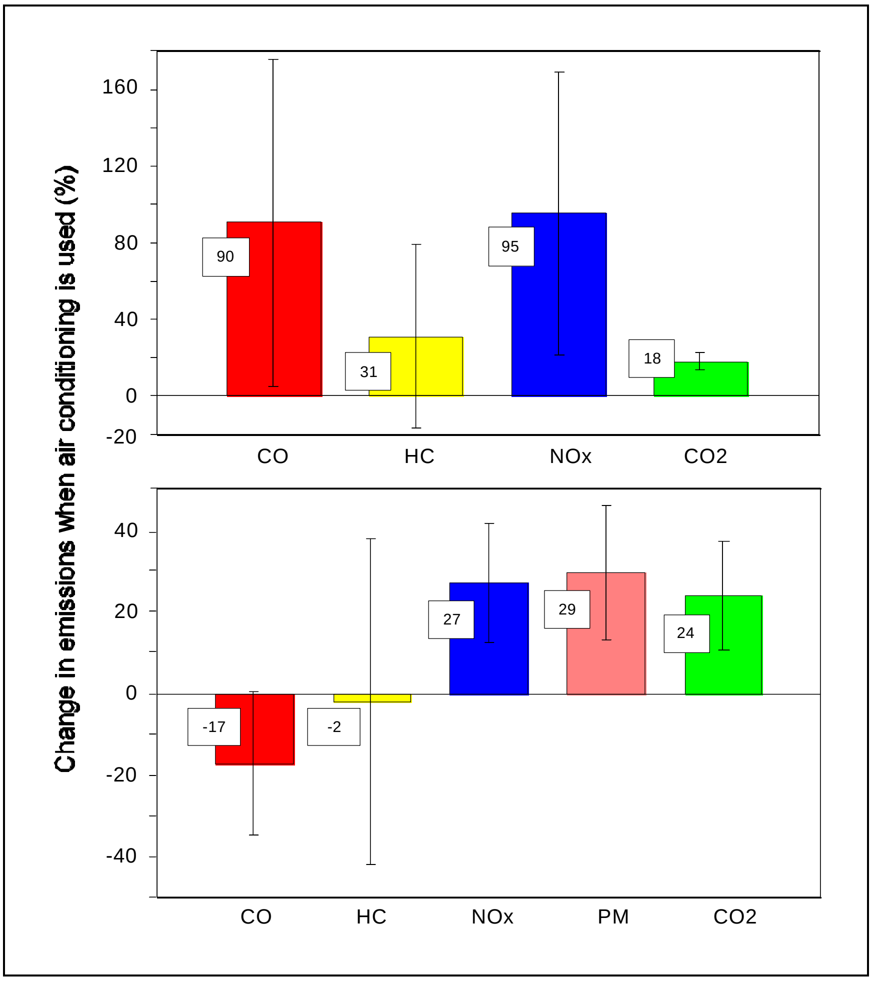

Figure A17. Effects of air conditioning on emissions from petrol (top) and diesel cars

For the petrol cars, all emissions increase on average, though there is considerable uncertainty except for CO_2, where there is statistically significant increase of almost 20%. The diesels showed significant increases for NO_X, PM and CO_2, of 20 to 30%, but decreases (not statistically significant) for CO and HC. Thus, it is clear that the use of air conditioning increases fuel consumption (indicated by the CO_2 results), while effects on other emissions depend on the combustion efficiency of the engine under the higher load and may, in some cases, decrease. There remain too many uncertainties to be able to propose quantitative factors to correct for the use of air conditioning systems: the data relate only to a single legislative cycle (the European test cycle), and they are from a small number of tests. Similarly, the operational data needed to evaluate this effect are not available: the frequency and level of use of air conditioning systems is not known.

More detailed studies are needed of the effect of air conditioning on emissions, covering more vehicles and a range of driving cycles, and surveys should be devised to provide suitable usage statistics.

A4.3. Summary

Hot emission factors are calculated firstly as a function of the average vehicle speed. Depending on the vehicle type, a number of corrections may be made to allow for the effects of road gradient, vehicle load, vehicle mileage and ambient temperature. Thus, for one vehicle type and pollutant:

$$e_{hot} = f(v) \times GC \times LC \times MC \times TC \tag{A19}$$

where:

e_{hot}	is the corrected hot emission factor
$f(v)$	is the average speed (v) dependent emission rate for standard conditions
GC, LC, MC & TC	are correction factors for gradient, load, mileage and temperature respectively

The corrected hot emission factor must then be combined with appropriate activity data (as discussed in A4.1, above), and a summation performed over the vehicle categories to give total fleet emissions.

Because of limitations in the available data, it has not been possible to provide a complete set of functions for all vehicle types. The average speed is taken into account in all cases, but the other dependencies are applicable only for those vehicle classes for which the necessary information is available, and for which the data demonstrate a significant effect. Table A49 provides a summary. It should also be noted that additional parameters are known to influence emissions, and some have been discussed briefly above, however although the principle of their effect is known, there are insufficient data to provide quantitative estimates.

Table A49. Parameters included in the calculation of hot emissions

Vehicle type	Average speed	Gradient	Load	Mileage	Temperature
Car - conventional	✓	✓			
- catalyst	✓	✓		✓	✓
- diesel	✓	✓			
LDV - conventional	✓	✓			
- catalyst	✓	✓		(✓)[31]	(✓)
- diesel	✓	✓			
HGV	✓	✓	✓		
Bus and coach	✓	✓			
Motorcycle	✓				

[31] These vehicles may be treated in the same way as catalyst cars.

A5. START-RELATED EXTRA EMISSIONS

The method proposed for estimating start-related emissions was developed empirically, using data assembled from many European test programmes. The basic requirement for the data was that it gave emission measurements for a vehicle with a cold engine and also with a hot engine, but otherwise the same test conditions. The difference between the measurements represented, therefore, the excess emissions resulting from the cold operation. The passenger car was the only type of vehicle for which sufficient data were available. Within that category, distinction was made between diesel and petrol vehicles with and without catalysts, but there were too few data from catalyst equipped diesels to allow a detailed analysis in that case [A33].

For each pollutant and vehicle type a reference value was defined for the excess emission as the value corresponding to a start temperature of 20^{o}C and for an average trip speed of 20 km/h. Functions were derived by which the reference value could be corrected for the actual start temperature and average speed and also for the distance travelled (some trips are shorter than the distance needed fully to warm up the engine, and on those trips, the total excess emission is not produced).

A5.1. General formula of start-related excess emissions of a trip

The excess emission can be expressed in terms of mean speed, ambient temperature[32] and travelled distance. So the formula has the following form :

$$\textit{excess emission} = \omega \times \left[f(V) + g(T) - 1 \right] \times h(d) \qquad \text{(A20)}$$

where:

excess emission	for a trip is expressed in g
V	is the mean speed in km/h during the cold period
T	is the temperature in °C (ambient temperature for cold start, engine start temperature for starts at an intermediate temperature)
d	is the distance travelled
w	is the reference excess emission (at 20 °C and 20 km/h)

A5.1.1 Reference excess emission

The reference value for the excess emission was defined to be the amount produced at an average speed of 20 km/h with a start temperature of 20^{o}C, and over a trip long enough for the engine to reach its fully warmed-up condition. Because the available data covered a variety of different test conditions, the reference values were derived using an iterative process in which the functional dependencies on speed, temperature and trip length were first determined, and subsequently used to quantify the excess emissions that would be produced under the reference

[32] Many trips start with an engine that is neither hot nor cold (i.e. at the ambient temperature), but there are very few data concerning intermediate starting temperatures. It has been assumed that the effect of starting when the engine temperature is higher than the ambient temperature is equivalent to a cold start at the temperature of the engine.

conditions. The values derived in this way are given in Table A50, classified by vehicle type and pollutant.

Table A50. Reference excess cold-start emission at 20 °C and 20 km/h (ω)

Technology	Pollutant				
	CO_2	CO	HC	NO_X	FC
Gasoline cars without catalyst	144.16	63.51	8.23	-0.30	83.71
Diesel cars without catalyst	182.57	2.18	0.82	0.06	62.95
Gasoline cars with catalyst	132.46	28.71	4.62	1.77	59.79
Diesel cars with catalyst	153.36	0.74	0.65	0.03	55.4

A5.1.2. Effect of average speed

Data from INRETS were used to derive functions to express the excess emissions in terms of the average vehicle speed. These data were chosen because they were measured using a single sample of cars and the tests used realistic driving cycles (many of the other data were derived from tests using legislative driving cycles). Although the data were considered most appropriate to define the basic relationship between excess emissions and average speed, they would not necessarily give the most accurate values for the absolute excess emissions, since they involved only a small number of vehicles. Therefore, a correction was made to bring the data into agreement with the far greater number of results obtained elsewhere. This was done on the basis of measurements over the FTP cycle. The principles of this procedure are illustrated in Figure A18.

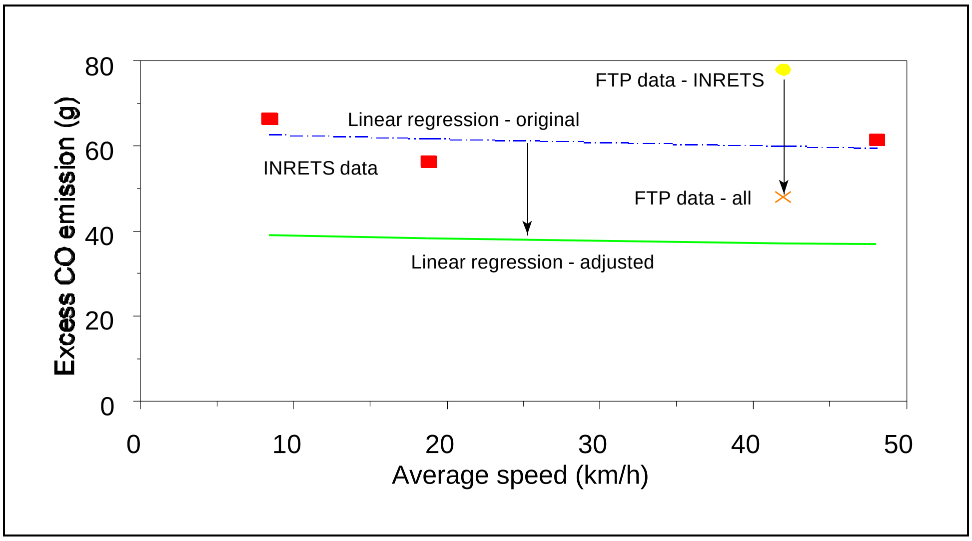

Figure A18. Relationship of excess emissions with average speed and method of adjustment

Because these functions are used to correct the reference excess emissions, they were finally normalised to give a value of one at 20 km/h. The resulting functions are presented in Table A51.

Table A51. Speed correction coefficients *f(V)* and boundaries

Technology	Pollutant	Correction coefficient *f(V)*	Boundary speed
Gasoline cars with catalyst	CO_2	0.0034V + 0.9321	-
	CO	-0.0013V + 1.0261	-
	HC	-0.0053V + 1.1060	-
	NO_X	0.0636V - 0.2712	V>5 km/h
	FC (calculated)	0.0015V + 0.9707	-
Diesel cars without catalyst	CO_2	1	-
	CO	-0.0185V + 1.3704	V<74 km/h
	HC	-0.0163V + 1.3252	V<81 km/h
	NO_X	-0.0227V + 1.4545	V<64 km/h
	FC (calculated)	1	-
Gasoline cars without catalyst	CO_2	-0.0101V + 1.2024	V<119 km/h
	CO	0.0288V + 0.4245	-
	HC	0.0142V + 0.7154	-
	NO_X	0.1136V - 1.2727	V>11 km/h
	FC (calculated)	0.0064V + 0.8716	-

A5.1.3. Effect of ambient temperature

The tests for which results were available covered the start temperature range from -10 to +26 ^oC. In many cases the excess emission tended to increase as the start temperature reduced. An example is shown in Figure A19 (for CO, catalyst cars). Using a simple linear model, functions were determined expressing the excess emission in terms of the start temperature, and were normalised to give a value of one for a start temperature of 20 ^oC. Table A52 gives the results.

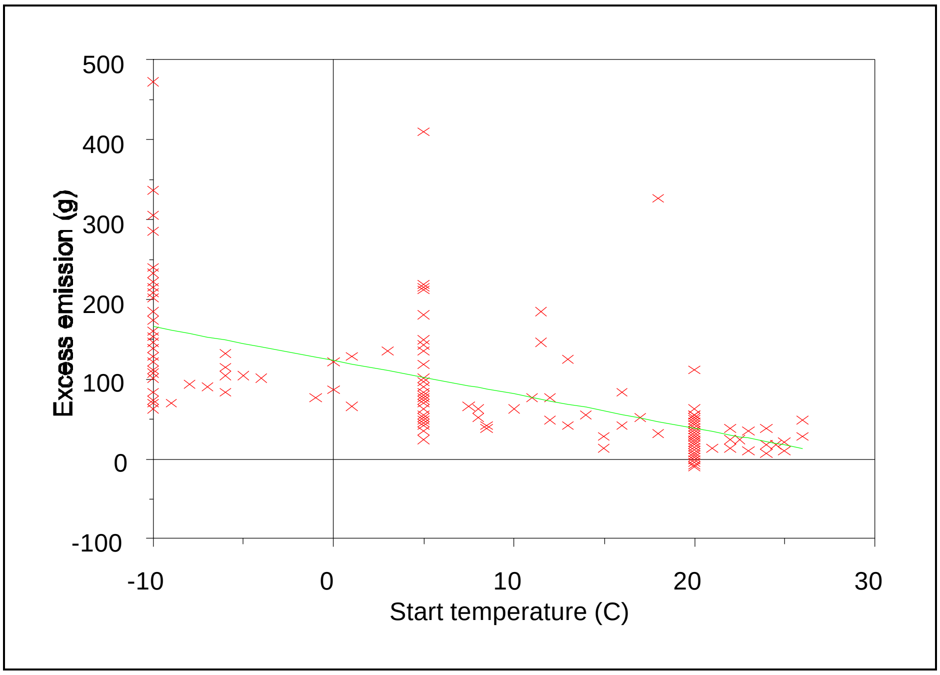

Figure A19. Effect of ambient temperature on excess emissions

Table A52. Temperature correction coefficients and boundaries

Technology	Pollutant	Correction coefficient *g(T)*	Boundary T
Gasoline cars with catalyst	CO_2	1	-
	CO	-0.2591T + 6.1829	T<23 °C
	HC	-0.1317T + 3.6331	T<27 °C
	NO_X	1	-
	FC	-0.0555T + 2.1092	T<38 °C
Diesel cars without catalyst	CO_2	-0.0458T + 1.9163	T<41 °C
	CO	-0.0602T + 2.2048	T<36 °C
	HC	-0.0976T + 2.9512	T<30 °C
	NO_X	-0.0893T + 2.7857	T<31 °C
	FC	-0.0439T + 1.8787	T<42 °C
Gasoline cars without catalyst	CO_2	1	-
	CO	-0.0918T + 2.8360	T<30 °C
	HC	-0.1344T + 3.6888	T<27 °C
	NO_X	1	-
	FC	-0.0431T + 1.8618	T<43 °C

A5.1.4. Effect of distance travelled

Only when a vehicle has fully warmed up will its emissions stabilize, and it is necessary to travel a certain distance (the 'cold distance') before that condition is reached. The distance needed varies according to the vehicle type and the pollutant, as well as the way the car is driven (here represented by the average speed). Functions to estimate the cold distance are given in Table A53. It will probably also vary with the ambient temperature, but data are not available to quantify any effect so it has been neglected. Excess emissions are produced during the whole of the cold distance. Any trips shorter than that distance will not, therefore, produce the total amount of excess emission that would result from a longer trip under the same conditions. Figure A20 shows this principle schematically. Naturally, any trips equal to or longer than the cold distance will produce the total excess emission.

Corrections to excess emissions for trips shorter than the cold distance are expressed as a function of the ratio of the trip length to the cold distance, thus:

$$distance\,correction = \frac{(1-e^{-a\delta})}{(1-e^{-a})} \qquad \text{(A21)}$$

where:

d is the ratio of the trip distance to the cold distance
a is a constant

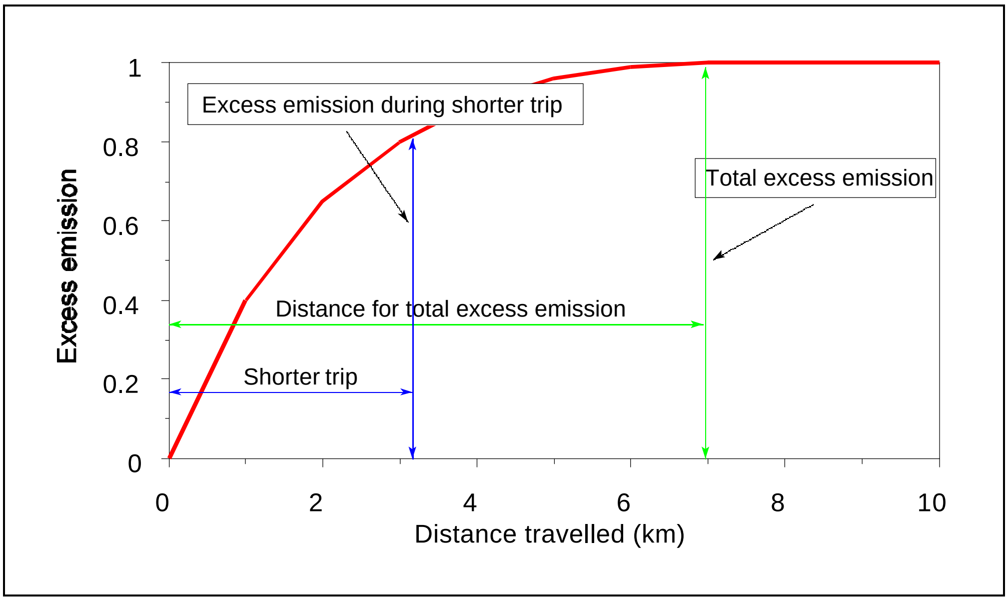

Figure A20. Schematic representation of the effect of trip length on the excess emission

Table A53. Cold distance d_c (km) as a function of the average speed V (km/h)

Technology	Pollutant	Cold distance d_c	Boundary distance
Gasoline cars with catalyst	CO_2	$d_c = 0.29V - 0.05$	d_c 0
	CO	$d_c = 0.24V - 0.14$	d_c 0
	HC	$d_c = 0.06V + 2.19$	-
	NO_X	$d_c = 0.19V + 3.4$	-
	FC	$d_c = 0.24V + 0.54$	-
Diesel cars without catalyst	CO_2	$d_c = 0.24V + 0.09$	-
	CO	$d_c = 0.08V + 4.83$	-
	HC	$d_c = 0.08V + 4.83$	-
	NO_X	$d_c = -0.07V + 7.50$	d_c 0
	FC	$d_c = 0.13V + 3.42$	-
Gasoline cars without catalyst	CO_2	$d_c = 0.15V + 2.68$	-
	CO	$d_c = 0.04V + 5.42$	-
	HC	$d_c = 0.09V + 1.94$	-
	NO_X	$d_c = 0.02V + 2.83$	-
	FC	$d_c = 0.28V + 0.47$	-

Clearly, when the trip distance is equal to the cold distance, the function is equal to one. An exponential function of this form gives a good fit to most of the available data showing the evolution of the excess emission with distance travelled. Figure A21 shows the example of catalyst equipped petrol cars, including both the basic data and estimates by this procedure. The coefficients (a) used in these equations are listed in Table A54, for the different pollutants and vehicle types.

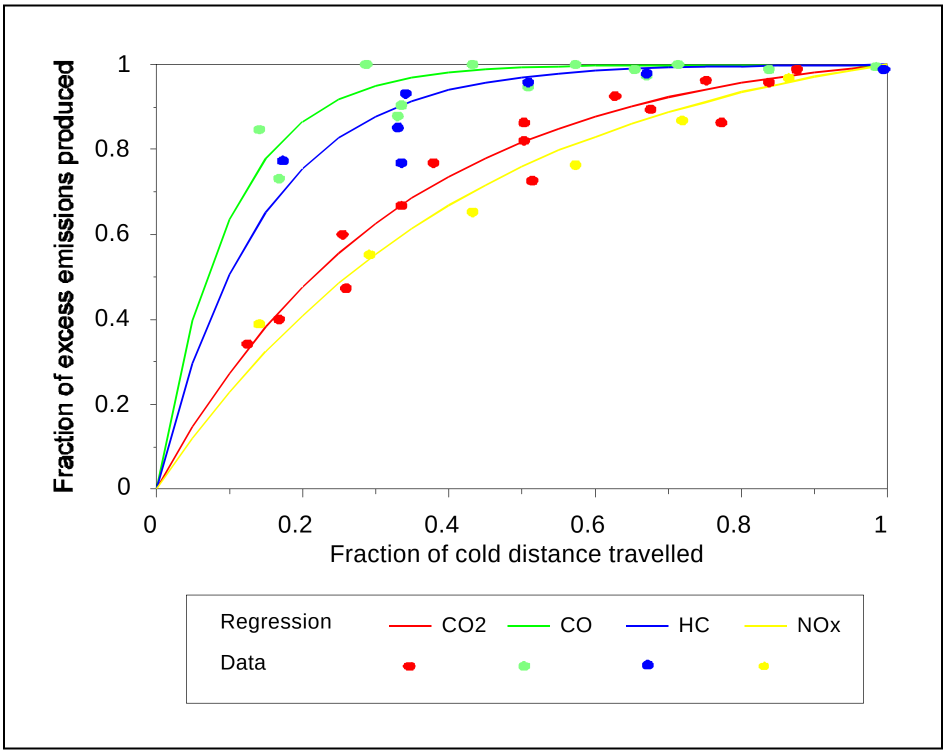

Figure A21. Evolution of excess emissions with distance travelled

Table A54. Coefficients *a* used to calculate the distance correction factor *h(d)*

Technology	Pollutant	Coefficient *a*
Gasoline cars with catalyst	CO_2	3.01
	CO	10.11
	HC	7.02
	NO_X	2.30
	FC	7.55
Diesel cars without catalyst	CO_2	3.95
	CO	3.43
	HC	2.48
	NO_X	0.89
	FC	11.46
Gasoline cars without catalyst	CO_2	2.85
	CO	6.70
	HC	10.96
	NO_X	2.54
	FC	7.97

A5.1.5. Example calculation

The procedure is illustrated by the example below. An estimate is made of excess CO emissions from a petrol car with catalyst during a 3 km trip, at an average speed of 30 km/h starting at 10°C.

The basic equation is (A5.1):

$$excess\ emission = \omega \times \left[f(V) + g(T) - 1 \right] \times h(d)$$

From Table A50, *w* = 28.71 g.

The speed correction function is (Table A51):

$$f(V) = 1.0261 - 0.0013V$$

Therefore, as V = 30 km/h, $f(V)$ = 0.987

The temperature correction function is (Table A52):

$$g(T) = 6.1829 - 0.2591T$$

which, for T = 10°C, gives a value of 3.592

The distance correction is given by the following expressions:

$$h(d) = \frac{(1 - e^{-a\delta})}{(1 - e^{-a})}\ ; \quad \delta = \frac{d}{d_c}\ ; \quad d_c = -0.14 + 0.24V \quad \text{(from Table A53)}$$

Given d = 3 km, V = 30 km/h and a = 10.11 (Table A54), $h(d)$ = 0.986

Then:

$$excess\,emission = 28.71 \times [0.987 + 3.592 - 1] \times 0.986\ ; \quad = 101.3g$$

A5.2. Other vehicle types

A5.2.1. Diesel passenger cars with catalysts

A few results were obtained from tests on diesel cars with catalysts, but they were too limited to allow a detailed analysis. They were, however, used to indicate the reference excess emission (*w*) for this type of vehicle, and values are included in Table A50. Until additional data are available, it is necessary to assume that the functions $f(V)$, $g(T)$ and $h(d)$ are the same as those derived for non-catalyst diesels.

A5.2.2. Light goods vehicles

Because no data are available for light goods vehicles, it is proposed that their excess emissions should be calculated in the same way as those of passenger cars with the same types of engine and emission control system.

A5.2.3. Heavy goods vehicles

There are again very few relevant data for this type of vehicle. Nevertheless, it is possible to give a rough estimate of their excess emissions, based on the analysis of results from tests on ten heavy duty engines [A34]. Tests were performed on an engine dynamometer, using the US heavy duty transient tests cycle. They were carried out with a cold engine (approximately 20 ^{o}C start temperature) and repeated with a hot start. The coolant temperature was monitored during the measurements, and was found typically to reach the hot start value after 600 to 800 seconds from a cold start: the total test duration was 1200 seconds. It may be assumed therefore that the tests included the whole of the cold start period, and that the difference between the emissions from the hot and cold tests gives a measure of the cold excess emission. Because the measurements only used one operating cycle and were only performed at one ambient temperature it is not possible to determine whether the excess emission depends on those parameters, as is the case for passenger cars.

The engines varied in cylinder capacity from 3.8 to 14 litres, and their power outputs from 79 to 370 BHP. An analysis of vehicle specification data showed a good correlation between engine power and the gross weight of vehicles, so it was possible to classify these engine data according to the vehicle weight classification adopted for heavy goods vehicles. However, only for CO_2 and NO_X was there any systematic relationship between engine or vehicle size and the excess emission. The results of this exercise are given in Table A55, which lists excess emissions in grams per cold start for the main regulated pollutants and the four classes of HGV used in the MEET classification system. Note that NO_X emissions from cold start tests were lower than corresponding hot start emissions and the excess emission is therefore negative.

Operational data for HGVs giving the number of cold starts per day (or other time period) are not known. It is proposed, therefore to assume that each vehicle makes one cold start per day. This assumption is made on the basis that the commercial use of HGVs is likely to mean that they are started from cold at the beginning of each working day, and then used throughout the day without being stopped for long enough to cool significantly. Some vehicles will make more than one cold start per day, but during weekends and holidays, some vehicles will not be used at all.

Table A55. Cold excess emissions from HGVs

Gross weight class (tonnes)	Cold excess emission (g/cold start)				
	CO	CO_2	HC	NO_X	PM
3.5 - 7.5	6	200	2	-1	0.6
7.5 - 16	6	300	2	-2	0.6
16 - 32	6	500	2	-5	0.6
32 - 40	6	750	2	-7	0.6

A5.2.4. Buses and coaches

Buses and coaches are powered normally by diesel engines of the type discussed above. The cold excess emissions may therefore be assumed to be the same as for HGVs of the same weight class. While there are significant variation in the weights of buses and coaches, depending on their size and seating capacity, the most common weight class is probably 16 to 32 tonnes. In the absence of precise information, it can again be assumed that each vehicle makes one cold start per day.

A5.3. Inventory of cold start related excess emissions

In some cases, assessing start-related excess emissions for a single trip is sufficient, but it is more often required to calculate excess emissions for the whole traffic characterised by a number of general parameters such as vehicle flow, average speed and environmental conditions (time of day, week, year, temperature). The formulae initially applied to a single trip must be extended to the whole traffic using available statistical data relating to characteristic traffic parameters.

When calculating traffic emission inventories, the only input data commonly available are:

- traffic flow and composition
- traffic average speed
- ambient temperature
- period (or season)

while the input data for the passenger car sub model of cold start related excess emissions are:

- average speed under cold engine conditions
- ambient temperature
- engine temperature at start up
- distance travelled

It is therefore necessary to express the required input parameters as functions of the more generally available data. A number of data are available from experimental surveys conducted on passenger cars (the Modem and Hyzem projects) [A35, A36, A37] and light duty commercial vehicles[33] [A38]. They are summarised in detail in MEET Deliverable 15 [A39], and examples of the types of information they provide are shown in Figures A22 to A24. Figures A22 and A23 show distributions of trip length and number for passenger cars according to the season[34], and Figure A24 shows the numbers of hot and cold started passenger car trips as a function of the trip length. It can be seen that differences exist in these distributions: for example, more long trips are started cold than hot, long trips are more

[33] In principle, data similar to those for passenger cars should be available, though the results for commercial vehicles have not yet been fully analysed.

[34] Three seasons are specified, each lasting four months. They are referred to as winter, summer and intermediate, or mid-season.

frequent in the summer than in the other two seasons, and so on. Consequently, it is desirable to differentiate the seasons when estimating start emissions, and the data given below provide seasonal as well as annual dependencies.

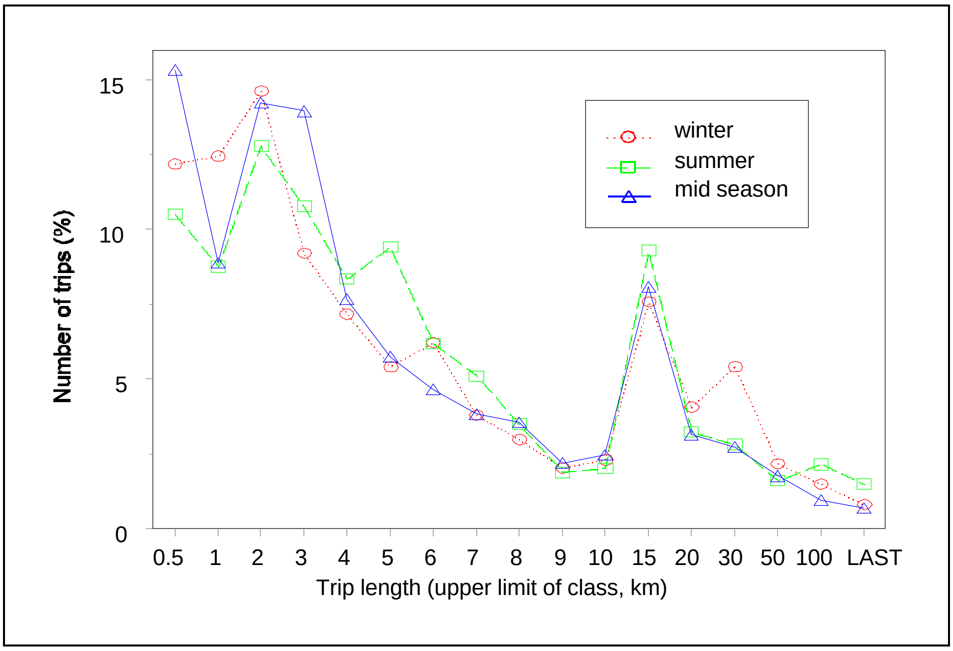

Figure A22. Trip number distribution as a function of trip length

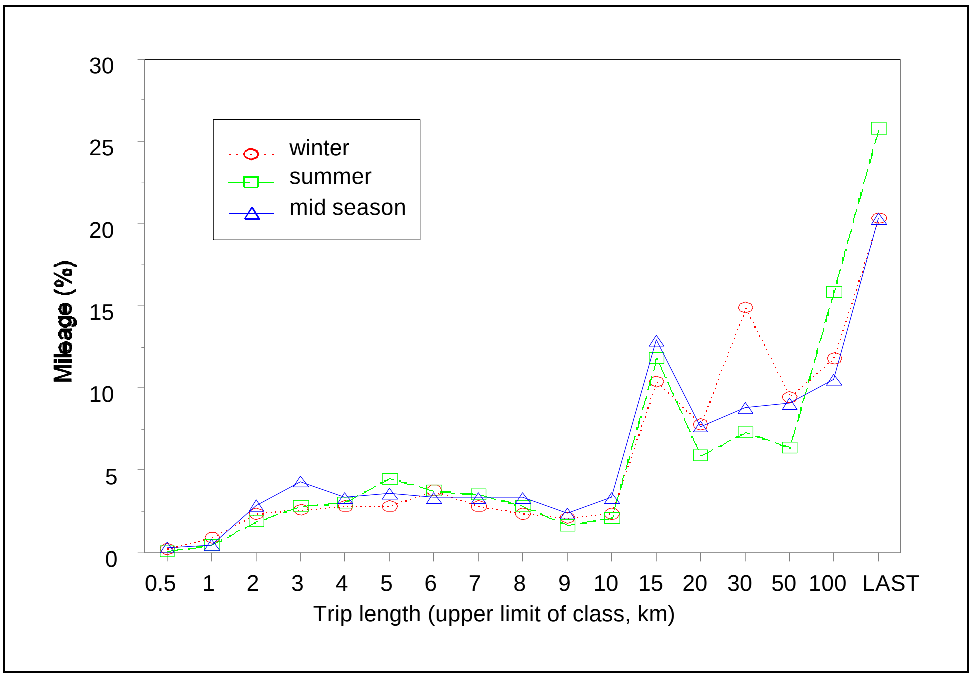

Figure A23. Trip mileage distribution as a function of trip lengths

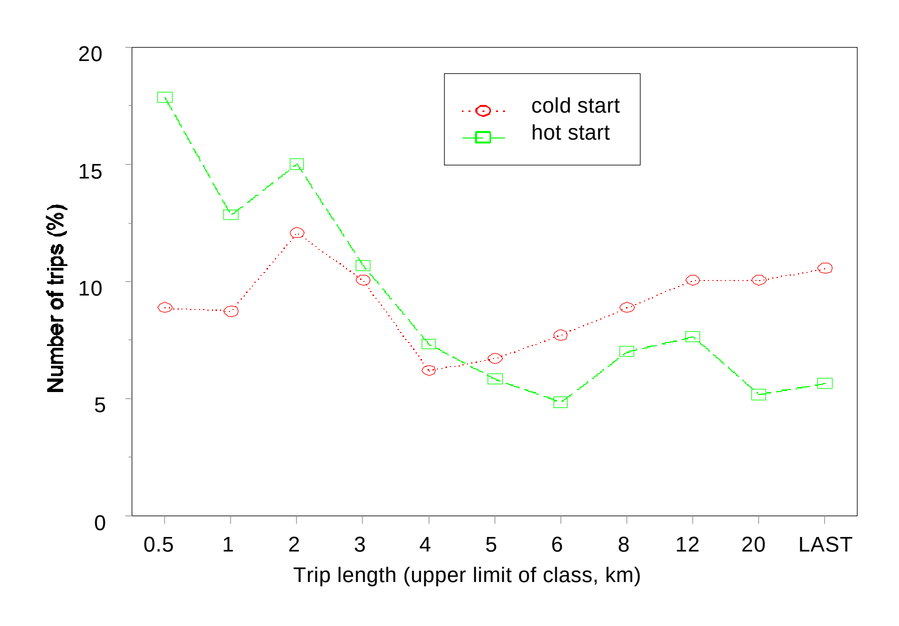

Figure A24. Cold and hot started trip number distributions as a function of trip length

A5.3.1. Start related activity data

The statistics given in the following tables have been compiled to allow the estimation of start related emissions and fuel consumption:

- *Table A56:* The proportion of total mileage that is influenced by cold starting. These data are given as a percentage of total mileage, and as a function of the average speed (of the whole trip), for the entire year and for each of the three seasons.

Table A56. Mileage percentage of trips started at cold or intermediate engine temperature as a function of the average trip speed

		Year	**Winter**	**Summer**	**Intermediate**
Duration (months)		**12**	**4**	**4**	**4**
Average speed over the whole trip (km/h)	<10	61.3	61.7	62.7	58.9
	10 to 20	67.7	71.9	71.1	56.9
	20 to 30	67.7	71.8	67.1	62.8
	30 to 40	72.2	78.8	68.6	64.8
	40 to 50	75.6	80.9	76.3	66.5
	50 to 60	71.7	77.0	76.7	60.6
	60 to 70	72.9	74.6	67.9	76.6
	> 70	62.9	67.3	58.9	57.6
	total	69.0	73.4	67.3	63.2

- *Table A57:* The link between the average speed of the cold part of a trip and the average speed of the whole trip. Percentages of trip numbers are given as a function of these two parameters, for the entire year and each of the three seasons.

Table A57. Percentage of trips classified by the cold average speed and overall average speed

Year	Average cold speed range and mean (km/h)					
Average speed over the whole trip (km/h)	< 10	10 to 20	20 to 30	30 to 40	40 to 50	> 50
	5.4	15.3	24.9	34.6	44.3	60.9
	Frequency (%)					
<10	72.2	24.6	2.6	0.6	0.0	0.0
10 to 20	22.3	53.5	20.0	3.6	0.5	0.1
20 to 30	9.9	27.6	47.9	12.5	1.9	0.2
30 to 40	7.3	15.2	27.6	37.3	10.5	2.0
40 to 50	4.4	13.5	22.5	26.5	24.4	8.7
50 to 60	3.0	13.9	24.6	20.2	18.6	19.7
60 to 70	9.7	10.4	14.2	19.5	25.5	20.6
> 70	8.5	11.4	17.8	22.3	14.1	25.9
Total in cold speed range (%)	12.9	25.7	29.6	18.6	8.6	4.5
Winter	Average cold speed range and mean (km/h)					
Average speed over the whole trip (km/h)	< 10	10 to 20	20 to 30	30 to 40	40 to 50	> 50
	5.2	15.4	24.9	34.6	44.4	59.6
	Frequency (%)					
<10	79.7	17.7	1.5	1.1	0.0	0.0
10 to 20	24.0	46.8	23.2	5.5	0.3	0.2
20 to 30	10.2	25.8	46.2	14.9	2.3	0.6
30 to 40	6.0	15.1	26.8	36.6	11.8	3.7
40 to 50	4.1	12.9	20.2	28.0	24.0	10.8
50 to 60	3.3	12.3	19.8	12.7	23.9	28.0
60 to 70	7.3	9.8	16.9	20.5	22.6	22.8
> 70	11.6	8.7	17.7	28.6	12.3	21.1
Total in cold speed range (%)	14.5	23.7	28.3	19.1	8.8	5.6
Summer	Average cold speed range and mean (km/h)					
Average speed over the whole trip (km/h)	< 10	10 to 20	20 to 30	30 to 40	40 to 50	> 50
	5.9	15.4	24.9	34.3	44.1	64.3
	Frequency (%)					
<10	52.1	47.9	0.0	0.0	0.0	0.0
10 to 20	17.5	63.7	18.8	0.0	0.0	0.0
20 to 30	8.8	29.9	50.6	9.8	0.9	0.0
30 to 40	6.9	23.2	31.0	30.5	7.8	0.5
40 to 50	4.5	13.5	24.7	31.2	22.0	4.0
50 to 60	0.8	15.7	26.6	24.4	17.6	14.8
60 to 70	10.0	14.1	14.3	17.9	27.8	15.8
> 70	6.4	17.1	16.8	15.3	21.3	23.1
Total in cold speed range (%)	9.5	29.7	31.6	17.4	8.5	3.3
Intermediate	Average cold speed range and mean (km/h)					
Average speed over the whole trip (km/h)	< 10	10 to 20	20 to 30	30 to 40	40 to 50	> 50
	5.4	14.9	25.0	34.7	44.1	61.3
	Frequency (%)					
<10	66.7	27.1	6.2	0.0	0.0	0.0
10 to 20	23.0	57.7	15.0	3.1	1.2	0.0
20 to 30	10.2	28.4	48.1	11.1	2.2	0.0
30 to 40	9.4	8.4	25.9	44.3	11.1	0.9
40 to 50	4.7	14.3	24.0	19.5	27.4	10.0
50 to 60	5.4	14.5	31.0	28.3	9.9	10.8
60 to 70	12.9	7.0	10.1	19.8	27.1	23.1
> 70	2.8	12.7	18.9	14.0	11.3	40.2
Total in cold speed range (%)	13.3	25.4	29.9	18.9	8.6	3.9

- *Table A58:* The relationship between ambient temperatures and engine start temperatures. Percentages of trips are given. Data were available for start temperatures between approximately -10 and 65 °C and ambient temperatures from 0 to 35 °C. They have been extrapolated to cover a larger temperature range.

Table A58. Percentage of trips classified by engine start temperature and ambient temperature

Engine start-up temperature		Ambient temperature range and average (°C)							
		-30 to -20	**-20 to -10**	**-10 to 0**	**0 - 10**	**10 - 20**	**20 - 30**	**30 - 40**	**40 - 50**
range	**average**	**-25**	**-15**	**-5**	**5**	**15**	**25**	**35**	**45**
<-40	-45.0	0.0							
-40 to -30	-35.0	0.0	0.0						
-30 to -20	-25.0	52.0	0.5	0.0					
-20 to -10	-15.0	26.0	43.0	1.0	0.0				
-10 to 0	-5.0	2.8	22.5	35.5	1.5	0.0			
0 - 10	5.0	2.8	4.9	19.5	28.5	2.0	0.0		
10 - 20	15.0	2.8	4.9	7.3	18.0	24.0	2.5	0.0	
20 - 30	25.0	2.8	4.9	7.3	10.4	14.8	19.0	3.0	0.0
30 - 40	35.0	2.8	4.9	7.3	10.4	14.8	19.6	17.0	3.5
40 - 50	45.0	2.8	4.9	7.3	10.4	14.8	19.6	26.7	22.0
50 - 60	55.0	2.8	4.9	7.3	10.4	14.8	19.6	26.7	37.3
60 - 70	65.0	2.8	4.9	7.3	10.4	14.8	19.6	26.7	37.3

- *Table A59:* The link between the average speed of the cold part of a trip and the total trip length. Percentages are given only for trips started with a cold or warm engine (i.e. hot trips are excluded). Data are given for the entire year and for each of the three seasons.

Table A59. Percentage of trips started with a cold engine classified by the trip length and the average speed of the cold part of the trip

Year		Range and mean average speed to reach hot conditions (km/h)						
Trip length (cold trips) (km)		< 10	10 to 20	20 to 30	30 to 40	40 to 50	> 50	Total in trip length class (%)
Range	Mean d_m	5.4	15.3	24.9	34.6	44.3	60.9	
		Frequency (%)						
< 0.5	0.21	11.7	2.1	0.5	0.0	0.0	0.0	2.2
0.5 - 1	0.75	8.8	6.0	2.3	0.2	0.0	0.0	3.4
1 - 2	1.46	14.7	14.3	10.8	4.7	0.9	0.7	9.7
2 - 3	2.49	12.3	15.1	15.9	6.7	3.2	0.0	11.7
3 - 4	3.44	6.4	7.5	9.5	9.4	6.5	1.9	8.0
4 - 5	4.50	7.3	9.0	10.4	8.2	6.2	4.8	8.6
5 - 6	5.51	7.2	8.9	8.9	9.1	5.8	6.5	8.3
6 - 7	6.51	6.1	6.5	6.4	7.6	5.3	3.5	6.4
7 - 8	7.44	3.1	3.9	4.6	4.1	8.4	2.9	4.4
8 - 9	8.49	2.3	2.2	2.7	3.8	2.3	2.2	2.7
9 - 10	9.54	1.1	1.6	3.3	5.7	3.9	3.9	3.1
10 - 11	10.46	1.2	3.0	2.3	5.6	6.4	2.7	3.3
11 - 12	11.47	2.0	1.8	2.5	4.4	2.4	2.4	2.6
> 12	34.63	16.1	18.2	20.0	30.4	48.7	68.6	25.6

Table A59. (continued) Percentage of trips started with a cold engine classified by the trip length and the average speed of the cold part of the trip

Winter		Range and mean average speed to reach hot conditions (km/h)						
trip length (cold trips) (km)		< 10	10 to 20	20 to 30	30 to 40	40 to 50	> 50	Total in trip length class (%)
class	Mean d_m	5.2	15.4	24.9	34.6	44.4	59.6	
		Frequency (%)						
< 0.5	0.22	15.5	2.4	0.8	0.0	0.0	0.0	3.0
0.5 - 1	0.76	7.3	6.6	2.5	0.2	0.0	0.0	3.4
1 - 2	1.45	14.2	13.8	11.0	5.0	1.3	0.0	9.5
2 - 3	2.46	11.8	10.8	13.8	6.4	3.3	0.0	9.7
3 - 4	3.45	9.1	8.6	9.8	10.1	5.4	1.0	8.6
4 - 5	4.57	5.2	7.7	10.0	8.4	5.7	5.5	7.8
5 - 6	5.48	6.8	11.5	9.2	8.4	6.1	3.3	8.6
6 - 7	6.52	5.8	6.5	5.2	8.2	1.1	3.0	5.7
7 - 8	7.42	1.5	4.4	4.8	4.0	3.6	3.2	3.9
8 - 9	8.47	1.8	3.6	3.5	3.5	3.0	2.8	3.2
9 - 10	9.39	1.1	1.6	3.4	5.1	3.8	5.9	3.1
10 - 11	10.36	1.2	2.9	2.4	5.9	9.0	3.6	3.6
11 - 12	11.43	2.3	1.2	2.1	1.6	1.2	1.9	1.7
> 12	33.29	16.4	18.4	21.6	33.1	56.6	69.8	28.0
Summer		Range and mean average speed to reach hot conditions (km/h)						
trip length (cold trips) (km)		< 10	10 to 20	20 to 30	30 to 40	40 to 50	> 50	Total in trip length class (%)
Range	Mean d_m	5.9	15.4	24.9	34.3	44.1	64.3	
		Frequency (%)						
< 0.5	0.19	6.6	1.2	0.3	0.0	0.0	0.0	1.1
0.5 - 1	0.73	3.9	5.9	1.9	0.0	0.0	0.0	2.7
1 - 2	1.46	17.2	15.0	10.1	5.8	0.0	3.6	10.4
2 - 3	2.51	10.6	14.1	12.1	6.5	4.6	0.0	10.5
3 - 4	3.42	3.9	4.2	8.8	9.0	3.4	3.7	6.4
4 - 5	4.43	11.4	11.5	14.7	11.1	11.3	5.4	12.2
5 - 6	5.53	13.0	8.4	11.2	9.7	3.4	14.0	9.7
6 - 7	6.53	4.9	6.0	7.3	8.6	8.1	6.4	6.9
7 - 8	7.45	7.0	4.0	6.1	3.5	6.5	3.1	5.1
8 - 9	8.60	4.2	1.3	1.7	2.7	1.7	3.1	2.0
9 - 10	9.69	0.0	1.3	3.0	1.9	3.5	3.1	2.0
10 - 11	10.51	0.9	3.6	3.0	6.5	5.4	0.0	3.7
11 - 12	11.52	0.0	2.3	2.7	4.6	2.4	1.9	2.6
> 12	38.25	16.4	21.2	17.2	30.0	49.8	55.7	24.6
Intermediate season		Range and mean average speed to reach hot conditions (km/h)						
trip length (cold trips) (km)		< 10	10 to 20	20 to 30	30 to 40	40 to 50	> 50	Total in trip length class (%)
Range	Mean d_m	5.4	14.9	25.0	34.7	44.1	61.3	
		Frequency (%)						
< 0.5	0.22	8.1	2.5	0.4	0.0	0.0	0.0	1.8
0.5 - 1	0.76	14.6	5.0	2.5	0.3	0.0	0.0	4.0
1 - 2	1.48	14.0	14.3	11.1	3.2	0.9	0.0	9.5
2 - 3	2.49	14.3	22.8	22.7	7.3	2.0	0.0	16.0
3 - 4	3.43	3.3	9.2	9.7	8.4	10.9	2.6	8.3
4 - 5	4.51	8.3	8.6	7.1	5.5	2.8	2.6	6.8
5 - 6	5.51	4.2	5.3	6.3	9.8	7.4	8.2	6.6
6 - 7	6.48	7.2	6.9	7.4	6.0	10.0	2.6	7.0
7 - 8	7.46	3.3	2.8	2.8	4.8	17.8	2.3	4.5
8 - 9	8.46	1.9	1.0	2.4	5.2	1.8	0.0	2.4
9 - 10	9.61	1.8	1.9	3.3	9.6	4.6	0.0	3.9
10 - 11	10.54	1.2	2.8	1.6	4.6	2.9	2.6	2.6
11 - 12	11.48	2.6	2.2	2.9	8.8	4.2	3.9	3.9
> 12	33.60	15.2	14.8	19.9	26.5	34.7	75.1	22.7

A5.3.2. Calculation method

$$E_c = \sum_i tf_i \cdot \frac{cm(s,v_i)}{100} \cdot \omega_i \cdot \sum_j \sum_k \sum_m \left[\frac{p_j \cdot p_k \cdot p_m}{10^6 \cdot d_m} \cdot \left\{ f(V_j) + g(T_k) - 1 \right\} \cdot h \left\{ \frac{d_m}{d_c(V_j)} \right\} \right] \quad \text{(A22)}$$

where

E_c is the traffic start-related excess emissions over 1 km for a given pollutant (in g)

tf_i, v_i, i and s are external data:

tf_i is the traffic flow for the studied vehicle type i (in.veh.km)
v_i is the traffic overall average speed for the studied vehicle type i (km/h)
i is the vehicle type
s is the season (winter, summer, intermediate)

The other parameters correspond to internal model data:

$cm(s, v_i)$ is the percentage of mileage recorded under cold start or intermediate temperature conditions for season s and overall speed v_i for vehicle type i - see Table A56
w_i is the reference excess emission for vehicle type i- see Table A50
j is the speed class for the cold part of the trip
k is the class of engine start temperature
m is the trip length class
p_j is the percentage of trips travelled at speed j with a cold engine, for the overall average speed considered - see Table A57
p_k is the percentage of the trips travelled with a start-up engine temperature T_k - see Table A58
p_m is the percentage of trips started with a cold engine according to the trip length and the average speed of the cold part of the trip - see Table A59
d_m is the average length of the trips under cold start conditions in class m (km) - see Table A59
V_j is the average speed of the cold part of a trip corresponding to class j (km/h) - see Table A59
T_k is the average engine start-up temperature corresponding to class k (°C) - see Table A58
f, g, h and d_c are functions defined in section A5.1. and given in Tables A51, A52, A54 and A53 respectively.

This procedure applies to light duty vehicles only (passenger cars and light goods vehicles). For heavy duty vehicles, cold excess emissions are specified simply as grams per cold start (see Table A55). It is further assumed that each vehicle makes one cold start per day, so the total excess emissions per day are derived simply as the multiple of the number of vehicles and the appropriate excess emission factor. Obviously, total annual emissions, or over any other period, will be obtained by multiplying by the number of days in the period.

A6. EVAPORATIVE LOSSES

Hydrocarbon emissions from motor vehicles arise from two major sources, exhaust emissions and evaporative losses through the vehicle’s fuel system (storage tank, carburettor or injection system, fuel pipes). Evaporative emissions occur as a result of fuel volatility combined with the variation of the ambient temperature and the temperature changes of the vehicle’s fuel system which occur during normal driving procedures (variation of temperature because of heat transfer from the vehicle’s engine to all the components of the fuel system).

In general there are four types of evaporative loss:

- *Filling losses.* These losses occur when the vehicle's fuel tank is filled. The contents of saturated vapours are displaced by liquid fuel, and usually vented to the atmosphere.

- *Diurnal breathing losses.* These losses are the result of the night-day temperature cycle causing the contents of the fuel tank to contract and expand, pushing saturated vapour out on expansion.

- *Hot soak losses.* These occur when a vehicle is switched off after operation and the equalisation of the temperatures leads to the evaporation of fuel in certain parts of the engine.

- *Running losses.* These evaporative losses occur during the operation of the vehicle.

Filling losses are usually attributed to the fuel handling chain and not to the vehicle emissions. This type of evaporative loss is not, therefore, covered by this part of the report, but in Part E.

Hot soak losses and diurnal losses constitute the main part of evaporative losses. In newer vehicles these losses should largely be captured by vapour traps (carbon canisters) installed on the vehicle. Depending on the temperature of the engine when it is switched off, a distinction between warm-soak and hot-soak losses can be made. For a short period, plastic fuel tanks were used that allowed the diffusion of fuel through the plastic; in later years covered plastics (so called sealed plastic tanks) have been used for fuel tanks that are impermeable to the fuel.

Running losses are the least documented source of evaporative emissions. On modern cars, equipped with carbon canisters, the canister should capture any running losses but there are reports which show that running losses would occur nevertheless. On vehicles without carbon canisters, running losses may be significant, but little quantitative information is known.

Evaporative losses from vehicles are known to depend on four major factors:

- vehicle technology (equipped or not with carbon canisters)
- ambient temperature and its daily variation
- gasoline volatility (depending on the temperature variation)
- driving conditions (average trip length, parking time etc.)

The effects of these factors on evaporative emissions were the subject of a number of research studies. The first study at a European level was carried out by CONCAWE in 1985 [A40]. The results from this project and the methodology it derived formed the basis of a more sophisticated methodology developed by the CORINAIR group. An updated methodology was proposed in 1990 by CONCAWE [A41], and was incorporated in the CORINAIR methodology of 1993 [A21] and the COPERT programme. A methodology was also developed by RWTÜV based on a specifically designed test programme and included in the German/Swiss Emission Factor Handbook [A22].

A detailed comparison of these methodologies led to the conclusion that the CORINAIR methodology should be adopted in the MEET procedure, mainly because of the transparency of the calculation method and the availability of the required input data [A42].

There are three sources of evaporative emissions from vehicles covered by the CORINAIR report of 1993:

- diurnal emissions
- hot soak emissions
- running losses

All three types of evaporative emissions are significantly affected by the volatility of the gasoline being used, the absolute ambient temperature and temperature changes, and vehicle design characteristics. For hot soak emissions and running losses the driving pattern is also of importance.

The main equation for estimating the evaporative emissions is:

$$E_{eva,voc,j} = 365 \times a_j \times (e^d + S^c + S^{fi}) + R \tag{A23}$$

where:

$E_{eva,voc,j}$	are the VOC emissions due to evaporative losses caused by vehicle category *j*
a_j	is the number of gasoline vehicles of category *j*
e^d	is the mean emission factor for diurnal losses of gasoline powered vehicles equipped with metal tanks, depending on average monthly ambient temperature, temperature variation, and fuel volatility (RVP)
S^c	is the average hot and warm soak emission factor of gasoline powered vehicles equipped with carburettor
S^{fi}	is the average hot and warm soak emission factor of gasoline powered vehicles equipped with fuel injection
R	are the hot and warm running losses

Functions to determine the appropriate emission factors are given in Table A60. Because of the lack of data, these functions must be applied for both passenger cars and light commercial vehicles.

Similarly, very few data exist on evaporative emission factors for two-wheel vehicles. However, some limited, average factors developed during the Swiss German Emission Factor Programme are presented in Table A61.

Table A60. Evaporative emission factors from CORINAIR

Emission factor (units)	Uncontrolled vehicle	Small carbon canister controlled vehicle
Diurnal (g/day)	9.1 exp(0.0158 (RVP - 61.2) + 0.0574 ($t_{a,min}$ - 22.5) + 0.0614 ($t_{a,rise}$ - 11.7))	0.2 × uncontrolled
warm soak (g/procedure)	exp (-1.644 + 0.01993 RVP + 0.07521 t_a)	0.2 exp (-2.41 + 0.02302 RVP + 0.09408 t_a)
hot soak (g/procedure)	3.0042 exp (0.02 RVP)	0.3 exp (-2.41 + 0.02302 RVP + 0.09408 t_a)
warm and hot soak for fuel injected vehicles (g/procedure)	0.7	none
warm running losses (g/km)	0.1 exp (-5.967 + 0.04259 RVP + 0.1773 t_a)	0.1 × uncontrolled
hot running losses (g/km)	0.136 exp (-5.967 + 0.04259 RVP + 0.1773 t_a)	0.1 × uncontrolled

Key:

RVP = fuel volatility in kPa
t_a = average monthly ambient temperature in °C
$t_{a,min}$ = minimum ambient temperature during the day °C (average for month)
$t_{a,rise}$ = temperature rise during the day in °C (average for month)

Table A61. Evaporative emission data for motorcycles

	Diurnal (g/day)	Hot / warm soak (g/test)
Small 2-stroke (125 cc)	5.7	7.5
Large 4-stroke (1000 cc)	17.3	26.1

As is the case for other types of emission, it is necessary to combine the emission factors with appropriate statistics on vehicle use and environmental conditions in order to derive traffic-related emission estimates. The following equations may be used:

$$S^c = (1-q) \times (pxe^{s,hot} + wxe^{s,warm}) \qquad \text{(A24)}$$

$$S^{fi} = qe^{fi}x \qquad \text{(A25)}$$

$$R = m_j \times (pe^{r,hot} + we^{r,warm}) \qquad \text{(A26)}$$

where:

q is the fraction of gasoline powered vehicles equipped with fuel injection

p is the fraction of trips finished with a hot engine (dependent on the average monthly ambient temperature)

w is the fraction of trips finished with a cold or warm engine (shorter trips) or with the catalyst below its light-off temperature

x is the mean number of trips per vehicle per day, averaged over the year, or shorter time period

$e^{s,hot}$ is the mean emission factor for hot soak emissions (which is dependent on fuel volatility RVP) (Table A52)

$e^{s,warm}$ is the mean emission factor for cold and warm soak emissions (which is dependent on fuel volatility RVP and average monthly ambient temperature) (Table A52)

e^{fi} is the mean emission factor for hot and warm soak emissions of gasoline powered vehicles equipped with fuel injection (Table A52)

$e^{r,hot}$ is the average emission factor for hot running losses of gasoline powered vehicles (which is dependent on fuel volatility RVP and average monthly ambient temperature) (Table A52)

$e^{r,warm}$ is the average emission factor for warm running losses of gasoline powered vehicles (which is dependent on fuel volatility RVP and average monthly ambient temperature) (Table A52)

m_j is the total annual mileage of gasoline powered vehicles of category j

Relevant activity data are presented in Tables A62 and A63. Table A62 gives statistics on the daily usage of passenger cars - the average number of trips, their average duration and distance - for the whole year and for the three seasons, and Table A63 provides details of the proportions of trips which end in different engine temperature classes as a function of the ambient temperature. These data are again provided for the whole year and for each season [A35, A36].

Table A62. Average daily use of passenger cars

	Average daily use - all days		
	Duration (min)	**Distance (km)**	**Number of trips**
Year	61.4	42.25	4.87
Winter	68.2	45.77	5.11
Summer	60.4	44.07	4.62
Intermediate	54.2	36.67	4.78
	Days with at least one use of the car		
Year	78.6	54.08	6.23
Winter	83.2	55.81	6.23
Summer	74.3	54.16	5.68
Intermediate	76.3	51.65	6.73

Table A63. Distribution of passenger car trips by ambient temperature and the engine temperature at the end of the trip

Year	Engine status at the end of the trip				
Ambient temperature range (°C)	Cold	Intermediate		Hot	Total
	<30°C	30 to 50°C	50 to 70°C	>70°C	
	Percent of ambient temperature range				
<5	7.1	13.6	26.9	52.3	100.0
5 to 15	2.1	8.0	17.4	72.5	100.0
15 to 25	0.7	4.8	15.4	79.0	100.0
>25	0.0	1.1	6.0	92.9	100.0
Total frequency	1.7	6.2	15.6	76.5	100.0
Winter	Engine status at the end of the trip				
Ambient temperature range (°C)	Cold	Intermediate		Hot	Total
	<30°C	30 to 50°C	50 to 70°C	>70°C	
	Percent of ambient temperature range				
<5	5.4	12.4	20.2	62.0	100.0
5 to 15	1.0	5.9	14.2	78.9	100.0
15 to 25	0.1	3.5	13.0	83.5	100.0
>25	0.0	0.0	3.9	96.1	100.0
Total frequency	1.3	5.8	14.1	78.8	100.0
Summer	Engine status at the end of the trip				
Ambient temperature range (°C)	Cold	Intermediate		Hot	Total
	<30°C	30 to 50°C	50 to 70°C	>70°C	
	Percent of ambient temperature range				
<5	-	-	-	-	-
5 to 15	5.1	6.7	15.4	72.8	100.0
15 to 25	1.3	6.8	14.6	77.2	100.0
>25	0.0	1.7	7.5	90.7	100.0
Total frequency	1.2	4.7	11.8	82.3	100.0
Intermediate	Percent of ambient temperature range				
Ambient temperature range (°C)	Cold	Intermediate		Hot	Total
	<30°C	30 to 50°C	50 to 70°C	>70°C	
	Frequency of trips (1 unit = 0.01 trip)				
<5	10.6	15.9	40.2	33.2	100.0
5 to 15	3.7	12.2	24.0	60.1	100.0
15 to 25	0.6	4.3	17.7	77.4	100.0
>25	0.0	0.4	3.8	95.8	100.0
Total frequency	2.4	7.7	19.9	70.0	100.0

A7. ROAD TRAFFIC COMPOSITION

A7.1. Traffic composition in terms of emission related categories

In Deliverable 15 of this Project [A39], an evaluation was made of the types of traffic statistics needed to estimate pollutant emissions from road transport, whether the data were available, and compatible with the objectives. Three broad types of data were identified:

- *localised data*: specifying traffic activity by its geographical location
- *quantified data*: specifying the amount of traffic activity
- *driving patterns*: specifying the nature of the traffic activity.

Most often, it was not possible to obtain consistent data in all three areas. International sources, such as the ECMT's 'Statistical trends in transport' [A43] and EUROSTAT's 'Transport annual statistics' [A44], provide harmonised data, easy to obtain and manage, but on a large scale. National surveys and specific studies are very heterogeneous in their methods and results, and access to them may be difficult. It was concluded that:

- significant discrepancies exist between data from different international organisations, between institutions in the same country and between different methods of investigation

- there can be great uncertainty even for data that would often be regarded as normal and basic (e.g. network length, traffic volume by different transport modes)

- it is even more difficult to satisfy the needs of a detailed classification, according to many categories of vehicle, different road types, gradients, etc.

In the MEET project, traffic activity data from many of sources have been used. Some, mainly from specific studies, have been given and discussed in earlier sections (when, for example, certain statistics are needed for a particular calculation, such as the use of trip length data in estimating start-related and evaporative emissions). This section deals with the more general traffic data, on a national basis, and draws mainly on internationally published material.

In section A3.1.2, a comprehensive classification system was proposed for road vehicles, based on properties such as size, fuel and age, that are likely to influence exhaust emissions (Table A5[35]). This section brings together data on the numbers of vehicles in each of the emission-related categories, data on their average annual mileage and representative speeds. Together, the first two factors - the numbers of vehicles and their annual mileages - may be used to specify the average composition of traffic on a national basis. There will, of course, be many significant deviations from these data, particularly on a more local scale, where any of the vehicle characteristics used in the classification may differ greatly from the national average. If

[35] The classification in Table A5 is used as the structure for data given later in this section with the following exceptions: only conventional fuels and engines are considered; the class of HGVs > 40 tonnes is excluded; there are some differences in terminology used for emission standards, although there is a direct correspondence between the classes (e.g. EC Directive 83/351, for passenger cars becomes ECE 15-04, with which it was equivalent).

more detailed, accurate or locally more specific data are available, they should be used in preference to the values given here. In this respect, attention is drawn to the data for France given in Tables A68 (a, b, c and d). Those in Tables A68a and A68b were generated in the same way as for the other countries, while those in Tables A68c and A68d represent an independent assessment. Differences between the two data sets are sometimes significant.

A standard format has been adopted in the presentation of the data. Firstly, for each Member State and for the EU as a whole, mileage and speed information is given for the base year of 1995. Secondly, the evolution of the vehicle fleet for each country and the EU is given (as the number of vehicles in each class) in 5 year intervals over the period from 1990 to 2020. The compilation of these data is described in more detail in MEET Deliverable 16 [A45], including the sources of historical data and the procedure used to make the forecasts. Furthermore, a number of comparisons are made between present conditions and trends in the different Member States. To give a general background to the data tables that follow, a number of these are reproduced below.

A7.2 Comparisons and trends

A7.2.1 Vehicle stock

Figure A25 illustrates the 1995 passenger car fleet broken down by fuel type and engine capacity, for each EU 15 Member State. It is clear that the great majority of cars have gasoline engines smaller than 2.0 l. Diesel cars were around 15% on average in 1995, while LPG vehicles have a significant presence only in Italy and the Netherlands.

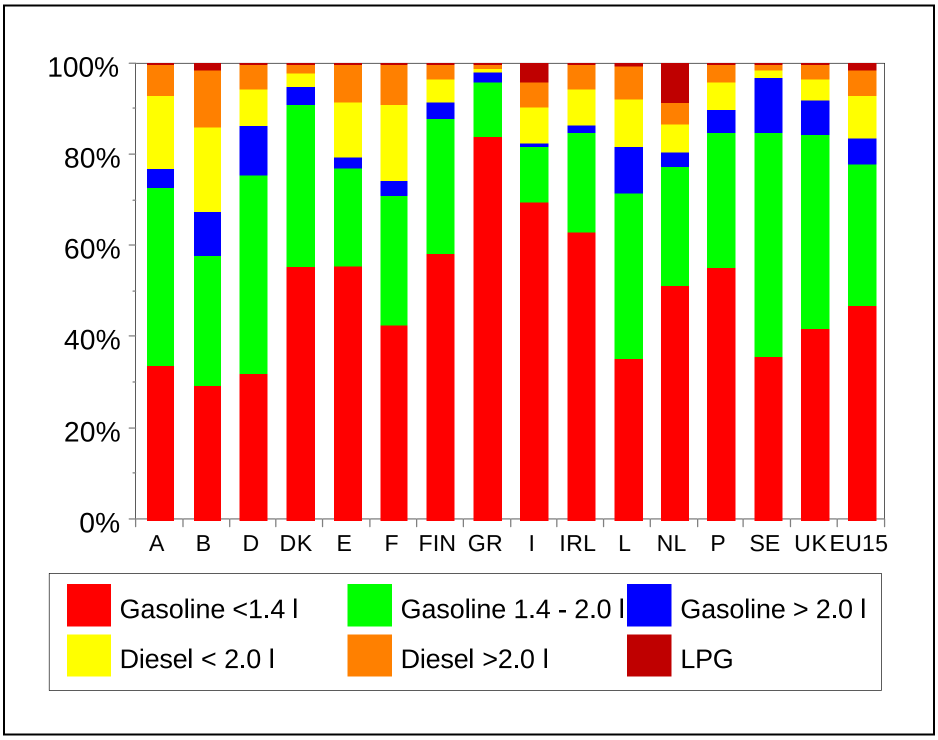

Figure A24. Passenger car fleet distribution (1995 data) for EU 15.

Passenger cars are by far the most abundant vehicle type, representing 80% of all vehicles in the EU. Light goods vehicles make up another 6.5%, of which some two thirds have diesel engines and the remainder petrol, heavy duty vehicles (effectively all diesel) comprise 3% of the fleet as HGVs and 0.25% as buses and coaches. Mopeds and motorcycles make up the remaining 10%. Within these average figures, there is significant variability between EU Member States. For example, the proportion of passenger cars varies between 55% (in Portugal) and 90% (in Sweden), while the proportion of two-wheelers varies from 1% (in Ireland) to 35% (in Portugal).

The distribution of the vehicles within the various emission categories is closely related to their age (since the various emission standards were introduced on a fixed time scale in most Member States). The average age of passenger cars is between 7 and 8 years, but there are again variations from country to country: the oldest cars are in Finland where the average age is about 11 years, while the youngest fleet is in Luxembourg, with an average age of about 4 years.

A7.2.2 Vehicle mileage

Many of the vehicle attributes discussed briefly above (size, age, fuel etc.) are related to the way they are used, and this is reflected in their typical annual mileage. For passenger cars, there is a general tendency for newer cars, cars with larger engines and diesel cars to be driven greater annual distances. Figure A27 shows the relationship with age for 6 Member States, and Figure A27 shows the relationship with engine size and fuel for the EU15.

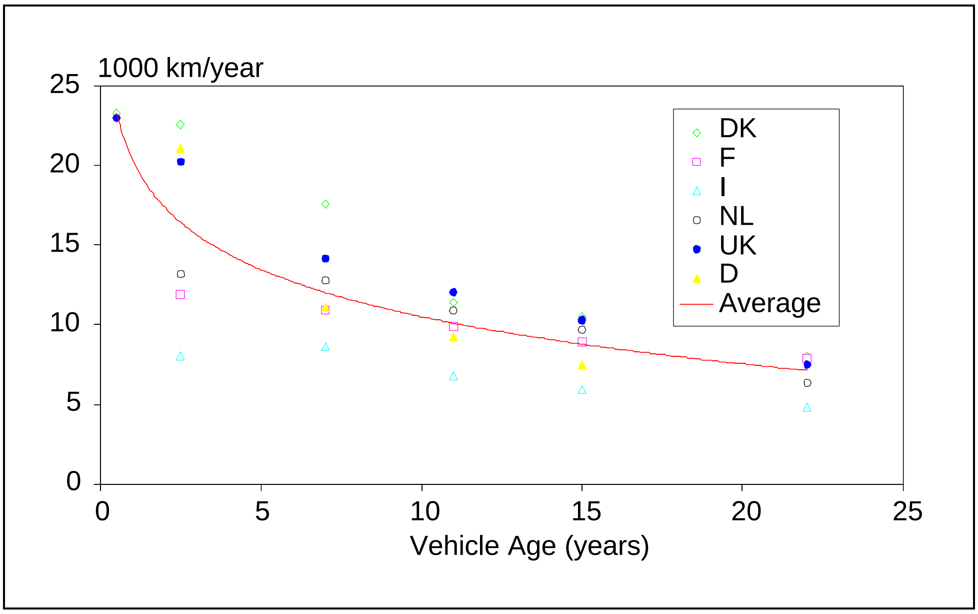

Figure A26. Annual mileage as a function of the passenger car age (1990 data)

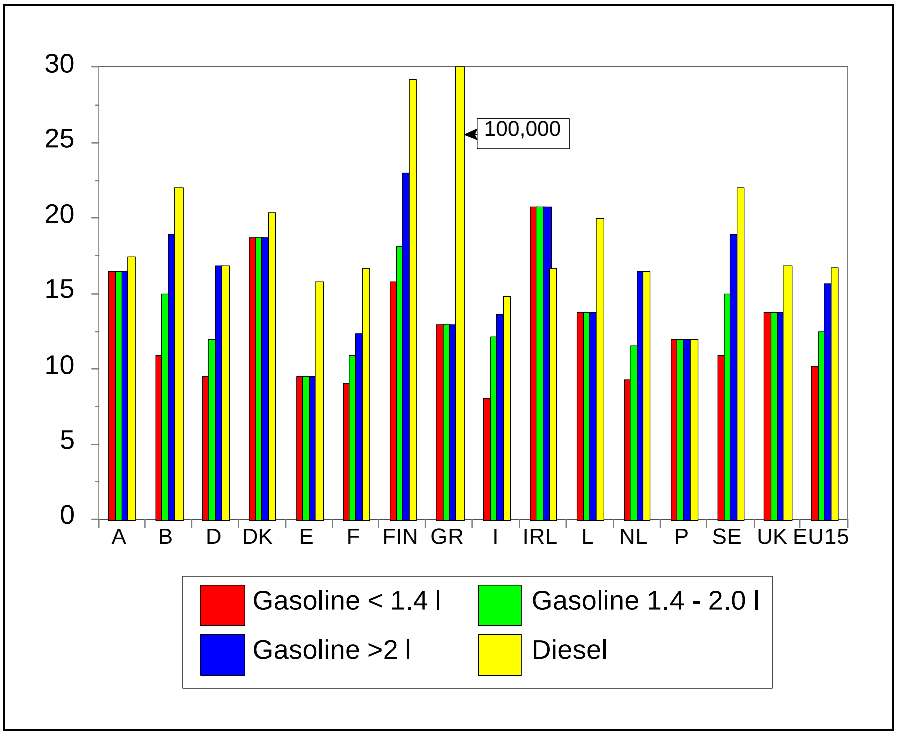

Figure A27. Relation between engine type/size and the annual mileage of passenger cars in EU 15 (1995 data)

Vehicles used for commercial purposes (light goods vehicles, heavy goods vehicles, buses and coaches) tend to be used much more than passenger cars. Compared with an overall annual mileage of about 12,000 km for cars, light goods vehicles cover approximately 20,000, heavy goods vehicles 50,000 and buses and coaches 45,000 km/year. Conversely, two-wheel vehicles cover considerably smaller annual mileages. Those less than 50 cc engine capacity, which are used mainly in urban areas for relatively short journeys, average 3,000 km/year while larger motorcycles have an average annual mileage of about 5,500 km/year.

A7.2.3 Traffic composition

The average composition of road traffic results from both the number of vehicles of each type and its annual mileage. Vehicle types that are most abundant, and those that cover high annual distances are more likely to be present in the traffic at any given time than less common or less frequently used vehicle types. Thus, by combining the statistics outlined above, it is possible to derive an average (and necessarily approximate) composition of traffic in the EU according to the emission-related classification. As an example, the average traffic composition for the EU15 has been calculated for 1995, and the result is shown graphically in Figure A28. The data are presented in units of billion vehicle.kilometres by each emission-related category of vehicles that made up the 1995 fleet[36] (i.e. EURO 2 and subsequent emission standards are not

[36] As a cross check of the procedure, the total vehicle.kilometres calculated here were compared with the value reported by the OECD [A46]. This procedure gave 2651 billion, while the OECD gave 2576 billion vehicle.kilometres, a difference of less than 3%.

included as they did not apply until 1996). As always, this average does not show the sometimes significant differences from country to country. For example, the category 'two-stroke passenger cars' represents only one in 100,000 vehicle.kilometres overall, but in Finland, while still quite low, the figure rises to one in 1500 vehicle.kilometres. Similarly, over the EU15, small, pre ECE, gasoline cars are responsible for approximately one vehicle kilometre in 4000, while in Greece they are driven one in each 130 vehicle kilometres.

Because country-specific data are given, they may be used in applications in which national differences are important. If variations within a country are important, external supplementary data will be required. The availability and comprehensiveness of such data differ widely in the EU Member States.

Another feature of the aggregation of the data in this way is that it gives no indication of the operation of the vehicles and, as has been seen, rates of emission vary significantly depending on a vehicle's operating condition. This factor has, however, been taken into account in the compilation of vehicle and traffic statistics by including data on the distribution of traffic in each Member State between 'urban' roads, 'rural' roads and 'highways'. Although it was not done in the example given, it is possible to subdivide the EU totals according to these road types making use of the data provided. Furthermore, representative average speeds are given for each road and vehicle type so that the data may be used with the average speed related emission functions presented in sections A4 and A5.

A7.3 Data tables

The following Tables (A64 to A79) contain the road traffic statistics discussed above. For each Member State, and for the EU15 combined, the data are given in two parts (a and b). The 'a' tables give the numbers of vehicles in each emission related category for the years 1990 to 2020, in five yearly intervals. The 'b' tables include the total annual mileage for each vehicle category, its split between urban roads, rural roads and highways, and representative speeds for the three road types, based on data for 1995.

As mentioned in A7.1, there is some inconsistency in the availability of data from different Member States, and also between statistics compiled by different organisations within a Member State. The values given in the following tables should therefore be regarded as default reference values. Any user with access to more recent information, or information that is locally more specific, may of course substitute this for the default values presented here.

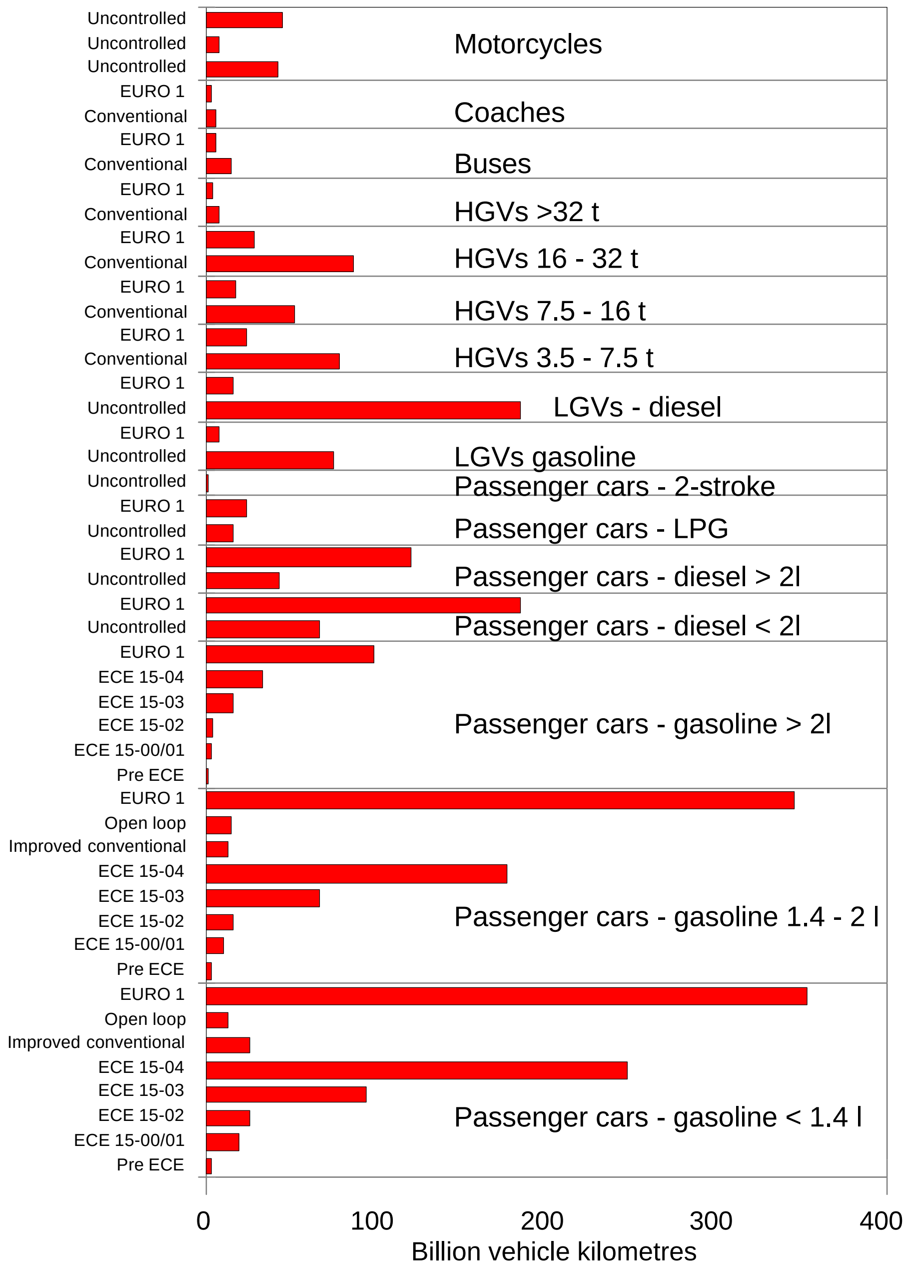

Figure A28. Average road traffic composition, EU15, 1995

Table A64a. Fleet composition of Austria

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Passenger cars	Gasoline	<1.4 l	Pre ECE	17	0	0	0	0	0	0
			ECE 15-00/01	59625	827	0	0	0	0	0
			ECE 15-02	176492	33813	17	0	0	0	0
			ECE 15-03	297640	197301	19344	1	0	0	0
			ECE 15-04	115444	104643	42136	547	0	0	0
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	388185	878328	769083	395769	52441	25	0
			EURO 2	0	0	513920	500359	362803	57195	27
			EURO 3	0	0	0	448787	434291	293919	27992
			EURO 4	0	0	0	119148	719773	1306169	1704291
		1.4 - 2.0 l	Pre ECE	20	0	0	0	0	0	0
			ECE 15-00/01	68067	944	0	0	0	0	0
			ECE 15-02	201478	38600	20	0	0	0	0
			ECE 15-03	339777	225233	22083	1	0	0	0
			ECE 15-04	131902	119457	48101	624	0	0	0
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	443139	1002672	877961	451797	59866	29	0
			EURO 2	0	0	586675	571194	414164	65293	31
			EURO 3	0	0	0	512322	495773	335528	31955
			EURO 4	0	0	0	136016	821670	1491082	1945566
		>2.0 l	Pre ECE	2	0	0	0	0	0	0
			ECE 15-00/01	6721	93	0	0	0	0	0
			ECE 15-02	19893	3811	2	0	0	0	0
			ECE 15-03	33458	22239	2180	0	0	0	0
			ECE 15-04	13023	11795	4749	62	0	0	0
			EURO 1	43754	99000	86687	44609	5911	3	0
			EURO 2	0	0	57926	56398	40893	6447	3
			EURO 3	0	0	0	50585	48951	33129	3155
			EURO 4	0	0	0	13430	81129	147224	192098
	Diesel	<2.0 l	Uncontrolled	324428	175543	35918	112	0	0	0
			EURO 1	164600	397106	399455	227793	44579	143	0
			EURO 2	0	0	198357	194743	151147	26828	13
			EURO 3	0	0	0	211536	204703	138539	13194
			EURO 4	0	0	0	56160	339265	615663	803318
		>2.0 l	Uncontrolled	139040	75233	15394	48	0	0	0
			EURO 1	70543	170188	171195	97625	19105	61	0
			EURO 2	0	0	85010	83461	64777	11498	6
			EURO 3	0	0	0	90658	87730	59374	5655
			EURO 4	0	0	0	24069	145399	263855	344279
	LPG	All	Uncontrolled	0	0	0	0	0	0	0
			EURO 1	0	0	0	0	0	0	0
			EURO 2	0	0	0	0	0	0	0
			EURO 3	0	0	0	0	0	0	0
			EURO 4	0	0	0	0	0	0	0
	2-stroke	All	Uncontrolled	0	0	0	0	0	0	0

Table A64a (continued). Fleet composition of Austria

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Light goods vehicles	Gasoline	All	Uncontrolled	22312	22864	8247	155	0	0	0
			EURO 1	0	3396	9990	3735	1	0	0
			EURO 2	0	0	11120	12931	2102	0	0
			EURO 3	0	0	0	15589	33151	37826	40171
			EURO 4	0	0	0	0	0	0	0
	Diesel	All	Uncontrolled	54307	55652	20074	376	0	0	0
			EURO 1	0	8265	33133	15530	54	0	0
			EURO 2	0	0	18250	25036	5065	0	0
			EURO 3	0	0	0	37944	80691	92069	97777
			EURO 4	0	0	0	0	0	0	0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	12074	9166	1925	0	0	0	0
			EURO 1	0	5044	6002	1013	0	0	0
			EURO 2	0	0	7960	6111	426	0	0
			EURO 3	0	0	0	10414	18651	20469	21737
			EURO 4	0	0	0	0	0	0	0
		7.5 - 16 t	Conventional	14294	10851	2279	0	0	0	0
			EURO 1	0	5972	7105	1199	0	0	0
			EURO 2	0	0	9424	7235	505	0	0
			EURO 3	0	0	0	12329	22081	24233	25735
			EURO 4	0	0	0	0	0	0	0
		16 - 32 t	Conventional	139116	105609	22180	5	0	0	0
			EURO 1	0	58124	69153	11668	0	0	0
			EURO 2	0	0	91716	70415	4911	0	0
			EURO 3	0	0	0	119990	214905	235848	250468
			EURO 4	0	0	0	0	0	0	0
		>32 t	Conventional	15147	11499	2415	1	0	0	0
			EURO 1	0	6329	7529	1270	0	0	0
			EURO 2	0	0	9986	7667	535	0	0
			EURO 3	0	0	0	13065	23399	25679	27271
			EURO 4	0	0	0	0	0	0	0
		Buses	Conventional	7488	6611	4283	2116	523	9	0
			EURO 1	0	1413	1857	1800	1378	329	2
			EURO 2	0	0	2136	2128	2027	1382	211
			EURO 3	0	0	0	2477	4805	7181	8831
			EURO 4	0	0	0	0	0	0	0
		Coaches	Conventional	1872	1653	1071	529	131	2	0
			EURO 1	0	353	464	450	344	82	0
			EURO 2	0	0	534	532	507	346	53
			EURO 3	0	0	0	619	1201	1795	2208
			EURO 4	0	0	0	0	0	0	0
Motorcycles	Gasoline	<50 cc	Uncontrolled	425298	440234	316967	171689	72440	N/A	N/A
			Stage I	0	0	66186	58031	39896	N/A	N/A
			Stage II	0	0	69897	232293	357667	N/A	N/A
		>50 cc 2-s	Uncontrolled	18328	18972	13659	7399	3122	N/A	N/A
			Controlled	0	0	5865	12512	17133	N/A	N/A
		>50 cc 4-s	Uncontrolled	82933	85845	61806	33480	14126	N/A	N/A
			Controlled	0	0	5865	12512	17133	N/A	N/A

Table A64b. Annual mileage, mileage distribution and representative speeds for Austria (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Passenger cars	Gasoline	<1.4 l	Pre ECE	7500	31.0	43.5	25.5	32.0	75.0	106.0
			ECE 15-00/01	9500	31.0	43.5	25.5	32.0	75.0	106.0
			ECE 15-02	12000	31.0	43.5	25.5	32.0	75.0	106.0
			ECE 15-03	13800	31.0	43.5	25.5	32.0	75.0	106.0
			ECE 15-04	17500	31.0	43.5	25.5	32.0	75.0	106.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	17500	31.0	43.5	25.5	32.0	75.0	106.0
			EURO 2	17500	31.0	43.5	25.5	32.0	75.0	106.0
			EURO 3	17500	31.0	43.5	25.5	32.0	75.0	106.0
			EURO 4	17500	31.0	43.5	25.5	32.0	75.0	106.0
		1.4 - 2.0 l	Pre ECE	7500	31.0	43.5	25.5	32.0	75.0	106.0
			ECE 15-00/01	9500	31.0	43.5	25.5	32.0	75.0	106.0
			ECE 15-02	12000	31.0	43.5	25.5	32.0	75.0	106.0
			ECE 15-03	13800	31.0	43.5	25.5	32.0	75.0	106.0
			ECE 15-04	17500	31.0	43.5	25.5	32.0	75.0	106.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	17500	31.0	43.5	25.5	32.0	75.0	106.0
			EURO 2	17500	31.0	43.5	25.5	32.0	75.0	106.0
			EURO 3	17500	31.0	43.5	25.5	32.0	75.0	106.0
			EURO 4	17500	31.0	43.5	25.5	32.0	75.0	106.0
		>2.0 l	Pre ECE	7500	31.0	43.5	25.5	32.0	75.0	106.0
			ECE 15-00/01	9500	31.0	43.5	25.5	32.0	75.0	106.0
			ECE 15-02	12000	31.0	43.5	25.5	32.0	75.0	106.0
			ECE 15-03	13800	31.0	43.5	25.5	32.0	75.0	106.0
			ECE 15-04	17500	31.0	43.5	25.5	32.0	75.0	106.0
			EURO 1	17500	31.0	43.5	25.5	32.0	75.0	106.0
			EURO 2	17500	31.0	43.5	25.5	32.0	75.0	106.0
			EURO 3	17500	31.0	43.5	25.5	32.0	75.0	106.0
			EURO 4	17500	31.0	43.5	25.5	32.0	75.0	106.0
	Diesel	<2.0 l	Uncontrolled	17500	31.0	43.5	25.5	32.0	75.0	106.0
			EURO 1	17500	31.0	43.5	25.5	32.0	75.0	106.0
			EURO 2	17500	31.0	43.5	25.5	32.0	75.0	106.0
			EURO 3	17500	31.0	43.5	25.5	32.0	75.0	106.0
			EURO 4	17500	31.0	43.5	25.5	32.0	75.0	106.0
		>2.0 l	Uncontrolled	17500	31.0	43.5	25.5	32.0	75.0	106.0
			EURO 1	17500	31.0	43.5	25.5	32.0	75.0	106.0
			EURO 2	17500	31.0	43.5	25.5	32.0	75.0	106.0
			EURO 3	17500	31.0	43.5	25.5	32.0	75.0	106.0
			EURO 4	17500	31.0	43.5	25.5	32.0	75.0	106.0
	LPG	All	Uncontrolled	-	-	-	-	-	-	-
			EURO 1	-	-	-	-	-	-	-
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
	2-stroke	All	Uncontrolled	-	-	-	-	-	-	-

Table A64b (continued). Annual mileage, mileage distribution and representative speeds for Austria (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Light goods vehicles	Gasoline	All	Uncontrolled	25000	32.0	40.0	28.0	20.0	60.0	90.0
			EURO 1	25000	32.0	40.0	28.0	20.0	60.0	90.0
			EURO 2	25000	32.0	40.0	28.0	20.0	60.0	90.0
			EURO 3	25000	32.0	40.0	28.0	20.0	60.0	90.0
			EURO 4	25000	32.0	40.0	28.0	20.0	60.0	90.0
	Diesel	All	Uncontrolled	25000	32.0	40.0	28.0	20.0	60.0	90.0
			EURO 1	25000	32.0	40.0	28.0	20.0	60.0	90.0
			EURO 2	25000	32.0	40.0	28.0	20.0	60.0	90.0
			EURO 3	25000	32.0	40.0	28.0	20.0	60.0	90.0
			EURO 4	25000	32.0	40.0	28.0	20.0	60.0	90.0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	38000	15.0	40.0	45.0	20.0	60.0	90.0
			EURO 1	38000	15.0	40.0	45.0	20.0	60.0	90.0
			EURO 2	38000	15.0	40.0	45.0	20.0	60.0	90.0
			EURO 3	38000	15.0	40.0	45.0	20.0	60.0	90.0
			EURO 4	38000	15.0	40.0	45.0	20.0	60.0	90.0
		7.5 - 16 t	Conventional	38000	15.0	40.0	45.0	20.0	60.0	90.0
			EURO 1	38000	15.0	40.0	45.0	20.0	60.0	90.0
			EURO 2	38000	15.0	40.0	45.0	20.0	60.0	90.0
			EURO 3	38000	15.0	40.0	45.0	20.0	60.0	90.0
			EURO 4	38000	15.0	40.0	45.0	20.0	60.0	90.0
		16 - 32 t	Conventional	73000	15.0	40.0	45.0	20.0	60.0	90.0
			EURO 1	73000	15.0	40.0	45.0	20.0	60.0	90.0
			EURO 2	73000	15.0	40.0	45.0	20.0	60.0	90.0
			EURO 3	73000	15.0	40.0	45.0	20.0	60.0	90.0
			EURO 4	73000	15.0	40.0	45.0	20.0	60.0	90.0
		>32 t	Conventional	73000	15.0	40.0	45.0	20.0	60.0	90.0
			EURO 1	73000	15.0	40.0	45.0	20.0	60.0	90.0
			EURO 2	73000	15.0	40.0	45.0	20.0	60.0	90.0
			EURO 3	73000	15.0	40.0	45.0	20.0	60.0	90.0
			EURO 4	73000	15.0	40.0	45.0	20.0	60.0	90.0
		Buses	Conventional	41573	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 1	41573	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 2	41573	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 3	41573	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 4	41573	100.0	0.0	0.0	20.0	60.0	90.0
		Coaches	Conventional	41573	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 1	41573	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 2	41573	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 3	41573	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 4	41573	0.0	50.0	50.0	20.0	60.0	90.0
Motorcycles	Gasoline	<50 cc	Uncontrolled	4500	60.0	40.0	0.0	N/A	N/A	N/A
			Stage I	4500	60.0	40.0	0.0	N/A	N/A	N/A
			Stage II	4500	60.0	40.0	0.0	N/A	N/A	N/A
		>50 cc 2-s	Uncontrolled	7800	15.0	65.0	20.0	N/A	N/A	N/A
			Controlled	7800	15.0	65.0	20.0	N/A	N/A	N/A
		>50 cc 4-s	Uncontrolled	7800	15.0	65.0	20.0	N/A	N/A	N/A
			Controlled	7800	15.0	65.0	20.0	N/A	N/A	N/A

Table A65a. Fleet composition of Belgium

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Passenger cars	Gasoline	<1.4 l	Pre ECE	3	0	0	0	0	0	0
			ECE 15-00/01	15666	14	0	0	0	0	0
			ECE 15-02	101800	2462	0	0	0	0	0
			ECE 15-03	280255	64676	643	0	0	0	0
			ECE 15-04	729905	553659	164624	3754	0	0	0
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	7952	631424	505003	152822	3461	0	0
			EURO 2	0	0	681711	555412	177413	4147	0
			EURO 3	0	0	0	581852	452442	112145	1070
			EURO 4	0	0	0	146600	886128	1469819	1641663
		1.4 - 2.0 l	Pre ECE	3	0	0	0	0	0	0
			ECE 15-00/01	15198	14	0	0	0	0	0
			ECE 15-02	98757	2388	0	0	0	0	0
			ECE 15-03	271879	62743	623	0	0	0	0
			ECE 15-04	695505	525431	153603	3377	0	0	0
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	20302	624235	496012	148520	3358	0	0
			EURO 2	0	0	661338	538813	172111	4023	0
			EURO 3	0	0	0	564463	438920	108794	1039
			EURO 4	0	0	0	142219	859646	1425894	1592602
		>2.0 l	Pre ECE	1	0	0	0	0	0	0
			ECE 15-00/01	5150	5	0	0	0	0	0
			ECE 15-02	33465	809	0	0	0	0	0
			ECE 15-03	92130	21261	211	0	0	0	0
			ECE 15-04	221921	165280	45381	854	0	0	0
			EURO 1	20639	224299	174749	50618	1138	0	0
			EURO 2	0	0	224103	182484	58322	1363	0
			EURO 3	0	0	0	191275	148734	36866	352
			EURO 4	0	0	0	48193	291302	483182	539673
	Diesel	<2.0 l	Uncontrolled	380222	114254	5635	1	0	0	0
			EURO 1	336783	676404	495333	148771	6837	1	0
			EURO 2	0	0	352669	300776	107367	2617	0
			EURO 3	0	0	0	367380	285671	70808	676
			EURO 4	0	0	0	92563	559500	928041	1036543
		>2.0 l	Uncontrolled	253481	76170	3757	1	0	0	0
			EURO 1	224522	450936	330222	99180	4558	1	0
			EURO 2	0	0	235113	200518	71578	1745	0
			EURO 3	0	0	0	244920	190447	47206	451
			EURO 4	0	0	0	61709	373000	618694	691029
	LPG	All	Uncontrolled	24746	7436	367	0	0	0	0
			EURO 1	21919	44023	32238	9683	445	0	0
			EURO 2	0	0	22953	19567	6988	170	0
			EURO 3	0	0	0	23911	18593	4609	44
			EURO 4	0	0	0	6024	36415	60401	67463
	2-stroke	All	Uncontrolled	0	0	0	0	0	0	0

Table A65a (continued). Fleet composition of Belgium

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Light goods vehicles	Gasoline	All	Uncontrolled	73103	75739	37912	4788	0	0	0
			EURO 1	0	8159	26216	20088	523	0	0
			EURO 2	0	0	30052	39109	19936	55	0
			EURO 3	0	0	0	40168	93329	122667	130986
			EURO 4	0	0	0	0	0	0	0
	Diesel	All	Uncontrolled	142260	147390	73778	9318	0	0	0
			EURO 1	0	15878	70199	57090	4617	0	0
			EURO 2	0	0	39301	58108	35196	108	0
			EURO 3	0	0	0	78168	181621	238712	254901
			EURO 4	0	0	0	0	0	0	0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	61710	51660	20284	385	0	0	0
			EURO 1	0	19163	25905	13625	40	0	0
			EURO 2	0	0	33314	31468	10588	1	0
			EURO 3	0	0	0	42443	85426	103595	110571
			EURO 4	0	0	0	0	0	0	0
		7.5 - 16 t	Conventional	39940	33435	13128	249	0	0	0
			EURO 1	0	12402	16766	8818	26	0	0
			EURO 2	0	0	21561	20367	6853	1	0
			EURO 3	0	0	0	27470	55289	67049	71564
			EURO 4	0	0	0	0	0	0	0
		16 - 32 t	Conventional	50004	41860	16436	312	0	0	0
			EURO 1	0	15528	20991	11040	33	0	0
			EURO 2	0	0	26994	25449	8579	1	0
			EURO 3	0	0	0	34391	69221	83943	89596
			EURO 4	0	0	0	0	0	0	0
		>32 t	Conventional	3542	2966	1164	22	0	0	0
			EURO 1	0	1100	1487	782	2	0	0
			EURO 2	0	0	1912	1806	608	0	0
			EURO 3	0	0	0	2436	4904	5947	6347
			EURO 4	0	0	0	0	0	0	0
		Buses	Conventional	13256	9987	5289	2403	468	6	0
			EURO 1	0	2161	2911	2713	1758	313	2
			EURO 2	0	0	2311	2284	2033	1072	105
			EURO 3	0	0	0	1013	1741	2201	1555
			EURO 4	0	0	0	0	0	0	0
		Coaches	Conventional	3314	2497	1322	601	117	2	0
			EURO 1	0	540	728	678	439	78	0
			EURO 2	0	0	578	571	508	268	26
			EURO 3	0	0	0	253	435	550	389
			EURO 4	0	0	0	0	0	0	0
Motorcycles	Gasoline	<50 cc	Uncontrolled	377399	320841	183839	77789	20959	N/A	N/A
			Stage I	0	0	44817	36750	18707	N/A	N/A
			Stage II	0	0	38487	100728	123840	N/A	N/A
		>50 cc 2-s	Uncontrolled	0	0	0	0	0	0	0
			Controlled	0	0	0	0	0	0	0
		>50 cc 4-s	Uncontrolled	137693	143096	95923	45582	12366	N/A	N/A
			Controlled	0	0	51136	105135	140961	N/A	N/A

Table A65b. Annual mileage, mileage distribution and representative speeds for Belgium (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Passenger cars	Gasoline	<1.4 l	Pre ECE	5000	27.1	48.8	27.1	25.0	50.0	103.0
			ECE 15-00/01	11000	27.1	48.8	27.1	25.0	50.0	103.0
			ECE 15-02	11000	27.1	48.8	27.1	25.0	50.0	103.0
			ECE 15-03	11000	27.1	48.8	27.1	25.0	50.0	103.0
			ECE 15-04	11000	27.1	48.8	27.1	25.0	50.0	103.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	11000	27.1	48.8	27.1	25.0	50.0	103.0
			EURO 2	11000	27.1	48.8	27.1	25.0	50.0	103.0
			EURO 3	11000	27.1	48.8	27.1	25.0	50.0	103.0
			EURO 4	11000	27.1	48.8	27.1	25.0	50.0	103.0
		1.4 - 2.0 l	Pre ECE	7000	27.1	48.8	27.1	25.0	50.0	105.0
			ECE 15-00/01	15000	27.1	48.8	27.1	25.0	50.0	105.0
			ECE 15-02	15000	27.1	48.8	27.1	25.0	50.0	105.0
			ECE 15-03	15000	27.1	48.8	27.1	25.0	50.0	105.0
			ECE 15-04	15000	27.1	48.8	27.1	25.0	50.0	105.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	15000	27.1	48.8	27.1	25.0	50.0	105.0
			EURO 2	15000	27.1	48.8	27.1	25.0	50.0	105.0
			EURO 3	15000	27.1	48.8	27.1	25.0	50.0	105.0
			EURO 4	15000	27.1	48.8	27.1	25.0	50.0	105.0
		>2.0 l	Pre ECE	9000	27.1	48.8	27.1	25.0	50.0	110.0
			ECE 15-00/01	19000	27.1	48.8	27.1	25.0	50.0	110.0
			ECE 15-02	19000	27.1	48.8	27.1	25.0	50.0	110.0
			ECE 15-03	19000	27.1	48.8	27.1	25.0	50.0	110.0
			ECE 15-04	19000	27.1	48.8	27.1	25.0	50.0	110.0
			EURO 1	19000	27.1	48.8	27.1	25.0	50.0	110.0
			EURO 2	19000	27.1	48.8	27.1	25.0	50.0	110.0
			EURO 3	19000	27.1	48.8	27.1	25.0	50.0	110.0
			EURO 4	19000	27.1	48.8	27.1	25.0	50.0	110.0
	Diesel	<2.0 l	Uncontrolled	20000	27.1	48.8	27.1	25.0	50.0	110.0
			EURO 1	20000	27.1	48.8	27.1	25.0	50.0	110.0
			EURO 2	20000	27.1	48.8	27.1	25.0	50.0	110.0
			EURO 3	20000	27.1	48.8	27.1	25.0	50.0	110.0
			EURO 4	20000	27.1	48.8	27.1	25.0	50.0	110.0
		>2.0 l	Uncontrolled	25000	27.1	48.8	27.1	25.0	50.0	110.0
			EURO 1	25000	27.1	48.8	27.1	25.0	50.0	110.0
			EURO 2	25000	27.1	48.8	27.1	25.0	50.0	110.0
			EURO 3	25000	27.1	48.8	27.1	25.0	50.0	110.0
			EURO 4	25000	27.1	48.8	27.1	25.0	50.0	110.0
	LPG	All	Uncontrolled	24450	27.1	48.8	27.1	25.0	50.0	110.0
			EURO 1	24450	27.1	48.8	27.1	25.0	50.0	110.0
			EURO 2	24450	27.1	48.8	27.1	25.0	50.0	110.0
			EURO 3	24450	27.1	48.8	27.1	25.0	50.0	110.0
			EURO 4	24450	27.1	48.8	27.1	25.0	50.0	110.0
	2-stroke	All	Uncontrolled	-	-	-	-	-	-	-

Table A65b (continued). Annual mileage, mileage distribution and representative speeds for Belgium (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Light goods vehicles	Gasoline	All	Uncontrolled	20000	27.1	48.8	24.1	20.0	60.0	90.0
			EURO 1	20000	27.1	48.8	24.1	20.0	60.0	90.0
			EURO 2	20000	27.1	48.8	24.1	20.0	60.0	90.0
			EURO 3	20000	27.1	48.8	24.1	20.0	60.0	90.0
			EURO 4	20000	27.1	48.8	24.1	20.0	60.0	90.0
	Diesel	All	Uncontrolled	35000	27.1	48.8	24.1	20.0	60.0	90.0
			EURO 1	35000	27.1	48.8	24.1	20.0	60.0	90.0
			EURO 2	35000	27.1	48.8	24.1	20.0	60.0	90.0
			EURO 3	35000	27.1	48.8	24.1	20.0	60.0	90.0
			EURO 4	35000	27.1	48.8	24.1	20.0	60.0	90.0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	65000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 1	65000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 2	65000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 3	65000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 4	65000	25.9	39.8	34.3	20.0	60.0	90.0
		7.5 - 16 t	Conventional	65000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 1	65000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 2	65000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 3	65000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 4	65000	25.9	39.8	34.3	20.0	60.0	90.0
		16 - 32 t	Conventional	60000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 1	60000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 2	60000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 3	60000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 4	60000	25.9	39.8	34.3	20.0	60.0	90.0
		>32 t	Conventional	60000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 1	60000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 2	60000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 3	60000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 4	60000	25.9	39.8	34.3	20.0	60.0	90.0
		Buses	Conventional	23209	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 1	23209	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 2	23209	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 3	23209	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 4	23209	100.0	0.0	0.0	20.0	60.0	90.0
		Coaches	Conventional	23209	0	50.0	50.0	20.0	60.0	90.0
			EURO 1	23209	0	50.0	50.0	20.0	60.0	90.0
			EURO 2	23209	0	50.0	50.0	20.0	60.0	90.0
			EURO 3	23209	0	50.0	50.0	20.0	60.0	90.0
			EURO 4	23209	0	50.0	50.0	20.0	60.0	90.0
Motorcycles	Gasoline	<50 cc	Uncontrolled	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			Stage I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			Stage II	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		>50 cc 2-s	Uncontrolled	-	-	-	-	N/A	N/A	N/A
			Controlled	-	-	-	-	N/A	N/A	N/A
		>50 cc 4-s	Uncontrolled	3000	48.3	40.3	11.4	N/A	N/A	N/A
			Controlled	3000	48.3	40.3	11.4	N/A	N/A	N/A

Table A66a. Fleet composition of Denmark

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Passenger cars	Gasoline	<1.4 l	Pre ECE	2265	46	0	0	0	0	0
			ECE 15-00/01	131316	34665	1244	1	0	0	0
			ECE 15-02	138711	72174	10018	85	0	0	0
			ECE 15-03	215670	172662	74444	7190	32	0	0
			ECE 15-04	386404	365573	272229	101986	9721	76	0
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	5415	282782	273480	222420	103230	13016	118
			EURO 2	0	0	344422	332866	269522	123068	15037
			EURO 3	0	0	0	281178	270022	211712	86285
			EURO 4	0	0	0	68134	390604	717112	983093
		1.4 - 2.0 l	Pre ECE	1443	29	0	0	0	0	0
			ECE 15-00/01	83647	22081	792	0	0	0	0
			ECE 15-02	88357	45974	6381	54	0	0	0
			ECE 15-03	137379	109958	47420	4580	20	0	0
			ECE 15-04	240820	227690	169095	62897	5947	47	0
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	8762	185303	178514	143746	66001	8293	75
			EURO 2	0	0	219392	212031	171682	78392	9578
			EURO 3	0	0	0	179106	172000	134858	54962
			EURO 4	0	0	0	43400	248810	456790	626217
		>2.0 l	Pre ECE	171	3	0	0	0	0	0
			ECE 15-00/01	9894	2612	94	0	0	0	0
			ECE 15-02	10451	5438	755	6	0	0	0
			ECE 15-03	16249	13006	5609	542	2	0	0
			ECE 15-04	23103	21637	15359	4837	272	1	0
			EURO 1	6418	27212	25757	19604	8238	986	9
			EURO 2	0	0	25950	25079	20306	9272	1133
			EURO 3	0	0	0	21185	20344	15951	6503
			EURO 4	0	0	0	5133	29429	54029	74069
	Diesel	<2.0 l	Uncontrolled	34264	22885	10016	1707	31	0	0
			EURO 1	10518	24344	25609	18428	7966	1273	23
			EURO 2	0	0	14046	13691	11473	5657	749
			EURO 3	0	0	0	14312	13744	10776	4392
			EURO 4	0	0	0	3468	19882	36502	50040
		>2.0 l	Uncontrolled	22842	15257	6677	1138	21	0	0
			EURO 1	7012	16229	17073	12286	5311	849	15
			EURO 2	0	0	9364	9127	7649	3772	499
			EURO 3	0	0	0	9541	9163	7184	2928
			EURO 4	0	0	0	2312	13255	24334	33360
	LPG	All	Uncontrolled	751	502	220	37	1	0	0
			EURO 1	231	534	562	404	175	28	0
			EURO 2	0	0	308	300	252	124	16
			EURO 3	0	0	0	314	301	236	96
			EURO 4	0	0	0	76	436	800	1097
	2-stroke	All	Uncontrolled	0	0	0	0	0	0	0

Table A66a (continued). Fleet composition of Denmark

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Light goods vehicles	Gasoline	All	Uncontrolled	63384	60449	26451	3839	0	0	0
			EURO 1	0	7070	23335	17901	462	0	0
			EURO 2	0	0	22091	27416	13293	34	0
			EURO 3	0	0	0	26510	65155	81608	84211
			EURO 4	0	0	0	0	0	0	0
	Diesel	All	Uncontrolled	105357	100479	43966	6382	0	0	0
			EURO 1	0	11752	52240	42377	3293	0	0
			EURO 2	0	0	23267	32949	19570	56	0
			EURO 3	0	0	0	44066	108300	135649	139975
			EURO 4	0	0	0	0	0	0	0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	21627	16585	5166	101	0	0	0
			EURO 1	0	6454	8993	4829	15	0	0
			EURO 2	0	0	10366	9747	3048	0	0
			EURO 3	0	0	0	11141	23862	27857	28734
			EURO 4	0	0	0	0	0	0	0
		7.5 - 16 t	Conventional	11993	9097	2865	56	0	0	0
			EURO 1	0	3579	4987	2678	8	0	0
			EURO 2	0	0	5748	5405	1690	0	0
			EURO 3	0	0	0	6178	13233	15448	15934
			EURO 4	0	0	0	0	0	0	0
		16 - 32 t	Conventional	87970	67459	21014	412	0	0	0
			EURO 1	0	26251	36580	19641	61	0	0
			EURO 2	0	0	42163	39648	12396	1	0
			EURO 3	0	0	0	45316	97061	113309	116876
			EURO 4	0	0	0	0	0	0	0
		>32 t	Conventional	9087	6969	2171	43	0	0	0
			EURO 1	0	2712	3779	2029	6	0	0
			EURO 2	0	0	4355	4096	1281	0	0
			EURO 3	0	0	0	4681	10026	11705	12073
			EURO 4	0	0	0	0	0	0	0
		Buses	Conventional	7910	5392	2708	161	0	0	0
			EURO 1	0	3698	4298	1992	21	0	0
			EURO 2	0	0	3342	3111	1177	3	0
			EURO 3	0	0	0	6297	11510	13772	14805
			EURO 4	0	0	0	0	0	0	0
		Coaches	Conventional	1977	1348	677	40	0	0	0
			EURO 1	0	924	1074	498	5	0	0
			EURO 2	0	0	835	778	294	1	0
			EURO 3	0	0	0	1574	2877	3443	3701
			EURO 4	0	0	0	0	0	0	0
Motorcycles	Gasoline	<50 cc	Uncontrolled	141945	119302	65937	25797	6954	N/A	N/A
			Stage I	0	0	15918	12716	6391	N/A	N/A
			Stage II	0	0	14179	33745	35470	N/A	N/A
		>50 cc 2-s	Uncontrolled	7375	7012	4324	1900	528	N/A	N/A
			Controlled	0	0	2185	3942	4531	N/A	N/A
		>50 cc 4-s	Uncontrolled	31854	30285	18674	8208	2282	N/A	N/A
			Controlled	0	0	9437	17026	19568	N/A	N/A

Table A66b. Annual mileage, mileage distribution and representative speeds for Denmark (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Passenger cars	Gasoline	<1.4 l	Pre ECE	11665	40.0	47.0	13.0	40.0	70.0	100.0
			ECE 15-00/01	13122	40.0	47.0	13.0	40.0	70.0	100.0
			ECE 15-02	14033	40.0	47.0	13.0	40.0	70.0	100.0
			ECE 15-03	15621	40.0	47.0	13.0	40.0	70.0	100.0
			ECE 15-04	18077	40.0	47.0	13.0	40.0	70.0	100.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	23505	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 2	23505	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 3	23505	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 4	23505	40.0	47.0	13.0	40.0	70.0	100.0
		1.4 - 2.0 l	Pre ECE	11665	40.0	47.0	13.0	40.0	70.0	100.0
			ECE 15-00/01	13122	40.0	47.0	13.0	40.0	70.0	100.0
			ECE 15-02	14033	40.0	47.0	13.0	40.0	70.0	100.0
			ECE 15-03	15621	40.0	47.0	13.0	40.0	70.0	100.0
			ECE 15-04	18054	40.0	47.0	13.0	40.0	70.0	100.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	23382	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 2	23382	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 3	23382	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 4	23382	40.0	47.0	13.0	40.0	70.0	100.0
		>2.0 l	Pre ECE	11665	40.0	47.0	13.0	40.0	70.0	100.0
			ECE 15-00/01	13122	40.0	47.0	13.0	40.0	70.0	100.0
			ECE 15-02	14033	40.0	47.0	13.0	40.0	70.0	100.0
			ECE 15-03	15621	40.0	47.0	13.0	40.0	70.0	100.0
			ECE 15-04	17581	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 1	22722	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 2	22722	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 3	22722	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 4	22722	40.0	47.0	13.0	40.0	70.0	100.0
	Diesel	<2.0 l	Uncontrolled	20000	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 1	20000	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 2	20000	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 3	20000	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 4	20000	40.0	47.0	13.0	40.0	70.0	100.0
		>2.0 l	Uncontrolled	20000	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 1	20000	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 2	20000	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 3	20000	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 4	20000	40.0	47.0	13.0	40.0	70.0	100.0
	LPG	All	Uncontrolled	48600	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 1	48600	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 2	48600	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 3	48600	40.0	47.0	13.0	40.0	70.0	100.0
			EURO 4	48600	40.0	47.0	13.0	40.0	70.0	100.0
	2-stroke	All	Uncontrolled	-	-	-	-	-	-	-

Table A66b (continued). Annual mileage, mileage distribution and representative speeds for Denmark (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Light goods vehicles	Gasoline	All	Uncontrolled	18253	40.0	46.0	14.0	20.0	60.0	90.0
			EURO 1	18253	40.0	46.0	14.0	20.0	60.0	90.0
			EURO 2	18253	40.0	46.0	14.0	20.0	60.0	90.0
			EURO 3	18253	40.0	46.0	14.0	20.0	60.0	90.0
			EURO 4	18253	40.0	46.0	14.0	20.0	60.0	90.0
	Diesel	All	Uncontrolled	15000	40.0	46.0	14.0	20.0	60.0	90.0
			EURO 1	15000	40.0	46.0	14.0	20.0	60.0	90.0
			EURO 2	15000	40.0	46.0	14.0	20.0	60.0	90.0
			EURO 3	15000	40.0	46.0	14.0	20.0	60.0	90.0
			EURO 4	15000	40.0	46.0	14.0	20.0	60.0	90.0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	35000	41.0	45.0	14.0	20.0	60.0	90.0
			EURO 1	35000	41.0	45.0	14.0	20.0	60.0	90.0
			EURO 2	35000	41.0	45.0	14.0	20.0	60.0	90.0
			EURO 3	35000	41.0	45.0	14.0	20.0	60.0	90.0
			EURO 4	35000	41.0	45.0	14.0	20.0	60.0	90.0
		7.5 - 16 t	Conventional	35000	41.0	45.0	14.0	20.0	60.0	90.0
			EURO 1	35000	41.0	45.0	14.0	20.0	60.0	90.0
			EURO 2	35000	41.0	45.0	14.0	20.0	60.0	90.0
			EURO 3	35000	41.0	45.0	14.0	20.0	60.0	90.0
			EURO 4	35000	41.0	45.0	14.0	20.0	60.0	90.0
		16 - 32 t	Conventional	40000	21.0	42.0	37.0	20.0	60.0	90.0
			EURO 1	40000	21.0	42.0	37.0	20.0	60.0	90.0
			EURO 2	40000	21.0	42.0	37.0	20.0	60.0	90.0
			EURO 3	40000	21.0	42.0	37.0	20.0	60.0	90.0
			EURO 4	40000	21.0	42.0	37.0	20.0	60.0	90.0
		>32 t	Conventional	40000	21.0	42.0	37.0	20.0	60.0	90.0
			EURO 1	40000	21.0	42.0	37.0	20.0	60.0	90.0
			EURO 2	40000	21.0	42.0	37.0	20.0	60.0	90.0
			EURO 3	40000	21.0	42.0	37.0	20.0	60.0	90.0
			EURO 4	40000	21.0	42.0	37.0	20.0	60.0	90.0
		Buses	Conventional	60038	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 1	60038	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 2	60038	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 3	60038	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 4	60038	100.0	0.0	0.0	20.0	60.0	90.0
		Coaches	Conventional	60038	0	50.0	50.0	20.0	60.0	90.0
			EURO 1	60038	0	50.0	50.0	20.0	60.0	90.0
			EURO 2	60038	0	50.0	50.0	20.0	60.0	90.0
			EURO 3	60038	0	50.0	50.0	20.0	60.0	90.0
			EURO 4	60038	0	50.0	50.0	20.0	60.0	90.0
Motorcycles	Gasoline	<50 cc	Uncontrolled	3300	85.0	15.0	0.0	N/A	N/A	N/A
			Stage I	3300	85.0	15.0	0.0	N/A	N/A	N/A
			Stage II	3300	85.0	15.0	0.0	N/A	N/A	N/A
		>50 cc 2-s	Uncontrolled	6700	40.0	47.0	13.0	N/A	N/A	N/A
			Controlled	6700	40.0	47.0	13.0	N/A	N/A	N/A
		>50 cc 4-s	Uncontrolled	6700	40.0	47.0	13.0	N/A	N/A	N/A
			Controlled	6700	40.0	47.0	13.0	N/A	N/A	N/A

Table A67a. Fleet composition of Finland

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Passenger cars	Gasoline	<1.4 l	Pre ECE	23963	12654	3946	0	0	0	0
			ECE 15-00/01	175625	158102	123867	46890	0	0	0
			ECE 15-02	134106	131068	121327	87592	13476	0	0
			ECE 15-03	222856	221704	216379	191502	119235	0	0
			ECE 15-04	472396	472167	470292	457766	401643	247194	15571
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	56211	277505	277368	276004	267439	231206	134982
			EURO 2	0	0	237987	237930	237233	232250	208490
			EURO 3	0	0	0	248081	248009	247155	241179
			EURO 4	0	0	0	73391	487030	956311	1438969
		1.4 - 2.0 l	Pre ECE	12008	6341	1977	0	0	0	0
			ECE 15-00/01	88005	79225	62069	23497	0	0	0
			ECE 15-02	67200	65678	60797	43892	6753	0	0
			ECE 15-03	111673	111095	108427	95961	59748	0	0
			ECE 15-04	224871	224757	223832	217685	190299	115667	7802
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	40013	150902	150818	150005	144976	124059	67639
			EURO 2	0	0	119255	119226	118877	116380	104474
			EURO 3	0	0	0	124313	124277	123849	120854
			EURO 4	0	0	0	36776	244050	479205	721063
		>2.0 l	Pre ECE	1589	839	262	0	0	0	0
			ECE 15-00/01	11644	10482	8213	3109	0	0	0
			ECE 15-02	8891	8690	8044	5807	893	0	0
			ECE 15-03	14776	14699	14346	12697	7905	0	0
			ECE 15-04	29753	29738	29616	28802	25179	15304	1032
			EURO 1	5294	19966	19955	19847	19182	16414	8949
			EURO 2	0	0	15779	15775	15729	15398	13823
			EURO 3	0	0	0	16448	16443	16387	15990
			EURO 4	0	0	0	4866	32291	63404	95405
	Diesel	<2.0 l	Uncontrolled	57702	54963	50085	38026	19900	4034	0
			EURO 1	31884	50147	53622	53013	49821	38851	15239
			EURO 2	0	0	16095	16092	16056	15782	14402
			EURO 3	0	0	0	20481	20475	20404	19911
			EURO 4	0	0	0	6059	40207	78949	118795
		>2.0 l	Uncontrolled	38468	36642	33390	25350	13267	2690	0
			EURO 1	21256	33431	35748	35342	33214	25901	10159
			EURO 2	0	0	10730	10728	10704	10522	9601
			EURO 3	0	0	0	13654	13650	13603	13274
			EURO 4	0	0	0	4039	26805	52633	79197
	LPG	All	Uncontrolled	0	0	0	0	0	0	0
			EURO 1	0	0	0	0	0	0	0
			EURO 2	0	0	0	0	0	0	0
			EURO 3	0	0	0	0	0	0	0
			EURO 4	0	0	0	0	0	0	0
	2-stroke	All	Uncontrolled	5300	6218	7088	7908	8665	9349	9960

Table A67a (continued). Fleet composition of Finland

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Light goods vehicles	Gasoline	All	Uncontrolled	50208	57095	55692	46191	21399	3022	23
			EURO 1	0	2148	5867	5860	5744	4572	835
			EURO 2	0	0	6356	8905	8880	8506	5603
			EURO 3	0	0	0	15250	47932	74954	91018
			EURO 4	0	0	0	0	0	0	0
	Diesel	All	Uncontrolled	136191	154875	151067	125295	58046	8197	61
			EURO 1	0	5828	21249	21230	20883	18195	12993
			EURO 2	0	0	11905	18821	18784	18195	12993
			EURO 3	0	0	0	41367	130017	203317	246892
			EURO 4	0	0	0	0	0	0	0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	11137	11885	11573	9469	4020	289	0
			EURO 1	0	1257	1662	1657	1586	1033	81
			EURO 2	0	0	1829	1829	1820	1695	904
			EURO 3	0	0	0	3948	11197	17182	20638
			EURO 4	0	0	0	0	0	0	0
		7.5 - 16 t	Conventional	15865	16929	16486	13489	5727	412	0
			EURO 1	0	1791	2368	2361	2259	1471	116
			EURO 2	0	0	2606	2605	2592	2414	1287
			EURO 3	0	0	0	6730	19086	29286	35178
			EURO 4	0	0	0	0	0	0	0
		16 - 32 t	Conventional	18983	20257	19727	16141	6853	492	0
			EURO 1	0	2142	2833	2825	2703	1760	138
			EURO 2	0	0	3118	3117	3101	2889	1540
			EURO 3	0	0	0	6730	19086	29286	35178
			EURO 4	0	0	0	0	0	0	0
		>32 t	Conventional	0	0	0	0	0	0	0
			EURO 1	0	0	0	0	0	0	0
			EURO 2	0	0	0	0	0	0	0
			EURO 3	0	0	0	0	0	0	0
			EURO 4	0	0	0	0	0	0	0
		Buses	Conventional	7174	6729	5065	2773	898	59	0
			EURO 1	0	555	805	799	734	411	29
			EURO 2	0	0	1470	1468	1448	1266	548
			EURO 3	0	0	0	2332	4279	5626	6753
			EURO 4	0	0	0	0	0	0	0
		Coaches	Conventional	1794	1682	1266	693	225	15	0
			EURO 1	0	139	201	200	183	103	7
			EURO 2	0	0	367	367	362	316	137
			EURO 3	0	0	0	583	1074	1406	1688
			EURO 4	0	0	0	0	0	0	0
Motorcycles	Gasoline	<50 cc	Uncontrolled	97498	101997	73324	40307	17533	N/A	N/A
			Stage I	0	0	16163	14170	9740	N/A	N/A
			Stage II	0	0	16805	54860	84875	N/A	N/A
		>50 cc 2-s	Uncontrolled	27113	25124	16849	8614	3503	N/A	N/A
			Controlled	0	0	6200	12071	14781	N/A	N/A
		>50 cc 4-s	Uncontrolled	27113	25124	16849	8614	3503	N/A	N/A
			Controlled	0	0	6200	12071	14781	N/A	N/A

Table A67b. Annual mileage, mileage distribution and representative speeds for Finland (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Passenger cars	Gasoline	<1.4 l	Pre ECE	3000	30.0	60.0	10.0	30.0	80.0	100.0
			ECE 15-00/01	6000	30.0	60.0	10.0	30.0	80.0	100.0
			ECE 15-02	9000	30.0	60.0	10.0	30.0	80.0	100.0
			ECE 15-03	14000	30.0	60.0	10.0	30.0	80.0	100.0
			ECE 15-04	20000	30.0	60.0	10.0	30.0	80.0	100.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	20000	30.0	60.0	10.0	30.0	80.0	100.0
			EURO 2	20000	30.0	60.0	10.0	30.0	80.0	100.0
			EURO 3	20000	30.0	60.0	10.0	30.0	80.0	100.0
			EURO 4	20000	30.0	60.0	10.0	30.0	80.0	100.0
		1.4 - 2.0 l	Pre ECE	4000	30.0	60.0	10.0	30.0	80.0	100.0
			ECE 15-00/01	7000	30.0	60.0	10.0	30.0	80.0	100.0
			ECE 15-02	10000	30.0	60.0	10.0	30.0	80.0	100.0
			ECE 15-03	18000	30.0	60.0	10.0	30.0	80.0	100.0
			ECE 15-04	22000	30.0	60.0	10.0	30.0	80.0	100.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	22000	30.0	60.0	10.0	30.0	80.0	100.0
			EURO 2	22000	30.0	60.0	10.0	30.0	80.0	100.0
			EURO 3	22000	30.0	60.0	10.0	30.0	80.0	100.0
			EURO 4	22000	30.0	60.0	10.0	30.0	80.0	100.0
		>2.0 l	Pre ECE	5000	30.0	60.0	10.0	30.0	80.0	100.0
			ECE 15-00/01	8000	30.0	60.0	10.0	30.0	80.0	100.0
			ECE 15-02	13000	30.0	60.0	10.0	30.0	80.0	100.0
			ECE 15-03	21000	30.0	60.0	10.0	30.0	80.0	100.0
			ECE 15-04	29000	30.0	60.0	10.0	30.0	80.0	100.0
			EURO 1	29000	30.0	60.0	10.0	30.0	80.0	100.0
			EURO 2	29000	30.0	60.0	10.0	30.0	80.0	100.0
			EURO 3	29000	30.0	60.0	10.0	30.0	80.0	100.0
			EURO 4	29000	30.0	60.0	10.0	30.0	80.0	100.0
	Diesel	<2.0 l	Uncontrolled	28000	30.0	60.0	10.0	30.0	80.0	100.0
			EURO 1	28000	30.0	60.0	10.0	30.0	80.0	100.0
			EURO 2	28000	30.0	60.0	10.0	30.0	80.0	100.0
			EURO 3	28000	30.0	60.0	10.0	30.0	80.0	100.0
			EURO 4	28000	30.0	60.0	10.0	30.0	80.0	100.0
		>2.0 l	Uncontrolled	31000	30.0	60.0	10.0	30.0	80.0	100.0
			EURO 1	31000	30.0	60.0	10.0	30.0	80.0	100.0
			EURO 2	31000	30.0	60.0	10.0	30.0	80.0	100.0
			EURO 3	31000	30.0	60.0	10.0	30.0	80.0	100.0
			EURO 4	31000	30.0	60.0	10.0	30.0	80.0	100.0
	LPG	All	Uncontrolled	-	-	-	-	-	-	-
			EURO 1	-	-	-	-	-	-	-
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
	2-stroke	All	Uncontrolled	5150	30.0	60.0	10.0	30.0	80.0	100.0

Table A67b (continued). Annual mileage, mileage distribution and representative speeds for Finland (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Light goods vehicles	Gasoline	All	Uncontrolled	8500	30.0	60.0	10.0	20.0	60.0	90.0
			EURO 1	8500	30.0	60.0	10.0	20.0	60.0	90.0
			EURO 2	8500	30.0	60.0	10.0	20.0	60.0	90.0
			EURO 3	8500	30.0	60.0	10.0	20.0	60.0	90.0
			EURO 4	8500	30.0	60.0	10.0	20.0	60.0	90.0
	Diesel	All	Uncontrolled	16000	30.0	60.0	10.0	20.0	60.0	90.0
			EURO 1	16000	30.0	60.0	10.0	20.0	60.0	90.0
			EURO 2	16000	30.0	60.0	10.0	20.0	60.0	90.0
			EURO 3	16000	30.0	60.0	10.0	20.0	60.0	90.0
			EURO 4	16000	30.0	60.0	10.0	20.0	60.0	90.0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	55000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 1	55000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 2	55000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 3	55000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 4	55000	40.0	50.0	10.0	20.0	60.0	90.0
		7.5 - 16 t	Conventional	55000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 1	55000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 2	55000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 3	55000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 4	55000	40.0	50.0	10.0	20.0	60.0	90.0
		16 - 32 t	Conventional	75000	20.0	50.0	30.0	20.0	60.0	90.0
			EURO 1	75000	20.0	50.0	30.0	20.0	60.0	90.0
			EURO 2	75000	20.0	50.0	30.0	20.0	60.0	90.0
			EURO 3	75000	20.0	50.0	30.0	20.0	60.0	90.0
			EURO 4	75000	20.0	50.0	30.0	20.0	60.0	90.0
		>32 t	Conventional	-	-	-	-	-	-	-
			EURO 1	-	-	-	-	-	-	-
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
		Buses	Conventional	70000	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 1	70000	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 2	70000	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 3	70000	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 4	70000	100.0	0.0	0.0	20.0	60.0	90.0
		Coaches	Conventional	70000	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 1	70000	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 2	70000	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 3	70000	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 4	70000	0.0	50.0	50.0	20.0	60.0	90.0
Motorcycles	Gasoline	<50 cc	Uncontrolled	2000	20.0	80.0	0.0	N/A	N/A	N/A
			Stage I	2000	20.0	80.0	0.0	N/A	N/A	N/A
			Stage II	2000	20.0	80.0	0.0	N/A	N/A	N/A
		>50 cc 2-s	Uncontrolled	5000	30.0	60.0	10.0	N/A	N/A	N/A
			Controlled	5000	30.0	60.0	10.0	N/A	N/A	N/A
		>50 cc 4-s	Uncontrolled	5000	30.0	60.0	10.0	N/A	N/A	N/A
			Controlled	5000	30.0	60.0	10.0	N/A	N/A	N/A

Table A68a. Fleet composition of France

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Passenger cars	Gasoline	<1.4 l	Pre ECE	238	0	0	0	0	0	0
			ECE 15-00/01	548448	19291	7	0	0	0	0
			ECE 15-02	1502258	260057	2617	0	0	0	0
			ECE 15-03	3051845	1475640	176270	626	0	0	0
			ECE 15-04	5872630	4789658	2713143	437712	4033	0	0
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	0	4173651	3813479	2245996	369918	3408	0
			EURO 2	0	0	4566877	4191812	2508077	420476	3863
			EURO 3	0	0	0	3881232	3501806	1914556	229642
			EURO 4	0	0	0	972818	5717561	10037558	12345457
		1.4 - 2.0 l	Pre ECE	159	0	0	0	0	0	0
			ECE 15-00/01	366271	12883	5	0	0	0	0
			ECE 15-02	1003257	173674	1747	0	0	0	0
			ECE 15-03	2038120	985480	117719	418	0	0	0
			ECE 15-04	3921931	3198688	1811924	292318	2693	0	0
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	0	2787299	2546764	1499949	247043	2276	0
			EURO 2	0	0	3049907	2799427	1674974	280807	2580
			EURO 3	0	0	0	2592012	2338619	1278602	153602
			EURO 4	0	0	0	649679	3818371	6703404	8244693
		>2.0 l	Pre ECE	19	0	0	0	0	0	0
			ECE 15-00/01	44106	1551	1	0	0	0	0
			ECE 15-02	120811	20914	210	0	0	0	0
			ECE 15-03	245428	118670	14176	50	0	0	0
			ECE 15-04	472274	385182	218190	35201	324	0	0
			EURO 1	0	335643	306678	180622	29749	274	0
			EURO 2	0	0	367266	337104	201698	33814	311
			EURO 3	0	0	0	312127	281614	153968	18468
			EURO 4	0	0	0	78234	459804	807216	992816
	Diesel	<2.0 l	Uncontrolled	1690735	1151362	230263	4618	0	0	0
			EURO 1	1038628	2979344	2685916	1307660	251149	4993	0
			EURO 2	0	0	1428069	1337708	859550	158367	1489
			EURO 3	0	0	0	1495781	1349555	737847	88501
			EURO 4	0	0	0	374913	2203481	3868357	4757794
		>2.0 l	Uncontrolled	910396	619964	123988	2487	0	0	0
			EURO 1	559261	1604262	1446262	704124	135234	2689	0
			EURO 2	0	0	768960	720304	462834	85274	802
			EURO 3	0	0	0	805421	726683	397302	47655
			EURO 4	0	0	0	201876	1186490	2082962	2561889
	LPG	All	Uncontrolled	0	0	0	0	0	0	0
			EURO 1	0	0	0	0	0	0	0
			EURO 2	0	0	0	0	0	0	0
			EURO 3	0	0	0	0	0	0	0
			EURO 4	0	0	0	0	0	0	0
	2-stroke	All	Uncontrolled	0	0	0	0	0	0	0

Table A68a (continued). Fleet composition of France

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Light goods vehicles	Gasoline	All	Uncontrolled	871400	896925	481374	93433	107	0	0
			EURO 1	0	81800	267880	225999	29377	0	0
			EURO 2	0	0	321141	422992	280161	10718	0
			EURO 3	0	0	0	408473	910003	1264078	1318559
			EURO 4	0	0	0	0	0	0	0
	Diesel	All	Uncontrolled	2163537	2226911	1195169	231979	265	0	0
			EURO 1	0	203096	920702	805292	175539	9	0
			EURO 2	0	0	541737	806040	592993	26601	0
			EURO 3	0	0	0	1014169	2259382	3138489	3273756
			EURO 4	0	0	0	0	0	0	0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	264428	231553	106787	7927	0	0	0
			EURO 1	0	65444	91115	62007	2606	0	0
			EURO 2	0	0	126912	121930	62914	598	0
			EURO 3	0	0	0	157378	304585	386242	400120
			EURO 4	0	0	0	0	0	0	0
		7.5 - 16 t	Conventional	119505	104648	48261	3583	0	0	0
			EURO 1	0	29577	41179	28023	1178	0	0
			EURO 2	0	0	57356	55105	28433	270	0
			EURO 3	0	0	0	71125	137654	174558	180830
			EURO 4	0	0	0	0	0	0	0
		16 - 32 t	Conventional	192412	168490	77704	5768	0	0	0
			EURO 1	0	47620	66300	45120	1896	0	0
			EURO 2	0	0	92348	88723	45779	435	0
			EURO 3	0	0	0	114516	221632	281050	291148
			EURO 4	0	0	0	0	0	0	0
		>32 t	Conventional	16179	14167	6534	485	0	0	0
			EURO 1	0	4004	5575	3794	159	0	0
			EURO 2	0	0	7765	7460	3849	37	0
			EURO 3	0	0	0	9629	18636	23632	24481
			EURO 4	0	0	0	0	0	0	0
		Buses	Conventional	60258	54019	33703	16533	3196	5	0
			EURO 1	0	9558	13812	13590	10883	2029	0
			EURO 2	0	0	18455	18429	17862	12209	983
			EURO 3	0	0	0	19391	37613	56490	70619
			EURO 4	0	0	0	0	0	0	0
		Coaches	Conventional	15065	13505	8426	4133	799	1	0
			EURO 1	0	2390	3453	3397	2721	507	0
			EURO 2	0	0	4614	4607	4466	3052	246
			EURO 3	0	0	0	4848	9403	14122	17655
			EURO 4	0	0	0	0	0	0	0
Motorcycles	Gasoline	<50 cc	Uncontrolled	3044839	2676265	1225798	223945	9176	N/A	N/A
			Stage I	0	0	528943	246419	28437	N/A	N/A
			Stage II	0	0	532713	1403980	1417105	N/A	N/A
		>50 cc 2-s	Uncontrolled	69785	76090	38488	7251	304	N/A	N/A
			Controlled	0	0	42323	76692	85994	N/A	N/A
		>50 cc 4-s	Uncontrolled	688752	750977	379864	71561	3001	N/A	N/A
			Controlled	0	0	417711	756912	848724	N/A	N/A

Table A68b. Annual mileage, mileage distribution and representative speeds for France (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Passenger cars	Gasoline	<1.4 l	Pre ECE	5371	40.0	50.0	10.0	30.0	70.0	95.0
			ECE 15-00/01	6079	40.0	50.0	10.0	30.0	70.0	95.0
			ECE 15-02	6492	40.0	50.0	10.0	30.0	70.0	95.0
			ECE 15-03	7141	40.0	50.0	10.0	30.0	70.0	95.0
			ECE 15-04	8578	40.0	50.0	10.0	30.0	70.0	95.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	10732	40.0	50.0	10.0	30.0	70.0	95.0
			EURO 2	10732	40.0	50.0	10.0	30.0	70.0	95.0
			EURO 3	10732	40.0	50.0	10.0	30.0	70.0	95.0
			EURO 4	10732	40.0	50.0	10.0	30.0	70.0	95.0
		1.4 - 2.0 l	Pre ECE	6347	40.0	50.0	10.0	30.0	70.0	105.0
			ECE 15-00/01	7184	40.0	50.0	10.0	30.0	70.0	105.0
			ECE 15-02	7672	40.0	50.0	10.0	30.0	70.0	105.0
			ECE 15-03	8439	40.0	50.0	10.0	30.0	70.0	105.0
			ECE 15-04	10137	40.0	50.0	10.0	30.0	70.0	105.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	12683	40.0	50.0	10.0	30.0	70.0	105.0
			EURO 2	12683	40.0	50.0	10.0	30.0	70.0	105.0
			EURO 3	12683	40.0	50.0	10.0	30.0	70.0	105.0
			EURO 4	12683	40.0	50.0	10.0	30.0	70.0	105.0
		>2.0 l	Pre ECE	7323	40.0	50.0	10.0	30.0	70.0	115.0
			ECE 15-00/01	8289	40.0	50.0	10.0	30.0	70.0	115.0
			ECE 15-02	8852	40.0	50.0	10.0	30.0	70.0	115.0
			ECE 15-03	9738	40.0	50.0	10.0	30.0	70.0	115.0
			ECE 15-04	11697	40.0	50.0	10.0	30.0	70.0	115.0
			EURO 1	14635	40.0	50.0	10.0	30.0	70.0	115.0
			EURO 2	14635	40.0	50.0	10.0	30.0	70.0	115.0
			EURO 3	14635	40.0	50.0	10.0	30.0	70.0	115.0
			EURO 4	14635	40.0	50.0	10.0	30.0	70.0	115.0
	Diesel	<2.0 l	Uncontrolled	13363	40.0	50.0	10.0	30.0	70.0	115.0
			EURO 1	17936	40.0	50.0	10.0	30.0	70.0	115.0
			EURO 2	17936	40.0	50.0	10.0	30.0	70.0	115.0
			EURO 3	17936	40.0	50.0	10.0	30.0	70.0	115.0
			EURO 4	17936	40.0	50.0	10.0	30.0	70.0	115.0
		>2.0 l	Uncontrolled	13363	40.0	50.0	10.0	30.0	70.0	115.0
			EURO 1	17936	40.0	50.0	10.0	30.0	70.0	115.0
			EURO 2	17936	40.0	50.0	10.0	30.0	70.0	115.0
			EURO 3	17936	40.0	50.0	10.0	30.0	70.0	115.0
			EURO 4	17936	40.0	50.0	10.0	30.0	70.0	115.0
	LPG	All	Uncontrolled	-	-	-	-	-	-	-
			EURO 1	-	-	-	-	-	-	-
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
	2-stroke	All	Uncontrolled	-	-	-	-	-	-	-

Table A68b (continued). Annual mileage, mileage distribution and representative speeds for France (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Light goods vehicles	Gasoline	All	Uncontrolled	16500	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 1	16500	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 2	16500	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 3	16500	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 4	16500	40.0	50.0	10.0	20.0	60.0	90.0
	Diesel	All	Uncontrolled	25000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 1	25000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 2	25000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 3	25000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 4	25000	40.0	50.0	10.0	20.0	60.0	90.0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	65000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 1	65000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 2	65000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 3	65000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 4	65000	40.0	50.0	10.0	20.0	60.0	90.0
		7.5 - 16 t	Conventional	65000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 1	65000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 2	65000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 3	65000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 4	65000	40.0	50.0	10.0	20.0	60.0	90.0
		16 - 32 t	Conventional	50000	20.0	60.0	20.0	20.0	60.0	90.0
			EURO 1	50000	20.0	60.0	20.0	20.0	60.0	90.0
			EURO 2	50000	20.0	60.0	20.0	20.0	60.0	90.0
			EURO 3	50000	20.0	60.0	20.0	20.0	60.0	90.0
			EURO 4	50000	20.0	60.0	20.0	20.0	60.0	90.0
		>32 t	Conventional	50000	20.0	60.0	20.0	20.0	60.0	90.0
			EURO 1	50000	20.0	60.0	20.0	20.0	60.0	90.0
			EURO 2	50000	20.0	60.0	20.0	20.0	60.0	90.0
			EURO 3	50000	20.0	60.0	20.0	20.0	60.0	90.0
			EURO 4	50000	20.0	60.0	20.0	20.0	60.0	90.0
		Buses	Conventional	39548	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 1	39548	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 2	39548	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 3	39548	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 4	39548	100.0	0.0	0.0	20.0	60.0	90.0
		Coaches	Conventional	39548	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 1	39548	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 2	39548	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 3	39548	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 4	39548	0.0	50.0	50.0	20.0	60.0	90.0
Motorcycles	Gasoline	<50 cc	Uncontrolled	3000	40.0	60.0	0.0	N/A	N/A	N/A
			Stage I	3000	40.0	60.0	0.0	N/A	N/A	N/A
			Stage II	3000	40.0	60.0	0.0	N/A	N/A	N/A
		>50 cc 2-s	Uncontrolled	8000	30.0	50.0	20.0	N/A	N/A	N/A
			Controlled	8000	30.0	50.0	20.0	N/A	N/A	N/A
		>50 cc 4-s	Uncontrolled	11000	30.0	50.0	20.0	N/A	N/A	N/A
			Controlled	11000	30.0	50.0	20.0	N/A	N/A	N/A

Table A68c. Alternative fleet composition of France

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Passenger cars	Gasoline	<1.4 l	Pre ECE	1038025	192540	0	0	0	0	0
			ECE 15-00/01	3290659	1546105	391933	0	0	0	0
			ECE 15-02	2404130	1437342	632825	124307	0	0	0
			ECE 15-03	4682793	3352110	1884248	749182	92918	0	0
			ECE 15-04	4174026	5199747	3820371	2235191	950192	171309	0
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	0	1970267	2584874	1925948	1141488	495209	88277
			EURO 2	0	0	3539600	3064251	2186708	1217963	476978
			EURO 3	0	0	0	4549103	3862268	2701377	1469294
			EURO 4	0	0	0	0	4721333	8901956	12023830
		1.4 - 2.0 l	Pre ECE	324344	44023	0	0	0	0	0
			ECE 15-00/01	860894	380738	96967	0	0	0	0
			ECE 15-02	602058	315282	130990	26815	0	0	0
			ECE 15-03	2062394	1221317	618945	236930	34039	0	0
			ECE 15-04	2639210	2870926	1740552	891006	350619	60352	0
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	0	880557	1110471	679642	354227	145121	26623
			EURO 2	0	0	1659717	1360247	792377	399013	149591
			EURO 3	0	0	0	2405199	1899832	1094093	541848
			EURO 4	0	0	0	0	2788017	5371457	7322094
		>2.0 l	Pre ECE	18196	3164	0	0	0	0	0
			ECE 15-00/01	117059	53376	12789	0	0	0	0
			ECE 15-02	54679	31161	12220	2721	0	0	0
			ECE 15-03	209692	128799	69535	24335	3879	0	0
			ECE 15-04	178505	120304	73946	37580	11141	830	0
			EURO 1	47957	259647	216245	131629	67888	22528	3109
			EURO 2	0	0	201444	145134	89386	47813	15942
			EURO 3	0	0	0	291738	204686	125466	65390
			EURO 4	0	0	0	0	340753	628668	858338
	Diesel	<2.0 l	Uncontrolled	2519783	1926106	1105085	537028	188953	23968	0
			EURO 1	30229	3438338	3399782	2034369	1034163	393908	59367
			EURO 2	0	0	2733395	2235514	1311482	662411	247721
			EURO 3	0	0	0	3302909	2600832	1507711	748119
			EURO 4	0	0	0	0	3204132	5628605	6915430
		>2.0 l	Uncontrolled	1243502	812534	445261	197555	56012	7205	0
			EURO 1	15035	800309	676640	414327	219625	75116	11360
			EURO 2	0	0	490860	350739	216012	114930	37818
			EURO 3	0	0	0	507341	351997	215597	111297
			EURO 4	0	0	0	0	402319	575972	568297
	LPG	All	Uncontrolled	0	0	0	0	0	0	0
			EURO 1	0	0	0	0	0	0	0
			EURO 2	0	0	0	0	0	0	0
			EURO 3	0	0	0	0	0	0	0
			EURO 4	0	0	0	0	0	0	0
	2-stroke	All	Uncontrolled	0	0	0	0	0	0	0

Table A68c (continued). Alternative fleet composition of France

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Light goods vehicles	Gasoline	All	Uncontrolled	1911210	1275166	665300	266505	52614	1063	0
			EURO 1	0	23415	64188	49463	30045	14356	0
			EURO 2	0	0	46022	39299	26962	16331	1112
			EURO 3	0	0	24420	114858	92518	59400	31974
			EURO 4	0	0	0	25425	145944	247840	319024
	Diesel	All	Uncontrolled	2040932	2551374	1759587	968502	357912	12100	0
			EURO 1	0	273616	772181	595935	362150	173864	0
			EURO 2	0	0	592102	505664	346883	210191	14513
			EURO 3	0	0	325981	1606450	1296505	834124	451310
			EURO 4	0	0	0	378346	2279376	4065333	5514031
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	43357	39476	23662	8634	917	32	0
			EURO 1	0	3651	5344	4746	2141	176	0
			EURO 2	0	0	5141	4961	4007	888	54
			EURO 3	0	0	1681	8005	7530	5206	944
			EURO 4	0	0	0	1541	8722	14781	18071
		7.5 - 16 t	Conventional	226337	148580	81705	29893	3298	114	0
			EURO 1	0	13492	19731	17560	7919	665	0
			EURO 2	0	0	18973	18300	14782	3263	207
			EURO 3	0	0	6195	29466	27715	19175	3473
			EURO 4	0	0	0	5665	31990	54093	65968
		16 - 32 t	Conventional	184224	142187	86107	33116	3615	113	0
			EURO 1	0	36307	23685	21032	9506	781	0
			EURO 2	0	0	23043	22173	17897	3950	242
			EURO 3	0	0	31585	36219	33969	23515	4273
			EURO 4	0	0	0	27211	56262	83040	97931
		>32 t	Conventional	168643	197250	133651	54509	5497	2	0
			EURO 1	0	31732	46111	39319	18998	1237	0
			EURO 2	0	0	58846	54135	42276	9227	3
			EURO 3	0	0	23562	113568	102070	71051	12685
			EURO 4	0	0	0	27421	165391	310512	437359
		Buses	Conventional	21484	17558	11060	5746	2191	324	17
			EURO 1	0	1387	2052	1893	1607	832	97
			EURO 2	0	0	2165	2043	1860	1406	388
			EURO 3	0	0	717	3505	3279	2931	2015
			EURO 4	0	0	0	699	4099	7191	9860
		Coaches	Conventional	68786	56216	35411	18398	7014	1036	54
			EURO 1	0	4439	6569	6060	5147	2665	310
			EURO 2	0	0	6931	6541	5956	4500	1241
			EURO 3	0	0	2295	11223	10500	9385	6451
			EURO 4	0	0	0	2238	13122	23025	31568
Motorcycles	Gasoline	<50 cc	Uncontrolled	2514360	2210000	1012237	184929	7577	N/A	N/A
			Stage I	0	0	436789	203487	23482	N/A	N/A
			Stage II	0	0	439902	1159375	1170214	N/A	N/A
		>50 cc 2-s	Uncontrolled	75349	82156	41557	7829	328	N/A	N/A
			Controlled	0	0	45697	82805	92849	N/A	N/A
		>50 cc 4-s	Uncontrolled	743658	810844	410146	77266	3240	N/A	N/A
			Controlled	0	0	451010	817253	916384	N/A	N/A

Table A68d. Alternative annual mileage, mileage distribution and representative speeds for France (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Passenger cars	Gasoline	<1.4 l	Pre ECE	1741	39.8	52.6	7.7	23.0	56.0	98.0
			ECE 15-00/01	4194	39.7	52.6	7.7	23.0	56.0	98.0
			ECE 15-02	5791	39.7	51.6	8.7	23.0	56.0	98.0
			ECE 15-03	7293	39.6	51.3	9.1	23.0	56.0	98.0
			ECE 15-04	9630	39.6	51.6	8.8	23.0	56.0	98.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	10774	39.6	51.2	9.2	23.0	56.0	98.0
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
		1.4 - 2.0 l	Pre ECE	2406	36.1	46.9	17.0	23.0	56.0	108.0
			ECE 15-00/01	5912	36.2	46.8	17.0	23.0	56.0	108.0
			ECE 15-02	7573	36.5	47.0	16.6	23.0	56.0	108.0
			ECE 15-03	9508	36.5	47.0	16.4	23.0	56.0	108.0
			ECE 15-04	12668	36.1	46.8	17.1	23.0	56.0	108.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	14071	36.1	46.8	17.1	23.0	56.0	108.0
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
		>2.0 l	Pre ECE	2037	29.6	44.2	26.2	23.0	56.0	118.0
			ECE 15-00/01	6604	30.3	41.4	28.3	23.0	56.0	118.0
			ECE 15-02	8243	29.6	39.8	30.6	23.0	56.0	118.0
			ECE 15-03	10355	30.7	42.0	27.3	23.0	56.0	118.0
			ECE 15-04	12678	30.1	40.7	29.2	23.0	56.0	118.0
			EURO 1	15246	30.0	40.3	29.6	23.0	56.0	118.0
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
	Diesel	<2.0 l	Uncontrolled	18045	31.3	52.4	16.3	23.0	56.0	108.0
			EURO 1	22224	28.9	52.1	19.0	23.0	56.0	108.0
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
		>2.0 l	Uncontrolled	17654	26.0	51.0	23.0	23.0	56.0	118.0
			EURO 1	23465	26.0	51.1	22.9	23.0	56.0	118.0
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
	LPG	All	Uncontrolled	-	-	-	-	-	-	-
			EURO 1	-	-	-	-	-	-	-
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
	2-stroke	All	Uncontrolled	-	-	-	-	-	-	-

Table A68d (continued). Alternative annual mileage, mileage distribution and representative speeds for France (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Light goods vehicles	Gasoline	All	Uncontrolled	8143	39.3	44.8	15.9	23.0	56.0	108.0
			EURO 1	12877	40.0	45.2	14.8	23.0	56.0	108.0
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
	Diesel	All	Uncontrolled	22728	27.5	51.9	20.6	23.0	56.0	108.0
			EURO 1	25542	27.5	52.4	20.1	23.0	56.0	108.0
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	40448	47.2	38.7	13.9	20.0	50.0	80.0
			EURO 1	54086	48.3	37.6	14.1	20.0	50.0	80.0
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
		7.5 - 16 t	Conventional	46111	48.6	36.8	14.6	20.0	50.0	80.0
			EURO 1	66839	50.2	34.8	15.0	20.0	50.0	80.0
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
		16 - 32 t	Conventional	74979	42.0	39.8	18.3	20.0	50.0	80.0
			EURO 1	41081	46.4	38.1	15.6	20.0	50.0	80.0
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
		>32 t	Conventional	151214	15.2	49.6	35.2	20.0	50.0	80.0
			EURO 1	164081	15.2	49.6	35.2	20.0	50.0	80.0
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
		Buses	Conventional	32134	92.8	5.9	1.3	18.0	40.0	70.0
			EURO 1	57469	92.8	5.9	1.3	18.0	40.0	70.0
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
		Coaches	Conventional	24206	28.3	55.3	16.4	20.0	50.0	80.0
			EURO 1	43290	28.3	55.3	16.4	20.0	50.0	80.0
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
Motorcycles	Gasoline	<50 cc	Uncontrolled	2500	80.0	20.0	0.0	23.0	30.0	-
			Stage I	-	-	-	-	-	-	-
			Stage II	-	-	-	-	-	-	-
		>50 cc 2-s	Uncontrolled	6500	33.0	46.0	21.0	30.0	70.0	90.0
			Controlled	-	-	-	-	-	-	-
		>50 cc 4-s	Uncontrolled	9000	33.0	46.0	21.0	30.0	70.0	90.0
			Controlled	-	-	-	-	-	-	-

Table A69a. Fleet composition of Germany

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Passenger cars	Gasoline	<1.4 l	Pre ECE	0	0	0	0	0	0	0
			ECE 15-00/01	126959	247	0	0	0	0	0
			ECE 15-02	1163530	74286	0	0	0	0	0
			ECE 15-03	2662579	1570490	30408	0	0	0	0
			ECE 15-04	1197648	1194007	198967	7	0	0	0
			Improved conventional	1900151	2118799	1060024	21895	0	0	0
			Open loop	1056633	1182054	666983	28621	0	0	0
			EURO 1	1239736	7146451	6493651	2985876	135031	0	0
			EURO 2	0	0	6081467	5777348	3241199	163637	0
			EURO 3	0	0	0	5412091	5079709	2476175	46246
			EURO 4	0	0	0	1379196	7962414	14386115	17438687
		1.4 - 2.0 l	Pre ECE	0	0	0	0	0	0	0
			ECE 15-00/01	171548	334	0	0	0	0	0
			ECE 15-02	1572170	100376	0	0	0	0	0
			ECE 15-03	3597694	2122056	41087	0	0	0	0
			ECE 15-04	1655456	1652711	283137	798	0	0	0
			Improved conventional	809017	908845	473438	8754	0	0	0
			Open loop	866979	955179	430081	8384	0	0	0
			EURO 1	3957181	12213081	10189995	4084866	182454	0	0
			EURO 2	0	0	8217317	7806390	4379529	221108	0
			EURO 3	0	0	0	7312853	6863735	3345824	62488
			EURO 4	0	0	0	1863579	10758865	19438612	23563267
		>2.0 l	Pre ECE	0	0	0	0	0	0	0
			ECE 15-00/01	41866	81	0	0	0	0	0
			ECE 15-02	383684	24496	0	0	0	0	0
			ECE 15-03	878009	517883	10027	0	0	0	0
			ECE 15-04	378054	380492	74845	105	0	0	0
			EURO 1	1400720	3458332	2701600	1001174	44528	0	0
			EURO 2	0	0	2005417	1905131	1068814	53961	0
			EURO 3	0	0	0	1784684	1675078	816540	15250
			EURO 4	0	0	0	454802	2625675	4743947	5750559
	Diesel	<2.0 l	Uncontrolled	1412440	826322	85632	3	0	0	0
			EURO 1	948006	2501833	2313108	1009105	94624	4	0
			EURO 2	0	0	1241321	1198687	751103	40987	0
			EURO 3	0	0	0	1355700	1272439	620268	11584
			EURO 4	0	0	0	345481	1994541	3603644	4368297
		>2.0 l	Uncontrolled	941627	550881	57088	2	0	0	0
			EURO 1	632004	1667889	1542072	672737	63083	2	0
			EURO 2	0	0	827548	799125	500735	27324	0
			EURO 3	0	0	0	903800	848293	413512	7723
			EURO 4	0	0	0	230321	1329694	2402429	2912198
	LPG	All	Uncontrolled	0	0	0	0	0	0	0
			EURO 1	0	0	0	0	0	0	0
			EURO 2	0	0	0	0	0	0	0
			EURO 3	0	0	0	0	0	0	0
			EURO 4	0	0	0	0	0	0	0
	2-stroke	All	Uncontrolled	0	0	0	0	0	0	0

Table A69a (continued). Fleet composition of Germany

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Light goods vehicles	Gasoline	All	Uncontrolled	265266	330040	173392	26823	1	0	0
			EURO 1	0	36044	111893	82751	3766	0	0
			EURO 2	0	0	109094	140007	70571	658	0
			EURO 3	0	0	0	171811	370158	464082	483160
			EURO 4	0	0	0	0	0	0	0
	Diesel	All	Uncontrolled	640500	796900	418665	64766	3	0	0
			EURO 1	0	87031	361963	284145	28847	0	0
			EURO 2	0	0	171622	253716	150644	1588	0
			EURO 3	0	0	0	414847	893768	1120553	1166617
			EURO 4	0	0	0	0	0	0	0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	360559	349667	142908	6102	0	0	0
			EURO 1	0	147928	192066	97780	930	0	0
			EURO 2	0	0	201079	186038	63117	72	0
			EURO 3	0	0	0	282850	540130	631619	656728
			EURO 4	0	0	0	0	0	0	0
		7.5 - 16 t	Conventional	213896	207435	84778	3620	0	0	0
			EURO 1	0	87765	113940	58007	552	0	0
			EURO 2	0	0	119287	110364	37443	43	0
			EURO 3	0	0	0	167797	320424	374699	389594
			EURO 4	0	0	0	0	0	0	0
		16 - 32 t	Conventional	163146	158217	64663	2761	0	0	0
			EURO 1	0	66934	86906	44244	421	0	0
			EURO 2	0	0	90984	84178	28559	33	0
			EURO 3	0	0	0	127984	244398	285795	297156
			EURO 4	0	0	0	0	0	0	0
		>32 t	Conventional	8926	8656	3538	151	0	0	0
			EURO 1	0	3662	4755	2421	23	0	0
			EURO 2	0	0	4978	4606	1563	2	0
			EURO 3	0	0	0	7002	13372	15637	16258
			EURO 4	0	0	0	0	0	0	0
		Buses	Conventional	56429	60347	37620	12468	237	0	0
			EURO 1	0	16305	21377	19256	6783	28	0
			EURO 2	0	0	22466	22266	18929	4495	2
			EURO 3	0	0	0	32058	63945	88718	96312
			EURO 4	0	0	0	0	0	0	0
		Coaches	Conventional	14107	15087	9405	3117	59	0	0
			EURO 1	0	4076	5344	4814	1696	7	0
			EURO 2	0	0	5617	5567	4732	1124	1
			EURO 3	0	0	0	8014	15986	22180	24078
			EURO 4	0	0	0	0	0	0	0
Motorcycles	Gasoline	<50 cc	Uncontrolled	1427532	1292540	843985	417354	165945	N/A	N/A
			Stage I	0	0	151802	133079	91470	N/A	N/A
			Stage II	0	0	152743	445977	591861	N/A	N/A
		>50 cc 2-s	Uncontrolled	0	0	0	0	0	N/A	N/A
			Controlled	0	0	0	0	0	N/A	N/A
		>50 cc 4-s	Uncontrolled	1543262	1888930	1470041	862614	387379	N/A	N/A
			Controlled	0	0	670867	1431937	1998269	N/A	N/A

Table A69b. Annual mileage, mileage distribution and representative speeds for Germany (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Passenger cars	Gasoline	<1.4 l	Pre ECE	-	-	-	-	-	-	-
			ECE 15-00/01	6287	37.2	38.4	24.4	36.9	75.0	105.9
			ECE 15-02	6706	37.2	38.4	24.4	36.9	75.0	105.9
			ECE 15-03	7380	37.2	38.4	24.4	36.9	75.0	105.9
			ECE 15-04	7967	37.2	38.4	24.4	36.9	75.0	105.9
			Improved conventional	8710	37.2	38.4	24.4	36.9	75.0	105.9
			Open loop	8906	37.2	38.4	24.4	36.9	75.0	105.9
			EURO 1	10762	37.2	38.4	24.4	36.9	75.0	105.9
			EURO 2	10762	37.2	38.4	24.4	36.9	75.0	105.9
			EURO 3	10762	37.2	38.4	24.4	36.9	75.0	105.9
			EURO 4	10762	37.2	38.4	24.4	36.9	75.0	105.9
		1.4 - 2.0 l	Pre ECE	-	-	-	-	-	-	-
			ECE 15-00/01	7789	37.2	38.4	24.4	36.9	75.0	125.1
			ECE 15-02	8309	37.2	38.4	24.4	36.9	75.0	125.1
			ECE 15-03	9144	37.2	38.4	24.4	36.9	75.0	125.1
			ECE 15-04	9885	37.2	38.4	24.4	36.9	75.0	125.1
			Improved conventional	10840	37.2	38.4	24.4	36.9	75.0	125.1
			Open loop	10652	37.2	38.4	24.4	36.9	75.0	125.1
			EURO 1	12806	37.2	38.4	24.4	36.9	75.0	125.1
			EURO 2	12806	37.2	38.4	24.4	36.9	75.0	125.1
			EURO 3	12806	37.2	38.4	24.4	36.9	75.0	125.1
			EURO 4	12806	37.2	38.4	24.4	36.9	75.0	125.1
		>2.0 l	Pre ECE	-	-	-	-	-	-	-
			ECE 15-00/01	11127	37.2	38.4	24.4	36.9	75.0	125.1
			ECE 15-02	11869	37.2	38.4	24.4	36.9	75.0	125.1
			ECE 15-03	13062	37.2	38.4	24.4	36.9	75.0	125.1
			ECE 15-04	14209	37.2	38.4	24.4	36.9	75.0	125.1
			EURO 1	17870	37.2	38.4	24.4	36.9	75.0	125.1
			EURO 2	17870	37.2	38.4	24.4	36.9	75.0	125.1
			EURO 3	17870	37.2	38.4	24.4	36.9	75.0	125.1
			EURO 4	17870	37.2	38.4	24.4	36.9	75.0	125.1
	Diesel	<2.0 l	Uncontrolled	13599	37.2	38.4	24.4	36.9	75.0	125.1
			EURO 1	18057	37.2	38.4	24.4	36.9	75.0	125.1
			EURO 2	18057	37.2	38.4	24.4	36.9	75.0	125.1
			EURO 3	18057	37.2	38.4	24.4	36.9	75.0	125.1
			EURO 4	18057	37.2	38.4	24.4	36.9	75.0	125.1
		>2.0 l	Uncontrolled	13599	37.2	38.4	24.4	36.9	75.0	125.1
			EURO 1	18057	37.2	38.4	24.4	36.9	75.0	125.1
			EURO 2	18057	37.2	38.4	24.4	36.9	75.0	125.1
			EURO 3	18057	37.2	38.4	24.4	36.9	75.0	125.1
			EURO 4	18057	37.2	38.4	24.4	36.9	75.0	125.1
	LPG	All	Uncontrolled	-	-	-	-	-	-	-
			EURO 1	-	-	-	-	-	-	-
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
	2-stroke	All	Uncontrolled	-	-	-	-	-	-	-

Table A69b (continued). Annual mileage, mileage distribution and representative speeds for Germany (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Light goods vehicles	Gasoline	All	Uncontrolled	17500	37.2	36.7	26.1	36.9	75.0	115.5
			EURO 1	17500	37.2	36.7	26.1	36.9	75.0	115.5
			EURO 2	17500	37.2	36.7	26.1	36.9	75.0	115.5
			EURO 3	17500	37.2	36.7	26.1	36.9	75.0	115.5
			EURO 4	17500	37.2	36.7	26.1	36.9	75.0	115.5
	Diesel	All	Uncontrolled	22000	40.5	42.4	17.1	36.9	75.0	115.5
			EURO 1	22000	40.5	42.4	17.1	36.9	75.0	115.5
			EURO 2	22000	40.5	42.4	17.1	36.9	75.0	115.5
			EURO 3	22000	40.5	42.4	17.1	36.9	75.0	115.5
			EURO 4	22000	40.5	42.4	17.1	36.9	75.0	115.5
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	60000	40.0	39.0	21.0	20.0	60.0	90.0
			EURO 1	60000	40.0	39.0	21.0	20.0	60.0	90.0
			EURO 2	60000	40.0	39.0	21.0	20.0	60.0	90.0
			EURO 3	60000	40.0	39.0	21.0	20.0	60.0	90.0
			EURO 4	60000	40.0	39.0	21.0	20.0	60.0	90.0
		7.5 - 16 t	Conventional	60000	40.0	39.0	21.0	20.0	60.0	90.0
			EURO 1	60000	40.0	39.0	21.0	20.0	60.0	90.0
			EURO 2	60000	40.0	39.0	21.0	20.0	60.0	90.0
			EURO 3	60000	40.0	39.0	21.0	20.0	60.0	90.0
			EURO 4	60000	40.0	39.0	21.0	20.0	60.0	90.0
		16 - 32 t	Conventional	80000	6.8	39.0	54.2	20.0	60.0	90.0
			EURO 1	80000	6.8	39.0	54.2	20.0	60.0	90.0
			EURO 2	80000	6.8	39.0	54.2	20.0	60.0	90.0
			EURO 3	80000	6.8	39.0	54.2	20.0	60.0	90.0
			EURO 4	80000	6.8	39.0	54.2	20.0	60.0	90.0
		>32 t	Conventional	80000	6.8	39.0	54.2	20.0	60.0	90.0
			EURO 1	80000	6.8	39.0	54.2	20.0	60.0	90.0
			EURO 2	80000	6.8	39.0	54.2	20.0	60.0	90.0
			EURO 3	80000	6.8	39.0	54.2	20.0	60.0	90.0
			EURO 4	80000	6.8	39.0	54.2	20.0	60.0	90.0
		Buses	Conventional	46998	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 1	46998	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 2	46998	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 3	46998	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 4	46998	100.0	0.0	0.0	20.0	60.0	90.0
		Coaches	Conventional	46998	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 1	46998	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 2	46998	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 3	46998	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 4	46998	0.0	50.0	50.0	20.0	60.0	90.0
Motorcycles	Gasoline	<50 cc	Uncontrolled	2040	45.0	55.0	0.0	N/A	N/A	N/A
			Stage I	2040	45.0	55.0	0.0	N/A	N/A	N/A
			Stage II	2040	45.0	55.0	0.0	N/A	N/A	N/A
		>50 cc 2-s	Uncontrolled	-	-	-	-	-	-	-
			Controlled	-	-	-	-	-	-	-
		>50 cc 4-s	Uncontrolled	4050	18.5	59.6	21.9	N/A	N/A	N/A
			Controlled	4050	18.5	59.6	21.9	N/A	N/A	N/A

Table A70a. Fleet composition of Greece

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Passenger cars	Gasoline	<1.4 l	Pre ECE	171558	31368	13390	1286	0	0	0
			ECE 15-00/01	360432	290011	216441	91181	0	0	0
			ECE 15-02	133662	130179	119004	84728	29478	0	0
			ECE 15-03	259047	257636	249809	217693	134650	33884	0
			ECE 15-04	428280	428014	425312	409800	349934	207199	50859
			Improved conventional	0	0	0	0	0	0	0
			Open loop	10710	10709	10692	10557	9870	7546	3144
			EURO 1	74275	689797	689379	685363	661884	569647	344153
			EURO 2	0	0	475638	475442	473369	460436	406522
			EURO 3	0	0	0	440858	440638	438373	424598
			EURO 4	0	0	0	116523	714703	1338994	2001015
		1.4 - 2.0 l	Pre ECE	24680	4513	1926	185	0	0	0
			ECE 15-00/01	51852	41721	31137	13117	0	0	0
			ECE 15-02	19229	18727	17120	12189	4241	0	0
			ECE 15-03	37266	37063	35937	31317	19371	4875	0
			ECE 15-04	61612	61574	61185	58954	50341	29808	7317
			Improved conventional	0	0	0	0	0	0	0
			Open loop	1541	1541	1538	1519	1420	1086	452
			EURO 1	10685	99234	99174	98596	95218	81949	49510
			EURO 2	0	0	68425	68397	68099	66238	58482
			EURO 3	0	0	0	63422	63390	63064	61082
			EURO 4	0	0	0	16763	102817	192627	287865
		>2.0 l	Pre ECE	4414	807	345	33	0	0	0
			ECE 15-00/01	9274	7462	5569	2346	0	0	0
			ECE 15-02	3439	3350	3062	2180	759	0	0
			ECE 15-03	6666	6629	6428	5601	3465	872	0
			ECE 15-04	10451	10444	10376	9983	8477	4922	1132
			EURO 1	2756	18594	18582	18468	17812	15261	9113
			EURO 2	0	0	12239	12234	12180	11847	10460
			EURO 3	0	0	0	11344	11338	11280	10925
			EURO 4	0	0	0	2998	18390	34454	51488
	Diesel	<2.0 l	Uncontrolled	10659	8536	7432	5339	2860	865	58
			EURO 1	3494	9552	10415	10308	9781	8024	4532
			EURO 2	0	0	3804	3803	3790	3705	3329
			EURO 3	0	0	0	4339	4337	4315	4179
			EURO 4	0	0	0	1147	7035	13179	19695
		>2.0 l	Uncontrolled	7106	5691	4954	3559	1907	577	0
			EURO 1	2329	6368	6943	6872	6520	5350	3022
			EURO 2	0	0	2536	2535	2527	2470	2219
			EURO 3	0	0	0	2893	2891	2877	2786
			EURO 4	0	0	0	765	4690	8786	13130
	LPG	All	Uncontrolled	2961	2371	2064	1483	794	240	16
			EURO 1	971	2653	2893	2863	2717	2229	1259
			EURO 2	0	0	1057	1056	1053	1029	925
			EURO 3	0	0	0	1205	1205	1199	1161
			EURO 4	0	0	0	319	1954	3661	5471
	2-stroke	All	Uncontrolled	0	0	0	0	0	0	0

Table A70a (continued). Fleet composition of Greece

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Light goods vehicles	Gasoline	All	Uncontrolled	578399	359950	333961	270621	181034	99894	39543
			EURO 1	0	11779	35806	35790	35616	34384	28636
			EURO 2	0	0	41837	58124	58068	57530	54215
			EURO 3	0	0	0	77917	190707	288469	366145
			EURO 4	0	0	0	0	0	0	0
	Diesel	All	Uncontrolled	5782	325692	302177	244865	163804	90387	35780
			EURO 1	0	10658	44115	44100	43920	42620	36370
			EURO 2	0	0	26137	40876	40847	40547	38595
			EURO 3	0	0	0	70501	172557	261014	331297
			EURO 4	0	0	0	0	0	0	0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	56841	24705	22777	18081	11462	5599	1698
			EURO 1	0	2872	3748	3744	3707	3480	2587
			EURO 2	0	0	4010	4009	4003	3948	3633
			EURO 3	0	0	0	6989	15356	22603	28325
			EURO 4	0	0	0	0	0	0	0
		7.5 - 16 t	Conventional	56841	51027	47045	37346	23674	11564	3507
			EURO 1	0	5933	7742	7734	7657	7189	5343
			EURO 2	0	0	8282	8281	8268	8154	7504
			EURO 3	0	0	0	14435	31717	46685	58504
			EURO 4	0	0	0	0	0	0	0
		16 - 32 t	Conventional	39346	77638	71580	56822	36021	17595	5335
			EURO 1	0	9027	11780	11768	11650	10938	8130
			EURO 2	0	0	12601	12600	12580	12406	11417
			EURO 3	0	0	0	21963	48258	71032	89015
			EURO 4	0	0	0	0	0	0	0
		>32 t	Conventional	13666	5242	4833	3836	2432	1188	360
			EURO 1	0	609	795	795	787	738	549
			EURO 2	0	0	851	851	849	838	771
			EURO 3	0	0	0	1483	3258	4796	6010
			EURO 4	0	0	0	0	0	0	0
		Buses	Conventional	8285	5805	3193	1725	207	0	0
			EURO 1	0	1788	2261	2177	1335	57	0
			EURO 2	0	0	1115	1111	1030	444	4
			EURO 3	0	0	0	245	1177	1745	1034
			EURO 4	0	0	0	0	0	0	0
		Coaches	Conventional	8285	5805	3193	1725	207	0	0
			EURO 1	0	1788	2261	2177	1335	57	0
			EURO 2	0	0	1115	1111	1030	444	4
			EURO 3	0	0	0	245	1177	1745	1034
			EURO 4	0	0	0	0	0	0	0
Motorcycles	Gasoline	<50 cc	Uncontrolled	281626	334291	297143	224563	148815	N/A	N/A
			Stage I	0	0	43431	40773	34984	N/A	N/A
			Stage II	0	0	46785	177689	312290	N/A	N/A
		>50 cc 2-s	Uncontrolled	41416	49160	43697	33024	21884	N/A	N/A
			Controlled	0	0	13267	32127	51070	N/A	N/A
		>50 cc 4-s	Uncontrolled	165662	196642	174790	132096	87538	N/A	N/A
			Controlled	0	0	53068	128507	204279	N/A	N/A

Table A70b. Annual mileage, mileage distribution and representative speeds for Greece (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Passenger cars	Gasoline	<1.4 l	Pre ECE	13000	44.0	42.0	14.0	20.0	60.0	90.0
			ECE 15-00/01	13000	44.0	42.0	14.0	20.0	60.0	90.0
			ECE 15-02	13000	44.0	42.0	14.0	20.0	60.0	90.0
			ECE 15-03	13000	44.0	42.0	14.0	20.0	60.0	90.0
			ECE 15-04	13000	44.0	42.0	14.0	20.0	60.0	90.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	13000	44.0	42.0	14.0	20.0	60.0	90.0
			EURO 1	13000	44.0	42.0	14.0	20.0	60.0	90.0
			EURO 2	13000	44.0	42.0	14.0	20.0	60.0	90.0
			EURO 3	13000	44.0	42.0	14.0	20.0	60.0	90.0
			EURO 4	13000	44.0	42.0	14.0	20.0	60.0	90.0
		1.4 - 2.0 l	Pre ECE	13000	44.0	42.0	14.0	20.0	60.0	90.0
			ECE 15-00/01	13000	44.0	42.0	14.0	20.0	60.0	90.0
			ECE 15-02	13000	44.0	42.0	14.0	20.0	60.0	90.0
			ECE 15-03	13000	44.0	42.0	14.0	20.0	60.0	90.0
			ECE 15-04	13000	44.0	42.0	14.0	20.0	60.0	90.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	13000	44.0	42.0	14.0	20.0	60.0	90.0
			EURO 1	13000	44.0	42.0	14.0	20.0	60.0	90.0
			EURO 2	13000	44.0	42.0	14.0	20.0	60.0	90.0
			EURO 3	13000	44.0	42.0	14.0	20.0	60.0	90.0
			EURO 4	13000	44.0	42.0	14.0	20.0	60.0	90.0
		>2.0 l	Pre ECE	13000	44.0	42.0	14.0	20.0	60.0	90.0
			ECE 15-00/01	13000	44.0	42.0	14.0	20.0	60.0	90.0
			ECE 15-02	13000	44.0	42.0	14.0	20.0	60.0	90.0
			ECE 15-03	13000	44.0	42.0	14.0	20.0	60.0	90.0
			ECE 15-04	13000	44.0	42.0	14.0	20.0	60.0	90.0
			EURO 1	13000	44.0	42.0	14.0	20.0	60.0	90.0
			EURO 2	13000	44.0	42.0	14.0	20.0	60.0	90.0
			EURO 3	13000	44.0	42.0	14.0	20.0	60.0	90.0
			EURO 4	13000	44.0	42.0	14.0	20.0	60.0	90.0
	Diesel	<2.0 l	Uncontrolled	100000	83.0	13.0	4.0	20.0	60.0	90.0
			EURO 1	100000	83.0	13.0	4.0	20.0	60.0	90.0
			EURO 2	100000	83.0	13.0	4.0	20.0	60.0	90.0
			EURO 3	100000	83.0	13.0	4.0	20.0	60.0	90.0
			EURO 4	100000	83.0	13.0	4.0	20.0	60.0	90.0
		>2.0 l	Uncontrolled	100000	83.0	13.0	4.0	20.0	60.0	90.0
			EURO 1	100000	83.0	13.0	4.0	20.0	60.0	90.0
			EURO 2	100000	83.0	13.0	4.0	20.0	60.0	90.0
			EURO 3	100000	83.0	13.0	4.0	20.0	60.0	90.0
			EURO 4	100000	83.0	13.0	4.0	20.0	60.0	90.0
	LPG	All	Uncontrolled	100000	83.0	13.0	4.0	20.0	60.0	90.0
			EURO 1	100000	83.0	13.0	4.0	20.0	60.0	90.0
			EURO 2	100000	83.0	13.0	4.0	20.0	60.0	90.0
			EURO 3	100000	83.0	13.0	4.0	20.0	60.0	90.0
			EURO 4	100000	83.0	13.0	4.0	20.0	60.0	90.0
	2-stroke	All	Uncontrolled	-	-	-	-	-	-	-

Table A70b (continued). Annual mileage, mileage distribution and representative speeds for Greece (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Light goods vehicles	Gasoline	All	Uncontrolled	13000	44.0	42.0	14.0	20.0	60.0	90.0
			EURO 1	13000	44.0	42.0	14.0	20.0	60.0	90.0
			EURO 2	13000	44.0	42.0	14.0	20.0	60.0	90.0
			EURO 3	13000	44.0	42.0	14.0	20.0	60.0	90.0
			EURO 4	13000	44.0	42.0	14.0	20.0	60.0	90.0
	Diesel	All	Uncontrolled	20000	44.0	42.0	14.0	20.0	60.0	90.0
			EURO 1	20000	44.0	42.0	14.0	20.0	60.0	90.0
			EURO 2	20000	44.0	42.0	14.0	20.0	60.0	90.0
			EURO 3	20000	44.0	42.0	14.0	20.0	60.0	90.0
			EURO 4	20000	44.0	42.0	14.0	20.0	60.0	90.0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	35000	35.0	35.0	30.0	20.0	60.0	90.0
			EURO 1	35000	35.0	35.0	30.0	20.0	60.0	90.0
			EURO 2	35000	35.0	35.0	30.0	20.0	60.0	90.0
			EURO 3	35000	35.0	35.0	30.0	20.0	60.0	90.0
			EURO 4	35000	35.0	35.0	30.0	20.0	60.0	90.0
		7.5 - 16 t	Conventional	35000	35.0	35.0	30.0	20.0	60.0	90.0
			EURO 1	35000	35.0	35.0	30.0	20.0	60.0	90.0
			EURO 2	35000	35.0	35.0	30.0	20.0	60.0	90.0
			EURO 3	35000	35.0	35.0	30.0	20.0	60.0	90.0
			EURO 4	35000	35.0	35.0	30.0	20.0	60.0	90.0
		16 - 32 t	Conventional	45000	14.0	42.0	44.0	20.0	60.0	90.0
			EURO 1	45000	14.0	42.0	44.0	20.0	60.0	90.0
			EURO 2	45000	14.0	42.0	44.0	20.0	60.0	90.0
			EURO 3	45000	14.0	42.0	44.0	20.0	60.0	90.0
			EURO 4	45000	14.0	42.0	44.0	20.0	60.0	90.0
		>32 t	Conventional	45000	14.0	42.0	44.0	20.0	60.0	90.0
			EURO 1	45000	14.0	42.0	44.0	20.0	60.0	90.0
			EURO 2	45000	14.0	42.0	44.0	20.0	60.0	90.0
			EURO 3	45000	14.0	42.0	44.0	20.0	60.0	90.0
			EURO 4	45000	14.0	42.0	44.0	20.0	60.0	90.0
		Buses	Conventional	16904	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 1	16904	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 2	16904	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 3	16904	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 4	16904	100.0	0.0	0.0	20.0	60.0	90.0
		Coaches	Conventional	16904	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 1	16904	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 2	16904	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 3	16904	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 4	16904	0.0	50.0	50.0	20.0	60.0	90.0
Motorcycles	Gasoline	<50 cc	Uncontrolled	6000	100.0	0.0	0.0	N/A	N/A	N/A
			Stage I	6000	100.0	0.0	0.0	N/A	N/A	N/A
			Stage II	6000	100.0	0.0	0.0	N/A	N/A	N/A
		>50 cc 2-s	Uncontrolled	9000	65.0	20.0	15.0	N/A	N/A	N/A
			Controlled	9000	65.0	20.0	15.0	N/A	N/A	N/A
		>50 cc 4-s	Uncontrolled	9000	65.0	20.0	15.0	N/A	N/A	N/A
			Controlled	9000	65.0	20.0	15.0	N/A	N/A	N/A

Table A71a. Fleet composition of Ireland

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Passenger cars	Gasoline	<1.4 l	Pre ECE	47	0	0	0	0	0	0
			ECE 15-00/01	17279	1099	2	0	0	0	0
			ECE 15-02	97801	24630	570	0	0	0	0
			ECE 15-03	160133	89742	14099	121	0	0	0
			ECE 15-04	244374	223086	139917	30558	614	0	0
			Improved conventional	0	0	0	0	0	0	0
			Open loop	5377	5255	4248	1520	50	0	0
			EURO 1	0	235935	219256	141824	31181	614	0
			EURO 2	0	0	253388	235994	153659	33835	655
			EURO 3	0	0	0	216049	198778	121309	20850
			EURO 4	0	0	0	57121	352767	634039	815466
		1.4 - 2.0 l	Pre ECE	16	0	0	0	0	0	0
			ECE 15-00/01	5909	376	1	0	0	0	0
			ECE 15-02	33448	8424	195	0	0	0	0
			ECE 15-03	54765	30692	4822	41	0	0	0
			ECE 15-04	78978	71801	44219	9151	167	0	0
			Improved conventional	0	0	0	0	0	0	0
			Open loop	6436	6291	5085	1820	60	0	0
			EURO 1	0	80689	74985	48504	10664	210	0
			EURO 2	0	0	86658	80709	52551	11571	224
			EURO 3	0	0	0	73888	67982	41487	7131
			EURO 4	0	0	0	19535	120645	216840	278887
		>2.0 l	Pre ECE	1	0	0	0	0	0	0
			ECE 15-00/01	449	29	0	0	0	0	0
			ECE 15-02	2542	640	15	0	0	0	0
			ECE 15-03	4162	2333	366	3	0	0	0
			ECE 15-04	5094	4569	2643	439	4	0	0
			EURO 1	1398	7498	6803	4081	823	16	0
			EURO 2	0	0	6586	6134	3994	879	17
			EURO 3	0	0	0	5615	5167	3153	542
			EURO 4	0	0	0	1485	9169	16480	21195
	Diesel	<2.0 l	Uncontrolled	43183	21685	4799	164	0	0	0
			EURO 1	22407	50743	48625	26928	6437	234	0
			EURO 2	0	0	25467	24131	16738	4070	82
			EURO 3	0	0	0	26991	24833	15155	2605
			EURO 4	0	0	0	7136	44071	79211	101876
		>2.0 l	Uncontrolled	28788	14457	3199	109	0	0	0
			EURO 1	14938	33828	32416	17952	4292	156	0
			EURO 2	0	0	16978	16088	11158	2713	54
			EURO 3	0	0	0	17994	16556	10103	1736
			EURO 4	0	0	0	4757	29381	52807	67918
	LPG	All	Uncontrolled	0	0	0	0	0	0	0
			EURO 1	0	0	0	0	0	0	0
			EURO 2	0	0	0	0	0	0	0
			EURO 3	0	0	0	0	0	0	0
			EURO 4	0	0	0	0	0	0	0
	2-stroke	All	Uncontrolled	0	0	0	0	0	0	0

Table A71a (continued). Fleet composition of Ireland

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Light goods vehicles	Gasoline	All	Uncontrolled	7486	7798	3387	257	0	0	0
			EURO 1	0	957	3053	1839	20	0	0
			EURO 2	0	0	3562	4438	1552	2	0
			EURO 3	0	0	0	4725	10981	13821	14984
			EURO 4	0	0	0	0	0	0	0
	Diesel	All	Uncontrolled	43859	45685	19846	1507	0	0	0
			EURO 1	0	5608	24671	16583	657	0	0
			EURO 2	0	0	14084	20190	8552	11	0
			EURO 3	0	0	0	27685	64337	80977	87785
			EURO 4	0	0	0	0	0	0	0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	22541	18723	5958	47	0	0	0
			EURO 1	0	7638	10105	3759	5	0	0
			EURO 2	0	0	14054	12301	2574	0	0
			EURO 3	0	0	0	17794	35219	41623	45116
			EURO 4	0	0	0	0	0	0	0
		7.5 - 16 t	Conventional	7376	6127	1950	15	0	0	0
			EURO 1	0	2500	3307	1230	2	0	0
			EURO 2	0	0	4599	4025	842	0	0
			EURO 3	0	0	0	5823	11525	13621	14764
			EURO 4	0	0	0	0	0	0	0
		16 - 32 t	Conventional	40198	33390	10626	84	0	0	0
			EURO 1	0	13622	18021	6704	9	0	0
			EURO 2	0	0	25063	21937	4590	0	0
			EURO 3	0	0	0	31734	62808	74228	80458
			EURO 4	0	0	0	0	0	0	0
		>32 t	Conventional	4466	3710	1181	9	0	0	0
			EURO 1	0	1514	2002	745	1	0	0
			EURO 2	0	0	2785	2437	510	0	0
			EURO 3	0	0	0	3526	6979	8248	8940
			EURO 4	0	0	0	0	0	0	0
		Buses	Conventional	3235	2972	1859	948	20	2	0
			EURO 1	0	703	1004	982	785	192	0
			EURO 2	0	0	1244	1241	1193	825	107
			EURO 3	0	0	0	1376	2812	4453	5791
			EURO 4	0	0	0	0	0	0	0
		Coaches	Conventional	809	743	465	237	55	0	0
			EURO 1	0	176	251	246	196	48	0
			EURO 2	0	0	311	310	298	206	27
			EURO 3	0	0	0	344	703	1113	1448
			EURO 4	0	0	0	0	0	0	0
Motorcycles	Gasoline	<50 cc	Uncontrolled	4251	3622	1307	81	0	N/A	N/A
			Stage I	0	0	788	214	2	N/A	N/A
			Stage II	0	0	829	1637	1052	N/A	N/A
		>50 cc 2-s	Uncontrolled	0	0	0	0	0	N/A	N/A
			Controlled	0	0	0	0	0	N/A	N/A
		>50 cc 4-s	Uncontrolled	11151	9290	3165	194	0	N/A	N/A
			Controlled	0	0	3544	3258	1220	N/A	N/A

Table A71b. Annual mileage, mileage distribution and representative speeds for Ireland (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Passenger cars	Gasoline	<1.4 l	Pre ECE	12199	25.0	55.0	20.0	30.0	50.0	85.0
			ECE 15-00/01	13808	25.0	55.0	20.0	30.0	50.0	85.0
			ECE 15-02	14763	25.0	55.0	20.0	30.0	50.0	85.0
			ECE 15-03	16108	25.0	55.0	20.0	30.0	50.0	85.0
			ECE 15-04	19528	25.0	55.0	20.0	30.0	50.0	85.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	21484	25.0	55.0	20.0	30.0	50.0	85.0
			EURO 1	24396	25.0	55.0	20.0	30.0	50.0	85.0
			EURO 2	24396	25.0	55.0	20.0	30.0	50.0	85.0
			EURO 3	24396	25.0	55.0	20.0	30.0	50.0	85.0
			EURO 4	24396	25.0	55.0	20.0	30.0	50.0	85.0
		1.4 - 2.0 l	Pre ECE	12199	25.0	55.0	20.0	30.0	50.0	85.0
			ECE 15-00/01	13808	25.0	55.0	20.0	30.0	50.0	85.0
			ECE 15-02	14763	25.0	55.0	20.0	30.0	50.0	85.0
			ECE 15-03	16108	25.0	55.0	20.0	30.0	50.0	85.0
			ECE 15-04	19406	25.0	55.0	20.0	30.0	50.0	85.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	21484	25.0	55.0	20.0	30.0	50.0	85.0
			EURO 1	24396	25.0	55.0	20.0	30.0	50.0	85.0
			EURO 2	24396	25.0	55.0	20.0	30.0	50.0	85.0
			EURO 3	24396	25.0	55.0	20.0	30.0	50.0	85.0
			EURO 4	24396	25.0	55.0	20.0	30.0	50.0	85.0
		>2.0 l	Pre ECE	12199	25.0	55.0	20.0	30.0	50.0	85.0
			ECE 15-00/01	13808	25.0	55.0	20.0	30.0	50.0	85.0
			ECE 15-02	14763	25.0	55.0	20.0	30.0	50.0	85.0
			ECE 15-03	16108	25.0	55.0	20.0	30.0	50.0	85.0
			ECE 15-04	19002	25.0	55.0	20.0	30.0	50.0	85.0
			EURO 1	23865	25.0	55.0	20.0	30.0	50.0	85.0
			EURO 2	23865	25.0	55.0	20.0	30.0	50.0	85.0
			EURO 3	23865	25.0	55.0	20.0	30.0	50.0	85.0
			EURO 4	23865	25.0	55.0	20.0	30.0	50.0	85.0
	Diesel	<2.0 l	Uncontrolled	13148	25.0	55.0	20.0	30.0	50.0	85.0
			EURO 1	18114	25.0	55.0	20.0	30.0	50.0	85.0
			EURO 2	18114	25.0	55.0	20.0	30.0	50.0	85.0
			EURO 3	18114	25.0	55.0	20.0	30.0	50.0	85.0
			EURO 4	18114	25.0	55.0	20.0	30.0	50.0	85.0
		>2.0 l	Uncontrolled	13148	25.0	55.0	20.0	30.0	50.0	85.0
			EURO 1	18114	25.0	55.0	20.0	30.0	50.0	85.0
			EURO 2	18114	25.0	55.0	20.0	30.0	50.0	85.0
			EURO 3	18114	25.0	55.0	20.0	30.0	50.0	85.0
			EURO 4	18114	25.0	55.0	20.0	30.0	50.0	85.0
	LPG	All	Uncontrolled	-	-	-	-	-	-	-
			EURO 1	-	-	-	-	-	-	-
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
	2-stroke	All	Uncontrolled	-	-	-	-	-	-	-

Table A71b (continued). Annual mileage, mileage distribution and representative speeds for Ireland (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Light goods vehicles	Gasoline	All	Uncontrolled	25000	35.0	45.0	20.0	20.0	60.0	90.0
			EURO 1	25000	35.0	45.0	20.0	20.0	60.0	90.0
			EURO 2	25000	35.0	45.0	20.0	20.0	60.0	90.0
			EURO 3	25000	35.0	45.0	20.0	20.0	60.0	90.0
			EURO 4	25000	35.0	45.0	20.0	20.0	60.0	90.0
	Diesel	All	Uncontrolled	27000	35.0	45.0	20.0	20.0	60.0	90.0
			EURO 1	27000	35.0	45.0	20.0	20.0	60.0	90.0
			EURO 2	27000	35.0	45.0	20.0	20.0	60.0	90.0
			EURO 3	27000	35.0	45.0	20.0	20.0	60.0	90.0
			EURO 4	27000	35.0	45.0	20.0	20.0	60.0	90.0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	30000	15.0	55.0	30.0	20.0	60.0	90.0
			EURO 1	30000	15.0	55.0	30.0	20.0	60.0	90.0
			EURO 2	30000	15.0	55.0	30.0	20.0	60.0	90.0
			EURO 3	30000	15.0	55.0	30.0	20.0	60.0	90.0
			EURO 4	30000	15.0	55.0	30.0	20.0	60.0	90.0
		7.5 - 16 t	Conventional	30000	15.0	55.0	30.0	20.0	60.0	90.0
			EURO 1	30000	15.0	55.0	30.0	20.0	60.0	90.0
			EURO 2	30000	15.0	55.0	30.0	20.0	60.0	90.0
			EURO 3	30000	15.0	55.0	30.0	20.0	60.0	90.0
			EURO 4	30000	15.0	55.0	30.0	20.0	60.0	90.0
		16 - 32 t	Conventional	40000	5.0	55.0	40.0	20.0	60.0	90.0
			EURO 1	40000	5.0	55.0	40.0	20.0	60.0	90.0
			EURO 2	40000	5.0	55.0	40.0	20.0	60.0	90.0
			EURO 3	40000	5.0	55.0	40.0	20.0	60.0	90.0
			EURO 4	40000	5.0	55.0	40.0	20.0	60.0	90.0
		>32 t	Conventional	40000	5.0	55.0	40.0	20.0	60.0	90.0
			EURO 1	40000	5.0	55.0	40.0	20.0	60.0	90.0
			EURO 2	40000	5.0	55.0	40.0	20.0	60.0	90.0
			EURO 3	40000	5.0	55.0	40.0	20.0	60.0	90.0
			EURO 4	40000	5.0	55.0	40.0	20.0	60.0	90.0
		Buses	Conventional	48136	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 1	48136	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 2	48136	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 3	48136	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 4	48136	100.0	0.0	0.0	20.0	60.0	90.0
		Coaches	Conventional	48136	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 1	48136	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 2	48136	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 3	48136	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 4	48136	0.0	50.0	50.0	20.0	60.0	90.0
Motorcycles	Gasoline	<50 cc	Uncontrolled	15000	30.0	55.0	15.0	N/A	N/A	N/A
			Stage I	15000	30.0	55.0	15.0	N/A	N/A	N/A
			Stage II	15000	30.0	55.0	15.0	N/A	N/A	N/A
		>50 cc 2-s	Uncontrolled	15000	30.0	55.0	15.0	N/A	N/A	N/A
			Controlled	15000	30.0	55.0	15.0	N/A	N/A	N/A
		>50 cc 4-s	Uncontrolled	15000	30.0	55.0	15.0	N/A	N/A	N/A
			Controlled	15000	30.0	55.0	15.0	N/A	N/A	N/A

Table A72a. Fleet composition of Italy

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Passenger cars	Gasoline	<1.4 l	Pre ECE	483169	27125	103	0	0	0	0
			ECE 15-00/01	2933615	1216933	178607	1792	0	0	0
			ECE 15-02	2557651	1751567	671635	45161	73	0	0
			ECE 15-03	4403337	3782111	2495801	657320	22286	11	0
			ECE 15-04	8450071	8239353	7519459	5081317	1546567	85944	130
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	0	6569859	6494222	5960355	4063889	1215608	63767
			EURO 2	0	0	6930127	6860736	6351000	4464100	1434888
			EURO 3	0	0	0	6487460	6408613	5853597	3898232
			EURO 4	0	0	0	1725119	10666971	19244428	26830521
		1.4 - 2.0 l	Pre ECE	85400	4794	18	0	0	0	0
			ECE 15-00/01	518516	215093	31569	317	0	0	0
			ECE 15-02	452064	309589	118711	7982	13	0	0
			ECE 15-03	778288	668487	441132	116181	3939	2	0
			ECE 15-04	1493548	1456303	1329062	898121	273355	15191	23
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	0	1161221	1147852	1053491	718291	214858	11271
			EURO 2	0	0	1224898	1212633	1122537	789028	253616
			EURO 3	0	0	0	1146657	1132721	1034622	689011
			EURO 4	0	0	0	304914	1885384	3401447	4742287
		>2.0 l	Pre ECE	4585	257	1	0	0	0	0
			ECE 15-00/01	27840	11549	1695	17	0	0	0
			ECE 15-02	24272	16622	6374	429	1	0	0
			ECE 15-03	41787	35892	23685	6238	211	0	0
			ECE 15-04	80190	78191	71359	48221	14677	816	1
			EURO 1	0	62347	61630	56563	38566	11536	605
			EURO 2	0	0	65766	65108	60270	42364	13617
			EURO 3	0	0	0	61565	60817	55550	36994
			EURO 4	0	0	0	16371	101229	182628	254619
	Diesel	<2.0 l	Uncontrolled	1454369	1032000	601926	192594	16406	67	0
			EURO 1	681959	1417393	1510044	1279285	743182	213337	16719
			EURO 2	0	0	644124	639355	600173	440805	153342
			EURO 3	0	0	0	736109	727162	664187	442319
			EURO 4	0	0	0	195743	1210343	2183596	2891020
		>2.0 l	Uncontrolled	969579	688000	401284	128396	10937	45	0
			EURO 1	454639	944929	1006696	852856	495455	142225	11146
			EURO 2	0	0	429416	426236	400115	293870	102228
			EURO 3	0	0	0	490739	484775	442791	294879
			EURO 4	0	0	0	130495	806895	1455731	2029575
	LPG	All	Uncontrolled	734530	521212	304003	97270	8286	34	0
			EURO 1	344424	715855	762648	646103	375344	107746	8444
			EURO 2	0	0	325315	322906	303118	222629	77446
			EURO 3	0	0	0	371772	367254	335448	223393
			EURO 4	0	0	0	98860	611284	1102826	1537557
	2-stroke	All	Uncontrolled	0	0	0	0	0	0	0

Table A72a (continued). Fleet composition of Italy

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Light goods vehicles	Gasoline	All	Uncontrolled	393348	428203	343994	201750	44938	885	0
			EURO 1	0	20424	70128	68939	56756	15198	39
			EURO 2	0	0	90233	124102	119205	82349	11111
			EURO 3	0	0	0	163072	385988	549498	669951
			EURO 4	0	0	0	0	0	0	0
	Diesel	All	Uncontrolled	1277270	1390449	1117008	655116	145921	2874	0
			EURO 1	0	66321	318997	314679	268380	92476	940
			EURO 2	0	0	201723	312158	302994	224275	35265
			EURO 3	0	0	0	529521	1253369	1784314	2175445
			EURO 4	0	0	0	0	0	0	0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	459904	455591	357306	193698	28242	45	0
			EURO 1	0	68946	96464	92649	64012	8743	3
			EURO 2	0	0	135923	135336	126761	73934	5167
			EURO 3	0	0	0	230570	490558	674838	791174
			EURO 4	0	0	0	0	0	0	0
		7.5 - 16 t	Conventional	253110	250736	196645	106603	15543	25	0
			EURO 1	0	37944	53090	50990	35229	4812	2
			EURO 2	0	0	74805	74483	69764	40690	2844
			EURO 3	0	0	0	126895	269980	371399	435425
			EURO 4	0	0	0	0	0	0	0
		16 - 32 t	Conventional	288058	285357	223797	121322	17689	28	0
			EURO 1	0	43184	60420	58030	40094	5476	2
			EURO 2	0	0	85134	84767	79396	46308	3236
			EURO 3	0	0	0	144416	307258	422681	495547
			EURO 4	0	0	0	0	0	0	0
		>32 t	Conventional	7622	7551	5922	3210	468	1	0
			EURO 1	0	1143	1599	1536	1061	145	0
			EURO 2	0	0	2253	2243	2101	1225	86
			EURO 3	0	0	0	3821	8130	11184	13113
			EURO 4	0	0	0	0	0	0	0
		Buses	Conventional	61592	59740	45428	26583	11500	1678	4
			EURO 1	0	5057	7421	7388	7007	4698	641
			EURO 2	0	0	14265	14259	14152	13047	7378
			EURO 3	0	0	0	20487	36857	50097	60890
			EURO 4	0	0	0	0	0	0	0
		Coaches	Conventional	15398	14935	11357	6646	2875	419	1
			EURO 1	0	1264	1855	1847	1752	1174	160
			EURO 2	0	0	3566	3565	3538	3262	1844
			EURO 3	0	0	0	5122	9214	12524	15223
			EURO 4	0	0	0	0	0	0	0
Motorcycles	Gasoline	<50 cc	Uncontrolled	2141525	2297894	1338077	352378	24014	N/A	N/A
			Stage I	0	0	508916	314590	61514	N/A	N/A
			Stage II	0	0	546860	1288974	1795807	N/A	N/A
		>50 cc 2-s	Uncontrolled	0	0	0	0	0	N/A	N/A
			Controlled	0	0	0	0	0	N/A	N/A
		>50 cc 4-s	Uncontrolled	2079151	2230965	1299104	342114	23315	N/A	N/A
			Controlled	0	0	1025025	2019363	2351471	N/A	N/A

Table A72b. Annual mileage, mileage distribution and representative speeds for Italy (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Passenger cars	Gasoline	<1.4 l	Pre ECE	4000	60.0	39.0	1.0	20.0	45.0	95.0
			ECE 15-00/01	5000	60.0	39.0	1.0	20.0	55.0	100.0
			ECE 15-02	5500	55.0	40.0	5.0	20.0	65.0	105.0
			ECE 15-03	8000	50.0	40.0	10.0	20.0	75.0	110.0
			ECE 15-04	8800	40.0	50.0	10.0	20.0	75.0	110.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	8500	35.0	55.0	10.0	20.0	75.0	110.0
			EURO 2	8500	35.0	55.0	10.0	20.0	75.0	110.0
			EURO 3	8500	35.0	55.0	10.0	20.0	75.0	110.0
			EURO 4	8500	35.0	55.0	10.0	20.0	75.0	110.0
		1.4 - 2.0 l	Pre ECE	6000	35.0	55.0	10.0	20.0	50.0	105.0
			ECE 15-00/01	7500	35.0	55.0	10.0	20.0	60.0	110.0
			ECE 15-02	10500	25.0	50.0	25.0	20.0	70.0	115.0
			ECE 15-03	12000	25.0	50.0	25.0	20.0	75.0	115.0
			ECE 15-04	12800	20.0	50.0	30.0	20.0	75.0	115.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	12500	20.0	50.0	30.0	20.0	75.0	115.0
			EURO 2	12500	20.0	50.0	30.0	20.0	75.0	115.0
			EURO 3	12500	20.0	50.0	30.0	20.0	75.0	115.0
			EURO 4	12500	20.0	50.0	30.0	20.0	75.0	115.0
		>2.0 l	Pre ECE	7000	20.0	60.0	20.0	20.0	55.0	120.0
			ECE 15-00/01	9000	20.0	60.0	20.0	20.0	65.0	120.0
			ECE 15-02	11500	20.0	60.0	20.0	20.0	75.0	125.0
			ECE 15-03	12500	20.0	50.0	30.0	20.0	80.0	125.0
			ECE 15-04	14600	20.0	50.0	30.0	20.0	85.0	130.0
			EURO 1	14000	15.0	55.0	30.0	20.0	85.0	125.0
			EURO 2	14000	15.0	55.0	30.0	20.0	85.0	120.0
			EURO 3	14000	15.0	55.0	30.0	20.0	85.0	120.0
			EURO 4	14000	15.0	55.0	30.0	20.0	85.0	120.0
	Diesel	<2.0 l	Uncontrolled	14000	20.0	60.0	20.0	20.0	70.0	110.0
			EURO 1	14000	20.0	60.0	20.0	20.0	70.0	110.0
			EURO 2	14000	20.0	60.0	20.0	20.0	70.0	110.0
			EURO 3	14000	20.0	60.0	20.0	20.0	70.0	110.0
			EURO 4	14000	20.0	60.0	20.0	20.0	70.0	110.0
		>2.0 l	Uncontrolled	16000	15.0	55.0	30.0	20.0	75.0	120.0
			EURO 1	16000	15.0	55.0	30.0	20.0	75.0	120.0
			EURO 2	16000	15.0	55.0	30.0	20.0	75.0	120.0
			EURO 3	16000	15.0	55.0	30.0	20.0	75.0	120.0
			EURO 4	16000	15.0	55.0	30.0	20.0	75.0	120.0
	LPG	All	Uncontrolled	21500	50.0	40.0	10.0	20.0	65.0	105.0
			EURO 1	21500	50.0	40.0	10.0	20.0	65.0	105.0
			EURO 2	21500	50.0	40.0	10.0	20.0	65.0	105.0
			EURO 3	21500	50.0	40.0	10.0	20.0	65.0	105.0
			EURO 4	21500	50.0	40.0	10.0	20.0	65.0	105.0
	2-stroke	All	Uncontrolled	-	-	-	-	-	-	-

Table A72b (continued). Annual mileage, mileage distribution and representative speeds for Italy (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Light goods vehicles	Gasoline	All	Uncontrolled	20000	40.0	35.0	25.0	20.0	60.0	90.0
			EURO 1	20000	40.0	35.0	25.0	20.0	60.0	90.0
			EURO 2	20000	40.0	35.0	25.0	20.0	60.0	90.0
			EURO 3	20000	40.0	35.0	25.0	20.0	60.0	90.0
			EURO 4	20000	40.0	35.0	25.0	20.0	60.0	90.0
	Diesel	All	Uncontrolled	17000	35.0	35.0	30.0	20.0	60.0	90.0
			EURO 1	17000	35.0	35.0	30.0	20.0	60.0	90.0
			EURO 2	17000	35.0	35.0	30.0	20.0	60.0	90.0
			EURO 3	17000	35.0	35.0	30.0	20.0	60.0	90.0
			EURO 4	17000	35.0	35.0	30.0	20.0	60.0	90.0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	32000	30.0	30.0	40.0	20.0	60.0	90.0
			EURO 1	32000	30.0	30.0	40.0	20.0	60.0	90.0
			EURO 2	32000	30.0	30.0	40.0	20.0	60.0	90.0
			EURO 3	32000	30.0	30.0	40.0	20.0	60.0	90.0
			EURO 4	32000	30.0	30.0	40.0	20.0	60.0	90.0
		7.5 - 16 t	Conventional	32000	30.0	30.0	40.0	20.0	60.0	90.0
			EURO 1	32000	30.0	30.0	40.0	20.0	60.0	90.0
			EURO 2	32000	30.0	30.0	40.0	20.0	60.0	90.0
			EURO 3	32000	30.0	30.0	40.0	20.0	60.0	90.0
			EURO 4	32000	30.0	30.0	40.0	20.0	60.0	90.0
		16 - 32 t	Conventional	55000	20.0	20.0	60.0	20.0	60.0	90.0
			EURO 1	55000	20.0	20.0	60.0	20.0	60.0	90.0
			EURO 2	55000	20.0	20.0	60.0	20.0	60.0	90.0
			EURO 3	55000	20.0	20.0	60.0	20.0	60.0	90.0
			EURO 4	55000	20.0	20.0	60.0	20.0	60.0	90.0
		>32 t	Conventional	55000	20.0	20.0	60.0	20.0	60.0	90.0
			EURO 1	55000	20.0	20.0	60.0	20.0	60.0	90.0
			EURO 2	55000	20.0	20.0	60.0	20.0	60.0	90.0
			EURO 3	55000	20.0	20.0	60.0	20.0	60.0	90.0
			EURO 4	55000	20.0	20.0	60.0	20.0	60.0	90.0
		Buses	Conventional	41000	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 1	41000	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 2	41000	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 3	41000	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 4	41000	100.0	0.0	0.0	20.0	60.0	90.0
		Coaches	Conventional	45000	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 1	45000	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 2	45000	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 3	45000	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 4	45000	0.0	50.0	50.0	20.0	60.0	90.0
Motorcycles	Gasoline	<50 cc	Uncontrolled	6000	70.0	30.0	0.0	N/A	N/A	N/A
			Stage I	6000	70.0	30.0	0.0	N/A	N/A	N/A
			Stage II	6000	70.0	30.0	0.0	N/A	N/A	N/A
		>50 cc 2-s	Uncontrolled	-	-	-	-	-	-	-
			Controlled	-	-	-	-	-	-	-
		>50 cc 4-s	Uncontrolled	6000	60.0	30.0	10.0	N/A	N/A	N/A
			Controlled	6000	60.0	30.0	10.0	N/A	N/A	N/A

Table A73a. Fleet composition of Luxembourg

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Passenger cars	Gasoline	<1.4 l	Pre ECE	0	0	0	0	0	0	0
			ECE 15-00/01	0	0	0	0	0	0	0
			ECE 15-02	37	0	0	0	0	0	0
			ECE 15-03	6425	8	0	0	0	0	0
			ECE 15-04	58395	19336	349	0	0	0	0
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	2645	61417	23460	413	0	0	0
			EURO 2	0	0	71763	30391	537	0	0
			EURO 3	0	0	0	60683	20580	104	0
			EURO 4	0	0	0	17820	101111	134473	146689
		1.4 - 2.0 l	Pre ECE	0	0	0	0	0	0	0
			ECE 15-00/01	0	0	0	0	0	0	0
			ECE 15-02	38	0	0	0	0	0	0
			ECE 15-03	6529	8	0	0	0	0	0
			ECE 15-04	52616	15069	176	0	0	0	0
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	9409	66987	24018	419	0	0	0
			EURO 2	0	0	72921	30881	546	0	0
			EURO 3	0	0	0	61661	20912	105	0
			EURO 4	0	0	0	18107	102742	136642	149055
		>2.0 l	Pre ECE	0	0	0	0	0	0	0
			ECE 15-00/01	0	0	0	0	0	0	0
			ECE 15-02	11	0	0	0	0	0	0
			ECE 15-03	1851	2	0	0	0	0	0
			ECE 15-04	13771	3492	19	0	0	0	0
			EURO 1	3810	19766	6838	119	0	0	0
			EURO 2	0	0	20669	8753	155	0	0
			EURO 3	0	0	0	17478	5927	30	0
			EURO 4	0	0	0	5132	29122	38731	42249
	Diesel	<2.0 l	Uncontrolled	6099	180	0	0	0	0	0
			EURO 1	13728	23541	10383	492	0	0	0
			EURO 2	0	0	17688	8556	158	0	0
			EURO 3	0	0	0	17823	6045	30	0
			EURO 4	0	0	0	5234	29698	39497	43085
		>2.0 l	Uncontrolled	4066	120	0	0	0	0	0
			EURO 1	9152	15694	6922	328	0	0	0
			EURO 2	0	0	11792	5704	105	0	0
			EURO 3	0	0	0	11882	4030	20	0
			EURO 4	0	0	0	3489	19799	26331	28723
	LPG	All	Uncontrolled	175	5	0	0	0	0	0
			EURO 1	393	674	297	14	0	0	0
			EURO 2	0	0	506	245	5	0	0
			EURO 3	0	0	0	510	173	1	0
			EURO 4	0	0	0	150	850	1130	1233
	2-stroke	All	Uncontrolled	0	0	0	0	0	0	0

Table A73a (continued). Fleet composition of Luxembourg

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Light goods vehicles	Gasoline	All	Uncontrolled	3122	2946	1313	114	0	0	0
			EURO 1	0	302	956	639	7	0	0
			EURO 2	0	0	1113	1391	544	0	0
			EURO 3	0	0	0	1293	2889	3405	3349
			EURO 4	0	0	0	0	0	0	0
	Diesel	All	Uncontrolled	1343	1267	565	49	0	0	0
			EURO 1	0	130	570	418	18	0	0
			EURO 2	0	0	320	455	218	0	0
			EURO 3	0	0	0	556	1242	1464	1440
			EURO 4	0	0	0	0	0	0	0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	5515	4143	1341	11	0	0	0
			EURO 1	0	1594	2055	822	1	0	0
			EURO 2	0	0	2579	2347	560	0	0
			EURO 3	0	0	0	2892	5514	6016	5917
			EURO 4	0	0	0	0	0	0	0
		7.5 - 16 t	Conventional	2221	1669	540	4	0	0	0
			EURO 1	0	642	828	331	0	0	0
			EURO 2	0	0	1039	945	226	0	0
			EURO 3	0	0	0	1165	2221	2423	2383
			EURO 4	0	0	0	0	0	0	0
		16 - 32 t	Conventional	8256	6202	2007	16	0	0	0
			EURO 1	0	2386	3076	1230	1	0	0
			EURO 2	0	0	3861	3514	839	0	0
			EURO 3	0	0	0	4329	8255	9007	8858
			EURO 4	0	0	0	0	0	0	0
		>32 t	Conventional	835	627	203	2	0	0	0
			EURO 1	0	241	311	124	0	0	0
			EURO 2	0	0	390	355	85	0	0
			EURO 3	0	0	0	738	835	911	896
			EURO 4	0	0	0	0	0	0	0
		Buses	Conventional	607	494	333	168	18	0	0
			EURO 1	0	178	225	210	111	5	0
			EURO 2	0	0	189	188	170	73	1
			EURO 3	0	0	0	247	574	853	988
			EURO 4	0	0	0	0	0	0	0
		Coaches	Conventional	152	124	83	42	2	0	0
			EURO 1	0	45	56	53	28	1	0
			EURO 2	0	0	47	47	42	18	0
			EURO 3	0	0	0	62	144	213	247
			EURO 4	0	0	0	0	0	0	0
Motorcycles	Gasoline	<50 cc	Uncontrolled	7192	6563	3172	878	144	N/A	N/A
			Stage I	0	0	1290	617	160	N/A	N/A
			Stage II	0	0	1422	3807	4388	N/A	N/A
		>50 cc 2-s	Uncontrolled	1599	1942	1055	306	52	N/A	N/A
			Controlled	0	0	1203	2292	2866	N/A	N/A
		>50 cc 4-s	Uncontrolled	1599	1942	1055	306	52	N/A	N/A
			Controlled	0	0	1203	2292	2866	N/A	N/A

Table A73b. Annual mileage, mileage distribution and representative speeds for Luxembourg (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Passenger cars	Gasoline	<1.4 l	Pre ECE	-	-	-	-	-	-	-
			ECE 15-00/01	-	-	-	-	-	-	-
			ECE 15-02	13800	45.0	35.0	20.0	40.0	60.0	95.0
			ECE 15-03	13800	45.0	35.0	20.0	40.0	60.0	95.0
			ECE 15-04	13800	45.0	35.0	20.0	40.0	60.0	95.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	13800	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 2	13800	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 3	13800	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 4	13800	45.0	35.0	20.0	40.0	60.0	95.0
		1.4 - 2.0 l	Pre ECE	-	-	-	-	-	-	-
			ECE 15-00/01	-	-	-	-	-	-	-
			ECE 15-02	13800	45.0	35.0	20.0	40.0	60.0	95.0
			ECE 15-03	13800	45.0	35.0	20.0	40.0	60.0	95.0
			ECE 15-04	13800	45.0	35.0	20.0	40.0	60.0	95.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	13800	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 2	13800	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 3	13800	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 4	13800	45.0	35.0	20.0	40.0	60.0	95.0
		>2.0 l	Pre ECE	-	-	-	-	-	-	-
			ECE 15-00/01	-	-	-	-	-	-	-
			ECE 15-02	13800	45.0	35.0	20.0	40.0	60.0	95.0
			ECE 15-03	13800	45.0	35.0	20.0	40.0	60.0	95.0
			ECE 15-04	13800	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 1	13800	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 2	13800	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 3	13800	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 4	13800	45.0	35.0	20.0	40.0	60.0	95.0
	Diesel	<2.0 l	Uncontrolled	20000	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 1	20000	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 2	20000	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 3	20000	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 4	20000	45.0	35.0	20.0	40.0	60.0	95.0
		>2.0 l	Uncontrolled	20000	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 1	20000	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 2	20000	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 3	20000	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 4	20000	45.0	35.0	20.0	40.0	60.0	95.0
	LPG	All	Uncontrolled	13800	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 1	13800	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 2	13800	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 3	13800	45.0	35.0	20.0	40.0	60.0	95.0
			EURO 4	13800	45.0	35.0	20.0	40.0	60.0	95.0
	2-stroke	All	Uncontrolled	-	-	-	-	-	-	-

Table A73b (continued). Annual mileage, mileage distribution and representative speeds for Luxembourg (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Light goods vehicles	Gasoline	All	Uncontrolled	40000	15.0	45.0	40.0	40.0	60.0	95.0
			EURO 1	40000	15.0	45.0	40.0	40.0	60.0	95.0
			EURO 2	40000	15.0	45.0	40.0	40.0	60.0	95.0
			EURO 3	40000	15.0	45.0	40.0	40.0	60.0	95.0
			EURO 4	40000	15.0	45.0	40.0	40.0	60.0	95.0
	Diesel	All	Uncontrolled	40000	15.0	45.0	40.0	40.0	60.0	95.0
			EURO 1	40000	15.0	45.0	40.0	40.0	60.0	95.0
			EURO 2	40000	15.0	45.0	40.0	40.0	60.0	95.0
			EURO 3	40000	15.0	45.0	40.0	40.0	60.0	95.0
			EURO 4	40000	15.0	45.0	40.0	40.0	60.0	95.0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	40000	15.0	45.0	40.0	20.0	60.0	90.0
			EURO 1	40000	15.0	45.0	40.0	20.0	60.0	90.0
			EURO 2	40000	15.0	45.0	40.0	20.0	60.0	90.0
			EURO 3	40000	15.0	45.0	40.0	20.0	60.0	90.0
			EURO 4	40000	15.0	45.0	40.0	20.0	60.0	90.0
		7.5 - 16 t	Conventional	40000	15.0	45.0	40.0	20.0	60.0	90.0
			EURO 1	40000	15.0	45.0	40.0	20.0	60.0	90.0
			EURO 2	40000	15.0	45.0	40.0	20.0	60.0	90.0
			EURO 3	40000	15.0	45.0	40.0	20.0	60.0	90.0
			EURO 4	40000	15.0	45.0	40.0	20.0	60.0	90.0
		16 - 32 t	Conventional	40000	15.0	45.0	40.0	20.0	60.0	90.0
			EURO 1	40000	15.0	45.0	40.0	20.0	60.0	90.0
			EURO 2	40000	15.0	45.0	40.0	20.0	60.0	90.0
			EURO 3	40000	15.0	45.0	40.0	20.0	60.0	90.0
			EURO 4	40000	15.0	45.0	40.0	20.0	60.0	90.0
		>32 t	Conventional	40000	15.0	45.0	40.0	20.0	60.0	90.0
			EURO 1	40000	15.0	45.0	40.0	20.0	60.0	90.0
			EURO 2	40000	15.0	45.0	40.0	20.0	60.0	90.0
			EURO 3	40000	15.0	45.0	40.0	20.0	60.0	90.0
			EURO 4	40000	15.0	45.0	40.0	20.0	60.0	90.0
		Buses	Conventional	47728	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 1	47728	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 2	47728	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 3	47728	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 4	47728	100.0	0.0	0.0	20.0	60.0	90.0
		Coaches	Conventional	47728	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 1	47728	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 2	47728	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 3	47728	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 4	47728	0.0	50.0	50.0	20.0	60.0	90.0
Motorcycles	Gasoline	<50 cc	Uncontrolled	1500	50.0	35.0	15.0	N/A	N/A	N/A
			Stage I	1500	50.0	35.0	15.0	N/A	N/A	N/A
			Stage II	1500	50.0	35.0	15.0	N/A	N/A	N/A
		>50 cc 2-s	Uncontrolled	4600	35.0	45.0	20.0	N/A	N/A	N/A
			Controlled	4600	35.0	45.0	20.0	N/A	N/A	N/A
		>50 cc 4-s	Uncontrolled	4600	35.0	45.0	20.0	N/A	N/A	N/A
			Controlled	4600	35.0	45.0	20.0	N/A	N/A	N/A

Table A74a. Fleet composition of the Netherlands

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Passenger cars	Gasoline	<1.4 l	Pre ECE	61	0	0	0	0	0	0
			ECE 15-00/01	123778	5394	4	0	0	0	0
			ECE 15-02	390650	80646	1243	0	0	0	0
			ECE 15-03	741615	412878	62703	391	0	0	0
			ECE 15-04	475708	389051	159680	12511	112	0	0
			Improved conventional	722224	656456	385270	56436	392	0	0
			Open loop	90329	85623	59791	14020	206	0	0
			EURO 1	271982	1424995	1273171	720221	125978	1712	0
			EURO 2	0	0	1299531	1203968	758264	148778	2051
			EURO 3	0	0	0	1115956	1016652	857320	84479
			EURO 4	0	0	0	276370	1617170	2871615	3600167
		1.4 - 2.0 l	Pre ECE	31	0	0	0	0	0	0
			ECE 15-00/01	62665	2731	2	0	0	0	0
			ECE 15-02	197774	40829	629	0	0	0	0
			ECE 15-03	375457	209028	31745	198	0	0	0
			ECE 15-04	343066	286653	126188	10255	58	0	0
			Improved conventional	72540	66993	41634	6987	64	0	0
			Open loop	230828	213849	136114	25682	311	0	0
			EURO 1	143469	726593	646794	363705	63705	867	0
			EURO 2	0	0	657913	609532	383886	75322	1038
			EURO 3	0	0	0	564975	514700	297342	42769
			EURO 4	0	0	0	139918	818724	1453811	1822655
		>2.0 l	Pre ECE	4	0	0	0	0	0	0
			ECE 15-00/01	7566	330	0	0	0	0	0
			ECE 15-02	23880	4930	76	0	0	0	0
			ECE 15-03	45334	25239	3833	24	0	0	0
			ECE 15-04	50682	42685	19069	1366	2	0	0
			EURO 1	44693	113568	95725	47732	7742	105	0
			EURO 2	0	0	79438	73597	46352	9095	125
			EURO 3	0	0	0	68217	62146	35902	5164
			EURO 4	0	0	0	16894	98855	175538	220073
	Diesel	<2.0 l	Uncontrolled	223677	115783	28054	816	0	0	0
			EURO 1	130760	268693	246003	125583	26634	727	0
			EURO 2	0	0	133871	126251	84737	18212	258
			EURO 3	0	0	0	140443	127945	73914	10632
			EURO 4	0	0	0	34781	203520	361392	453080
		>2.0 l	Uncontrolled	149118	77189	18703	544	0	0	0
			EURO 1	87173	179129	164002	83722	17756	485	0
			EURO 2	0	0	89247	84167	56491	12142	172
			EURO 3	0	0	0	93629	85297	49276	7088
			EURO 4	0	0	0	23187	135680	240928	302053
	LPG	All	Uncontrolled	290028	150129	36376	1058	0	0	0
			EURO 1	169548	348398	318978	162835	34534	942	0
			EURO 2	0	0	173582	163702	109873	23615	335
			EURO 3	0	0	0	182104	165899	95840	13785
			EURO 4	0	0	0	45099	263892	468595	587481
	2-stroke	All	Uncontrolled	0	0	0	0	0	0	0

Table A74a (continued). Fleet composition of the Netherlands

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Light goods vehicles	Gasoline	All	Uncontrolled	4375	4460	1770	60	0	0	0
			EURO 1	0	567	1846	960	1	0	0
			EURO 2	0	0	2059	2515	617	0	0
			EURO 3	0	0	0	2799	6340	7546	8114
			EURO 4	0	0	0	0	0	0	0
	Diesel	All	Uncontrolled	0	0	0	0	0	0	0
			EURO 1	0	0	0	0	0	0	0
			EURO 2	0	0	0	0	0	0	0
			EURO 3	0	0	0	0	0	0	0
			EURO 4	0	0	0	0	0	0	0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	80629	62851	15811	11	0	0	0
			EURO 1	0	29818	38294	9966	0	0	0
			EURO 2	0	0	50502	43018	5123	0	0
			EURO 3	0	0	0	63741	123107	139080	149553
			EURO 4	0	0	0	0	0	0	0
		7.5 - 16 t	Conventional	166536	129817	32657	23	0	0	0
			EURO 1	0	61587	79096	20584	0	0	0
			EURO 2	0	0	104311	88852	10581	0	0
			EURO 3	0	0	0	131656	254274	287264	308897
			EURO 4	0	0	0	0	0	0	0
		16 - 32 t	Conventional	253388	197519	49689	36	0	0	0
			EURO 1	0	93706	120345	31318	0	0	0
			EURO 2	0	0	158711	135191	16098	0	0
			EURO 3	0	0	0	200317	386882	437078	469992
			EURO 4	0	0	0	0	0	0	0
		>32 t	Conventional	17108	13336	3355	2	0	0	0
			EURO 1	0	6327	8125	2115	0	0	0
			EURO 2	0	0	10716	9128	1087	0	0
			EURO 3	0	0	0	13525	26121	29510	31732
			EURO 4	0	0	0	0	0	0	0
		Buses	Conventional	9631	8610	5392	2207	102	0	0
			EURO 1	0	1633	2307	2234	1345	30	0
			EURO 2	0	0	3109	3102	2912	1243	4
			EURO 3	0	0	0	3833	7516	11052	12755
			EURO 4	0	0	0	0	0	0	0
		Coaches	Conventional	2408	2152	1348	552	26	0	0
			EURO 1	0	408	577	558	336	7	0
			EURO 2	0	0	777	775	728	311	1
			EURO 3	0	0	0	958	1879	2763	3189
			EURO 4	0	0	0	0	0	0	0
Motorcycles	Gasoline	<50 cc	Uncontrolled	801961	728473	434385	183803	43894	N/A	N/A
			Stage I	0	0	111798	89512	42013	N/A	N/A
			Stage II	0	0	100283	286049	382892	N/A	N/A
		>50 cc 2-s	Uncontrolled	22348	26161	18409	8495	2047	N/A	N/A
			Controlled	0	0	11412	24829	34641	N/A	N/A
		>50 cc 4-s	Uncontrolled	130720	153027	107680	49690	11974	N/A	N/A
			Controlled	0	0	66751	145233	202629	N/A	N/A

Table A74b. Annual mileage, mileage distribution and representative speeds for the Netherlands (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Passenger cars	Gasoline	<1.4 l	Pre ECE	5516	32.7	38.0	29.3	25.0	60.0	100.0
			ECE 15-00/01	6243	32.7	38.0	29.3	25.0	60.0	100.0
			ECE 15-02	6669	32.7	38.0	29.3	25.0	60.0	100.0
			ECE 15-03	7357	32.7	38.0	29.3	25.0	60.0	100.0
			ECE 15-04	8143	32.7	38.0	29.3	25.0	60.0	100.0
			Improved conventional	8707	32.7	38.0	29.3	25.0	60.0	100.0
			Open loop	9203	32.7	38.0	29.3	25.0	60.0	100.0
			EURO 1	10767	32.7	38.0	29.3	25.0	60.0	100.0
			EURO 2	10767	32.7	38.0	29.3	25.0	60.0	100.0
			EURO 3	10767	32.7	38.0	29.3	25.0	60.0	100.0
			EURO 4	10767	32.7	38.0	29.3	25.0	60.0	100.0
		1.4 - 2.0 l	Pre ECE	6834	32.7	38.0	29.3	25.0	60.0	100.0
			ECE 15-00/01	7735	32.7	38.0	29.3	25.0	60.0	100.0
			ECE 15-02	8263	32.7	38.0	29.3	25.0	60.0	100.0
			ECE 15-03	9115	32.7	38.0	29.3	25.0	60.0	100.0
			ECE 15-04	10186	32.7	38.0	29.3	25.0	60.0	100.0
			Improved conventional	10955	32.7	38.0	29.3	25.0	60.0	100.0
			Open loop	11060	32.7	38.0	29.3	25.0	60.0	100.0
			EURO 1	13310	32.7	38.0	29.3	25.0	60.0	100.0
			EURO 2	13310	32.7	38.0	29.3	25.0	60.0	100.0
			EURO 3	13310	32.7	38.0	29.3	25.0	60.0	100.0
			EURO 4	13310	32.7	38.0	29.3	25.0	60.0	100.0
		>2.0 l	Pre ECE	9763	32.7	38.0	29.3	25.0	60.0	100.0
			ECE 15-00/01	11050	32.7	38.0	29.3	25.0	60.0	100.0
			ECE 15-02	11804	32.7	38.0	29.3	25.0	60.0	100.0
			ECE 15-03	13021	32.7	38.0	29.3	25.0	60.0	100.0
			ECE 15-04	14558	32.7	38.0	29.3	25.0	60.0	100.0
			EURO 1	18359	32.7	38.0	29.3	25.0	60.0	100.0
			EURO 2	18359	32.7	38.0	29.3	25.0	60.0	100.0
			EURO 3	18359	32.7	38.0	29.3	25.0	60.0	100.0
			EURO 4	18359	32.7	38.0	29.3	25.0	60.0	100.0
	Diesel	<2.0 l	Uncontrolled	13436	41.1	33.3	25.6	25.0	60.0	100.0
			EURO 1	17939	41.1	33.3	25.6	25.0	60.0	100.0
			EURO 2	17939	41.1	33.3	25.6	25.0	60.0	100.0
			EURO 3	17939	41.1	33.3	25.6	25.0	60.0	100.0
			EURO 4	17939	41.1	33.3	25.6	25.0	60.0	100.0
		>2.0 l	Uncontrolled	13436	41.1	33.3	25.6	25.0	60.0	100.0
			EURO 1	17939	41.1	33.3	25.6	25.0	60.0	100.0
			EURO 2	17939	41.1	33.3	25.6	25.0	60.0	100.0
			EURO 3	17939	41.1	33.3	25.6	25.0	60.0	100.0
			EURO 4	17939	41.1	33.3	25.6	25.0	60.0	100.0
	LPG	All	Uncontrolled	13436	32.4	38.2	29.4	25.0	60.0	100.0
			EURO 1	17939	32.4	38.2	29.4	25.0	60.0	100.0
			EURO 2	17939	32.4	38.2	29.4	25.0	60.0	100.0
			EURO 3	17939	32.4	38.2	29.4	25.0	60.0	100.0
			EURO 4	17939	32.4	38.2	29.4	25.0	60.0	100.0
	2-stroke	All	Uncontrolled	-	-	-	-	-	-	-

Table A74b (continued). Annual mileage, mileage distribution and representative speeds for the Netherlands (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Light goods vehicles	Gasoline	All	Uncontrolled	35000	41.1	33.3	25.6	25.0	60.0	100.0
			EURO 1	35000	41.1	33.3	25.6	25.0	60.0	100.0
			EURO 2	35000	41.1	33.3	25.6	25.0	60.0	100.0
			EURO 3	35000	41.1	33.3	25.6	25.0	60.0	100.0
			EURO 4	35000	41.1	33.3	25.6	25.0	60.0	100.0
	Diesel	All	Uncontrolled	-	-	-	-	-	-	-
			EURO 1	-	-	-	-	-	-	-
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	22000	21.5	43.6	34.9	20.0	60.0	90.0
			EURO 1	22000	21.5	43.6	34.9	20.0	60.0	90.0
			EURO 2	22000	21.5	43.6	34.9	20.0	60.0	90.0
			EURO 3	22000	21.5	43.6	34.9	20.0	60.0	90.0
			EURO 4	22000	21.5	43.6	34.9	20.0	60.0	90.0
		7.5 - 16 t	Conventional	22000	21.5	43.6	34.9	20.0	60.0	90.0
			EURO 1	22000	21.5	43.6	34.9	20.0	60.0	90.0
			EURO 2	22000	21.5	43.6	34.9	20.0	60.0	90.0
			EURO 3	22000	21.5	43.6	34.9	20.0	60.0	90.0
			EURO 4	22000	21.5	43.6	34.9	20.0	60.0	90.0
		16 - 32 t	Conventional	30000	25.6	33.4	41.0	20.0	60.0	90.0
			EURO 1	30000	25.6	33.4	41.0	20.0	60.0	90.0
			EURO 2	30000	25.6	33.4	41.0	20.0	60.0	90.0
			EURO 3	30000	25.6	33.4	41.0	20.0	60.0	90.0
			EURO 4	30000	25.6	33.4	41.0	20.0	60.0	90.0
		>32 t	Conventional	30000	25.6	33.4	41.0	20.0	60.0	90.0
			EURO 1	30000	25.6	33.4	41.0	20.0	60.0	90.0
			EURO 2	30000	25.6	33.4	41.0	20.0	60.0	90.0
			EURO 3	30000	25.6	33.4	41.0	20.0	60.0	90.0
			EURO 4	30000	25.6	33.4	41.0	20.0	60.0	90.0
		Buses	Conventional	35000	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 1	35000	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 2	35000	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 3	35000	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 4	35000	100.0	0.0	0.0	20.0	60.0	90.0
		Coaches	Conventional	35000	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 1	35000	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 2	35000	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 3	35000	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 4	35000	0.0	50.0	50.0	20.0	60.0	90.0
Motorcycles	Gasoline	<50 cc	Uncontrolled	3220	90.0	10.0	0.0	N/A	N/A	N/A
			Stage I	3220	90.0	10.0	0.0	N/A	N/A	N/A
			Stage II	3220	90.0	10.0	0.0	N/A	N/A	N/A
		>50 cc 2-s	Uncontrolled	7380	63.0	25.0	12.0	N/A	N/A	N/A
			Controlled	7380	63.0	25.0	12.0	N/A	N/A	N/A
		>50 cc 4-s	Uncontrolled	7380	63.0	25.0	12.0	N/A	N/A	N/A
			Controlled	7380	63.0	25.0	12.0	N/A	N/A	N/A

Table A75a. Fleet composition of Portugal

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Passenger cars	Gasoline	<1.4 l	Pre ECE	115281	927	0	0	0	0	0
			ECE 15-00/01	269623	80366	1808	0	0	0	0
			ECE 15-02	145788	109036	22958	68	0	0	0
			ECE 15-03	259103	239891	141354	14308	7	0	0
			ECE 15-04	620003	615711	570181	352457	55302	151	0
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	0	693821	690085	646915	416615	64870	169
			EURO 2	0	0	644037	640572	600714	388849	62840
			EURO 3	0	0	0	583418	579700	537936	324270
			EURO 4	0	0	0	160568	1059997	2001452	2848718
		1.4 - 2.0 l	Pre ECE	61945	498	0	0	0	0	0
			ECE 15-00/01	144879	43184	971	0	0	0	0
			ECE 15-02	78337	58589	12336	37	0	0	0
			ECE 15-03	139226	128903	75955	7688	4	0	0
			ECE 15-04	333151	330845	306380	189388	29716	81	0
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	0	372816	370809	347612	223863	34857	91
			EURO 2	0	0	346065	344204	322786	208943	33766
			EURO 3	0	0	0	313492	311495	289053	174242
			EURO 4	0	0	0	86279	569576	1075455	1530723
		>2.0 l	Pre ECE	9919	80	0	0	0	0	0
			ECE 15-00/01	23198	6915	156	0	0	0	0
			ECE 15-02	12543	9381	1975	6	0	0	0
			ECE 15-03	22293	20640	12162	1231	1	0	0
			ECE 15-04	53344	52975	49058	30325	4758	13	0
			EURO 1	0	59696	59374	55660	35845	5581	15
			EURO 2	0	0	55412	55114	51685	33456	5407
			EURO 3	0	0	0	50197	49877	46283	27900
			EURO 4	0	0	0	13815	91201	172203	245101
	Diesel	<2.0 l	Uncontrolled	103953	64746	33510	7431	81	0	0
			EURO 1	48623	123539	134549	115798	62840	12074	107
			EURO 2	0	0	56013	55810	53165	37046	6712
			EURO 3	0	0	0	63140	62738	58218	35094
			EURO 4	0	0	0	17378	114718	216607	308303
		>2.0 l	Uncontrolled	69302	43164	22340	4954	54	0	0
			EURO 1	32415	82359	89699	77199	41894	8049	71
			EURO 2	0	0	37342	37207	35444	24697	4475
			EURO 3	0	0	0	42094	41825	38812	23396
			EURO 4	0	0	0	11585	76479	144405	205535
	LPG	All	Uncontrolled	0	0	0	0	0	0	0
			EURO 1	0	0	0	0	0	0	0
			EURO 2	0	0	0	0	0	0	0
			EURO 3	0	0	0	0	0	0	0
			EURO 4	0	0	0	0	0	0	0
	2-stroke	All	Uncontrolled	0	0	0	0	0	0	0

Table A75a (continued). Fleet composition of Portugal

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Light goods vehicles	Gasoline	All	Uncontrolled	0	0	0	0	0	0	0
			EURO 1	0	0	0	0	0	0	0
			EURO 2	0	0	0	0	0	0	0
			EURO 3	0	0	0	0	0	0	0
			EURO 4	0	0	0	0	0	0	0
	Diesel	All	Uncontrolled	264343	306842	245388	174346	98154	27283	1128
			EURO 1	0	24140	99189	98566	93097	67558	19034
			EURO 2	0	0	53254	80587	79595	72190	43695
			EURO 3	0	0	0	110397	256017	415874	567165
			EURO 4	0	0	0	0	0	0	0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	134845	133347	102041	66341	30882	5087	47
			EURO 1	0	35493	47832	47060	41779	23490	3123
			EURO 2	0	0	53067	52953	51630	43630	20422
			EURO 3	0	0	0	70286	144470	225143	298303
			EURO 4	0	0	0	0	0	0	0
		7.5 - 16 t	Conventional	62889	62190	47590	30940	14402	2372	22
			EURO 1	0	16553	22308	21948	19485	10955	1457
			EURO 2	0	0	24749	24696	24079	20348	9524
			EURO 3	0	0	0	32780	67378	105002	139122
			EURO 4	0	0	0	0	0	0	0
		16 - 32 t	Conventional	37887	37466	28670	18640	8677	1429	13
			EURO 1	0	9972	13439	13222	11739	6600	878
			EURO 2	0	0	14910	14878	14506	12259	5738
			EURO 3	0	0	0	19748	40591	63258	83813
			EURO 4	0	0	0	0	0	0	0
		>32 t	Conventional	2131	2107	1612	1048	488	80	1
			EURO 1	0	561	756	744	660	371	49
			EURO 2	0	0	838	837	816	689	323
			EURO 3	0	0	0	1111	2283	3557	4713
			EURO 4	0	0	0	0	0	0	0
		Buses	Conventional	6077	5866	4694	3254	1848	792	53
			EURO 1	0	1031	1401	1401	1389	1264	624
			EURO 2	0	0	1631	1631	1630	1606	1390
			EURO 3	0	0	0	2291	4557	6542	8841
			EURO 4	0	0	0	0	0	0	0
		Coaches	Conventional	6077	5866	4694	3254	1848	792	53
			EURO 1	0	1031	1401	1401	1389	1264	624
			EURO 2	0	0	1631	1631	1630	1606	1390
			EURO 3	0	0	0	2291	4557	6542	8841
			EURO 4	0	0	0	0	0	0	0
Motorcycles	Gasoline	<50 cc	Uncontrolled	1725875	1934868	1343043	534441	57767	N/A	N/A
			Stage I	0	0	401849	328529	113460	N/A	N/A
			Stage II	0	0	402567	1497931	2404474	N/A	N/A
		>50 cc 2-s	Uncontrolled	61638	69102	47966	19087	2063	N/A	N/A
			Controlled	0	0	28729	65231	89926	N/A	N/A
		>50 cc 4-s	Uncontrolled	61638	69102	47966	19087	2063	N/A	N/A
			Controlled	0	0	28729	65231	89926	N/A	N/A

Table A75b. Annual mileage, mileage distribution and representative speeds for Portugal (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Passenger cars	Gasoline	<1.4 l	Pre ECE	12000	24.0	68.8	7.2	30.0	70.0	90.0
			ECE 15-00/01	12000	24.0	68.8	7.2	30.0	70.0	90.0
			ECE 15-02	12000	24.0	68.8	7.2	30.0	70.0	90.0
			ECE 15-03	12000	24.0	68.8	7.2	30.0	70.0	90.0
			ECE 15-04	12000	24.0	68.8	7.2	30.0	70.0	90.0
			Improved conventional	12000	24.0	68.8	7.2	30.0	70.0	90.0
			Open loop	12000	24.0	68.8	7.2	30.0	70.0	90.0
			EURO 1	12000	24.0	68.8	7.2	30.0	70.0	90.0
			EURO 2	12000	24.0	68.8	7.2	30.0	70.0	90.0
			EURO 3	12000	24.0	68.8	7.2	30.0	70.0	90.0
			EURO 4	12000	24.0	68.8	7.2	30.0	70.0	90.0
		1.4 - 2.0 l	Pre ECE	12000	24.0	68.8	7.2	30.0	70.0	90.0
			ECE 15-00/01	12000	24.0	68.8	7.2	30.0	70.0	90.0
			ECE 15-02	12000	24.0	68.8	7.2	30.0	70.0	90.0
			ECE 15-03	12000	24.0	68.8	7.2	30.0	70.0	90.0
			ECE 15-04	12000	24.0	68.8	7.2	30.0	70.0	90.0
			Improved conventional	12000	24.0	68.8	7.2	30.0	70.0	90.0
			Open loop	12000	24.0	68.8	7.2	30.0	70.0	90.0
			EURO 1	12000	24.0	68.8	7.2	30.0	70.0	90.0
			EURO 2	12000	24.0	68.8	7.2	30.0	70.0	90.0
			EURO 3	12000	24.0	68.8	7.2	30.0	70.0	90.0
			EURO 4	12000	24.0	68.8	7.2	30.0	70.0	90.0
		>2.0 l	Pre ECE	12000	24.0	68.8	7.2	30.0	70.0	90.0
			ECE 15-00/01	12000	24.0	68.8	7.2	30.0	70.0	90.0
			ECE 15-02	12000	24.0	68.8	7.2	30.0	70.0	90.0
			ECE 15-03	12000	24.0	68.8	7.2	30.0	70.0	90.0
			ECE 15-04	12000	24.0	68.8	7.2	30.0	70.0	90.0
			EURO 1	12000	24.0	68.8	7.2	30.0	70.0	90.0
			EURO 2	12000	24.0	68.8	7.2	30.0	70.0	90.0
			EURO 3	12000	24.0	68.8	7.2	30.0	70.0	90.0
			EURO 4	12000	24.0	68.8	7.2	30.0	70.0	90.0
	Diesel	<2.0 l	Uncontrolled	12000	24.0	68.8	7.2	30.0	70.0	90.0
			EURO 1	12000	24.0	68.8	7.2	30.0	70.0	90.0
			EURO 2	12000	24.0	68.8	7.2	30.0	70.0	90.0
			EURO 3	12000	24.0	68.8	7.2	30.0	70.0	90.0
			EURO 4	12000	24.0	68.8	7.2	30.0	70.0	90.0
		>2.0 l	Uncontrolled	12000	24.0	68.8	7.2	30.0	70.0	90.0
			EURO 1	12000	24.0	68.8	7.2	30.0	70.0	90.0
			EURO 2	12000	24.0	68.8	7.2	30.0	70.0	90.0
			EURO 3	12000	24.0	68.8	7.2	30.0	70.0	90.0
			EURO 4	12000	24.0	68.8	7.2	30.0	70.0	90.0
	LPG	All	Uncontrolled	-	-	-	-	-	-	-
			EURO 1	-	-	-	-	-	-	-
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
	2-stroke	All	Uncontrolled	-	-	-	-	-	-	-

Table A75b (continued). Annual mileage, mileage distribution and representative speeds for Portugal (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Light goods vehicles	Gasoline	All	Uncontrolled	-	-	-	-	-	-	-
			EURO 1	-	-	-	-	-	-	-
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
	Diesel	All	Uncontrolled	15000	4.3	20.7	75.0	20.0	60.0	90.0
			EURO 1	15000	4.3	20.7	75.0	20.0	60.0	90.0
			EURO 2	15000	4.3	20.7	75.0	20.0	60.0	90.0
			EURO 3	15000	4.3	20.7	75.0	20.0	60.0	90.0
			EURO 4	15000	4.3	20.7	75.0	20.0	60.0	90.0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	25000	20.8	77.0	2.2	20.0	60.0	90.0
			EURO 1	25000	20.8	77.0	2.2	20.0	60.0	90.0
			EURO 2	25000	20.8	77.0	2.2	20.0	60.0	90.0
			EURO 3	25000	20.8	77.0	2.2	20.0	60.0	90.0
			EURO 4	25000	20.8	77.0	2.2	20.0	60.0	90.0
		7.5 - 16 t	Conventional	25000	20.8	77.0	2.2	20.0	60.0	90.0
			EURO 1	25000	20.8	77.0	2.2	20.0	60.0	90.0
			EURO 2	25000	20.8	77.0	2.2	20.0	60.0	90.0
			EURO 3	25000	20.8	77.0	2.2	20.0	60.0	90.0
			EURO 4	25000	20.8	77.0	2.2	20.0	60.0	90.0
		16 - 32 t	Conventional	35000	20.8	77.0	2.2	20.0	60.0	90.0
			EURO 1	35000	20.8	77.0	2.2	20.0	60.0	90.0
			EURO 2	35000	20.8	77.0	2.2	20.0	60.0	90.0
			EURO 3	35000	20.8	77.0	2.2	20.0	60.0	90.0
			EURO 4	35000	20.8	77.0	2.2	20.0	60.0	90.0
		>32 t	Conventional	35000	20.8	77.0	2.2	20.0	60.0	90.0
			EURO 1	35000	20.8	77.0	2.2	20.0	60.0	90.0
			EURO 2	35000	20.8	77.0	2.2	20.0	60.0	90.0
			EURO 3	35000	20.8	77.0	2.2	20.0	60.0	90.0
			EURO 4	35000	20.8	77.0	2.2	20.0	60.0	90.0
		Buses	Conventional	30223	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 1	30223	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 2	30223	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 3	30223	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 4	30223	100.0	0.0	0.0	20.0	60.0	90.0
		Coaches	Conventional	30223	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 1	30223	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 2	30223	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 3	30223	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 4	30223	0.0	50.0	50.0	20.0	60.0	90.0
Motorcycles	Gasoline	<50 cc	Uncontrolled	528	15.2	84.8	0.0	N/A	N/A	N/A
			Stage I	528	15.2	84.8	0.0	N/A	N/A	N/A
			Stage II	528	15.2	84.8	0.0	N/A	N/A	N/A
		>50 cc 2-s	Uncontrolled	380	21.8	66.7	11.5	N/A	N/A	N/A
			Controlled	380	21.8	66.7	11.5	N/A	N/A	N/A
		>50 cc 4-s	Uncontrolled	380	21.8	66.7	11.5	N/A	N/A	N/A
			Controlled	380	21.8	66.7	11.5	N/A	N/A	N/A

Table A76a. Fleet composition of Spain

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Passenger cars	Gasoline	<1.4 l	Pre ECE	195833	12423	156	0	0	0	0
			ECE 15-00/01	1399387	588773	93098	2087	0	0	0
			ECE 15-02	773876	534591	184832	15678	108	0	0
			ECE 15-03	1151532	992997	578672	143423	7184	23	0
			ECE 15-04	3144335	3065010	2633307	1585524	444174	30917	192
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	0	2616746	2550804	2213462	1357507	387242	27238
			EURO 2	0	0	2765378	2698111	2349248	1452664	419735
			EURO 3	0	0	0	2377765	2309952	1973412	1151544
			EURO 4	0	0	0	626888	3892126	7023573	9578214
		1.4 - 2.0 l	Pre ECE	75535	4792	60	0	0	0	0
			ECE 15-00/01	539764	227098	35909	805	0	0	0
			ECE 15-02	298495	206199	71292	6047	42	0	0
			ECE 15-03	444162	383013	223202	55320	2771	9	0
			ECE 15-04	1212815	1182218	1015704	611559	171324	11925	74
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	0	1009316	983881	853764	523610	149365	10506
			EURO 2	0	0	1066646	1040700	906138	560313	161898
			EURO 3	0	0	0	917138	890981	761173	444167
			EURO 4	0	0	0	241800	1501249	2709092	3694454
		>2.0 l	Pre ECE	8393	532	7	0	0	0	0
			ECE 15-00/01	59974	25233	3990	89	0	0	0
			ECE 15-02	33166	22911	7921	672	5	0	0
			ECE 15-03	49351	42557	24800	6147	308	1	0
			ECE 15-04	134757	131358	112856	67951	19036	1325	8
			EURO 1	0	112146	109320	94863	58179	16596	1167
			EURO 2	0	0	118516	115633	100682	62257	17989
			EURO 3	0	0	0	101904	98998	84575	49352
			EURO 4	0	0	0	26867	166805	301010	410495
	Diesel	<2.0 l	Uncontrolled	940179	630754	317033	93581	9503	119	0
			EURO 1	498819	1055250	1101842	870635	467533	130962	11997
			EURO 2	0	0	481545	472508	420093	272514	84474
			EURO 3	0	0	0	512480	497880	425404	248346
			EURO 4	0	0	0	135281	840257	1514319	2065686
		>2.0 l	Uncontrolled	626786	420503	211355	62387	6336	79	0
			EURO 1	332546	703500	734561	580423	311689	87308	7998
			EURO 2	0	0	321030	315006	280062	181676	56316
			EURO 3	0	0	0	341653	331920	283602	165564
			EURO 4	0	0	0	90187	560171	1009546	1377124
	LPG	All	Uncontrolled	470	315	159	47	5	0	0
			EURO 1	249	528	551	436	234	66	6
			EURO 2	0	0	241	236	210	136	42
			EURO 3	0	0	0	257	249	213	124
			EURO 4	0	0	0	68	420	758	1034
	2-stroke	All	Uncontrolled	0	0	0	0	0	0	0

Table A76a (continued). Fleet composition of Spain

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Light goods vehicles	Gasoline	All	Uncontrolled	562773	630652	494872	284250	70462	1600	0
			EURO 1	0	43541	135066	131839	103582	24389	66
			EURO 2	0	0	152906	208867	198028	128577	15633
			EURO 3	0	0	0	262312	611320	909438	1111222
			EURO 4	0	0	0	0	0	0	0
	Diesel	All	Uncontrolled	1397270	1565801	1228682	705743	174944	3972	0
			EURO 1	0	108104	456087	447198	365757	111500	1092
			EURO 2	0	0	258898	398717	383089	268289	37886
			EURO 3	0	0	0	651275	1517803	2257979	2758975
			EURO 4	0	0	0	0	0	0	0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	170775	166776	125710	63672	9315	22	0
			EURO 1	0	37809	51271	48600	31507	3803	2
			EURO 2	0	0	60575	60191	55286	29806	1885
			EURO 3	0	0	0	96781	202304	289243	340080
			EURO 4	0	0	0	0	0	0	0
		7.5 - 16 t	Conventional	77180	75373	56813	28776	4210	10	0
			EURO 1	0	17087	23171	21964	14239	1719	1
			EURO 2	0	0	27376	27202	24986	13471	852
			EURO 3	0	0	0	43739	91429	130720	153696
			EURO 4	0	0	0	0	0	0	0
		16 - 32 t	Conventional	124265	121355	91473	46331	6778	16	0
			EURO 1	0	27512	37307	35364	22926	2767	1
			EURO 2	0	0	44078	43798	40229	21689	1371
			EURO 3	0	0	0	70432	147208	210469	247461
			EURO 4	0	0	0	0	0	0	0
		>32 t	Conventional	10449	10204	7691	3896	570	1	0
			EURO 1	0	2313	3137	2974	1928	233	0
			EURO 2	0	0	3706	3683	3383	1824	115
			EURO 3	0	0	0	5921	12378	17697	20807
			EURO 4	0	0	0	0	0	0	0
		Buses	Conventional	22879	20222	13316	8412	2540	23	0
			EURO 1	0	3280	4811	4777	4249	1414	2
			EURO 2	0	0	5905	5902	5811	4641	752
			EURO 3	0	0	0	5434	12330	19044	24342
			EURO 4	0	0	0	0	0	0	0
		Coaches	Conventional	22879	20222	13316	8412	2540	23	0
			EURO 1	0	3280	4811	4777	4249	1414	2
			EURO 2	0	0	5905	5902	5811	4641	752
			EURO 3	0	0	0	5434	12330	19044	24342
			EURO 4	0	0	0	0	0	0	0
Motorcycles	Gasoline	<50 cc	Uncontrolled	2751658	2812006	2046913	1159151	532885	N/A	N/A
			Stage I	0	0	397550	355471	258432	N/A	N/A
			Stage II	0	0	415588	1361987	2101322	N/A	N/A
		>50 cc 2-s	Uncontrolled	876754	895982	652203	369337	169792	N/A	N/A
			Controlled	0	0	259088	547230	751882	N/A	N/A
		>50 cc 4-s	Uncontrolled	472098	482452	351186	198874	91426	N/A	N/A
			Controlled	0	0	139509	294662	404860	N/A	N/A

Table A76b. Annual mileage, mileage distribution and representative speeds for Spain (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Passenger cars	Gasoline	<1.4 l	Pre ECE	5794	30.5	30.6	38.9	20.0	60.0	83.0
			ECE 15-00/01	6537	30.5	30.6	38.9	20.0	60.0	83.0
			ECE 15-02	7058	30.5	30.6	38.9	20.0	60.0	83.0
			ECE 15-03	7742	30.5	30.6	38.9	20.0	60.0	83.0
			ECE 15-04	9344	30.5	30.6	38.9	20.0	60.0	83.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	11723	30.5	30.6	38.9	20.0	60.0	83.0
			EURO 2	11723	30.5	30.6	38.9	20.0	60.0	83.0
			EURO 3	11723	30.5	30.6	38.9	20.0	60.0	83.0
			EURO 4	11723	30.5	30.6	38.9	20.0	60.0	83.0
		1.4 - 2.0 l	Pre ECE	5794	30.5	30.6	38.9	20.0	60.0	83.0
			ECE 15-00/01	6537	30.5	30.6	38.9	20.0	60.0	83.0
			ECE 15-02	7058	30.5	30.6	38.9	20.0	60.0	83.0
			ECE 15-03	7742	30.5	30.6	38.9	20.0	60.0	83.0
			ECE 15-04	9344	30.5	30.6	38.9	20.0	60.0	83.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	11723	30.5	30.6	38.9	20.0	60.0	83.0
			EURO 2	11723	30.5	30.6	38.9	20.0	60.0	83.0
			EURO 3	11723	30.5	30.6	38.9	20.0	60.0	83.0
			EURO 4	11723	30.5	30.6	38.9	20.0	60.0	83.0
		>2.0 l	Pre ECE	5794	30.5	30.6	38.9	20.0	60.0	83.0
			ECE 15-00/01	6537	30.5	30.6	38.9	20.0	60.0	83.0
			ECE 15-02	7058	30.5	30.6	38.9	20.0	60.0	83.0
			ECE 15-03	7742	30.5	30.6	38.9	20.0	60.0	83.0
			ECE 15-04	9344	30.5	30.6	38.9	20.0	60.0	83.0
			EURO 1	11723	30.5	30.6	38.9	20.0	60.0	83.0
			EURO 2	11723	30.5	30.6	38.9	20.0	60.0	83.0
			EURO 3	11723	30.5	30.6	38.9	20.0	60.0	83.0
			EURO 4	11723	30.5	30.6	38.9	20.0	60.0	83.0
	Diesel	<2.0 l	Uncontrolled	12633	68.8	13.7	17.5	20.0	60.0	83.0
			EURO 1	17916	68.8	13.7	17.5	20.0	60.0	83.0
			EURO 2	17916	68.8	13.7	17.5	20.0	60.0	83.0
			EURO 3	17916	68.8	13.7	17.5	20.0	60.0	83.0
			EURO 4	17916	68.8	13.7	17.5	20.0	60.0	83.0
		>2.0 l	Uncontrolled	12633	68.8	13.7	17.5	20.0	60.0	83.0
			EURO 1	17916	68.8	13.7	17.5	20.0	60.0	83.0
			EURO 2	17916	68.8	13.7	17.5	20.0	60.0	83.0
			EURO 3	17916	68.8	13.7	17.5	20.0	60.0	83.0
			EURO 4	17916	68.8	13.7	17.5	20.0	60.0	83.0
	LPG	All	Uncontrolled	12633	100.0	0.0	0.0	20.0	60.0	83.0
			EURO 1	17916	100.0	0.0	0.0	20.0	60.0	83.0
			EURO 2	17916	100.0	0.0	0.0	20.0	60.0	83.0
			EURO 3	17916	100.0	0.0	0.0	20.0	60.0	83.0
			EURO 4	17916	100.0	0.0	0.0	20.0	60.0	83.0
	2-stroke	All	Uncontrolled	-	-	-	-	-	-	-

Table A76b (continued). Annual mileage, mileage distribution and representative speeds for Spain (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Light goods vehicles	Gasoline	All	Uncontrolled	22500	42.0	27.0	31.0	20.0	60.0	83.0
			EURO 1	22500	42.0	27.0	31.0	20.0	60.0	83.0
			EURO 2	22500	42.0	27.0	31.0	20.0	60.0	83.0
			EURO 3	22500	42.0	27.0	31.0	20.0	60.0	83.0
			EURO 4	22500	42.0	27.0	31.0	20.0	60.0	83.0
	Diesel	All	Uncontrolled	30000	78.0	10.0	12.0	20.0	60.0	83.0
			EURO 1	30000	78.0	10.0	12.0	20.0	60.0	83.0
			EURO 2	30000	78.0	10.0	12.0	20.0	60.0	83.0
			EURO 3	30000	78.0	10.0	12.0	20.0	60.0	83.0
			EURO 4	30000	78.0	10.0	12.0	20.0	60.0	83.0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	55000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 1	55000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 2	55000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 3	55000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 4	55000	40.0	50.0	10.0	20.0	60.0	90.0
		7.5 - 16 t	Conventional	55000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 1	55000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 2	55000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 3	55000	40.0	50.0	10.0	20.0	60.0	90.0
			EURO 4	55000	40.0	50.0	10.0	20.0	60.0	90.0
		16 - 32 t	Conventional	70000	24.9	27.8	47.3	20.0	60.0	90.0
			EURO 1	70000	24.9	27.8	47.3	20.0	60.0	90.0
			EURO 2	70000	24.9	27.8	47.3	20.0	60.0	90.0
			EURO 3	70000	24.9	27.8	47.3	20.0	60.0	90.0
			EURO 4	70000	24.9	27.8	47.3	20.0	60.0	90.0
		>32 t	Conventional	70000	24.9	27.8	47.3	20.0	60.0	90.0
			EURO 1	70000	24.9	27.8	47.3	20.0	60.0	90.0
			EURO 2	70000	24.9	27.8	47.3	20.0	60.0	90.0
			EURO 3	70000	24.9	27.8	47.3	20.0	60.0	90.0
			EURO 4	70000	24.9	27.8	47.3	20.0	60.0	90.0
		Buses	Conventional	27987	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 1	27987	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 2	27987	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 3	27987	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 4	27987	100.0	0.0	0.0	20.0	60.0	90.0
		Coaches	Conventional	27987	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 1	27987	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 2	27987	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 3	27987	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 4	27987	0.0	50.0	50.0	20.0	60.0	90.0
Motorcycles	Gasoline	<50 cc	Uncontrolled	2067	100.0	0.0	0.0	N/A	N/A	N/A
			Stage I	2067	100.0	0.0	0.0	N/A	N/A	N/A
			Stage II	2067	100.0	0.0	0.0	N/A	N/A	N/A
		>50 cc 2-s	Uncontrolled	3403	73.7	12.7	13.6	N/A	N/A	N/A
			Controlled	3403	73.7	12.7	13.6	N/A	N/A	N/A
		>50 cc 4-s	Uncontrolled	3403	73.7	12.7	13.6	N/A	N/A	N/A
			Controlled	3403	73.7	12.7	13.6	N/A	N/A	N/A

Table A77a. Fleet composition of Sweden

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Passenger cars	Gasoline	<1.4 l	Pre ECE	28635	1712	12	0	0	0	0
			ECE 15-00/01	209862	116427	28850	431	0	0	0
			ECE 15-02	160249	136341	79272	10009	0	0	0
			ECE 15-03	266301	254778	213064	94641	6200	0	0
			ECE 15-04	592683	589656	572049	473730	214761	19452	0
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	0	279190	278476	270875	226603	104158	9790
			EURO 2	0	0	305124	304524	297723	255833	128687
			EURO 3	0	0	0	328324	327501	318553	265643
			EURO 4	0	0	0	92306	597099	1066186	1457917
		1.4 - 2.0 l	Pre ECE	38691	2314	16	0	0	0	0
			ECE 15-00/01	283567	157316	38983	583	0	0	0
			ECE 15-02	216530	184225	107113	13524	0	0	0
			ECE 15-03	359827	344258	287893	127880	8377	0	0
			ECE 15-04	800838	796748	772957	640107	290186	26284	0
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	0	377243	376279	366008	306187	140739	13228
			EURO 2	0	0	412286	411474	402286	345684	173882
			EURO 3	0	0	0	443633	442522	430431	358938
			EURO 4	0	0	0	124724	806804	1440637	1969947
		>2.0 l	Pre ECE	9443	565	4	0	0	0	0
			ECE 15-00/01	69204	38393	9514	142	0	0	0
			ECE 15-02	52844	44960	26141	3300	0	0	0
			ECE 15-03	87815	84015	70260	31209	2044	0	0
			ECE 15-04	195442	194444	188638	156217	70819	6414	0
			EURO 1	0	92065	91830	89323	74724	34347	3228
			EURO 2	0	0	100617	100419	98177	84363	42436
			EURO 3	0	0	0	108268	107996	105046	87598
			EURO 4	0	0	0	30439	196899	351584	480761
	Diesel	<2.0 l	Uncontrolled	40125	32548	23047	10440	1536	7	0
			EURO 1	20299	33659	35644	32767	22240	7627	930
			EURO 2	0	0	12261	12244	12029	10595	5723
			EURO 3	0	0	0	15773	15734	15304	12762
			EURO 4	0	0	0	4435	28686	51222	70041
		>2.0 l	Uncontrolled	26750	21699	15364	6960	1024	5	0
			EURO 1	13533	22439	23762	21844	14827	5085	620
			EURO 2	0	0	8174	8162	8019	7063	3815
			EURO 3	0	0	0	10516	10489	10203	8508
			EURO 4	0	0	0	2956	19124	34148	46694
	LPG	All	Uncontrolled	0	0	0	0	0	0	0
			EURO 1	0	0	0	0	0	0	0
			EURO 2	0	0	0	0	0	0	0
			EURO 3	0	0	0	0	0	0	0
			EURO 4	0	0	0	0	0	0	0
	2-stroke	All	Uncontrolled	0	0	0	0	0	0	0

Table A77a (continued). Fleet composition of Sweden

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Light goods vehicles	Gasoline	All	Uncontrolled	178390	202076	197059	163168	75183	10484	78
			EURO 1	0	6824	18607	18586	18217	14500	2650
			EURO 2	0	0	20920	29576	29494	28265	18678
			EURO 3	0	0	0	52770	167930	263693	321729
			EURO 4	0	0	0	0	0	0	0
	Diesel	All	Uncontrolled	28402	32173	31374	25979	11970	1669	12
			EURO 1	0	1087	3979	3975	3911	3238	842
			EURO 2	0	0	2314	3693	3686	3571	2554
			EURO 3	0	0	0	8402	26737	41984	51224
			EURO 4	0	0	0	0	0	0	0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	21275	22650	22051	18016	7616	541	0
			EURO 1	0	2264	2951	2942	2813	1817	139
			EURO 2	0	0	3213	3212	3196	2979	1596
			EURO 3	0	0	0	7326	21059	32462	39188
			EURO 4	0	0	0	0	0	0	0
		7.5 - 16 t	Conventional	23374	24884	24227	19794	8368	595	0
			EURO 1	0	2488	3242	3233	3090	1997	152
			EURO 2	0	0	3530	3529	3511	3272	1753
			EURO 3	0	0	0	8049	23137	35665	43055
			EURO 4	0	0	0	0	0	0	0
		16 - 32 t	Conventional	27666	29454	28676	23428	9904	704	0
			EURO 1	0	2944	3838	3826	3658	2363	180
			EURO 2	0	0	4178	4177	4156	3873	2075
			EURO 3	0	0	0	9527	27386	42213	50961
			EURO 4	0	0	0	0	0	0	0
		>32 t	Conventional	397	423	412	336	142	10	0
			EURO 1	0	42	55	55	53	34	3
			EURO 2	0	0	60	60	60	56	30
			EURO 3	0	0	0	137	393	606	732
			EURO 4	0	0	0	0	0	0	0
		Buses	Conventional	11119	9153	2940	72	0	0	0
			EURO 1	0	1874	2773	1601	18	0	0
			EURO 2	0	0	4996	4683	1716	2	0
			EURO 3	0	0	0	3991	8190	9453	8958
			EURO 4	0	0	0	0	0	0	0
		Coaches	Conventional	2780	2288	735	18	0	0	0
			EURO 1	0	469	693	400	4	0	0
			EURO 2	0	0	1249	1171	429	0	0
			EURO 3	0	0	0	998	2048	2363	2239
			EURO 4	0	0	0	0	0	0	0
Motorcycles	Gasoline	<50 cc	Uncontrolled	0	0	0	0	0	0	0
			Stage I	0	0	0	0	0	0	0
			Stage II	0	0	0	0	0	0	0
		>50 cc 2-s	Uncontrolled	0	0	0	0	0	0	0
			Controlled	0	0	0	0	0	0	0
		>50 cc 4-s	Uncontrolled	105311	123897	28351	1001	5	N/A	N/A
			Controlled	0	0	113353	155494	169780	N/A	N/A

Table A77b. Annual mileage, mileage distribution and representative speeds for Sweden (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Passenger cars	Gasoline	<1.4 l	Pre ECE	5000	27.1	48.8	24.1	25.0	50.0	103.0
			ECE 15-00/01	11000	27.1	48.8	24.1	25.0	50.0	103.0
			ECE 15-02	11000	27.1	48.8	24.1	25.0	50.0	103.0
			ECE 15-03	11000	27.1	48.8	24.1	25.0	50.0	103.0
			ECE 15-04	11000	27.1	48.8	24.1	25.0	50.0	103.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	11000	27.1	48.8	24.1	25.0	50.0	103.0
			EURO 2	11000	27.1	48.8	24.1	25.0	50.0	103.0
			EURO 3	11000	27.1	48.8	24.1	25.0	50.0	103.0
			EURO 4	11000	27.1	48.8	24.1	25.0	50.0	103.0
		1.4 - 2.0 l	Pre ECE	7000	27.1	48.8	24.1	25.0	50.0	105.0
			ECE 15-00/01	15000	27.1	48.8	24.1	25.0	50.0	105.0
			ECE 15-02	15000	27.1	48.8	24.1	25.0	50.0	105.0
			ECE 15-03	15000	27.1	48.8	24.1	25.0	50.0	105.0
			ECE 15-04	15000	27.1	48.8	24.1	25.0	50.0	105.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	15000	27.1	48.8	24.1	25.0	50.0	105.0
			EURO 2	15000	27.1	48.8	24.1	25.0	50.0	105.0
			EURO 3	15000	27.1	48.8	24.1	25.0	50.0	105.0
			EURO 4	15000	27.1	48.8	24.1	25.0	50.0	105.0
		>2.0 l	Pre ECE	9000	27.1	48.8	24.1	25.0	50.0	110.0
			ECE 15-00/01	19000	27.1	48.8	24.1	25.0	50.0	110.0
			ECE 15-02	19000	27.1	48.8	24.1	25.0	50.0	110.0
			ECE 15-03	19000	27.1	48.8	24.1	25.0	50.0	110.0
			ECE 15-04	19000	27.1	48.8	24.1	25.0	50.0	110.0
			EURO 1	19000	27.1	48.8	24.1	25.0	50.0	110.0
			EURO 2	19000	27.1	48.8	24.1	25.0	50.0	110.0
			EURO 3	19000	27.1	48.8	24.1	25.0	50.0	110.0
			EURO 4	19000	27.1	48.8	24.1	25.0	50.0	110.0
	Diesel	<2.0 l	Uncontrolled	22000	27.1	48.8	24.1	25.0	50.0	105.0
			EURO 1	22000	27.1	48.8	24.1	25.0	50.0	105.0
			EURO 2	22000	27.1	48.8	24.1	25.0	50.0	105.0
			EURO 3	22000	27.1	48.8	24.1	25.0	50.0	105.0
			EURO 4	22000	27.1	48.8	24.1	25.0	50.0	105.0
		>2.0 l	Uncontrolled	22000	27.1	48.8	24.1	25.0	50.0	105.0
			EURO 1	22000	27.1	48.8	24.1	25.0	50.0	105.0
			EURO 2	22000	27.1	48.8	24.1	25.0	50.0	105.0
			EURO 3	22000	27.1	48.8	24.1	25.0	50.0	105.0
			EURO 4	22000	27.1	48.8	24.1	25.0	50.0	105.0
	LPG	All	Uncontrolled	-	-	-	-	-	-	-
			EURO 1	-	-	-	-	-	-	-
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
	2-stroke	All	Uncontrolled	-	-	-	-	-	-	-

Table A77b (continued). Annual mileage, mileage distribution and representative speeds for Sweden (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Light goods vehicles	Gasoline	All	Uncontrolled	20000	27.1	48.8	24.1	25.0	50.0	105.0
			EURO 1	20000	27.1	48.8	24.1	25.0	50.0	105.0
			EURO 2	20000	27.1	48.8	24.1	25.0	50.0	105.0
			EURO 3	20000	27.1	48.8	24.1	25.0	50.0	105.0
			EURO 4	20000	27.1	48.8	24.1	25.0	50.0	105.0
	Diesel	All	Uncontrolled	35000	27.1	48.8	24.1	25.0	50.0	105.0
			EURO 1	35000	27.1	48.8	24.1	25.0	50.0	105.0
			EURO 2	35000	27.1	48.8	24.1	25.0	50.0	105.0
			EURO 3	35000	27.1	48.8	24.1	25.0	50.0	105.0
			EURO 4	35000	27.1	48.8	24.1	25.0	50.0	105.0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	55000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 1	55000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 2	55000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 3	55000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 4	55000	25.9	39.8	34.3	20.0	60.0	90.0
		7.5 - 16 t	Conventional	55000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 1	55000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 2	55000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 3	55000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 4	55000	25.9	39.8	34.3	20.0	60.0	90.0
		16 - 32 t	Conventional	60000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 1	60000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 2	60000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 3	60000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 4	60000	25.9	39.8	34.3	20.0	60.0	90.0
		>32 t	Conventional	60000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 1	60000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 2	60000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 3	60000	25.9	39.8	34.3	20.0	60.0	90.0
			EURO 4	60000	25.9	39.8	34.3	20.0	60.0	90.0
		Buses	Conventional	60000	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 1	60000	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 2	60000	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 3	60000	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 4	60000	100.0	0.0	0.0	20.0	60.0	90.0
		Coaches	Conventional	60000	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 1	60000	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 2	60000	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 3	60000	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 4	60000	0.0	50.0	50.0	20.0	60.0	90.0
Motorcycles	Gasoline	<50 cc	Uncontrolled	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			Stage I	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			Stage II	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		>50 cc 2-s	Uncontrolled	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			Controlled	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		>50 cc 4-s	Uncontrolled	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			Controlled	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table A78a. Fleet composition of the United Kingdom

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Passenger cars	Gasoline	<1.4 l	Pre ECE	0	0	0	0	0	0	0
			ECE 15-00/01	104116	611	0	0	0	0	0
			ECE 15-02	746658	67584	21	0	0	0	0
			ECE 15-03	2380213	1054306	42462	2	0	0	0
			ECE 15-04	5341606	4678292	2126571	139706	37	0	0
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	0	3795650	3446297	1751745	130665	39	0
			EURO 2	0	0	4958416	4489256	2241637	159697	46
			EURO 3	0	0	0	4084097	3614563	1554697	58030
			EURO 4	0	0	0	1011362	6340473	11426410	13868684
		1.4 - 2.0 l	Pre ECE	0	0	0	0	0	0	0
			ECE 15-00/01	105721	620	0	0	0	0	0
			ECE 15-02	758170	68626	21	0	0	0	0
			ECE 15-03	2416912	1070562	43116	2	0	0	0
			ECE 15-04	5423965	4750424	2159360	141861	38	0	0
			Improved conventional	0	0	0	0	0	0	0
			Open loop	0	0	0	0	0	0	0
			EURO 1	0	3854174	3499434	1778755	132680	39	0
			EURO 2	0	0	5034867	4558474	2276199	162159	47
			EURO 3	0	0	0	4147067	3670294	1578668	58924
			EURO 4	0	0	0	1026956	6438233	11602588	14082518
		>2.0 l	Pre ECE	0	0	0	0	0	0	0
			ECE 15-00/01	19493	114	0	0	0	0	0
			ECE 15-02	139793	12653	4	0	0	0	0
			ECE 15-03	445635	197392	7950	0	0	0	0
			ECE 15-04	842656	722906	288749	10825	0	0	0
			EURO 1	157425	863625	754630	343302	24470	7	0
			EURO 2	0	0	928338	840499	419690	29899	9
			EURO 3	0	0	0	764644	676735	291078	10865
			EURO 4	0	0	0	189352	1187093	2139306	2596560
	Diesel	<2.0 l	Uncontrolled	524269	253064	29902	44	0	0	0
			EURO 1	406261	788602	679205	285204	33253	50	0
			EURO 2	0	0	438645	407359	224258	17289	5
			EURO 3	0	0	0	443317	392350	168758	6299
			EURO 4	0	0	0	109780	688240	1240304	1505405
		>2.0 l	Uncontrolled	349513	168710	19934	29	0	0	0
			EURO 1	270840	525734	452803	190136	22169	33	0
			EURO 2	0	0	292430	271573	149573	11526	3
			EURO 3	0	0	0	295545	261567	112505	4199
			EURO 4	0	0	0	73187	458827	826869	1003604
	LPG	All	Uncontrolled	0	0	0	0	0	0	0
			EURO 1	0	0	0	0	0	0	0
			EURO 2	0	0	0	0	0	0	0
			EURO 3	0	0	0	0	0	0	0
			EURO 4	0	0	0	0	0	0	0
	2-stroke	All	Uncontrolled	0	0	0	0	0	0	0

Table A78a (continued). Fleet composition of the United Kingdom

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Light goods vehicles	Gasoline	All	Uncontrolled	1004364	984086	478685	62722	5	0	0
			EURO 1	0	103652	321880	230174	10105	0	0
			EURO 2	0	0	367218	471063	229689	2178	0
			EURO 3	0	0	0	478443	1075058	1384688	1459565
			EURO 4	0	0	0	0	0	0	0
	Diesel	All	Uncontrolled	908774	890426	433126	56752	5	0	0
			EURO 1	0	93787	398368	305252	30246	0	0
			EURO 2	0	0	225145	329245	186726	1971	0
			EURO 3	0	0	0	432908	972740	1252901	1320652
			EURO 4	0	0	0	0	0	0	0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	74509	58969	22487	608	0	0	0
			EURO 1	0	21726	28500	14117	139	0	0
			EURO 2	0	0	35646	32707	10962	15	0
			EURO 3	0	0	0	44736	86443	102871	108279
			EURO 4	0	0	0	0	0	0	0
		7.5 - 16 t	Conventional	153897	121799	46446	1257	0	0	0
			EURO 1	0	44874	58865	29158	287	0	0
			EURO 2	0	0	73626	67556	22641	31	0
			EURO 3	0	0	0	92401	178545	212476	223647
			EURO 4	0	0	0	0	0	0	0
		16 - 32 t	Conventional	234157	185319	70668	1912	0	0	0
			EURO 1	0	68276	89564	44364	437	0	0
			EURO 2	0	0	112024	102787	34448	47	0
			EURO 3	0	0	0	140589	271660	323268	340282
			EURO 4	0	0	0	0	0	0	0
		>32 t	Conventional	15810	12512	4771	129	0	0	0
			EURO 1	0	4610	6047	2995	29	0	0
			EURO 2	0	0	7563	6940	2326	3	0
			EURO 3	0	0	0	9492	18342	21827	22975
			EURO 4	0	0	0	0	0	0	0
		Buses	Conventional	63552	42475	20272	875	0	0	0
			EURO 1	0	21121	24987	13787	89	0	0
			EURO 2	0	0	17845	17130	7325	5	0
			EURO 3	0	0	0	30190	52985	58383	55931
			EURO 4	0	0	0	0	0	0	0
		Coaches	Conventional	15888	10619	5068	219	0	0	0
			EURO 1	0	5280	6247	3447	22	0	0
			EURO 2	0	0	4461	4283	1831	1	0
			EURO 3	0	0	0	7548	13246	14596	13983
			EURO 4	0	0	0	0	0	0	0
Motorcycles	Gasoline	<50 cc	Uncontrolled	368000	336099	208266	100465	36092	N/A	N/A
			Stage I	0	0	49118	44083	28558	N/A	N/A
			Stage II	0	0	44996	122379	166139	N/A	N/A
		>50 cc 2-s	Uncontrolled	196060	195568	133339	68844	23920	N/A	N/A
			Controlled	0	0	61174	123938	167069	N/A	N/A
		>50 cc 4-s	Uncontrolled	1372418	1368973	933372	481906	167441	N/A	N/A
			Controlled	0	0	428216	867567	1169480	N/A	N/A

Table A78b. Annual mileage, mileage distribution and representative speeds for the United Kingdom (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Passenger cars	Gasoline	<1.4 l	Pre ECE	-	-	-	-	-	-	-
			ECE 15-00/01	5376	46.0	40.0	14.0	25.0	75.0	115.0
			ECE 15-02	6560	46.0	40.0	14.0	25.0	75.0	115.0
			ECE 15-03	8422	46.0	40.0	14.0	25.0	75.0	115.0
			ECE 15-04	11907	46.0	40.0	14.0	25.0	75.0	115.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	17563	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 2	17563	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 3	17563	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 4	17563	46.0	40.0	14.0	25.0	75.0	115.0
		1.4 - 2.0 l	Pre ECE	-	-	-	-	-	-	-
			ECE 15-00/01	5376	46.0	40.0	14.0	25.0	75.0	115.0
			ECE 15-02	6560	46.0	40.0	14.0	25.0	75.0	115.0
			ECE 15-03	8422	46.0	40.0	14.0	25.0	75.0	115.0
			ECE 15-04	11907	46.0	40.0	14.0	25.0	75.0	115.0
			Improved conventional	-	-	-	-	-	-	-
			Open loop	-	-	-	-	-	-	-
			EURO 1	17563	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 2	17563	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 3	17563	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 4	17563	46.0	40.0	14.0	25.0	75.0	115.0
		>2.0 l	Pre ECE	-	-	-	-	-	-	-
			ECE 15-00/01	5376	46.0	40.0	14.0	25.0	75.0	115.0
			ECE 15-02	6560	46.0	40.0	14.0	25.0	75.0	115.0
			ECE 15-03	8422	46.0	40.0	14.0	25.0	75.0	115.0
			ECE 15-04	11482	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 1	16916	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 2	16916	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 3	16916	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 4	16916	46.0	40.0	14.0	25.0	75.0	115.0
	Diesel	<2.0 l	Uncontrolled	13613	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 1	17904	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 2	17904	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 3	17904	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 4	17904	46.0	40.0	14.0	25.0	75.0	115.0
		>2.0 l	Uncontrolled	13613	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 1	17904	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 2	17904	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 3	17904	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 4	17904	46.0	40.0	14.0	25.0	75.0	115.0
	LPG	All	Uncontrolled	-	-	-	-	-	-	-
			EURO 1	-	-	-	-	-	-	-
			EURO 2	-	-	-	-	-	-	-
			EURO 3	-	-	-	-	-	-	-
			EURO 4	-	-	-	-	-	-	-
	2-stroke	All	Uncontrolled	-	-	-	-	-	-	-

Table A78b (continued). Annual mileage, mileage distribution and representative speeds for the United Kingdom (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Light goods vehicles	Gasoline	All	Uncontrolled	17000	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 1	17000	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 2	17000	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 3	17000	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 4	17000	46.0	40.0	14.0	25.0	75.0	115.0
	Diesel	All	Uncontrolled	16500	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 1	16500	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 2	16500	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 3	16500	46.0	40.0	14.0	25.0	75.0	115.0
			EURO 4	16500	46.0	40.0	14.0	25.0	75.0	115.0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	60000	29.0	43.0	28.0	20.0	60.0	90.0
			EURO 1	60000	29.0	43.0	28.0	20.0	60.0	90.0
			EURO 2	60000	29.0	43.0	28.0	20.0	60.0	90.0
			EURO 3	60000	29.0	43.0	28.0	20.0	60.0	90.0
			EURO 4	60000	29.0	43.0	28.0	20.0	60.0	90.0
		7.5 - 16 t	Conventional	60000	29.0	43.0	28.0	20.0	60.0	90.0
			EURO 1	60000	29.0	43.0	28.0	20.0	60.0	90.0
			EURO 2	60000	29.0	43.0	28.0	20.0	60.0	90.0
			EURO 3	60000	29.0	43.0	28.0	20.0	60.0	90.0
			EURO 4	60000	29.0	43.0	28.0	20.0	60.0	90.0
		16 - 32 t	Conventional	60000	29.0	43.0	28.0	20.0	60.0	90.0
			EURO 1	60000	29.0	43.0	28.0	20.0	60.0	90.0
			EURO 2	60000	29.0	43.0	28.0	20.0	60.0	90.0
			EURO 3	60000	29.0	43.0	28.0	20.0	60.0	90.0
			EURO 4	60000	29.0	43.0	28.0	20.0	60.0	90.0
		>32 t	Conventional	60000	29.0	43.0	28.0	20.0	60.0	90.0
			EURO 1	60000	29.0	43.0	28.0	20.0	60.0	90.0
			EURO 2	60000	29.0	43.0	28.0	20.0	60.0	90.0
			EURO 3	60000	29.0	43.0	28.0	20.0	60.0	90.0
			EURO 4	60000	29.0	43.0	28.0	20.0	60.0	90.0
		Buses	Conventional	60000	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 1	60000	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 2	60000	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 3	60000	100.0	0.0	0.0	20.0	60.0	90.0
			EURO 4	60000	100.0	0.0	0.0	20.0	60.0	90.0
		Coaches	Conventional	60000	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 1	60000	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 2	60000	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 3	60000	0.0	50.0	50.0	20.0	60.0	90.0
			EURO 4	60000	0.0	50.0	50.0	20.0	60.0	90.0
Motorcycles	Gasoline	<50 cc	Uncontrolled	5000	100.0	0.0	0.0	N/A	N/A	N/A
			Stage I	5000	100.0	0.0	0.0	N/A	N/A	N/A
			Stage II	5000	100.0	0.0	0.0	N/A	N/A	N/A
		>50 cc 2-s	Uncontrolled	5000	54.0	39.0	7.0	N/A	N/A	N/A
			Controlled	5000	54.0	39.0	7.0	N/A	N/A	N/A
		>50 cc 4-s	Uncontrolled	5000	54.0	39.0	7.0	N/A	N/A	N/A
			Controlled	5000	54.0	39.0	7.0	N/A	N/A	N/A

Table A79a. Fleet composition of the EU15

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Passenger cars	Gasoline	<1.4 l	Pre ECE	1021070	86255	17607	1286	0	0	0
			ECE 15-00/01	6475731	2512760	643928	142382	0	0	0
			ECE 15-02	8223269	3408434	1213514	243321	43135	0	0
			ECE 15-03	16358551	10786820	4315452	1327218	289594	33918	0
			ECE 15-04	28129882	25727216	18008216	9087375	3026898	590933	66752
			Improved conventional	2622375	2775255	1445294	78331	392	0	0
			Open loop	1163049	1283641	741714	54718	10126	7546	3144
			EURO 1	2046401	29757551	27797214	18670060	7945842	2591545	580217
			EURO 2	0	0	30129786	28534721	20022398	8364965	2682841
			EURO 3	0	0	0	26547831	24903256	16910963	6860060
			EURO 4	0	0	0	6843364	41505927	74614254	96699551
		1.4 - 2.0 l	Pre ECE	299931	23281	3997	185	0	0	0
			ECE 15-00/01	2505609	803620	201438	38319	0	0	0
			ECE 15-02	5085304	1321898	396362	83725	11049	0	0
			ECE 15-03	11108954	6488579	1481161	439587	94230	4886	0
			ECE 15-04	16671074	14900369	8504923	3137095	1014124	199003	15216
			Improved conventional	881557	975838	515072	15741	64	0	0
			Open loop	1105784	1176860	572818	37405	1791	1086	452
			EURO 1	4632960	24711765	21663290	11389737	2777916	757541	152320
			EURO 2	0	0	21824563	20404085	12466365	2985261	799616
			EURO 3	0	0	0	19017002	17548321	9823400	2261164
			EURO 4	0	0	0	4850665	29097586	52224126	65251799
		>2.0 l	Pre ECE	38541	3083	619	33	0	0	0
			ECE 15-00/01	336379	104849	29232	5703	0	0	0
			ECE 15-02	869685	179605	54579	12400	1658	0	0
			ECE 15-03	1984944	1122457	196033	63742	13936	873	0
			ECE 15-04	2524515	2235188	1130907	395188	143548	28795	2173
			EURO 1	1686907	5513757	4520158	2026585	366907	101126	23086
			EURO 2	0	0	4084022	3799462	2198947	394415	105330
			EURO 3	0	0	0	3565536	3270165	1705738	289058
			EURO 4	0	0	0	908011	5418393	9710936	11967161
	Diesel	<2.0 l	Uncontrolled	7246304	4504625	1463252	354876	50317	5092	58
			EURO 1	4356769	10400150	9749753	5511770	1826876	418300	49547
			EURO 2	0	0	5063975	4811714	3311837	1054474	270578
			EURO 3	0	0	0	5425605	5005611	3023927	900494
			EURO 4	0	0	0	1389559	8323444	14830483	18592978
		>2.0 l	Uncontrolled	4536862	2813680	937427	235964	33546	3396	0
			EURO 1	2732163	6456915	6060376	3452626	1175107	278194	33031
			EURO 2	0	0	3145670	2989941	2061771	676292	180190
			EURO 3	0	0	0	3374939	3115316	1888370	585842
			EURO 4	0	0	0	86493	5185689	9244458	11696308
	LPG	All	Uncontrolled	1053661	681970	343189	99895	9086	274	16
			EURO 1	537735	1112665	1118167	822338	413449	111011	9709
			EURO 2	0	0	523962	508012	421499	247703	78764
			EURO 3	0	0	0	580073	553674	437546	238603
			EURO 4	0	0	0	150596	915251	1638171	2201336
	2-stroke	All	Uncontrolled	5300	6218	7088	7908	8665	9349	9960

Table A79a (continued). Fleet composition of the EU15

Vehicle class	Fuel	Size	Emission class	1990	1995	2000	2005	2010	2015	2020
Light goods vehicles	Gasoline	All	Uncontrolled	4077930	4063283	2638109	1158171	393129	115885	39644
			EURO 1	0	326663	1032523	845100	264177	93043	32226
			EURO 2	0	0	1179702	1551436	1032140	318872	105240
			EURO 3	0	0	0	1721132	3970941	5465773	6103164
			EURO 4	0	0	0	0	0	0	0
	Diesel	All	Uncontrolled	7169195	8040542	5280885	2302473	653112	134382	36981
			EURO 1	0	641685	2805462	2456435	1039219	335596	71271
			EURO 2	0	0	1587957	2380591	1827959	657402	170988
			EURO 3	0	0	0	3461806	7918581	11025296	12473901
			EURO 4	0	0	0	0	0	0	0
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	1758369	1618271	964125	384469	91537	11583	1745
			EURO 1	0	453450	606963	404570	149140	42366	5935
			EURO 2	0	0	741029	703197	402008	156678	33607
			EURO 3	0	0	0	1049289	2107881	2720843	3044463
			EURO 4	0	0	0	0	0	0	0
		7.5 - 16 t	Conventional	1218917	1106017	621710	245755	71924	14978	3529
			EURO 1	0	330694	437994	258258	84012	28143	7071
			EURO 2	0	0	538299	500650	242414	88694	23764
			EURO 3	0	0	0	748572	1497973	1890528	2098328
			EURO 4	0	0	0	0	0	0	0
		16 - 32 t	Conventional	1704852	1535592	798910	293990	85922	20264	5348
			EURO 1	0	487228	640553	340364	95628	29904	9329
			EURO 2	0	0	807883	735179	310167	99941	25377
			EURO 3	0	0	0	1091982	2166609	2682465	2946809
			EURO 4	0	0	0	0	0	0	0
		>32 t	Conventional	125365	99969	45802	13170	4100	1280	361
			EURO 1	0	35167	45952	22379	4709	1521	601
			EURO 2	0	0	58158	52169	19053	4674	1325
			EURO 3	0	0	0	76567	149056	180936	196348
			EURO 4	0	0	0	0	0	0	0
		Buses	Conventional	339492	298422	186095	80698	21557	2574	57
			EURO 1	0	70355	92250	74707	37885	10770	1300
			EURO 2	0	0	100479	98933	79415	42313	11485
			EURO 3	0	0	0	131662	250891	335610	378405
			EURO 4	0	0	0	0	0	0	0
		Coaches	Conventional	112805	98526	62426	30218	8884	1254	54
			EURO 1	0	22163	29416	24943	14699	4742	793
			EURO 2	0	0	31607	31217	26206	15596	4481
			EURO 3	0	0	0	38893	76274	104399	120265
			EURO 4	0	0	0	0	0	0	0
Motorcycles	Gasoline	<50 cc	Uncontrolled	13596599	13404995	8382156	3512641	1136618	N/A	N/A
			Stage I	0	0	2338569	1674954	733764	N/A	N/A
			Stage II	0	0	2384154	7012036	9779182	N/A	N/A
		>50 cc 2-s	Uncontrolled	1322416	1365113	969989	524257	227215	N/A	N/A
			Controlled	0	0	431446	900864	1219893	N/A	N/A
		>50 cc 4-s	Uncontrolled	6911355	7560547	4989826	2255237	806471	N/A	N/A
			Controlled	0	0	3020614	6017200	7635947	N/A	N/A

Table A79b. Annual mileage, mileage distribution and representative speeds for the EU15 (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Passenger cars	Gasoline	<1.4 l	Pre ECE	7495	44	42	14	21	59	91
			ECE 15-00/01	6977	43	42	15	22	59	94
			ECE 15-02	7060	42	43	15	24	65	98
			ECE 15-03	8501	41	43	16	26	71	103
			ECE 15-04	9543	38	46	16	25	70	103
			Improved conventional	8709	36	38	26	34	71	105
			Open loop	9011	37	39	24	36	74	105
			EURO 1	11810	37	44	19	28	71	103
			EURO 2	11810	37	44	19	28	71	103
			EURO 3	11810	37	44	19	28	71	103
			EURO 4	11810	37	44	19	28	71	103
		1.4 - 2.0 l	Pre ECE	7005	36	47	17	22	61	95
			ECE 15-00/01	9328	31	48	21	24	60	99
			ECE 15-02	10058	31	47	22	26	65	105
			ECE 15-03	10030	35	44	21	29	70	112
			ECE 15-04	11747	37	45	18	27	70	109
			Improved conventional	10848	37	38	25	36	74	123
			Open loop	10787	36	39	25	35	72	120
			EURO 1	13934	37	42	21	31	72	115
			EURO 2	13934	37	42	21	31	72	115
			EURO 3	13934	37	42	21	31	72	115
			EURO 4	13934	37	42	21	31	72	115
		>2.0 l	Pre ECE	8319	34	47	19	23	61	97
			ECE 15-00/01	12550	29	49	22	25	57	104
			ECE 15-02	12473	31	48	21	27	63	109
			ECE 15-03	12366	36	43	21	31	70	117
			ECE 15-04	13727	36	44	20	28	68	113
			EURO 1	17401	37	40	23	33	73	120
			EURO 2	17401	37	40	23	33	73	120
			EURO 3	17401	37	40	23	33	73	120
			EURO 4	17401	37	40	23	33	73	120
	Diesel	<2.0 l	Uncontrolled	14214	38	44	18	27	69	109
			EURO 1	17619	39	43	18	29	69	112
			EURO 2	17619	39	43	18	29	69	112
			EURO 3	17619	39	43	18	29	69	112
			EURO 4	17619	39	43	18	29	69	112
		>2.0 l	Uncontrolled	14873	36	43	21	27	70	112
			EURO 1	18259	38	42	20	28	69	113
			EURO 2	18259	38	42	20	28	69	113
			EURO 3	18259	38	42	20	28	69	113
			EURO 4	18259	38	42	20	28	69	113
	LPG	All	Uncontrolled	20046	44	37	19	21	64	104
			EURO 1	20696	41	38	21	22	63	104
			EURO 2	20696	41	38	21	22	63	104
			EURO 3	20696	41	38	21	22	63	104
			EURO 4	20696	41	38	21	22	63	104
	2-stroke	All	Uncontrolled	5150	30	60	10	30	80	100

Table A79b (continued). Annual mileage, mileage distribution and representative speeds for the EU15 (Reference year 1995)

Vehicle class	Fuel	Size	Emission class	Total annual mileage per vehicle (km)	Mileage distribution (%)			Representative vehicle speed for road class (km/h)		
					Urban	Rural	Highway	Urban	Rural	Highway
Light goods vehicles	Gasoline	All	Uncontrolled	17947	41	40	19	23	64	97
			EURO 1	17974	41	40	19	23	66	99
			EURO 2	17974	41	40	19	23	66	99
			EURO 3	17974	41	40	19	23	66	99
			EURO 4	17974	41	40	19	23	66	99
	Diesel	All	Uncontrolled	22713	48	35	17	22	63	92
			EURO 1	22940	47	37	16	23	64	94
			EURO 2	22940	47	37	16	23	64	94
			EURO 3	22940	47	37	16	23	64	94
			EURO 4	22940	47	37	16	23	64	94
Heavy duty vehicles	Diesel	3.5 - 7.5 t	Conventional	46849	35	43	22	20	60	90
			EURO 1	49647	36	43	21	20	60	90
			EURO 2	49647	36	43	21	20	60	90
			EURO 3	49647	36	43	21	20	60	90
			EURO 4	49647	36	43	21	20	60	90
		7.5 - 16 t	Conventional	45546	34	42	24	20	60	90
			EURO 1	46888	34	43	23	20	60	90
			EURO 2	46888	34	43	23	20	60	90
			EURO 3	46888	34	43	23	20	60	90
			EURO 4	46888	34	43	23	20	60	90
		16 - 32 t	Conventional	55295	19	38	43	20	60	90
			EURO 1	55214	19	40	41	20	60	90
			EURO 2	55214	19	40	41	20	60	90
			EURO 3	55214	19	40	41	20	60	90
			EURO 4	55214	19	40	41	20	60	90
		>32 t	Conventional	54876	19	40	41	20	60	90
			EURO 1	55182	19	41	40	20	60	90
			EURO 2	55182	19	41	40	20	60	90
			EURO 3	55182	19	41	40	20	60	90
			EURO 4	55182	19	41	40	20	60	90
		Buses	Conventional	43999	100	0	0	20	-	-
			EURO 1	47669	100	0	0	20	-	-
			EURO 2	47669	100	0	0	20	-	-
			EURO 3	47669	100	0	0	20	-	-
			EURO 4	47669	100	0	0	20	-	-
		Coaches	Conventional	40328	0	50	50	-	60	90
			EURO 1	43243	0	50	50	-	60	90
			EURO 2	43243	0	50	50	-	60	90
			EURO 3	43243	0	50	50	-	60	90
			EURO 4	43243	0	50	50	-	60	90
Motorcycles	Gasoline	<50 cc	Uncontrolled	2981	69	31	0	N/A	N/A	-
			Stage I	2981	69	31	0	N/A	N/A	-
			Stage II	2981	69	31	0	N/A	N/A	-
		>50 cc 2-s	Uncontrolled	3406	63	22	15	N/A	N/A	N/A
			Controlled	3406	63	22	15	N/A	N/A	N/A
		>50 cc 4-s	Uncontrolled	5593	45	40	15	N/A	N/A	N/A
			Controlled	5593	45	40	15	N/A	N/A	N/A

A8. DRIVING STATISTICS

In previous sections, a wide range of driving statistics necessary for the estimation of road vehicle emissions have been discussed and presented. In an attempt to provide a coherent description of the various calculations, they have been included in the sections for which they are relevant, and not given separately. They were, however, considered in much greater detail in MEET Deliverable 15 [A39], and it is relevant here to repeat the conclusions of that study.

The estimation of air pollutant emissions from road transport in Europe requires traffic related data corresponding to various aspects: the quantification of the transport activity, its breakdown according to geographical areas, vehicle categories, etc., and the characterisation of the corresponding driving and operating conditions.

The synthesis of statistics from France, Sweden, Great Britain, Switzerland, Germany and from the international institutions has allowed various aspects and difficulties to be highlighted:

- Most often, it is not possible to associate data on the three themes. Location and quantification data rarely satisfies the objectives of environmental estimation, or does not exist according to the envisaged categories; driving conditions are known for a limited number of specific situations that are not always consistent with the two previous aspects.

- International statistics sources provide harmonised data, easy to obtain and to work with, but at a large scale. Such data should nevertheless be considered, at least in approaches that do not rely on precise statistics, and also for international assessment and comparison[37].

- National surveys and specific studies are very heterogeneous in their methods and results, and access to them may be difficult (finding the appropriate institutions, difficulties of understanding, national or regional distinctions, data harmonisation, etc. may be problems). As travel surveys seem to exist in most countries, it is also useful to consider the resulting data. Specific studies should be used as correction factors, or to analyse specific factors.

- Significant discrepancies of the statistics can be observed between different international organisations, between institutions in the same country and between different methods of investigation.

- A great uncertainty and low reliability can be observed even for data that are very basic (network length, traffic volume by transport modes, etc.).

- It is difficult to satisfy the need for detailed vehicle categories with regard to traffic volumes, driving conditions, type of road, gradient, etc.

[37] Many of the data given in this report, such as those in Tables A64 to A79, fall into this general category.

This synthesis has also allowed the provision of a very large quantity of traffic related statistics:

- Description of the road network.
- Analysis of the traffic volume according to geographical areas and vehicle categories.
- Characterisation of driving conditions and speeds.
- A large number of speed statistics are proposed that highlight the impact of numerous factors, but also the necessity to validate the reference speed values used in emission inventories.
- Annual mileage, trip characteristics, parking conditions, load factors, gradient, fuel properties and thermal operating conditions are also described.

As regards the initial objective - i.e. to provide a comprehensive set of traffic related data, complementary to the existing emission data, factors and functions, with detailed vehicle categories, differentiation between urban and extra-urban areas, information on gradient, etc. - we have to conclude that the goal has not been reached. We can also assume that it will not be achieved in a short- or medium- term period: most of the required data does not exist with a sufficient level of detail, or is not available for the different countries. We must even conclude that information that was considered relatively obvious, such as traffic distribution according to areas, corresponding average speeds, etc., does not exist, or is often contradictory.

Objectives are not reached because the existing data does not provide a way to reach them (speed information according to the area, distribution of traffic volume according to gradient, etc.). It is therefore necessary to conceive alternatives, simplifications to satisfy the initial objectives to a certain extent. We think also that it is desirable to consider traffic and pollutant emission data simultaneously, very early in the process of estimating emissions, as this should allow a better harmonisation of the classes and categories, and provide assurance that the data is compatible and available.

We observe also that the efficiency of data collection is relatively low: for four or five countries, we have obtained a large quantity of comprehensive information (although not always relevant or consistent). For other countries, only very limited data was found, and for most of them we have nothing at all. Furthermore, detailed statistics have been made available when the institutions were simultaneously involved in that task. This suggests that it will be difficult to get the same level of information and to harmonise data from other countries.

Further work has to be conducted to extend this synthesis to other countries, but also to set the methodological basis for further data collection to ensure the harmonisation and the quality of the results collected by the different European countries.

A9. FUTURE EMISSION FACTORS

A9.1. Improved fuels - current and near future

Based on the results of the Auto/Oil programme, new improved fuels (both gasoline and diesel), giving rise to lower emissions, are expected to start appearing in the market by the turn of the decade. Directive 98/70/EC gives environmental specifications for petrol and diesel that will be effective in two stages: the first stage being introduced in 2000 and the second in 2005. Table A80 shows the specifications for petrol and Table A81 those for diesel.

Table A80. Environmental specifications for petrol

Parameter	Unit	2000		2005[38]
		Minimum	**Maximum**	**Maximum**
Research octane number		95		
Motor octane number		85		
Reid vapour pressure (summer)	kPa		60.0	
Distillation - evaporated at 100 °C - evaporated at 150 °C	 % v/v % v/v	 46.0 75.0		
Hydrocarbon analysis - olefins - aromatics - benzene	 % v/v % v/v % v/v		 18.0 42.0 1.0	 35.0
Oxygen content	% m/m		2.7	
Oxygenates - methanol - ethanol - iso-propyl alcohol - tertiary-butyl alcohol - iso-butyl alcohol - ethers with 5 or more carbon atoms	 % v/v % v/v % v/v % v/v % v/v % v/v		 3.0 5.0 10.0 7.0 10.0 15.0	
Other oxygenates	% v/v		10.0	
Sulphur content	mg/kg		150	50
Lead content	g/l		0.005	

Table A81. Environmental specifications for diesel

Parameter	Unit	2000		2005[38]
		Minimum	**Maximum**	**Maximum**
Cetane number		51		
Density at 15 °C	kg/m^3		845	
Distillation (95% point)	°C		360	
Polycyclic aromatic hydrocarbons	% m/m		11	
Sulphur content	mg/kg		350	50

[38] As 2000 except where shown

However, for the calculation of the effects of these improved fuels on exhaust and evaporative losses only few data exist and these are to be found in the results of the EPEFE [A47] programme and the evaluation of the American Auto/Oil activities conducted by the Working Group 1 of the European Auto/Oil Programme [A48]. Despite the fact that these data refer exclusively to new and well tuned engines and emission control systems, they are introduced in MEET as an indicator of the expected effects on the emissions of actual vehicles.

The following parameters are covered by the Auto/Oil results, and also specified in Directive 98/70/EC:

- Gasoline

  i. Reduced lead content (Lead)
  ii. Reduced sulphur content (S)
  iii. Increased oxygenates (O_2)
  iv. Reduced aromatics (ARO)
  v. Reduced benzene (BENZ)
  vi. Reduced olefins (OLEFIN)
  vii. Reduced Reid vapour pressure (RVP)
  viii. Increased mid range (E100) and tail end (E150) volatility

- Diesel

  i. Reduced sulphur content (S)
  ii. Reduced polyaromatics (POLY)
  iii. Increased cetane number (CN)
  iv. Reduced back end distillation (T_{95})
  v. Density (DEN)

The effects are presented in Tables A82 to A86.

Table A82. Effect of improved gasoline on the emissions of non-catalyst light duty vehicles (based on [A48])

Property	Change	Change in emissions (%)				
		Pb	**CO**	**VOC exh**	**VOC evap**	**NO_X**
Lead	0.15 $\rightarrow$ 0.08 g/l	-50	0	0	0	0
Oxygenates	0 $\rightarrow$ 2.7% O_2	0	-20 to -40	-2 to -10	0 to 10	-2 to 2
Aromatics	40 $\rightarrow$ 25%	0	0	-2 to -10	0	-2 to -10
Benzene	3 $\rightarrow$ 2%	0	0	0	0	0
Olefins	10 $\rightarrow$ 5%	0	-2 to 2	2 to 5	-2 to 0	-2 to -10
Sulphur	300 $\rightarrow$ 100 ppm	0	0	0	0	0
RVP	70 $\rightarrow$ 60 kPa	0	0	-2 to 2	-20	0
E 100	50 $\rightarrow$ 60%	0	0 to 2	-2 to -10	-2 to 2	0
E 150	85 $\rightarrow$ 90%	0	0	-10 to -20	0	2 to 10

Table A83. Relations between emissions and fuel properties for catalyst light duty vehicles (based on [A49])

Emission (g/km)	Equation
CO	$[2.459 - 0.05513 \cdot E100 + 0.0005343 \cdot E100^2 + 0.009226 \cdot ARO - 0.0003101 \cdot (97\text{-}S)] \times [1\text{-}0.037 \cdot (O_2 - 1.75)] \times [1\text{-}0.008 \cdot (E150 - 90.2)]$
VOC	$[0.1347 + 0.0005489 \cdot ARO + 25.7 \cdot ARO \cdot e^{(-0.2642 \cdot E100)} - 0.0000406 \cdot (97\text{-}S)] \times [1\text{-}0.004 \cdot (OLEFIN - 4.97)] \times [1\text{-}0.022 \cdot (O_2 - 1.75)] \times [1 - 0.01 \cdot (E150 - 90.2)]$
NO_X	$[0.1884 - 0.001438 \cdot ARO + 0.00001959 \cdot ARO \cdot E100 - 0.00005302 \cdot (97 - S)] \times [1+0.004 \cdot (OLEFIN - 4.97)] \times [1+0.001 \cdot (O_2 - 1.75)] \times [1 + 0.008 \cdot (E150 - 90.2)]$
Benzene	$[0.454 + 0.5374 \cdot BENZ + 0.0913 \cdot (ARO\text{-}BENZ)] \times VOC$

Table A84. Effect of other properties of gasoline on the emissions of catalyst light duty vehicles (based on [A48])

Property	Change	Change in emissions (%)				
		Pb	CO	VOC exh	VOC evap	NO_X
Lead	0.013 $\rightarrow$ 0.005 g/l	-2 to-10	0 to -2	0 to -2	0	0 to -2
Benzene	3 $\rightarrow$ 2%	0	0	0	0	0
RVP	70 $\rightarrow$ 60 kPa	0	0	0 to -2	-2 to -10	0

Table A85. Relations between emissions and fuel properties for diesel light duty vehicles (based on [A49])

Emission (g/km)	Equation
CO	$-1.3250726 + 0.003037 \cdot DEN - 0.0025643 \cdot POLY - 0.015856 \cdot CN + 0.0001706 \cdot T_{95}$
VOC	$-0.293192 + 0.0006759 \cdot DEN - 0.0007306 \cdot POLY - 0.0032733 \cdot CN - 0.000038 \cdot T_{95}$
NO_X	$1.0039726 - 0.0003113 \cdot DEN + 0.0027263 \cdot POLY - 0.0000883 \cdot CN - 0.0005805 \cdot T_{95}$
PM	$[-0.3879873 + 0.0004677 \cdot DEN + 0.0004488 \cdot POLY + 0.0004098 \cdot CN + 0.0000788 \cdot T_{95}] \times [1 - 0.015 \cdot (450 - S)]$

Table A86. Relations between emissions and fuel properties for diesel heavy duty vehicles (based on [A49])

Emission (g/kWh)	Equation
CO	$2.24407 - 0.0011 \cdot DEN + 0.00007 \cdot POLY - 0.00768 \cdot CN - 0.00087 \cdot T_{95}$
VOC	$1.61466 - 0.00123 \cdot DEN + 0.00133 \cdot POLY - 0.00181 \cdot CN - 0.00068 \cdot T_{95}$
NO_X	$-1.75444 + 0.00906 \cdot DEN + 0.0163 \cdot POLY - 0.00493 \cdot CN + 0.00266 \cdot T_{95}$
PM	$[0.06959 + 0.00006 \cdot DEN + 0.00065 \cdot POLY - 0.00001 \cdot CN] \cdot [1\text{-}0.0086 \cdot (450 - S)/100]$

A9.2. Near future vehicle categories

In the following paragraphs, reduction factors are proposed in order to adapt emission factors of the different vehicle categories to future engine technologies. The adaptation is based, where possible on proposed changes to vehicle emission standards. Whereas emission reduction targets have been defined for passenger cars, LDV and HDV, no standards have been proposed for two-wheelers for the years beyond 2000.

A9.2.1 Passenger cars and light duty vehicles

The emission data for PC and LDV represent vehicles from those before regulations were introduced in the EU to Directive 91/441/EEC (EURO I). In the following sections reduction rates for gasoline and diesel vehicles are derived for EURO II and further steps of legislation.

Gasoline vehicles

The derivation of reduction rates for future vehicles is based on the EU emission legislation. As it is the test specified in the legislation, it is sensible to establish an emission data set to show the emission behaviour of EURO I vehicles over the New European Driving Cycle (NEDC) with cold start. Many data are available since many measurements in Europe include the NEDC so, from a statistical point of view, no problems occur. The data bases of the Swiss/ German Emission Factor Programme and of the Commission's I/M project [A50] were used.

In order to comply with the future standards, automobile manufacturers may reduce the hot emission level in the stabilised part of the test, the cold extra emission at the start of the test, or both. For future vehicle technologies, therefore, the intention is to assess reduction rates for both hot emissions and cold start emissions, taking into account abatement concepts that will probably be introduced. Thus, the results of the NEDC must be divided into two parts (the urban part (UDC) and the extra urban part (EUDC)), and the urban part has to be divided into a part including the cold start and another part representing the hot phase of the UDC. It is assumed that the EUDC is not influenced by the cold start.

The following assumptions have been made for the estimation of reduction rates:

- The overall reduction over the NEDC expressed by the reduction of the standards shall be achieved for each step of legislation.
- For EURO II and later emission levels it is further assumed that the difference between the standards and the actual emission levels should be comparable with that of EURO I vehicles.

An iterative procedure was used to calculate the emission reduction rates. Firstly, an *a priori* set of reduction rates was assumed for both the cold excess and hot emissions. Using those in conjunction with the data on EURO I emissions in the various parts of the NEDC, emission rates for future categories were calculated. Then, compliance with the assumptions given above was achieved by modifying the reduction rates (the cold and hot reduction rates were equally modified). An example of the estimation of EURO I to EURO II reductions for CO emissions is given below as an illustration.

The analysis of the EURO I data provided the following average emission rates for the different parts of the NEDC:

UDC cold: 4.05 g/km
UDC hot: 0.96 g/km
EUDC: 0.66 g/km
NEDC cold: 1.90 g/km
NEDC hot: 0.77 g/km
Cold excess emission: 12.55 g

The assumed *a priori* reduction rates were 30% for the cold excess emission and 10% for the hot emission. Applying these reductions to the EURO I data gives:

UDC hot: 0.87 g/km
EUDC 0.60 g/km
NEDC hot: 0.70 g/km
Cold excess emission: 8.79 g

It is then possible to calculate emission rates for the cold UDC and the cold NEDC as follows:

$$UDC_{cold} = \frac{(UDC_{hot} \times distance\,UDC + cold\ excess\,emission)}{distance\,UDC}$$

and:

$$NEDC_{cold} = \frac{(UDC_{cold} \times distance\,UDC + EUDC \times distance\ EUDC)}{distance\ NEDC}$$

giving:

UDC cold: 3.03 g/km
NEDC cold: 1.49 g/km

Comparing the overall NEDC cold emissions with the EURO I value shows a reduction rate of 22%, whereas the change in the standard from EURO I to EURO II is 19%. In order that the achieved reduction is calculated to be equal to the reduction in standards, it is therefore necessary to reduce the *a priori* reduction rates slightly.

Similar calculations were performed for all the regulated pollutants and for EURO II, III and IV standards. It should also be mentioned that the test procedure will be modified, beginning with EURO III (40s idle before starting the measurements will be eliminated, and the start of the measurements will coincide with the engine start). This change in the test procedure results in an increase in emissions during the test, so the effective reductions in emission standards are greater than the numerical changes indicate. This has been taken into account in the derivation of the reduction factors.

Table A87 presents the resulting reduction rates, related to the EURO I emission level. While the reduction rates of the cold start extra emissions and hot emissions for NO_X and VOC are the same or very similar, the reduction rates for hot CO emissions are much lower than those for cold start extra emissions.

Table A87. Reduction rates of emissions for EURO II to EURO IV gasoline vehicles

Reduction rates of cold excess emissions referred to EURO I emission levels (%)			
	CO	VOC	NO_X
EURO II	30	40	55
EURO III	51	67	73
EURO IV	80	84	88
Reduction rates of hot emissions referred to EURO I emission levels (%)			
	CO	VOC	NO_X
EURO II	5	40	55
EURO III	24	61	73
EURO IV	62	79	87

Diesel vehicles

For diesel vehicles the same method has been used to derive reduction rates for future vehicles, again using data from the Swiss/German Emission Factor Programme and the I/M project of the Commission. The reduction rates are compiled in Table A88. In contrast to the gasoline vehicles the differences between reduction rates for cold extra emissions and hot emission are small. Note that EURO I vehicles are already well able to achieve the EURO II standard for CO, so no reduction has been applied even though the standard reduced significantly.

Table A88. Reduction rates of emissions for EURO II to EURO IV diesel vehicles

Reduction rates of cold excess emissions referred to EURO I emission levels (%)				
	CO	VOC	NO_X	particles
EURO II	0	30	40	30
EURO III	35	51	58	51
EURO IV	55	76	79	76
Reduction rates of hot emissions referred to EURO I emission level (%)				
	CO	VOC	NO_X	particles
EURO II	0	30	30	40
EURO III	45	51	51	64
EURO IV	56	76	76	84

A9.2.2 Heavy duty vehicles

For heavy duty vehicles, insufficient data for EURO I vehicles are available to allow them to be used as the base vehicle type (introduced in 1992 for new engine types and 1993 for all new engines). Instead, well maintained vehicles representing the mix in 1990 have been taken as the reference type. Taking into account available measurement results from 13 mode tests, typical mean values for this category of vehicles were derived (see Table A89).

Reduction rates for EURO I, II and III vehicles have been estimated from these base values and from the requirements of the published or proposed changes in legislation. Thus, for example, a reduction rate of 40% for NO_X emissions from EURO II engines is proposed: this corresponds with the change from pre-EURO I emissions (11 g/kW.h) and the EURO II requirement (7 g/kW.h). For VOC and CO the existing standards have little or no limiting effect. For example, the average VOC type approval data for pre-EURO I engines is about 0.6 g/kWh in the 13 mode test and below even the EURO III standard (0.66 g/kW.h). Nevertheless it is assumed that VOC and CO emissions will be reduced, even if it is not required by legislation, because of the improvements in engine technology needed to satisfy the other standards. The standards and reduction rates are shown in Table A89.

In 1999 the Commission will submit a proposal for the EURO IV standards. The intention is that these will represent a 'substantial reduction from EURO III, however, numerical proposals have not yet been published by the Commission. In June 1996 the German Environmental Agency (UBA) in Berlin proposed emission reduction targets from an environmental point of view which may come into force in 2005 or later and may be taken as EURO IV standards for scenario investigation.

For CO no reduction targets have been defined because the air pollution concentrations are no longer of major concern. For NO_X UBA proposed a reduction of 75 % relative to EURO II which would result in a standard of 1.75 g/kWh in the 13 mode test. For PM the proposal is also based on the existing EURO II standard of 0.15 g/kWh. From scenario investigations the need for a further reduction of 50 % was derived leading to a proposed EURO IV limit of 0.075 g/kWh in the 13 mode test. For VOC a need for a further reduction of 60 % was derived, but this reduction has to be applied to today’s average emissions. In order to assure this emission target, the EURO II standard has to be decreased by 84 % (0.18 g/kWh).

The reduction rates defined in Table A81 for EURO IV HDVs are based on the UBA emission reduction targets and related to pre-EURO I emission rates.

Table A89. Emission standards and reduction factors for heavy duty vehicles

	CO	VOC	NO_X	PM
Pre EURO I (base case, g/kW.h)	2.5	0.6	11	0.4
EURO I standards (g/kW.h)[a]	4.5	1.1	8	0.36
EURO I (percentage reduction)[e]	10	10	30	20
EURO II standards (g/kW.h)[b]	4.0	1.1	7	0.15
EURO II (percentage reduction)[e]	20	20	40	70
EURO III standards (g/kW.h)[c]	2.1	0.66	5	0.10
EURO III (percentage reduction)[e]	20	20	60	80
EURO IV standards (g/kW.h)[d]	2.1	0.18	1.75	0.075
EURO IV (percentage reduction)[e]	20	70	85	85

[a] Directive 91/542/EEC Stage 1
[b] Directive 91/542/EEC Stage 2
[c] Commission proposal 98/C173/01
[d] Based on UBA emission reduction targets
[e] All percentage reductions are relative to the pre-EURO I case

A9.3. New vehicle technologies

A number of new vehicle technologies are emerging that may have significant market penetration over the next 20 years. A study has been carried out to assess the technologies most likely be in use by 2020 and to provide estimates of the emissions they will produce [A51]. Candidate technologies that were considered include:

- Electric vehicles
- Hybrid electric vehicles
- Fuel cell electric vehicles
- Gas turbine engines
- Stirling engines
- Direct injection gasoline engines
- Particulate traps

Of these, however, only the electric vehicles (including hybrids and fuel cell vehicles) were assessed in detail. The alternative combustion engines, such as the Stirling, did not appear to have reached a sufficient level of development for automotive applications and are unlikely to appear in significant numbers by 2020. Developments of conventional engines and emission control systems, such as direct injection for gasoline engines, were considered to be evolutionary, rather than new, technologies, and they will contribute to improvements in emissions required by the future emission standards: in effect, they are implicitly included in the evaluation of emission factors for near future vehicle categories (A9.2).

A9.3.1. The new technologies

Electric vehicles

Electric vehicles have a long history, and competed on equal terms with the internal combustion engined vehicles until the 1920s. However, as the performance of internal combustion engines was developed, that of electric vehicles was unable to keep pace, and their popularity declined. Recently developed vehicles are able to perform much better (prototypes have shown top speeds over 150 km/h and acceleration times of less than 8 seconds from 0 to 100 km/h), but they still have a limited range between charges.

One of the main stimuli for recent research and development was the requirement of the California Air Resources Board (CARB) that increasing proportions of car sales should be 'zero emission' vehicles (ZEVs). The original requirements were for 2% of ZEV sales in 1998, 5% by 2003 and 10% by 2007. Subsequently, the 2% ruling for 1998 was dropped, but the 2003 target increased to 10%. Over a dozen other states have followed California's lead, and most manufacturers are developing electric vehicles for production.

Some characteristics of electric vehicles are superior to those of internal combustion engined vehicles. They are quiet, emission free at point of use, they do not use energy while stationary and do not incur warm up losses. Electric motors provide very high torque at low speeds and a wide speed range, and their efficiency is reasonably constant over their performance range. However, the performance and range of conventional electric vehicles is limited by the battery which accounts for a quarter of the vehicle's weight. Considerable research and development into battery technology is being conducted by many organisations. Chrysler, Ford and General Motors, for example, formed the US Advanced Battery Consortium to produce batteries suitable for use in electric vehicles. Their objectives for battery performance are compared with the present status in Table A90 [A52].

Table A90. Goals and current status of battery performance for electric vehicles

	Specific power (W/kg)	Energy density (Wh/l)	Specific energy (Wh/kg)	Life (y)	Cycle life (cycles)	Cost ($/kWh)
US Advanced Battery Consortium goals						
Mid term	150	135	80	5	600	<150
Long term	400	300	200	10	1000	<100
Current status						
Lead-acid	67 - 183	50 - 82	18 - 56	2 - 3	450 - 1000	70 - 100
Nickel-iron	70 - 132	60 - 115	39 - 70	n/a	440 - 2000	160 - 300
Nickel-cadmium	100 - 200	60 - 115	33 - 70	n/a	1500 - 2000	300
Nickel-metal hydride	200	152 - 215	54 - 80	10	1000	200
Sodium-sulphur	90 - 130	76 - 120	80 - 140	n/a	250 - 600	>100
Sodium-nickel chloride	150	160	100	5	600	>350

Most current electric vehicles use lead-acid or nickel-cadmium batteries, which are the longest established technologies. Lead-acid batteries are cheap and offer a long cycle life, but have low power and energy densities. Nickel-cadmium batteries have a higher energy density and longer cycle life, but their cost is more than three times greater than lead-acid, and there are also concerns over the large amount of cadmium that may be introduced into the environment. The most likely candidate battery for future electric vehicles is the nickel-metal hydride. It has high power and energy densities and a long cycle life, but is expensive in comparison with lead-acid.

Although the average power required by an electric vehicle may range from 10 - 20 kW, peak demands for acceleration and hill climbing may be ten times higher. A battery capable of delivering such power would be inhibitively large and heavy. Therefore the additional use of a high density power source such as a flywheel or ultracapacitor is an attractive option.

Hybrid electric vehicles

Hybrid electric vehicles combine an electric motor and a combustion engine: traditionally, there have been two main power train configurations, series and parallel. The series configuration consists of an engine which drives a generator producing electricity to drive the motor. This system operates a small engine at its most efficient condition, resulting in good fuel economy and low emissions. The parallel configuration permits both the combustion engine and the electric motor to drive the vehicle. Systems are designed for the engine to work under high load conditions, where it is most efficient. Such a vehicle could operate as a battery electric vehicle in urban areas or at low speeds, while on the highway, the combustion engine would be the main source of power with the electric drive offering assistance when accelerating. The motor can also act as a generator, and be used to feed energy to the battery either from regenerative braking or when not all of the engine power is being used for propulsion.

Fuel cell electric vehicles

Fuel cells generate electricity directly from the chemical reaction of hydrogen and oxygen, and avoid the inefficiencies of conventional electricity production. Many vehicle manufacturers now have some involvement in fuel cell development for automotive applications. The most promising types for this purpose are the phosphoric acid and proton exchange membrane (PEM) fuel cells; most development programs are now moving towards the PEM fuel cell.

Although the reaction responsible for generating the electricity is that between hydrogen and oxygen, a variety of fuels can be used to provide the hydrogen. Hydrogen itself can be used, but is not convenient to store in the vehicle and has no suitable distribution infrastructure. Most development is focusing on organic liquid fuels, using an on-board reformer to extract the hydrogen. Methanol and gasoline have received the most attention, but other fuels may also be suitable (in theory, any fuel that can be reformed to produce hydrogen may be used).

A9.3.2. Emission factors

The emission and energy consumption factors given below are meant only as a guide. They were developed using very little data, both because of time constraints and the apparent lack of data in the public domain. What data are available usually refer to prototypes which may prove technical feasibility, but not commercial viability or customer acceptance. Compromises needed to bring the technology to production may result in significant differences between prototype and production vehicles. Additionally, as technology in some of these fields is advancing very quickly, it is difficult to predict what the status will be, even in the near future.

Emission factors for each vehicle type are given by the following equation:

$$F = av^2 + bv + c \qquad \text{(A27)}$$

where:

F	is the emission factor (g/km)
a, b, c	are coefficients
v	is the average vehicle speed (km/h)

Electric vehicles

Two new vehicle categories have been introduced for electric vehicles, passenger cars and light duty vehicles. The emission factors depend on the mix of generating plant used to produce the electricity, and thus vary between countries. Those for each country may be calculated by inserting the necessary values from Table A91 into the following equations. European average emission coefficients have been calculated as an example (Table A92).

$$F_{passenger\ car} = (0.0508v^2 - 8.08v + 432) \times E \times 3.6 \times 10^{-6} \qquad \text{(A28)}$$

$$F_{LDV} = (0.0915v^2 - 12.8v + 778) \times E \times 3.6 \times 10^{-6} \qquad \text{(A29)}$$

where:

F is the emissions factor (g/km)
E is the average emissions output by pollutant and country (g/GJ) (Table A83)
v is the average vehicle speed (km/h)

Table A91. Emission factors for the average electricity generating mix by country (1997 data)

Country	Emission factor (g/GJ)						
	CO_2	CO	NO_X	NMHC	SO_2	CH_4	PM
Austria	62900	14.5	92.7	16	74.2	80.3	6.9
Belgium	94300	16.7	289.4	12.2	533.5	240.3	27.2
Denmark	257300	43	811.6	24.7	912.9	902.7	62.7
Finland	155100	38.6	307.3	15.6	198	310.9	23.4
France	17600	3.2	61	3.2	183.9	36.1	7.9
Germany	189700	27.3	306.3	9.4	931.5	465.1	56.2
Greece	296400	38.7	393.6	38.9	979.2	604	62.4
Ireland	212900	33.8	672	44.6	1639.5	466.7	74.3
Italy	162500	33.4	551.7	105.3	977.2	111.8	41.1
Luxembourg	101900	16.2	90.1	16.9	71.1	27.3	3.7
Netherlands	175700	31.6	281.8	32	185.2	392.5	19
Norway	1700	0.6	2.8	0.2	3.7	6	0.2
Portugal	170400	34	507.1	53.7	1260.7	359	59.4
Spain	126800	19.4	414.2	16	1235.8	306.8	57.8
Sweden	20600	6	42.2	6.6	34.7	22.2	3.1
Switzerland	6600	2.5	12.9	1.4	21.5	0.7	1.1
UK	167800	27.4	631.8	20.2	1445.8	458.9	69.9
European Average	127400	21.3	325.9	22.6	744.9	282.6	39.1

Table A92. Electric vehicle emission coefficients for European average electricity generation.

Pollutant	Passenger car coefficients			LDV coefficients		
	a	b	c	a	b	c
CO_2	0.0233	-3.249	198	0.0419	-5.848	356
CO	0.0000	-0.001	0.03	0.0000	-0.001	0.06
NO_X	0.0001	-0.008	0.51	0.0001	-0.015	0.91
NMHC	0.0000	-0.001	0.04	0.0000	-0.001	0.06
SO_2	0.0001	-0.019	1.16	0.0002	-0.034	2.09
CH_4	0.0001	-0.007	0.44	0.0001	-0.013	0.79
PM	0.0000	-0.001	0.06	0.0000	-0.002	0.11

Hybrid electric vehicles

Two types of hybrid electric vehicle are considered, again being passenger cars and light duty vehicles. Table A93 shows vehicle emission coefficients for gasoline hybrid electric vehicles. The calculated results are not speed dependent and therefore only the c coefficient is listed. Table A94 lists the energy production emission coefficients for gasoline HEVs. These include the pollutants generated at the vehicle and during fuel extraction, processing and transport.

Table A93. Vehicle emission coefficients for gasoline hybrid electric vehicles

Emission Coefficients (c)	CO_2	CO	NO_X	HC	PM
Passenger car	112	0.166	0.017	0.010	0
LDV	202	0.299	0.031	0.019	0

Table A94. Energy production emission coefficients for gasoline hybrid electric vehicles

Emission Coefficients (c)	CO_2	CO	NO_X	HC	SO_2	PM
Passenger car	127	0.17	0.09	0.37	0.12	0.004
LDV	228	0.31	0.16	0.66	0.21	0.006

Fuel cell electric vehicles

Three categories of fuel cell electric vehicle are included, passenger cars, light duty vehicles and urban buses. The vehicle emission coefficients for methanol fuel cell vehicles are shown in Table A95. These account for the vehicle output from methanol reformation only. The energy production emission coefficients are shown in Table A96. These include pollutants generated by the vehicle and during fuel production. Note that the fuel production emissions have been calculated with respect to speed and therefore the a and b coefficients are also used.

Table A95. Vehicle emission coefficients for methanol fuel cell electric vehicles

Emissions coefficient (c)	CO_2	CO	NO_X	HC	PM
Passenger car	113	0	0	0.0046	0
LDV	203	0	0	0.0082	0
Urban bus	979	0	0	0.0397	0

Table A96. Energy production emission coefficients for methanol fuel cell electric vehicles

Pollutant	Passenger car coefficients			LDV coefficients			Urban bus coefficients		
	a	b	c	a	b	c	a	b	c
CO_2	0.0071	-0.990	173	0.0128	-1.783	312	0.0000	0.000	1358
CO	0.0000	-0.001	0.07	0.0000	-0.002	0.13	0.0000	0.000	0.44
NO_X	0.0000	-0.004	0.26	0.0001	-0.008	0.47	0.0000	0.000	1.63
HC	0.0000	-0.006	0.40	0.0001	-0.012	0.72	0.0000	0.000	2.52
PM	0.0000	0.000	0.01	0.0000	-0.004	0.26	0.0000	0.000	0.09
SO_2	0.0000	-0.001	0.05	0.0000	-0.002	0.09	0.0000	0.000	0.32

A9.3.3. Projected European vehicle fleet composition

Estimating the penetration of new technologies over the next 20 years is difficult. Historically, many new technologies have promised, but failed, to break the internal combustion engine monopoly. However, increasing pressure on the transport sector to mitigate its environmental impact will undoubtedly encourage change.

A new vehicle must be technically and commercially viable and must meet customer demands if it is to gain a significant market share. The internal combustion engine is a well established and familiar technology that has developed a huge support industry with massive investment in production facilities and operational infrastructure. In recent years globalisation has promoted commonisation and increased the size of many operations, adding to the inertia of the industry. It may be expected that investments will require a return over a significant period and the rate of change in the industry will be largely governed by economic factors. A revolutionary movement towards a new technology has been considered unlikely.

Electric vehicles (EVs), have been present for many years and development has been promoted by legislation in California. It is likely that new generation EVs will be available in the near future. However, they are likely to appeal to only a small market segment unless there is a breakthrough in battery technology. Europe lacks political incentives, and EV sales may not be expected to capture the same market share as in California. It is likely that their widespread use in Europe will require political assistance and new infrastructure, and both will take time to secure. It has been assumed therefore that EV sales in Europe will not be significant until the latter half of the next century and may account for 5 to 10% of the car market by 2020.

Hybrid electric vehicles (HEVs), are likely to make some impact in the near future. Concerns regarding the cost/benefit balance are being challenged. The Toyota Prius is now selling at far above projected rates since its introduction to the Japanese market in December 1997. Apart from high initial cost and possible high maintenance costs, it appears that HEVs offering good performance and very low fuel consumption and emission levels will be acceptable to the environmentally aware customer. It has been assumed therefore that this vehicle will account for 1-2 % of vehicle sales by 2010, rising to 5-10 % by 2020.

The fuel cell electric vehicle (FCEV) is still far from production. The most visible prototype, the NeCar III, has many issues to overcome. The power to weight ratio of its fuel cell system is high (around 15 kg/kW), the time to develop full power is over 5 seconds, and production targets are directed towards the years post 2005 [A53]. The creation of a new supplier base and the development of new techniques for mass production must be completed before FCEVs will be available. It has been estimated that FCEVs will be available from the latter half of the next decade and that the market share in 2010 will be 0 %, rising to 10-20 % by 2020. The American Methanol Institute estimated 2 million methanol fuelled vehicles world wide by 2010 and 35 million by 2020 [A54]. This would need significant investment in new methanol production plants, but it is reported that production may be increased sufficiently to meet this demand. The National Renewable Energy Laboratory, USA, estimated a negligible FCEV penetration by 2010 and three different scenarios for the year 2020, low, base and high cases of 2.5, 12.5 and 17.5 % of sales respectively [A55]. This is similar to the range predicted here.

The estimated new technology vehicle penetration is shown in Table A97, and applies to all classifications of vehicle. It is difficult to justify any of these predictions. They are based on continued economic and social conditions and an evolutionary technology advancement: events which may radically change these trends cannot be predicted. It has been assumed that each technology class will have a significant market share in the year 2020. However, it is possible that one will establish itself and dominate the market for new technology vehicles. Again this cannot be predicted so all technologies have been included in the projection.

Table A97. Estimated percentage market share for new technology vehicles during the years 2010 and 2020.

Vehicle type	% market share			
	Low case		High case	
	2010	2020	2010	2020
EV	0.5	5	1	10
HEV	1	10	2	20
FCEV	0	5	0	10

To find the number of new technology vehicles in the European fleet the number of new vehicle entering the fleet each year had to be estimated. This was found by summing the fleet growth and the old vehicles which had been replaced. It was assumed that the average car life was 15 years and that after 15 years the vehicle left the fleet. Fleet growth between 1990 and 2020 [A45] was extrapolated back to 1980, as shown in Figure A29. At this point it was assumed that the demographic composition of the fleet was evenly distributed, with the same number of vehicles for each age group. So, for example, the number of 1 year old and 14 year old vehicles were equal. From these assumptions the number of cars leaving the fleet were estimated allowing the total number of new vehicles to be approximated each year.

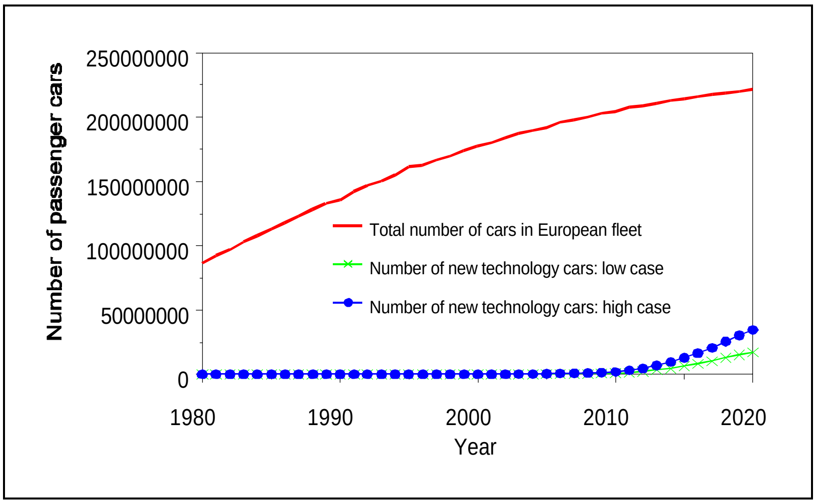

Figure A29. Total European fleet and estimates of new technology vehicles

The percentage penetration of new technology vehicles into the European fleet is summarised in Table A98. The full data tables may be found in Tables A99 and A100.

Table A98. Percentage of new technology vehicles as part of the European fleet.

	Percentage of new technology vehicles						
	1990	1995	2000	2005	2010	2015	2020
Low case	0	0	0	0	1	3	8
High case	0	0	0	0	1	6	16

Table A99. Low case penetration of new technology vehicles

Year	Total number of cars in European fleet	Total new cars entering European fleet	Estimated percentage market share			Total number of vehicles				Percentage of fleet			
			EV	HEV	FCEV	EV	HEV	FCEV	All	EV	HEV	FCEV	All
1980	87000000	5800000	0	0	0	0	0	0	0	0	0	0	0
1981	92500000	11300000	0	0	0	0	0	0	0	0	0	0	0
1982	97500000	10800000	0	0	0	0	0	0	0	0	0	0	0
1983	103000000	11300000	0	0	0	0	0	0	0	0	0	0	0
1984	108000000	10800000	0	0	0	0	0	0	0	0	0	0	0
1985	113500000	11300000	0	0	0	0	0	0	0	0	0	0	0
1986	118500000	10800000	0	0	0	0	0	0	0	0	0	0	0
1987	123000000	10300000	0	0	0	0	0	0	0	0	0	0	0
1988	128500000	11300000	0	0	0	0	0	0	0	0	0	0	0
1989	133000000	10300000	0	0	0	0	0	0	0	0	0	0	0
1990	135786474	8586474	0	0	0	0	0	0	0	0	0	0	0
1991	142500000	12513526	0	0	0	0	0	0	0	0	0	0	0
1992	147000000	10300000	0	0	0	0	0	0	0	0	0	0	0
1993	150500000	9300000	0	0	0	0	0	0	0	0	0	0	0
1994	155000000	10300000	0	0	0	0	0	0	0	0	0	0	0
1995	161381721	12181721	0	0	0	0	0	0	0	0	0	0	0
1996	163000000	12918279	0	0	0	0	0	0	0	0	0	0	0
1997	167000000	14800000	0	0	0	0	0	0	0	0	0	0	0
1998	170000000	14300000	0	0	0	0	0	0	0	0	0	0	0
1999	174000000	14800000	0	0	0	0	0	0	0	0	0	0	0
2000	177381107	14681107	0.0	0.3	0.0	0	36703	0	36703	0	0	0	0
2001	180000000	13418893	0.0	0.3	0.0	0	76959	0	76959	0	0	0	0
2002	184000000	14300000	0.0	0.4	0.0	0	127009	0	127009	0	0	0	0
2003	187500000	14800000	0.0	0.4	0.0	0	186209	0	186209	0	0	0	0
2004	190000000	12800000	0.0	0.5	0.0	0	243809	0	243809	0	0	0	0
2005	191752427	10338901	0.3	0.5	0.0	25847	295504	0	321351	0	0	0	0
2006	196000000	16761099	0.3	0.6	0.0	76131	396071	0	472201	0	0	0	0
2007	198000000	12300000	0.4	0.7	0.0	119181	482171	0	601351	0	0	0	0
2008	200000000	11300000	0.4	0.8	0.0	164381	572571	0	736951	0	0	0	0
2009	203000000	13300000	0.5	0.9	0.0	224231	692271	0	916501	0	0	0	0
2010	204045186	13226907	0.5	1.0	0.0	290365	824540	0	1114905	0	0	0	1
2011	207500000	16373093	0.9	1.8	0.5	437723	1119255	81865	1638844	0	1	0	1
2012	209000000	16300000	1.3	2.6	1.0	649623	1543055	244865	2437544	0	1	0	1
2013	211000000	16300000	1.7	3.4	1.5	926723	2097255	489365	3513344	0	1	0	2
2014	213000000	16800000	2.1	4.2	2.0	1279523	2802855	825365	4907744	1	1	0	2
2015	214065256	15746363	2.5	5.0	2.5	1673182	3590173	1219025	6482380	1	2	1	3
2016	216000000	15353637	3.0	6.0	3.0	2133791	4474689	1679634	8288114	1	2	1	4
2017	218000000	16300000	3.5	7.0	3.5	2704291	5538729	2250134	10493154	1	3	1	5
2018	219000000	15800000	4.0	8.0	4.0	3336291	6675720	2882134	12894145	2	3	1	6
2019	220000000	13800000	4.5	9.0	4.5	3957291	7731511	3503134	15191935	2	4	2	7
2020	222011534	12350435	5.0	10.0	5.0	4574813	8722745	4120655	17418213	2	4	2	8

Table A100. High case penetration of new technology vehicles

Year	Total number of cars in European fleet	Total new cars entering European fleet	Estimated percentage market share			Total number of vehicles				Percentage of fleet			
			EV	HEV	FCEV	EV	HEV	FCEV	All	EV	HEV	FCEV	All
1980	87000000	5800000	0.0	0.0	0.0	0	0	0	0	0	0	0	0
1981	92500000	11300000	0.0	0.0	0.0	0	0	0	0	0	0	0	0
1982	97500000	10800000	0.0	0.0	0.0	0	0	0	0	0	0	0	0
1983	103000000	11300000	0.0	0.0	0.0	0	0	0	0	0	0	0	0
1984	108000000	10800000	0.0	0.0	0.0	0	0	0	0	0	0	0	0
1985	113500000	11300000	0.0	0.0	0.0	0	0	0	0	0	0	0	0
1986	118500000	10800000	0.0	0.0	0.0	0	0	0	0	0	0	0	0
1987	123000000	10300000	0.0	0.0	0.0	0	0	0	0	0	0	0	0
1988	128500000	11300000	0.0	0.0	0.0	0	0	0	0	0	0	0	0
1989	133000000	10300000	0.0	0.0	0.0	0	0	0	0	0	0	0	0
1990	135786474	8586474	0.0	0.0	0.0	0	0	0	0	0	0	0	0
1991	142500000	12513526	0.0	0.0	0.0	0	0	0	0	0	0	0	0
1992	147000000	10300000	0.0	0.0	0.0	0	0	0	0	0	0	0	0
1993	150500000	9300000	0.0	0.0	0.0	0	0	0	0	0	0	0	0
1994	155000000	10300000	0.0	0.0	0.0	0	0	0	0	0	0	0	0
1995	161381721	12181721	0.0	0.0	0.0	0	0	0	0	0	0	0	0
1996	163000000	12918279	0.0	0.0	0.0	0	0	0	0	0	0	0	0
1997	167000000	14800000	0.0	0.0	0.0	0	0	0	0	0	0	0	0
1998	170000000	14300000	0.0	0.0	0.0	0	0	0	0	0	0	0	0
1999	174000000	14800000	0.0	0.0	0.0	0	0	0	0	0	0	0	0
2000	177381107	14681107	0.0	0.5	0.0	0	73406	0	73406	0	0	0	0
2001	180000000	13418893	0.0	0.6	0.0	0	153919	0	153919	0	0	0	0
2002	184000000	14300000	0.0	0.7	0.0	0	254019	0	254019	0	0	0	0
2003	187500000	14800000	0.0	0.8	0.0	0	372419	0	372419	0	0	0	0
2004	190000000	12800000	0.0	0.9	0.0	0	487619	0	487619	0	0	0	0
2005	191752427	10338901	0.5	1.0	0.0	51695	591008	0	642702	0	0	0	0
2006	196000000	16761099	0.6	1.2	0.0	152261	792141	0	944402	0	0	0	0
2007	198000000	12300000	0.7	1.4	0.0	238361	964341	0	1202702	0	0	0	1
2008	200000000	11300000	0.8	1.6	0.0	328761	1145141	0	1473902	0	1	0	1
2009	203000000	13300000	0.9	1.8	0.0	448461	1384541	0	1833002	0	1	0	1
2010	204045186	13226907	1.0	2.0	0.0	580730	1649079	0	2229809	0	1	0	1
2011	207500000	16373093	1.8	3.6	1.0	875446	2238511	163731	3277687	0	1	0	2
2012	209000000	16300000	2.6	5.2	2.0	1299246	3086111	489731	4875087	1	1	0	2
2013	211000000	16300000	3.4	6.8	3.0	1853446	4194511	978731	7026687	1	2	0	3
2014	213000000	16800000	4.2	8.4	4.0	2559046	5605711	1650731	9815487	1	3	1	5
2015	214065256	15746363	5.0	10.0	5.0	3346364	7180347	2438049	12964760	2	3	1	6
2016	216000000	15353637	6.0	12.0	6.0	4267582	8949378	3359267	16576227	2	4	2	8
2017	218000000	16300000	7.0	14.0	7.0	5408582	11077459	4500267	20986308	2	5	2	10
2018	219000000	15800000	8.0	16.0	8.0	6672582	13351440	5764267	25788290	3	6	3	12
2019	220000000	13800000	9.0	18.0	9.0	7914582	15463021	7006267	30383871	4	7	3	14
2020	222011534	12350435	10.0	20.0	10.0	9149626	17445489	8241311	34836426	4	8	4	16

A9.4 Alternative fuels

A9.4.1. Introduction

This section examines alternative fuels for automotive applications and focuses on those fuels which may have significant market penetration over the next 20 years. These include natural gas, methanol, ethanol, biodiesel and dimethyl ether.

Emission factors have been produced in relation to vehicles of current technologies to provide figures for emission reduction potential for the regulated pollutants and energy consumption. Owing to the small amount of experimental data, it was not possible to differentiate between different types of emission (i.e. cold and hot operation). Therefore the overall reduction potentials should be applied to average emission factors of conventional vehicles and include both cold and hot start, and all types of driving (urban, rural and highway).

Only emissions produced during vehicle use are presented and analysed, with limited reference to life cycle emissions[39]. It should be noted, though, that interest in many of these fuels is very much related to their life-cycle potential. Thus the proposed emission factors must be used with caution, bearing in mind that a more extensive analysis is required when their introduction is discussed. Comments are given in several cases on possible drawbacks of alternative fuels such as their effect on engine thermal efficiency, emissions of non regulated pollutants, etc. A complete report of the study of alternative fuels can be found in MEET Deliverable 26 [A51].

A9.4.2. Natural Gas

General

Compressed natural gas (CNG) can be used in either dedicated or dual-fuel engines. In a dual-fuel engine, the CNG is mixed with air in the cylinder and the mixture is ignited by injecting a small amount of diesel as the piston approaches the end of the compression stroke. The diesel rapidly ignites due to the heat of compression, and then ignites the air/CNG mixture. Among the advantages of dual-fuel engines is that they can be designed to operate interchangeably on natural gas with a diesel pilot or on 100% diesel. The CNG dedicated engine requires the installation of a spark ignition system, but has the advantage of needing only one fuel system.

One major difficulty in using CNG is the need for special refuelling stations. They are supplied with low pressure gas, while the storage pressure on the vehicle is much higher, meaning that a multi-stage compressor is needed at the fuelling station. Another difficulty is that CNG composition tends to vary significantly both over time and from city to city [A56]. CNG has both good anti-knock properties (RON is 120) and stable lean combustion properties [A57].

Emissions

Based the data review, emission correction factors calculated for various vehicle categories are listed in Table A101. Because of the limited amount of experimental data, only three vehicle

[39] Emissions from the production of some of these fuels are considered in Part E.

categories are covered (gasoline passenger cars, gasoline light duty vehicles and diesel heavy duty vehicles). It was not possible to derive speed dependent correlations, the figures given in Table A101 referring almost exclusively to the average speed of the FTP cycle. It is also emphasised that the correction factors refer mainly to the cold start temperature legislated in the USA (20 - 30°C). Commenting on the figures of Table A101, it can be stated that:

- There is a general agreement that CO emissions are reduced with the use of CNG.
- There is a general agreement that HC emissions are increased. This is because of high methane emissions and the reduced efficiency of the 3-way catalyst for this pollutant.
- NO_X is generally reduced.
- Emissions of particles are much lower than from diesel engines.
- The fuel consumption of CNG vehicles is similar to that of conventionally fuelled vehicles.
- The emission of some unregulated pollutants (NMHC, benzene, butadiene, formaldehyde and acetaldehyde) is also reduced.

Table A101. Emission correction factors for various CNG fuelled vehicle categories.

	Petrol car with TWC			**Petrol LDV with TWC**			**Diesel heavy duty vehicles**		
	min	**average**	**max**	**min**	**average**	**max**	**min**	**average**	**max**
CO	0.192	0.383	0.593	0.270	0.520	0.711	0.061	0.464	1.101
HC	1.179	1.810	2.366	1.518	1.802	2.365	0.204	3.380	6.280
NO_X	0.118	0.367	0.494	0.224	0.606	0.917	0.112	0.583	0.995
PM	n/a	n/a	n/a	n/a	n/a	n/a	0.020	0.085	0.208
NMHC	(1)	0.128	(1)	0.082	0.106	0.130	n/a	n/a	n/a
Methane	(1)	9.452	(1)	11.25	14.21	16.71	n/a	n/a	n/a
Benzene	(1)	0.003	(1)	0.004	0.005	0.006	n/a	n/a	n/a
Butadiene	(1)	0.000	(1)	0.000	0.022	0.067	n/a	n/a	n/a
Formaldehyde	(1)	0.882	(1)	0.488	0.568	0.639	n/a	n/a	n/a
Acetaldehyde	(1)	0.339	(1)	0.100	0.136	0.170	n/a	n/a	n/a

(1) only one test result.
n/a data not available.

A9.4.3. Methanol

General

Methanol has many desirable combustion and emission characteristics. Its octane number of 110 and excellent lean burn properties make it a good fuel for lean-burn Otto-cycle engines. Because of its low vapour pressure, methanol produces low evaporative emissions. It can be produced from natural gas, crude oil, biomass and urban refuse. At current prices the most economical feedstock for methanol production is natural gas.

The low energy density of methanol means that roughly twice the mass is required to give the same power output as gasoline. The high heat of vaporisation of methanol, combined with the large amounts required, makes it difficult to ensure complete vaporisation. Otto cycle engines using pure methanol become nearly impossible to start below 5°C without special pilot fuels or supplementary heating. This has led to the use of a blend of 85% methanol and 15% gasoline (M85) for current generation light duty methanol vehicles. Most of the emissions benefits of methanol (such as low evaporative emissions) are lost with the switch to M85, however. Flexible fuel vehicles capable of running on combinations of gasoline and up to 85% methanol have been developed, and fleets of these vehicles are being tested. The engines and emission control systems are similar to those of advanced technology gasoline vehicles and the overall energy efficiency and emission properties are also similar. Heavy-duty engine also can be operated on methanol, using a variety of technical approaches.

Methanol can be distributed using the same type of equipment and procedures as are presently used for gasoline, though changes in some materials are necessary because of methanol's greater corrosiveness than gasoline [A59].

Emissions

Based on the data review, the emission correction factors calculated for passenger cars and buses are listed in Table A102. Differences in emissions of some unregulated compounds are also significant. Emissions of benzene and PAH are much less than from gasoline and diesel vehicles, but formaldehyde emissions are more than five times higher.

Table A102. Emission correction factors for methanol fuelled vehicles

	Passenger car (gasoline)			**Buses M100/Diesel**		
	min	**average**	**max**	**min**	**average**	**max**
CO	0.14	0.91	2.47		9.09	
HC	0.09	0.67	2.25		3.65	
NMHC	0.04	0.6	2.00			
NOx	0.21	1.14	3.14		0.20	
CO_2	0.84	0.92	2.47			
PM					0.59	

A9.4.4. Ethanol

General

As the next higher of the alcohols in molecular weight, ethanol resembles methanol in most combustion and physical properties. Ethanol can be produced by processing agricultural crops such as sugar cane or corn but it is more expensive to produce than methanol and requires large harvests of these crops and large amounts of energy for its production [A58]. As for methanol, it has a lower energy density than gasoline and is difficult to vaporise because of its low vapour pressure and high heat of vaporisation [A59]. When ethanol is blended with gasoline in proportions up to 22%, the resulting fuel may be burned in ordinary spark-ignition engines. Ethanol is used extensively as a blendstock for gasoline in Brazil, South Africa and the

United States. Ethanol can be distributed using the same type of equipment and procedures used for gasoline. Although ethanol is not as corrosive as methanol, it is still incompatible with certain materials.

Emissions

Based on the data review, the emission correction factors calculated for regulated emissions from various vehicle categories using ethanol fuel are listed in Table A103. Emissions of acetaldehyde are much higher from ethanol than gasoline or diesel, while those of benzene, butadiene and PAH are considerably reduced.

Table A103. Emission correction factors for various ethanol fuelled vehicle categories

	Passenger car E85/RGF			**Heavy duty truck E100/diesel**			**Heavy duty truck E95/diesel**			**Bus E95/diesel**		
	min	**average**	**max**	**min**	**average**	**max**	**min**	**average**	**max**	**min**	**average**	**max**
CO	0.44	1.43	3.67	3.35	4.02	5.29	2.78	3.59	4.63	0.64	1.18	1.61
HC	0.51	1.30	3.15	3.64	3.97	4.21	3.23	3.58	3.84	0.67	2.96	6.04
NMHC	0.30	1.02	2.67	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
NO_X	0.39	1.03	3.00	0.66	0.81	0.89	0.72	0.80	0.94	0.78	0.88	0.95
CO_2	0.90	0.94	0.98	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
PM	n/a	n/a	n/a	0.96	1.00	1.07	0.25	1.14	1.37	0.53	0.62	0.73

n/a data not available

A9.4.5. Biodiesel

General

The American Society for Testing of Materials has defined biodiesel as "mono alkyl esters of long chain fatty acids derived from renewable lipid feedstocks, such as vegetable oils and animal fats, for use in compression ignition (diesel) engines". In 1970s and 80s, research was conducted with pure and partly esterified vegetable oils in their neat form and in blends with fossil diesel. However, they cause a variety of engine and injector problems, and are no longer used without esterification. In comparison with fossil diesel, biodiesel is characterised by:

- No sulphur content
- No aromatic and PAH content
- About 11% oxygen content (while fossil diesel contains no oxygen)
- Higher cetane value
- Lower heating value
- Better lubricity
- Higher viscosity
- Higher freezing point
- Higher flash point
- No or low toxicity
- Different corrosive properties

Some of these items, such as the higher cetane number and the good lubricity, are obvious advantages of biodiesel, while others, such as the lower heating value, the higher freezing point and the corrosive properties, are its drawbacks [A60].

Emissions

Studies have been conducted throughout the world on the exhaust emissions from biodiesel fuels (e.g. [A61], [A62], [A63]), but their results are often inconclusive and, sometimes, contradictory. Therefore, it has not been possible to suggest reliable, quantitative emission factors for vehicles fuelled with either methyl esters or methyl ester / diesel blends.

Based on the experimental results available in the literature, the apparent influence of biodiesel on emissions relative to fossil diesel can be summarised qualitatively as in Table A104.

Table A104. Influence of biodiesel on emissions

Emission	Trend
Total particulate matter (TPM)	inconclusive
Organic fraction of particulates (SOF)	increase
Sulphate fraction of particulates	decrease
Carbon fraction of particulates	decrease
Visible smoke	decrease
Nitrogen oxides (NO_X)	increase
Hydrocarbons	decrease
Carbon monoxide	decrease
PAH	decrease
Aldehydes	increase
increase - biodiesel increases emissions relative to fossil diesel decrease - biodiesel decreases emissions relative to fossil diesel	

A9.4.6. Dimethyl ether

General

Dimethyl ether (DME) has recently emerged as an attractive alternative fuel for diesel engines. DME can be made from a wide variety of fossil feedstock, including natural gas and coal, and from renewable feedstock and waste [A64]. From a physical point of view, DME resembles liquefied petroleum gas (LPG), with a relatively low vapour pressure at ambient temperature. It has a relatively high cetane number (55 - 60), but an inferior heating value compared to diesel fuel. The most significant property of DME, in terms of operation in a diesel engine, is its low self-ignition temperature, which is close to that of normal diesel fuel.

Preliminary results have shown that the use of DME as a diesel fuel substitute requires little modification to the engine. The injection pressure for DME is much lower than for DI diesel (about 20 and 120 MPa, respectively), and, because of the different injection parameters, dedicated DME engines will be most likely developed rather than flexible, dual fuel diesel-DME units.

Emissions

Based on the data review, the correction factors calculated for regulated emissions from the various DME fuelled vehicle categories are listed in Table A105. Since DME fuel contains no or few carbon-carbon bonds there are no or low PAH or benzene, toluene, xylene emissions during combustion. Aldehyde emissions from DME were reported to be lower than those from diesel engines [A65].

Table A105. Emission correction factors for various DME fuelled vehicle categories

	Light duty vehicle (diesel)			Test engine (diesel)			Heavy duty vehicle (diesel)		
	min	**average**	**max**	**min**	**average**	**max**	**min**	**average**	**max**
CO	(1)	0.22	(1)	(1)	1.42	(1)	0.25	0.32	0.40
HC	(1)	0.22	(1)	(1)	1.00	(1)	n/a	n/a	n/a
NOx	(1)	0.21	(1)	(1)	0.10	(1)	0.40	0.42	0.44
PM	(1)	0.00	(1)	(1)	0.05	(1)	n/a	n/a	n/a

(1) only one test result
n/a data not available

A9.4.7. Summary

Tables A106 and A107 summarise the properties of the alternative fuels considered.

Table A106. Advantages and disadvantages of alternative fuels

Fuel	Advantages	Disadvantages
Natural Gas	Very low particulate emission compared to diesel Low NO_X emissions compared to advanced diesel engines	More complex refuelling system 4 times larger tank size requirement Engine efficiency in bus operation is approximately 20% lower diesel Lean burn engines often have problems with methane emissions
Alcohols	High octane number Low NO emissions Low evaporative losses	Cold start problems Increased aldehydes More corrosive than hydrocarbons Larger fuel tanks Safety and handling problems
Biodiesel	Higher cetane number Good lubricity Zero sulphate and SO_2 emission Particulates of lower toxicity (same mass emission)	Corrosion properties Lower heating value Higher freezing point Increased NO_X emission Increased odour
Dimethyl ether	Little modification to the diesel engine required Very low particle emission Lower engine noise Low NO_X levels without after-treatment	Lower well-to-wheel efficiency Lower viscosity The injection system needs to be developed

Table A107. Effects of alternative fuels on the regulated emissions

Comparison	CO	HC	NOx	PM
NG with gasoline in TWC light duty vehicles	Decrease (0.4 to 0.5)	Increase (1.5 to 2.0)	Decrease (0.4 - 0.6)	n/a
NG with diesel in heavy duty vehicles (lean burn)	Decrease (0.1 to 0.2)	Increase (1.5 to 3.0)	Decrease (~0.6)	Decrease (0.05 to 0.15)
Methanol with gasoline in TWC light duty vehicles	No change (0.7 to 1.1)	Decrease (0.5 to 0.8)	Decrease (0.8 to 0.9)	n/a
Ethanol with gasoline in TWC light duty vehicles	No change (0.4 to 1.1)	Decrease (0.5 to 1.0)	Decrease (0.4 to 0.8)	n/a
Methanol with diesel in heavy duty vehicles	Decrease (0.5 to 0.8)	Decrease (0.4 to 0.6)	Decrease (0.4 to 0.75)	Decrease (0.1 to 0.2)
Ethanol with diesel in heavy duty vehicles	Increase (1.1 to 1.3)	No change (0.7 to 1.5)	Decrease (0.6 to 0.9)	Decrease (~0.2)
Biodiesel with diesel in heavy duty vehicles	Decrease (0.75 to 0.8)	Decrease (0.2 to 0.8)	Increase (1.1 to 1.2)	No change (0.6 to 1.2)
DME with diesel in heavy duty vehicles	n/a	n/a	Decrease (0.2 to 0.5)	Decrease (0.05 to 0.3)

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Part B. RAIL TRANSPORT

Contributors to this section

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B1. INTRODUCTION

This part discusses methods that can be used to estimate emissions from rail traffic. It is based on the methodology described in greater detail in Reference [B1]. Emissions must be estimated on the basis of activity and unit emissions factors for that activity.

$$\dot{E} = \text{Å} \times E' \tag{B1}$$

Where :

- $\dot{E}$ is the emission
- *Å* is the activity
- *E'* is the emission factor for that activity

Rail traffic is characterised by its diversity. Typically, each country in Europe has a national railway system and/or a number of railways which may be owned publicly or by private companies, and within each of these systems there is a variety of applications. Passenger traffic varies from smaller urban trains, usually electrically powered with a low maximum speed and frequent stops and starts, to very high speed passenger trains with infrequent stops. Trains are also used to carry goods, and there are again differences from shunting to high speed international freight traffic. Traffic data for passenger trains are available from time tables, from which average speeds and distances can be determined, but freight traffic is less scheduled and it is more difficult to obtain traffic information.

Another problem is that a significant proportion of European rail traffic uses electrically driven locomotives, and to allocate emissions, the distribution of electricity generation sources in each country must be known. Further complications arise through international sales of electricity, so that the electrical power used to operate a train in a non-nuclear country may actually have been produced by nuclear power in a neighbouring country, and so on. Similarly, it is difficult to allocate emissions in countries where electricity generation is coupled to district heating systems, when an allocation must be made that reflects the multiple use of the primary energy.

Thus, the calculation of emissions from rail transport involves an enormous amount of information, even for a single country. It is more complicated when the calculations concern 15 different countries (and almost as many languages). It is difficult to obtain information that is consistent (in the same units, for example), and one of the results of this work was the clarification of the need for a collection and coordination of the existing data for railway traffic and equipment. There is a large amount of data, which is not generally available for research purposes, in the area of railway emissions and fuel consumption. Obtaining access to, and compiling this information is a need that should be addressed in future studies.

The concern with emissions from trains is only around ten years old, so the results of detailed emission calculations are quite limited. From the limited available literature, it has been attempted to make a calculation model that is better than those previously used, that simply use an emission factor which is multiplied by the total amount of rail traffic (passenger.km or tonne.km) regardless of its type. To improve the existing model, the degree of detail is increased with regard to the speed and number of stops of train services.

B2. CALCULATION METHODS

B2.1Total fuel/energy consumption known

The activity is represented by the consumption of primary fuel or energy. For diesel powered locomotives, the estimate of emissions from the fuel consumed can be obtained by multiplying the fuel consumption by an energy specific emissions factor, as shown in Equation B2.

$$E_i = F \times FSEF_i \tag{B2}$$

Where:

E_i	is the total emission of pollutant, i in the time frame under consideration
F	is the total fuel consumption in the time frame under consideration
$FSEF_i$	is the fuel specific emission factor, typically in grams of pollutant per kg fuel

Typical factors and fuel consumption for diesel locomotive engines are given in Table B1.

Table B1. Typical emissions and fuel consumption factors for diesel railway locomotives

Emission	Power Specific g/kW-h	Fuel Specific - g/kg
CO	1 - 10	5 - 40
VOC	0.5 - 4.0	3 - 25
NO_X	6 - 16	30 - 70
Particulate	0.2 - 1.2	1 - 6
SO_2	0.2 - 2	1 - 10
Fuel Consumption	190 - 220	-

For electric locomotives, emissions estimates can be made on the basis of electrical power consumption. Where the power consumed by railway trains is known, emissions may be calculated using emissions factors for the electrical power generated in the geographical area under consideration. In this case, the calculation is as shown in Equation B3.

$$E_i = El \times ElSEF_i \tag{B3}$$

Where:

E_i	is the total emission of pollutant, i in the time frame under consideration
El	is the total electricity consumption used to power the trains in the time frame under consideration
$ElSEF_i$	is the electrical specific emission factor, typically in grams of pollutant per kWh of electricity consumed

In the calculation of emissions based on electricity consumption, it must be determined whether the specific emission factors for the electricity generation network are given in terms of primary power plant energy consumption, or the amount of electrical energy sent out over the network. The ratio of emissions factors on these different bases is equal to the efficiency of the power generating process, typically in the vicinity of 40 %. Since the energy consumption modelled is for train usage, it would also be appropriate to apply a suitable transmission loss. A summary of European emissions factors for power generation can be found in Part E.

The emissions derived using the above approach will typically be valid for the entire mix of trains. It is not normally possible to distinguish between electricity used for a passenger train or for a freight train on the same line at the same time. Similarly, if all diesel locomotives use common fuelling facilities and diesel locomotives are used for both freight and different types of passenger operation, it is difficult to attribute a fuel consumption to a given type of traffic.

B2.2. Total fuel/energy consumption not known

When calculating emissions for a smaller local area or for a given type of train, the energy or fuel consumption data required for emission calculations may not be known. The same is true for making estimates of emissions for future scenarios. It is then necessary to use additional methods to estimate the energy consumption, and hence, emissions from this type of traffic.

The fundamental step in the calculation procedure is the estimation of the energy consumption of a given type of train in kJ per tonne-km. This energy is the energy required to move the train and is essentially independent of the type of locomotion used, diesel or electric. This enables the same methodology to be used for trains driven by either engine type. The differences in emissions arise primarily through the difference in emissions factors for diesel engines and for electrical power generation. The use of energy consumption on a mass specific basis allows for estimates in future technology based on mass reduction of trains.

Activities are given in terms of passenger.km of passenger transport, and tonne.km of freight transport. Such data are often available from statistical surveys or annual reports of railways.

For passenger trains, emissions can be estimated in the following manner:

$$E_i = WSEC \times \frac{Pkm}{Pps} \times W \times BSEF_i \times 0.0036 \tag{B4}$$

where:

E_i	is the total emission of air pollutant i in the time frame under consideration, tonnes
$WSEC$	is the weight specific energy consumption of the train in kJ/tonne-km
Pkm	is the amount of passenger-km transported by the given train type in the time frame under consideration
Pps	is the load factor of the train, in passengers/seat
W	is the train weight in tonne per seat
$BSEF_i$	is the brake specific emission factor in g/kWh of energy produced.

For freight trains, the estimation can be done in the following way:

$$E_i = WSEC \times \frac{Tkm}{Tpt} \times BSEF_i \times 0.0036 \tag{B5}$$

where:

E_i	is the total emission of air pollutant i in the time frame under consideration, tonnes
WSEC	is the weight specific energy consumption of the train in kJ/tonne-km
Tkm	is the amount of freight transported by the given train type in the time frame under consideration in tonne-km
Tpt	is the load factor of the train, in tonne-freight/total train tonne
$BSEF_i$	is the brake specific emission factor in g/kWh of energy produced.

The activity is represented by traffic data. In reference [B1], typical values are given for European rail traffic. Parameters presented include network length, railway track type, degree of electrification, passenger traffic, and freight traffic on national levels. In order to obtain typical traffic data on a local level, traffic census data were obtained for some Danish passenger types. These data indicate occupancy rates, so that it is possible to convert typical national transport statistics in units such as passenger.km to actual train.km. Fleet data are given for several countries, including the numbers of power units of different types. In addition, weights are given for typical diesel and electric locomotives, and for passenger cars and train sets. Train weight is important, since it is the most significant parameter determining the energy consumption and emissions. The methods recommended for estimating train energy consumption are based on train work per unit mass, and therefore it is important to be able to determine the mass of a train. Some typical values are presented in Section B3.

B2.3. Energy consumption method 1

Average speed also plays a major role in the determination of energy consumption and air pollutant emissions from rail traffic, typical speeds are presented in reference [B1] for a variety of rail traffic, including high speed trains, inter city trains, interregional trains and local trains. Figure B1 shows some results for German traffic, and indicates that speeds depend on train type and distance between stops. Empirical correlations were obtained for train energy consumption in kJ per tonne.km, as a function of average train speed and distance between stops. This method gives a reasonable estimate for the trains considered. An example is shown in Figure B2, and reference [B1] contains similar data for other types of train.

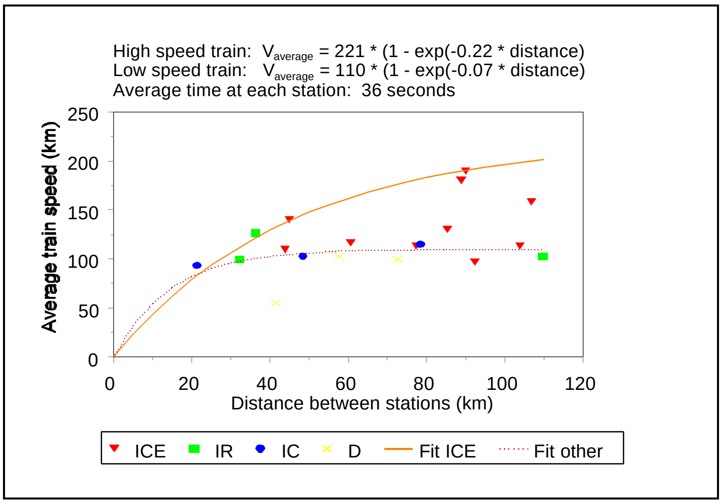

Figure B1. Average train speed as a function of average distance between stops for a variety of German trains

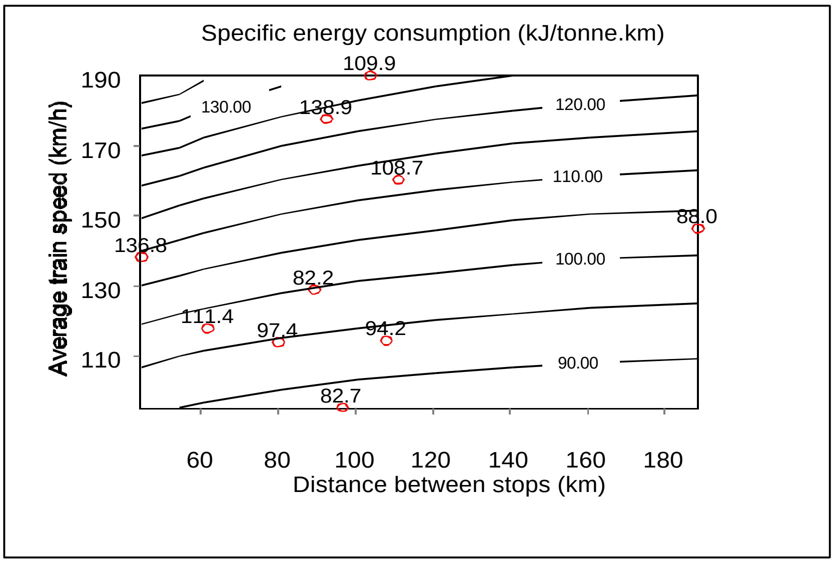

Figure B2. Specific energy consumption for the German ICE train. Lines are for the empirical correlation, and the number are measured values.

The correlations for trains where information was available are given in the following equations. The distances for which the equations are valid are approximate.

$V_{average}$ is the average train speed over the section of the route in question
x is the distance between stops in km

ICE trains:

$$\frac{kJ}{tonne.km} = 0.0070 \times \frac{V_{average}^{2}}{ln(x)} + 74 \qquad \text{(B6)}$$

80 km $\leq$ x $\leq$ 200 km

TGV trains:

$$\frac{kJ}{tonne.km} = 0.0097 \times \frac{V_{average}^{2}}{ln(x)} + 70 \qquad \text{(B7)}$$

150 km $\leq$ x $\leq$ 300 km

British HST passenger trains, Danish IC3:

$$\frac{kJ}{tonne.km} = 0.012 \times \frac{V_{average}^{2}}{ln(x)} + 70 \qquad \text{(B8)}$$

40 km $\leq$ x $\leq$ 100 km

Large freight trains (600 tonne empty mass):

$$\frac{kJ}{tonne.km} = 0.019 \times \frac{V_{average}{}^{2}}{ln(x)} + 63 \qquad \text{(B9)}$$

80 km ≤ x ≤ 200 km

Swedish RC trains:

$$\frac{kJ}{tonne.km} = 0.015 \times \frac{V_{average}{}^{2}}{ln(x)} + 81 \qquad \text{(B10)}$$

30 km ≤ x ≤ 800 km

Urban trains:

Urban train energy consumption is estimated to lie between 200 and 270 kJ/tonne-km

B2.4. Energy consumption method 2

An alternative method for calculating the energy consumption is based on the steady state loading of the train. Steady state train loads in kN have been converted to kJ/tonne.km for several types of train and have a second order dependence on train speed because of aerodynamic loading, as shown in Equation B11.

$$F' = B_0 + B_1 v + B_2 v^2 \qquad \text{(B11)}$$

Where:

F'	is the train force in kN/tonne
B_o, B_1 and B_2	are constants
v	is the train velocity in m/s.

Constants for equation B11 are given in Table B2. Figure B3 shows the steady state loads for a variety of train types.

Table B2. Correlations for the steady state train force in kN/tonne for velocity in m/s for different train types

Train Type	B_0	B_1	B_2
British APT	16.6	36.6×10^{-2}	26.0×10^{-3}
Older British Trains	15.5	29.2×10^{-2}	57.4×10^{-3}
Freight Trains	24.7	0	84.5×10^{-3}
Danish IC3 - Single set	19.7	0	42.5×10^{-3}
Danish IC3 - Multiple set	19.7	0	24.0×10^{-3}
German IC - BR103 Loco	16	0	22.5×10^{-3}

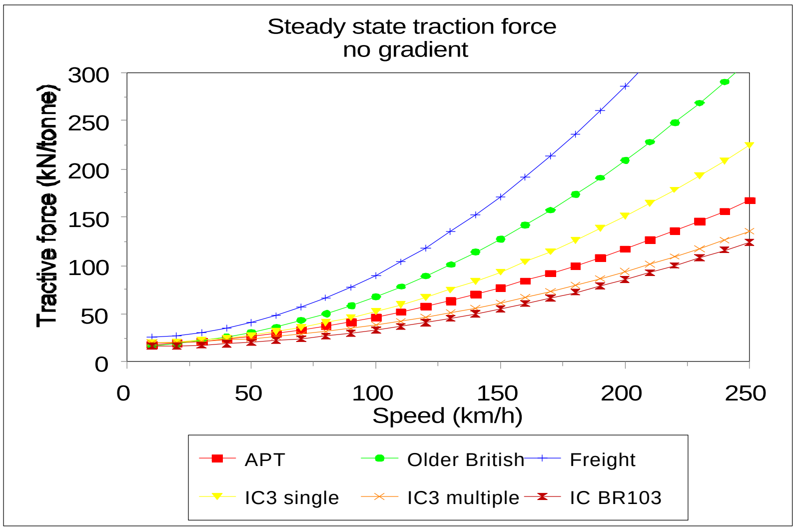

Figure B3 Traction force in kN/tonne for different types of train as a function of train speed

The steady state load can be combined with the acceleration energy and the energy needed to move up or down a gradient to estimate the instantaneous energy consumption of a train in order to estimate emissions for a more detailed route description. For emissions estimations from traffic, the energy consumption must be integrated over a trip length with a representative value for the average speed. If the steady state load is given by a second order polynomial, the integrated energy consumption for a train over a given route is given by:

$$E' = \frac{(N_{stops} + 1)}{L} \times \frac{v_{max}{}^2}{2} + B_0 + B_1 v_{ave} + B_2 v_{ave}{}^2 + g\frac{\Delta h}{L} \qquad \text{(B12)}$$

Where:

B_0, B_1 and B_2	are empirical coefficients for the steady state load
N_{stops}	is the number of time the train stops along the route
$D h$	is the change in elevation between the start and end of the route in m
v_{ave}	is the average train speed on the route in m/s
v_{max}	is the maximum speed to which the train accelerates in m/s

Equation B12 applies where the maximum speed of the train is approximately constant along the route. Where there are significant changes in these variables, it would be best to apply Equation B12 to separate sections of the route. An example would be a high speed train which also runs on track sections where the maximum allowed speed is much lower.

This method is also based on a mass specific energy consumption, and is general, in that most trains of a given type have very similar loading characteristics when expressed in these units. For example, the weight.km specific energy consumption of freight trains and the most modern passenger trains differs by a factor of less than three. It also has the advantage that it is more reliable for small distances between stops than the above empirical relationships. The major difficulty is determining the true number of accelerations, since traffic limitations cause accelerations which are not station related, and the first term in Equation B12 underestimates acceleration energy consumption.

B3. TYPICAL VALUES

B3.1. Passenger train occupancy

Occupancy of trains is depends on the attractiveness of a route, the time of day, and the time of year. As a first approximation, the following estimates for occupancy rates on a yearly average may be used. They are based primarily on German and Danish data:

Urban:	30 %
Regional:	40 %
Inter City/International	50 %

B3.2. Passenger train weight

Passenger train weights vary considerably for different types and within a type, depending on the specific train and configuration for each route. Reference [B1] illustrates weights for several types of passenger trains. Some representative values for common train types are:

High speed:	1.1 tonnes/seat.
Inter city:	1.0 tonnes/seat for conventional trains
	0.7 tonnes/seat for modern light weight
Regional traffic:	0.8 tonnes/seat for conventional trains
	0.4 tonnes/seat for modern light weight electric
Urban transport:	0.7 tonnes/seat for conventional trains
	0.4 tonnes/seat for modern

B3.3. Freight train weight

For freight traffic, an input parameter is often the amount of freight shipped in tonne-kilometres. In addition to the weight of the freight, one must also consider the weight of the cars that carry the freight. The load capacity of freight cars depends largely on the allowable loading per axle. Modern trains in international traffic permit axles loads of about 22.5 tons per axle. Older trains, and trains in some countries allow 20 tons per axle or lower. If a larger loading per axle is permissible without significantly increasing the weight of a given freight car, then the effectiveness of the traffic is higher, assuming of course that cars are fully loaded.

Based on some summaries of Finnish and Spanish railway cars, some approximate factors for freight car weights have been obtained. These are given as the ratio of the tare weight of the car, to the total capacity of the car when fully loaded, and are given in Table B3.

Table B3. Ratio of tare weight to total maximum loaded weight for European freight cars

Axle rating - maximum tonnes per axle	*WR* = Tare weight/total weight
20.0	0.33
22.5	0.27

The actual weight of the train required to transport a given quantity of goods is a function of the degree of loading of the train. Then for a given fraction of loading, *X*, the ratio of the total car weight to the weight of the freight carried, *FR* is given in Equation B13:

$$FR = 1 + \frac{WR}{(1 - WR) \times X} \qquad \text{(B13)}$$

B3.4. Locomotive weight

In addition to the weight of the cars, the locomotive must also be considered. The following general correlations may be used to estimate the weight of the locomotives:

Diesel locomotives

$$ln(M) = -0.255 + 0.658 ln(P) \qquad \text{(B14)}$$

Electric locomotives and power units

$$ln(M) = 1.29 + 0.395 ln(P) \qquad \text{(B15)}$$

Where:

M is the locomotive mass in tonnes
P is the locomotive power in kW

B4. FUTURE EMISSIONS

In order that the methodology may be used to investigate future conditions and scenarios, it is necessary to estimate what changes in rail transport are likely. Emissions are estimated fundamentally as the product of a quantity of traffic activity and the emission rate per unit of activity, and so future developments in parameters describing both the activity and the rates of emission must be examined.

Any estimate of future conditions has to be based on many assumptions that cannot be validated. Changes in economic and political conditions can have a large effect on the composition of traffic for passenger and goods transport, and developments in those areas are difficult or impossible to predict. These estimates assume a steady development in the factors influencing the transport system: no catastrophic scenarios are assumed to occur, and no dramatic technological breakthroughs affecting the railway system are foreseen. The following paragraphs summarise a more extensive evaluation contained in MEET Deliverable 25 [B2]

B4.1. Trends in rail traffic

To provide a basis for determining future developments in rail traffic, past trends were examined. In all 15 EU countries except Belgium, there was an increase in rail passenger transport between 1970 and 1990: the biggest increase, more than 50%, was in France. Conversely, rail freight transport has declined in many countries, by about a third, for example, in the UK. The overall average changes in the EU were an increase of 30% in rail passenger-km and a reduction of 9% in rail tonne.km of freight over this 20 year period. Expressed as annual growth rates, these figures become 1.3% per year for passenger transport and -0.5% per year for freight. As well as significant variation between countries, these average figures also mask differences between various types of rail transport.

High speed trains

High speed trains first entered service in France in 1980, and are now operated successfully in many countries. Figure B4 shows how the total tonnage of high speed trains in Europe has increased since 1980. These trains also have relatively high occupancy rates, averaging around 50%, but more than 95% on the most popular services. In view of the success of the high speed lines, it is expected that their expansion will continue rapidly into the next century. The growth rate is expected to be around 8 to 10% per year, expressed in passenger.km.

Local urban trains

All major cities in the EU have a local train system using underground or surface lines or both, and many are being expanded and improved. Road congestion, and other impacts of road traffic are among the main reasons for improving public transport systems (both buses and trains). On the basis of expected changes in urban populations, and assuming that there are no widespread restrictions on passenger car traffic, it is expected that there will be an annual increase of 2% in local urban train transport (as passenger.km). Because of the extensive use of local urban trains by commuters, their occupancy is relatively low during off-peak periods, and averages around 30%, despite very high occupancies during rush hours.

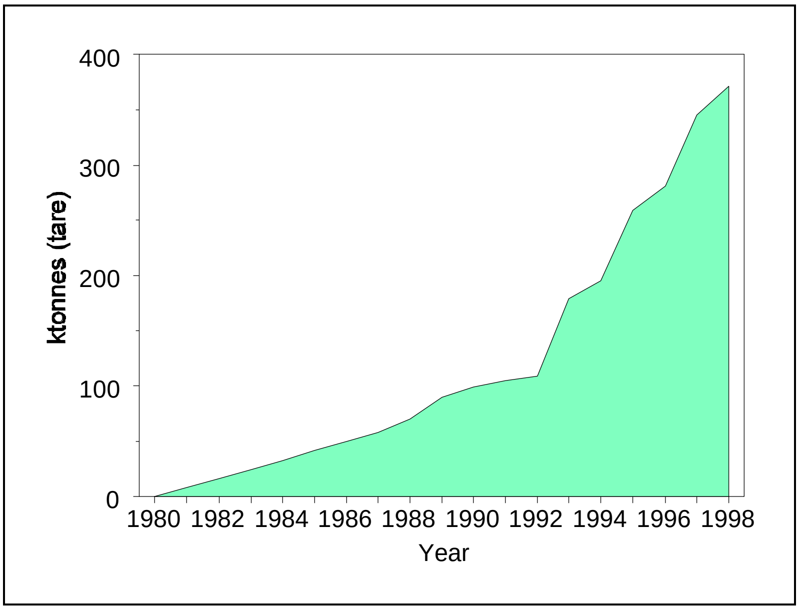

Figure B4. The increase in the total tonnage of high speed trains in Europe

Regional trains

Considerations similar to those for local trains are also applicable to regional trains. No significant changes are expected since the network is more or less fully expanded in most places. A minor loss of passengers to high speed trains is likely to occur on certain lines. Thus, an annual increase of 1% (in passenger.km) is expected, with no change in train occupancy, which currently averages about 40% for this type of service.

Freight trains

It is more difficult to predict the development of rail freight traffic. As already noted, there has been a general decline since 1970, but a small increase has been seen in more recent years. Assuming that there are no major political incentives to promote rail freight transport (by imposing extra taxes on road freight, for example), it is expected that rail freight traffic will grow slowly, at a rate of 1% per year, in tonne.km. Occupancies are likely to remain unchanged.

B4.2. Trends in propulsion type

Emissions depend on the type of locomotive (electric or diesel) that is used. There is no direct relationship between the extent to which the rail network is electrified and the amount of traffic powered by electricity. In France and Germany, for example, more than 80% of traffic was electrically operated in 1994, but both countries have less than 40% of the network electrified.

In most EU countries it is expected that the amount of electrically powered traffic will increase, either because of increased use of the existing electrified network or by increasing the electrified share of the network. The proportion of European rail traffic powered by electricity in 2020 is expected to increase to 80% from the present share of about 65 to 70%.

B4.3. Trends in rail technology

B4.3.1 Train construction

A running train has to overcome several resistances - inertia, rolling/bearing and aerodynamic resistance. Reductions in any of these will lower the energy consumption and emissions.

Inertia

A train's inertia depends on its weight, and weight reductions can be achieved either by improving construction to use less material or using materials with a lower density. A recent study has shown that a weight reduction of 24% could be achieved on a standard rail car body by using ultra high strength steel. It is unrealistic, though, to assume that such a reduction will be possible for trains, and a more realistic figure is probably 10 to 15%. Substitute materials, mainly aluminium, are already widely used in the construction of the bodies of modern train wagons. Reductions in car weight could allow the weight of the locomotive also to be reduced, but are more likely to be used to allow locomotives to pull longer trains.

Passenger train weight is often expressed as the specific weight per seat, and Table B4 lists the specific weight for a wide range of train types. Conventional trains represent the average of those now operating, modern trains are those now being built and advanced trains are those expected as the market standard in 2020.

Table B4. Specific weights of passenger trains

Train type	Specific train weight (tonnes/seat)		
	Conventional	Modern	Advanced
High speed	1.2	1.0	0.4
Inter city	1.0	0.7	0.4
Regional	0.8	0.4	0.3
Urban	0.7	0.4	0.3

Table B3 shows that the ratio of tare weight to total weight for freight wagons is around 0.3, depending on the maximum permitted axle load. It is expected that future constructions because of improvements in the use and type of materials could reduce this ratio to 0.2. However, freight wagons have very long lifetimes and it is not likely that this will have a significant impact on the average fleet ratio.

Rolling/bearing resistance

Rolling resistance arises from the wheels rolling on the track and bearing resistance from friction in the axle bearings. They are dependent on the weight, train speed and number of axles, and reductions of any of these will reduce the resistance. Weight reductions have been considered above. It is not likely that train speeds will decrease. Regarding the number of axles, there is a tendency for passenger trains to have fewer, but for freight trains to have more to allow for higher loads. Bearing resistance can be virtually eliminated by the use of ball bearings, but it is not expected that rolling resistance will change significantly.

Aerodynamic resistance

Aerodynamic resistance depends strongly on the train speed and on the dimensions and shape of the train. The train frontal area will probably remain constant for trains developed in the near future: increases would require major infrastructural changes (bridges, track width etc.); decreases would reduce the train's carrying capacity. Thus, the only way of limiting the general increase in aerodynamic resistance is to modify the styling of the train. Advanced aerodynamic shapes are already used for high speed trains, and it is difficult to make further significant improvements.

B4.3.2 Power technology

Diesel engine technology

Emission reduction technologies for diesel engines have been driven by the requirements for less polluting road vehicles. However, the basic emissions from heavy duty road and railway diesel engines are similar, and the technologies developed for emission control could be applied equally to railway engines. Table B5 shows typical emission factors for heavy duty road diesel engines, and demonstrates that significant reductions in NO_X and particulates are possible. The major factor that will determine whether equivalent improvements are achieved for railway locomotives is the legislative process. Given the long lifetime of railway locomotives, there will not be a significant impact on overall emissions until perhaps the year 2015, even though new railway engines are then expected to have very low emissions.

Table B5. Emission factors for heavy duty road diesel engines

	Time frame	Emission limit (g/kW.h)			
		CO	HC	NO_X	PM
Pre-regulation	1980 - 1990	3.5	1.0	12.0	0.60
EURO I (>85 kW)	1992	4.5	1.1	8.0	0.60
EURO II	1996	4.0	1.1	7.0	0.25
EURO II	1998	4.0	1.1	7.0	0.15
EURO III	2003	2.0	0.6	5.0	0.10

Electricity generating technology

Methods used to generate electricity vary greatly throughout Europe, and the production of emissions depends strongly on the generating mix. Technologies include combustion (oil, coal, gas), nuclear power, hydro-power and other renewable sources. Only the emissions from combustion plant are significant (disregarding those from nuclear generation, which are outside the scope of this work), and the most important compounds are NO_X and SO_2. Emissions of both compounds can be greatly reduced by aftertreatment (e.g. selective catalytic reduction), and new power plants are generally equipped with emission control equipment.

It is expected that the mix of generating plant will remain unchanged until 2020, but that new combustion plants will be less polluting and steps will be taken to reduce pollution from existing plants. Figure B5 shows the expected effect of the likely improvements.

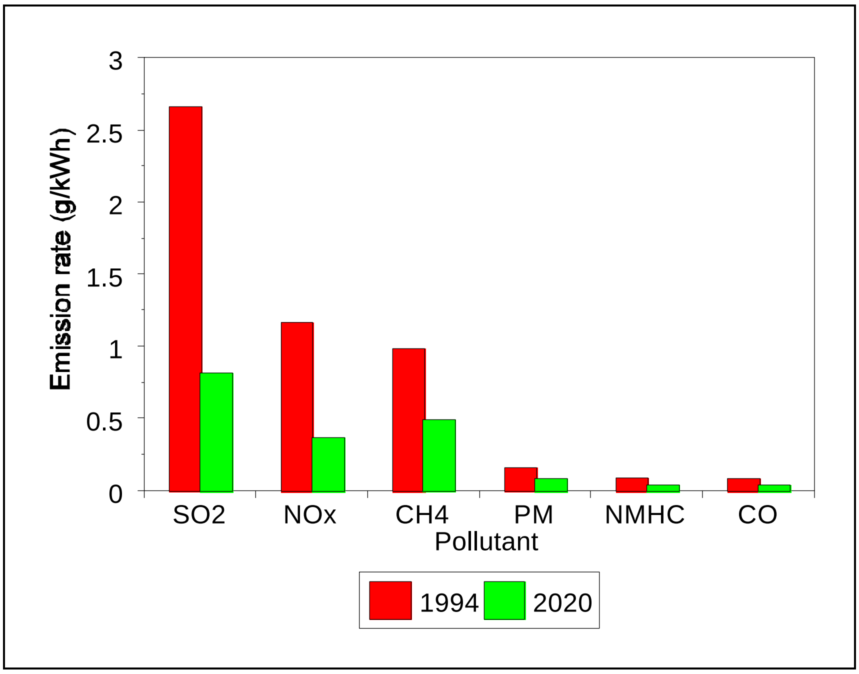

Figure B5. Current and estimated future emissions from electricity generation in Europe

B4.4 Summary

A summary of the potential changes in rail traffic and emissions is given below.

Passenger traffic (passenger.km)

High speed services:	8 - 10% annual growth
Regional services:	1% annual growth
Urban services:	2% annual growth

Freight traffic (tonne.km)

1% annual growth

Share of traffic powered by electricity

1998: 65 - 70%   2020: 80%

Specific weight

	1998	2020
High speed trains:	1.0 t/seat	0.4 t/seat
Inter city trains:	0.7 t/seat	0.4 t/seat
Regional trains:	0.4 t/seat	0.3 t/seat
Urban trains:	0.4 t/seat	0.3 t/seat
Freight trains (loading ratio):	0.27	0.22

Electrical power generation emissions (g/kW.h)

	1998	2020
SO_2:	2.7	0.8
NO_X:	1.2	0.35
HC:	1.1	0.55
CO:	0.08	0.04
PM:	0.14	0.07

Railway diesel locomotive emissions (g/kW.h)

	1998	2020
SO_2:	1.0	0.03
NO_X:	12	3.5
HC:	1.0	0.50
CO:	4.0	0.50
PM:	0.25	0.08

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Part C. SHIP TRANSPORT

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C1. INTRODUCTION

Methods to estimate the energy consumption and pollutant emissions from ships are described in this part. Two procedures have been developed, a simplified method and one that is more detailed. The choice of method for a particular application depends mainly on the amount of information that is available to describe the shipping activity. A more detailed account is contained in MEET Deliverables 19 and 25 [C1, C2].

Ship traffic can be represented as in Figure C1, which shows two cases: a typical cargo, container or similar ship and a ferry. Each journey can be classified according to three basic phases, cruising between ports, manoeuvring in the harbour area, and hotelling at the dockside.

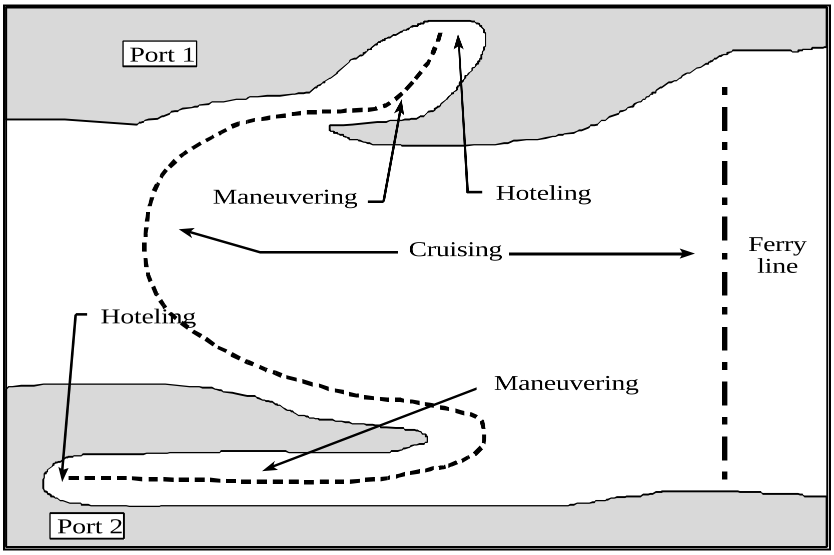

Figure C1. Ship traffic

The distinction between the two cases is that the cargo ship's activities are generally more complex than those of the ferry. The cruising phase is important for both types of vessel. After its arrival in harbour a ship continues to consume energy and emit pollutants during its hotelling phase. Power must be generated in order to supply the ship's lighting, heating, refrigeration, ventilation, etc. To some extent, this is true for all types of ship, but the dockside activities of the cargo ship are of more significance than those of the ferry. Its time spent in the harbour is longer than a typical ferry, and energy is used for loading and unloading its cargo as well as the maintenance of on-board services. Liquid bulk ships, for example, use pumps for tanker loading and unloading. In smaller tankers the pumping power requirement will add to the electrical load whereas for larger ships steam turbine driven pumps are generally used with a consequent boiler load. These power requirements and associated emissions can be relatively high.

In ferry traffic the hotelling and manoeuvring phases are not as important as the cruising phase. Although it could be necessary to take into account the manoeuvring phase for short routes, as the passage length increases (i.e. over a few hours) the proportional contribution from this phase will reduce and under those circumstances could be neglected.

The more detailed methodology has been developed to take into account transient operations, port loading and unloading and auxiliary power generation, thus providing an estimate of emissions from ships cruising and in port. The simplified methodology has been developed for use when dockside activities are unimportant or when information on harbour activities is not available.

As well as distinctions between types of activity, the other main aspects of ship transport that must be taken into account are the type of ship, the type of engine and the type of fuel used, and both the simple and detailed methodologies provide a classification according to these properties. The principle used in both methods is initially to calculate the energy consumption associated with the defined shipping activity and then to estimate pollutant emissions using fuel specific emission factors.

The basic information on fuel consumption and emission factors was derived from an extensive literature review and contacts with main organisations (EPA, IMO, CONCAWE, Lloyd's Register and organisations which work on maritime activities such as Marintek and Mariterm). The resulting data were analysed to provide a coherent set of consumption and emission rates.

C2. CLASSIFICATION SYSTEM

Both the simplified and detailed methodologies use a classification system describing the pollutant, the type of ship, its engine type and the fuel it uses. The classes are given in Tables C1 to C4. Additionally, the detailed method takes account of a number of distinctive operating modes of the ship. These are listed in Table C5.

Table C1. Pollutant classification

Code	Name
NO_X	Nitrogen oxides
SO_X	Sulphur oxides
CO	Carbon monoxide
VOC	Volatile organic compounds
PM	Particulate matter
CO_2	Carbon dioxide

Table C2. Ship type classification

Code	Name
SB	Solid Bulk
LB	Liquid Bulk
GC	General Cargo
CO	Container
PC	Passenger/Ro-Ro/Cargo
PA	Passenger
HS	High speed ferries
IC	Inland Cargo
SS	Sail ships
TU	Tugs
FI	Fishing
OT	Other

Table C3. Engine type classification

Code	Name
SE	Steam turbines
HS	High speed motor engines
MS	Medium speed motor engines
SS	Slow speed motor engines
IP	Inboard engines - pleasure craft (only for detailed methodology)
OP	Outboard engines (only for detailed methodology)
TO	Tanker loading and offloading (only for detailed methodology)

Table C4. Fuel classification[40]

Code	Name
BFO	Bunker fuel oil
MDO	Marine diesel oil
MGO	Marine gas oil
GF	Gasoline fuel

Table C5. Operating modes (for detailed methodology)

Code	Name
C	Cruising
M	Manoeuvring
H	Hotelling
T	Tanker offloading
A	Auxiliary generators

[40] Fuel for shipping is essentially covered by oil products, described as marine distillates and marine fuels. Two types of marine distillates exists, marine gas oil (MGO) and marine diesel oil (MDO), a heavier distillate fuel, which may contain a proportion of residual fuel oil. Marine distillates are normally used for the main engines of small vessels and for the auxiliary engines of larger vessels. Large vessels normally use marine fuels. These are supplied in many grades classified by viscosity. The most common grade has a maximum viscosity of 380 cSt at 50 ^{o}C and is normally termed bunker fuel oil (BFO). The major component of BFO is heavy residue from refining processing.

C3. OUTLINE METHODOLOGIES

In the simplified methodology an estimate of the number of working days is required for each class of ship, engine type and fuel.

The emissions are obtained as:

$$E_i = \sum_{j,k,l} E_{i,j,k,l} \tag{C1}$$

with

$$E_{i,j,k,l} = S_{j,k}(GT) \times t_{j,k,l} \times F_{i,j,l} \tag{C2}$$

where

i	is the pollutant (see Table C1)
j	is the fuel (see Table C4)
k	is the ship class (see Table C2)
l	is the engine type class (see Table C3)
E_i	is the total emissions of pollutant i
E_{ijkl}	is the total emission of pollutant i from use of fuel j on ship class k with engine type l
$S_{jk}(GT)$	is the daily consumption of fuel j in ship class k as a function of gross tonnage
t_{jkl}	is the number of days in navigation of ships of class k with engine type l using fuel j
F_{ijl}	is the average emission factor of pollutant i from fuel j in engines type l

The detailed methodology differs only by distinguishing between the different operating modes of the ships. In this case, the emissions are obtained as:

$$E_i = \sum_{j,k,l,m} E_{i,j,k,l,m} \tag{C3}$$

with

$$E_{i,j,k,l} = S_{j,k,m}(GT) \times t_{j,k,l,m} \times F_{i,j,l,m} \tag{C4}$$

where

i	is the pollutant (see Table C1)
j	is the fuel (see Table C4)
k	is the ship class (see Table C2)
l	is the engine type class (see Table C3)
m	is the operating mode (see Table C5)
E_i	is the total emissions of pollutant i
E_{ijklm}	is the total emission of pollutant i from use of fuel j on ship class k with engine type l in operating mode m
$S_{jkm}(GT)$	is the daily consumption of fuel j in ship class k in mode m as a function of gross tonnage
t_{jklm}	is the number of days in navigation of ships of class k with engine type l using fuel j in mode m
F_{ijlm}	is the average emission factor of pollutant i from fuel j in engines type l in mode m

C4. ENERGY CONSUMPTION

The first requirement for a calculation of emissions is to determine the fuel consumption of the ship or ships involved. Data for this purpose have been derived from information supplied by Lloyd's Maritime Information Services Ltd. In the Lloyds database there are approximately 15000 vessels with fuel consumption data and, of these, about 11000 vessels have tonnage measured in accordance with the 1969 International Tonnage Convention[41]. The distribution of vessels in the sample is shown in Tables C6 (according to propulsion type), C7 (according to speed class) and C8 (according to the ship type classification in Table C2). There are no data for inland cargo vessels and it is suggested that general cargo data be used for this class.

Table C6. Distribution of the ship sample by propulsion type

Propulsion	Number of ships
Diesel engines	10796
Gas turbines	12
Steam turbines	221
Sail	6
Total	11035

Table C7. Distribution of the ship sample by speed class

Speed class (knots)	Number of ships
0-10	201
10-20	10021
20-30	664
30-40	17
40-45	4
Unknown	128

Table C8. Distribution of the ship sample by ship class

Class no.	Ship class	Number of ships
01	Solid bulk	2206
02	Liquid bulk	2542
03	General cargo	3450
04	Container	858
05	Passenger/Ro-Ro/Cargo	856
06	Passenger	83
07	High speed ferry	18
08	Inland cargo	0
09	Sail ships	6
10	Tugs	499
11	Fishing	147
12	Other	370

[41] The world fleet consists of 86000 vessels. About a half of these vessels are cargo-carrying vessels (approximately 40000), many of the other vessels are small non-cargo carrying vessels such as fishing vessels (over 22000) and tugs (over 9000).

A statistical analysis was carried out using this sample of 11000 vessels. Particularly, regression analyses on fuel consumption as a function of gross tonnage were performed for each ship class. The data are highly correlated ($r > 0.68$ for all cases) and all the regressions are significant at a confidence level greater than 99%. Table C9 presents the functions derived for each type of ship. It also provides an average function for all ships in the database, for use when no information about ship class is available, and an average fuel consumption for each ship class that may be used if no information on gross tonnage is available.

Table C9. Average fuel consumption at full power and linear regression equations of consumption at full power as a function of gross tonnage

Ship type	Average consumption (t/day)	Consumption at full power (t/day) as function of gross tonnage (GT)
Solid bulk	33.80	C_{jk} = 20.186 + .00049 * GT
Liquid bulk	41.15	C_{jk} = 14.685 + .00079 * GT
General cargo	21.27	C_{jk} = 9.8197 + .00143 * GT
Container	65.88	C_{jk} = 8.0552 + .00235 * GT
Passenger/Ro-Ro/Cargo	32.28	C_{jk} = 12.834 + .00156 * GT
Passenger	70.23	C_{jk} = 16.904 + .00198 * GT
High speed ferry	80.42	C_{jk} = 39.483 + .00972 * GT
Inland cargo	21.27	C_{jk} = 9.8197 + .00143 * GT
Sail ships	3.38	C_{jk} = .42682 + .00100 * GT
Tugs	14.35	C_{jk} = 5.6511 + .01048 * GT
Fishing	5.51	C_{jk} = 1.9387 + .00448 * GT
Other ships	26.40	C_{jk} = 9.7126 + .00091 * GT
All ships	32.78	C_{jk} = 16.263 + 0.001 * GT

j is the fuel type and k is the ship class

The data from Lloyd's provide fuel consumption figures at full power. A correction may be made to take into account the different throttle settings according to the data in Table C10 [C3].

Table C10. Percentage of full power for different throttle settings

Throttle setting	% of full power	
	Ship	Tug
Stop and idle	0	5
Dead slow	10	10
One third and slow	20	20
Half power	40	40
Three quarters	60	60
Full power	80	80

The effective fuel consumption can be obtained, in the simplified methodology as:

$$S_{jk}(GT) = C_{jk}(GT) * 0.8 \qquad \text{(C5)}$$

and in the detailed methodology as:

$$S_{jkm}(GT) = C_{jk}(GT) * pm \tag{C6}$$

where

$S_{jk}(GT)$	is the daily consumption of fuel *j* in ship class *k* as a function of gross tonnage
$C_{jk}(GT)$	is the daily consumption at full power of fuel *j* in ship class *k* as a function of gross tonnage
$S_{jkm}(GT)$	is the daily consumption of fuel *j* in ship class *k* in mode *m* as a function of gross tonnage
pm	is the fraction of maximum fuel consumption in mode *m*.

The default fractions in Table C11 can be used for the different operating modes.

Table C11. Fraction of maximum fuel consumption in different mode

Mode		Fraction
Cruising		0.80
Manoeuvring		0.40
Hotelling		0.20
	passenger	0.32
	tanker	0.20
	other	0.12
Tug	ship assistance	0.20
	moderate activity	0.50
	under tow	0.80

For tanker offloading a fuel consumption of 0.7 kg/ton of product offloaded can be used as a default [C4].

C5. POLLUTANT EMISSIONS

Pollutant emission factors have been derived from a review of all the emission data available in the literature. They are reported as fuel or energy specific emission factors, in units of kg/tonne of fuel or g/kW.h respectively. Emission factors for sulphur oxides, and in some cases particulates, are given as a function of the sulphur content of the fuel. The data identified by this review are tabulated in Tables C12 and C13. Ships in the hotelling mode often use auxiliary electricity generators, and Table C14 provides emission factors for diesel generators.

The data from the review have been used to specify default emission factors for use in both the simplified and detailed methodologies, and these are given in Tables C15 to C20. The data for particulate emissions is expressed as the total particulate mass. However, there is greater concern about the effects of smaller particles, and health standards are often given in terms of PM_{10} (i.e. particles with a diameter less than 10 µm). It is possible to estimate PM10 using the following factors: 0.86 of total PM for steam residual oil engines, 0.5 of total PM for steam distillate oil engines and 0.82 of PM for diesel engines.

Table C12. Emission factor review (data in kg/ton of fuel)

Engine type	Load %	NO_X	CO	CO_2	VOC	PM	SO_X	Ref.
Medium speed diesel engines*		59	8	3250	2.7		21S	[C5]
Slow speed diesel engines*		84	9	3165	2.5		21S	[C6]
Medium speed diesel engines*		57	7.4	3170	2.4		20S	[C7]
Slow speed diesel engines*		87	7.4	3170	2.4		20S	[C8]
Medium-slow speed diesel engines*	25	88.5	8.3	3270	2.85		56.5	[C8]
	50	79.6	5.5	3200	2.33		56.2	[C8]
	85	68.3	3.8	3250	1.92		57.3	[C8]
Medium-slow speed diesel engines*						1.2		[C8]
Medium-slow speed engines -fuel oil*						7.6		[C8]
Motor ships - fuel oil & diesel		70	1.5	3110	3	2.5		[C9]
Steamships - fuel oil & diesel		8	0.8	3110	0.3	3.9		[C9]
High speed engines - diesel		70	9		3	1.5		[C9]
Medium speed engines - diesel		80	2		2	1.2		[C9]
Low speed engines - diesel		95	1.5		4	3.5		[C9]
All engines - Manoeuvring		47	32		13			[C10]
All engines - Berthing		22.2	2.7		0.4			[C10]
Inland navigation		76	31		9.1	13	8	[C11]
Inboard pleasure craft - diesel		48	20		26		19S	[C11]
Inboard pleasure craft - gasoline		21.2	201		13.9		24S	[C11]
Outboard craft - gasoline		1.07	540		176		24S	[C11]
Diesel motor ships - river		39	14		7.0		19S	[C11]

* Under steady state (SS) conditions: in transient (T) mode, E(T) = a * E(SS) with a = 1.5 for VOC, 3.8 for CO and 0.9 for NO_X.

S is the sulphur content of the fuel.

Table C12 (continued). Emission factor review (data in kg/ton of fuel)

Engine type	Load %	NO_X	CO	CO_2	VOC	PM	SO_X	Ref.
Diesel motor ships - lake		36	15		8.2		19S	[C11]
Diesel motor ships - coastal		37	15		7.0		19S	[C11]
Steamships - hotelling - residual oil		4.55	neg.		0.40	1.25	20S	[C11]
Steamships - cruise - residual oil		6.98	0.43		0.09	2.50	20S	[C11]
Steamships - full - residual oil		7.95	0.91		0.22	7.06	20S	[C11]
Steamships - hotelling - distillate oil		3.11	0.6		0.5	2.11	20S	[C11]
Steamships - cruise - distillate oil		3.31	0.6		0.5	2.08	20S	[C11]
Steamships - full - distillate oil		6.25	0.6		0.5	2.08	20S	[C11]
Steamships - Cruise and Transit		8	0.9		0.01	1.2S+0.4	20S	[C4]
Steamships - Manoeuvring		7	0.4		0.1	1.2S+0.4	20S	[C4]
Diesel motor ships		42	9		3.4	5	22S	[C4]
Tanker offloading		12	1		0.01	1.4S+0.4	22S	[C4]
Sailing ships - 4 stroke		55.9						[C12]
Sailing ships - 2 stroke		72.8						[C12]
Diesel vessel - 200HP - Idle		0.9	29.5		54.9			[C11]
Diesel vessel - 200HP - Slow		29.3	20.4		14.5			[C11]
Diesel vessel - 200HP - Cruise		59.4	17.7		23.9			[C11]
Diesel vessel - 200HP - Full		35.8	19.9		8.4			[C11]
Diesel vessel - 300HP - Slow		47.3	8.3		8.0			[C11]
Diesel vessel - 300HP - Cruise		54.7	6.7		7.1			[C11]
Diesel vessel - 300HP - Full		38.6	8.2		2.9			[C11]
Diesel vessel - 500HP - Idle		13.9	39.6		16.5			[C11]
Diesel vessel - 500HP - Cruise		47.5	13.9		6.2			[C11]
Diesel vessel - 500HP - Full		37.8	11.8		3.2			[C11]
Diesel vessel - 600HP - Idle		43.1	24.1		9.6			[C11]
Diesel vessel - 600HP - Slow		35.2	7.1		2.3			[C11]
Diesel vessel - 600HP - Cruise		48.9	10.9		3.4			[C11]
Diesel vessel - 700HP - Idle		34.5	41.1		13.5			[C11]
Diesel vessel - 700HP - Cruise		63.5	5.0		1.3			[C11]
Diesel vessel - 900HP - Idle		15.1	31.4		34.9			[C11]
Diesel vessel - 900HP - 2/3		23.4	8.8		2.3			[C11]
Diesel vessel - 900HP - Cruise		50.5	11.4		2.5			[C11]
Diesel vessel - 1580HP - Slow		52.1	17.2					[C11]
Diesel vessel - 1580HP - Cruise		87.4	6.2					[C11]
Diesel vessel - 1580HP - Full		66.7	33.4		2.3			[C11]
Diesel vessel - 2500HP - Slow		58.9	8.4		3.2			[C11]
Diesel vessel - 2500HP - 2/3		45.8	17.8		2.1			[C11]
Diesel vessel - 2500HP - Cruise		54.9	11.0		2.3			[C11]
Diesel vessel - 2500HP - Full		56.1	13.5		3.0			[C11]
Diesel vessel - 3600HP - Slow		51.5	20.8		8.4			[C11]
Diesel vessel - 3600HP - 2/3		50.4	4.0		3.5			[C11]
Diesel vessel - 3600HP - Cruise		47.7	5.9		4.7			[C11]
Diesel vessel - 3600HP - Full		43.1	8.8		4.1			[C11]

Table C13. Emission factor review (data in g/kWh)

Engine type	Load %	NOx	CO	CO2	VOC	PM	Ref.
Slow speed two stroke	80	17.7	0.2	600	0.8	0.9	[C13]
	20	17.1	0.6	1000	1.3	0.9	[C13]
Medium speed four stroke	80	14.0	1.0	620	0.2	0.4	[C13]
	20	21.0	2.2	1120	0.4	0.6	[C13]
Medium speed diesel engines*		12.4	0.73	676	0.2		[C14]
Supply vessel/ice breaker*		11.8	0.98	646	0.027		[C14]
Medium speed engines - emission rating†		9.87			0.42	0.43	[C15]
High speed craft‡		15.3			0.25	1.18	[C15]
Fishing vessels¶		12.0			0.30	0.25	[C15]
Gas turbines		2 - 4					[C16]
Gasoline Two Stroke Outboard <3.9 hp		2.4	505		336		
Gasoline Two Stroke Outboard 3.9 - 9.9 hp		1.5	571		329		
Gasoline Two Stroke Outboard 9.9 - 29.9 hp		1.6	462		185		
Gasoline Two Stroke Outboard 29.9 - 49.9 hp		2.2	298		140		
Gasoline Two Stroke Outboard 49.9 - 74.9 hp		2.4	299		150		
Gasoline Two Stroke Outboard 74.9 - 99.9 hp		2.2	332		155		
Gasoline Two Stroke Outboard 99.9 - 149.9 hp		1.7	338		152		
Gasoline Two Stroke Outboard 149.9 - 199.9 hp		1.7	380		150		
Gasoline Two Stroke Outboard >199.9 hp		1.4	378		165		
Gasoline Four Stroke Outboard <3.9		8.7	380		47.0		
Gasoline Four Stroke Outboard 3.9 - 9.9		5.7	300		28.3		
Gasoline Four Stroke Outboard 9.9 - 29.9		6.5	280		15.6		
Gasoline Four Stroke Outboard 29.9 - 49.9		10.2	250		10.9		
Gasoline Four Stroke Outboard 49.9 - 74.9		11.3	250		8.4		
Gasoline Four Stroke Outboard 74.9 - 99.9		9.2	225		14.5		
Gasoline Four Stroke Outboard 99.9 - 149.9		11.2	225		11.1		
Gasoline Four Stroke Outboard 149.9 - 199.9		6.5	200		15.0		
Gasoline Four Stroke Outboard >199.9		6.5	200		15.0		
Gasoline Personal Watercraft (2 stroke) 30 - 50 hp		0.95	346		181		
Gasoline Personal Watercraft (4 stroke) 30 - 50 hp§		6.5	280		15.6		
Gasoline Personal Watercraft 50 - 75 hp		1.37	339		206		
Gasoline Inboard 100 - 150 hp		7.6	175		7.2		
Gasoline Inboard 150 - 200		7.6	175		7.0		
Gasoline Inboard >200		10.4	174		5.4		

* based on single ferry measurements
† average of four car and passenger ferries and two fishing vessels after adjustments and adaptations to existing engine design with the purpose of reducing NO_X emissions
‡ only one craft
¶ average of two fishing vessels
§ taken from the 4-stroke outboard emission factors

Table C14. Emission factors for diesel powered electricity generators in vessels (kg/ton of fuel)

Rated output (generator electrical output) kW	Load (% rated output)	NOx	CO	CO2	VOC	PM	SOx	Ref.
20	0	60.89	21.08		36.89		19	[C11]
20	25	62.30	11.18		28.57		19	[C11]
20	50	66.98	7.49		20.26		19	[C11]
20	75	69.44	4.00		11.94		19	[C11]
40	0	29.98	21.43		81.97		19	[C11]
40	25	30.68	12.53		51.87		19	[C11]
40	50	31.73	9.48		40.05		19	[C11]
40	75	32.67	8.99		32.44		19	[C11]
200	0	19.91	18.85		18.97		19	[C11]
200	25	19.79	13.70		4.70		19	[C11]
200	50	19.67	8.75		2.49		19	[C11]
200	75	19.20	3.75		2.46		19	[C11]
500	0	21.43	8.20		29.27		19	[C11]
500	25	31.15	7.49		15.22		19	[C11]
500	50	41.10	6.74		11.48		19	[C11]
500	75	51.05	6.14		8.29		19	[C11]

Table C15. Proposed emission factors (kg/ton of fuel) for use in the simplified methodology

Engine type	NO_X	CO	CO_2	VOC	PM	SO_X
Steam turbines - BFO engines	6.98	0.431	3200	0.085	2.50	20S
Steam turbines - MDO engines	6.25	0.6	3200	0.5	2.08	20S
High speed diesel engines	70	9	3200	3	1.5	20S
Medium speed diesel engines	57	7.4	3200	2.4	1.2	20S
Slow speed diesel engines	87	7.4	3200	2.4	1.2	20S
Gas turbines*	16	0.5	3200	0.2	1.1	20S

* Evaluated on the basis of available information on land-based installation. For NO_X the emission factor is 14-19 kg/ton for marine engines [C16] and 16 kg/ton for land-based gas turbines [C17]. For the other pollutants the emission factors are for land-based gas turbines [C17, C18].

Table C16. Proposed cruising emission factors (kg/ton of fuel) for use in the detailed methodology

Engine type	NO_X	CO	CO_2	VOC	PM	SO_X
Steam turbines - BFO engines	6.98	0.431	3200	0.085	2.50	20S
Steam turbines - MDO engines	6.25	0.6	3200	0.5	2.08	20S
High speed diesel engines	70	9	3200	3	1.5	20S
Medium speed diesel engines	57	7.4	3200	2.4	1.2	20S
Slow speed diesel engines	87	7.4	3200	2.4	1.2	20S
Gas turbines	16	0.5	3200	0.2	1.1	20S
Inboard engine - pleasure craft - diesel	48	20	3200	26	neg.	20S
Inboard engine - pleasure craft - gasoline	21.2	201	3200	13.9	neg.	20S
Outboard engines - gasoline	1.07	540	3000	176	neg.	20S

Table C17. Proposed manoeuvring emission factors (kg/ton of fuel) for use in the detailed methodology

Engine type	NO_X	CO	CO_2	VOC	PM	SO_X
Steam turbines - BFO engines	6.11	0.19	3200	0.85	2.50	20S
Steam turbines - MDO engines	5.47	0.27	3200	5.0	2.08	20S
High speed diesel engines	63	34	3200	4.5	1.5	20S
Medium speed diesel engines	51	28	3200	3.6	1.2	20S
Slow speed diesel engines	78	28	3200	3.6	1.2	20S
Gas turbines	14	1.9	3200	0.3	1.1	20S
Inboard engines - pleasure craft - diesel	48	20	3200	26	neg.	20S
Inboard eng. -pleasure craft - gasoline	21.2	201	3200	13.9	neg.	20S
Outboard engines gasoline	1.07	540	3000	176	neg.	20S

Table C18. Proposed hotelling emission factors (kg/ton of fuel) for use in the detailed methodology

Engine type	NO_X	CO	CO_2	VOC	PM	SO_X
Steam turbines - BFO engines	4.55	0	3200	0.4	1.25	20S
Steam turbines - MDO engines	3.11	0.6	3200	0.5	2.11	20S
High speed diesel engines	28	120	3200	28.9	1.5	20S
Medium speed diesel engines	23	99	3200	23.1	1.2	20S
Slow speed diesel engines	35	99	3200	23.1	1.2	20S
Gas turbines	6	7	3200	1.9	1.1	20S
Inboard engine - pleasure craft - diesel	neg.	neg.	neg.	neg.	neg.	neg.
Inboard engine -pleasure craft - gasoline	neg.	neg.	neg.	neg.	neg.	neg.
Outboard engines gasoline	neg.	neg.	neg.	neg.	neg.	neg.

Table C19. Proposed tanker offloading emission factors (kg/ton of fuel) for use in the detailed methodology

NO_X	CO	CO_2	VOC	PM	SO_X
12	1	3200	0.01	2.11	20S

Table C20. Emission factors for diesel powered electrical generators in vessels (kg/ton of fuel)

Pollutant	Emission factor (kg/ton)	Comment
NO_X	$108.6 - 2.47.P + 0.0136.P^2 - 0.000018.P^3 + 0.000684.P.L$	F test value is 117.7
CO	$20.7 - 0.218.L - 0.0231.P + 0.000345.P.L$	F test value is 27.1
CO_2	3200	
VOC	$3.27 + 2.16.P - 0.0144.P^2 + 0.0000203.P^3 - 0.719.L + 0.00476. L^2$	F test value is 28.5
PM	1.1	
SO_X	20S	

P is the rated output (generator electrical output) kW; L is the load in % of the rated output

C6. DAYS IN NAVIGATION

If the number of days in navigation are not known, they can be estimate from the speed of the ship and the distance covered. In Table C21, average speed data from Lloyd's are presented and may be used for this purpose.

Table C21. Average ship speeds

Ship type	Average speed (knots)
Solid bulk	14.32
Liquid bulk	14.20
General	14.29
Container	19.09
Passenger/Ro-Ro/Cargo	16.49
Passenger	17.81
High speed ferry	36.64
Inland cargo	14.29
Sail ships	9.63
Tugs	12.91
Fishing	11.96
Other ships	13.45
All ships	14.77

C7. EXAMPLE CALCULATIONS

Two simple example calculations are presented below to illustrate the application of both the simplified and detailed methods. Because they are given only to demonstrate the procedures, each considers only a limited number of ships, and only NO_X emissions have been determined. However, estimates for other types of vessel and other pollutants are derived in exactly the same way.

C7.1 Example of application of the simplified methodology

The following ships are taken into account:

Ship	Number and type of ship	Gross tonnage	Nautical miles	Engine
A	2 Passenger/Ro-Ro/Cargo	3000	3000	Medium speed diesel
B	1 Passenger/Ro-Ro/Cargo	8000	3000	Medium speed diesel

The basic equation for the calculation is:

$$E_{NO_X} = \sum_{jkl} S_{jk}(GT) \times t_{jkl} \times F_{NO_X\,jl}$$

where

E_{NO_X}	is the total NO_X emissions from the shipping activity considered
j	is the fuel type
k	is the ship class
l	is the engine type
$S_{jk}(GT)$	is the daily consumption of fuel *j* in ship class *k* as a function of gross tonnage
t_{jkl}	is the number of days in navigation of ships in class *j* with an engine of type *l* using fuel *j*
$F_{NO_X\,jl}$	is the NOx emission factor for engine type *l* using fuel *j*

As the ships of both type A and type B are in the same class, the daily fuel consumption at full power varies only because of the different gross tonnages, and is given by (from Table C9):

$$C_{jk} = 12.834 + 0.00156 \times GT$$

For the type A ships, with a gross tonnage of 3000, this evaluates as 17.514 tonnes/day, and for the type B ship, with a gross tonnage of 8000, the consumption is 25.314 tonnes/day. The effective fuel consumption $S_{jk}(GT)$ is then given by multiplying by 0.8 and becomes, for type A ships 14.01 tonnes/day, and for the type B ship, 20.25 tonnes/day.

The number of days in navigation is derived from the distance travelled and the average speed for the type of ship. Table C21 shows that the average speed of Passenger/Ro-Ro/Cargo ships is 16.49 knots, and thus, for both A and B types of ship, the time taken to travel 3000 nautical miles is 7.58 days.

Both types of ship have medium speed diesel engines, and Table C15 shows the NO_X emission factor to be 57 kg/tonne of fuel.

Substituting these values into the basic equation gives:

$$E_{NO_X} = 2\times(14.01\times7.58\times57)+(20.25\times7.58\times57) = 20855.5kg$$

C7.2 Example of application of the detailed methodology

In this example, the following ships are taken into account:

Ship	Number and type of ships	Gross tonnage	Hotel days	Manoeuvre days	Cruise days	Engine
A	2 Passenger/Ro-Ro/cargo	3000		18	180	Medium speed diesel
B	1 Passenger/Ro-Ro/cargo	8000		18	180	Medium speed diesel
C	1 Liquid bulk	80000	45	20	300	Steam residual oil engine

The basic equation for the detailed methodology is:

$$E_{NO_X} = \sum_{jklm} S_{jkm}(GT)\times t_{jklm}\times F_{NO_X\,jlm}$$

where

- E_{NO_X} is the total emissions NO_X from the shipping activity considered
- j is the fuel
- k is the ship class
- l is the engine type class
- m is the operating mode
- $S_{jkm}(GT)$ is the daily consumption of fuel j in ship class k in mode m as a function of gross tonnage
- t_{jklm} is the number of days in navigation of ships of class k with engine type l using fuel j in mode m
- $F_{NO_X\,jlm}$ is the average emission factor of NO_X from fuel j in engines type l in mode m

The ships of types A and B are the same as those in the simplified example, and their fuel consumption at full power is as already calculated, i.e. 17.514 for type A and 25.314 for type B. From Table C9, the fuel consumption at full power for the liquid bulk carrier is given by:

$$C_{jk} = 14.685 + 0.00079\times GT$$

giving, for a gross tonnage of 80000, a consumption of 77.885 tonnes/day.

The fractions of fuel consumption at full power that are used in the different operating modes are given in Table C11. This shows factors for cruise consumption of 0.8, for manoeuvring of 0.4 and for a tanker hotelling of 0.2. Applying these factors gives the following fuel consumption rates for the ships and modes considered.

Ship	Fuel consumption rates (tonnes/day)			
	Full power	Cruise	Manoeuvre	Hotel
Type A	17.514	14.011	7.006	N/A
Type B	25.314	20.251	10.126	N/A
Type C	77.885	62.308	31.154	15.577

In this example, the numbers of days in navigation are given by mode for the three types of ship. Emission factors for the engine types are contained in Table C16 for the cruise mode, Table C17 for manoeuvring and Table C18 for hotelling. For the ships in this example, they are:

Ship	NO_X emission factor (kg/tonne of fuel)		
	Cruise	Manoeuvre	Hotel
Types A and B (medium speed diesel engines)	57	51	N/A
Type C (Steam residual oil engine)	6.98	6.11	4.55

Table C19 gives the NO_X emission factor for tanker offloading as 12 kg/tonne of fuel, and it is assumed that 100 tonnes of fuel is used for this operation.

These values are substituted into the basic equation to give the emissions for each ship, in each mode of operation, and summed to give the total emissions, as follows:

Ship	Mode	Emissions
A (2 ships)	Cruise	2 × (14.011 × 180 × 57) = 287506 kg
A (2 ships)	Manoeuvre	2 × (7.006 × 18 × 51) = 12863 kg
B	Cruise	(20.251 × 180 × 57) = 207775 kg
B	Manoeuvre	(10.126 × 18 × 51) = 9296 kg
C	Cruise	(62.308 × 300 × 6.98) = 130473 kg
C	Manoeuvre	(31.154 × 20 × 6.11) = 3807 kg
C	Hotel	(15.577 × 45 × 4.55) = 3189 kg
C	Offloading	(100 × 12) = 1200 kg
	Total	469109 kg

C8. FUTURE EMISSIONS

In the future, it is likely that there will be changes in the emissions from waterborne transport. The changes will result from legal requirements regarding ship engines and the fuels they use, and also from engineering improvements providing improved technologies and emission control systems. Quantitative estimates of future improvements in emissions have been based on a review of legal developments and of the technologies available to reduce emissions from ship engines. The findings of the review are given briefly below, and the future emission factors are presented.

C8.1. Legislation

Present and proposed standards for marine fuels and emissions from ships are discussed according to the pollutant they concern.

C8.1.1 Sulphur oxides

The amount of sulphur oxides emitted by an engine depends primarily on its fuel consumption and on the amount of sulphur in the fuel (indeed, emission factors are usually expressed as a function of the sulphur content, see, for example, Table C12). The sulphur content of current market fuels varies according to the supply port, the supplier and the time. Mean values are:

- Bunker fuel oil 3% (by weight)
- Marine diesel oil 1% (by weight)

EU legislation

Directive 93/12/EEC sets a limit of 0.2% by weight for the sulphur content of gas oils[42]. In 1997, the European Commission made a proposal to amend this directive to include a limit of 1% for the sulphur content of fuel oils.

International Maritime Organisation

In 1997 the International Maritime Organisation (IMO) adopted a global limit of 4.5% on the sulphur content of fuel oil and provisions allowing for special Sulphur Oxides Emission Control Areas [C19]. In a Sulphur Oxides Emission Control Area, at least one of the following conditions shall be fulfilled:

- the sulphur content of fuel oil used on board ship does not exceed 1.5%
- an exhaust gas cleaning system is used to reduce the total emission of sulphur oxides from ships, including both auxiliary and main propulsion engines, to 6.0 g/kW.h or less

[42] Gas oil is a term used to describe certain medium distillates including diesel. It differs from fuel oil, which is a term for heavier oil.

Swedish national regulations

Vessels using high sulphur fuels (above 1% for cargo ships and 0.5% for ferries) are charged an additional $0.12 per gross tonne in fairway fees.

C8.1.2 Nitrogen oxides (see also C8.1.3)

International Maritime Organisation

The IMO recently approved a technical code on nitrogen oxides emissions reductions, to apply to new diesel engines with a power output of more than 130 kW, installed in ships that are built or have a major conversion[43] after 1 January 2000.

The following limits on nitrogen oxides emissions from diesel engines are introduced:

17.0 g/kWh when n is less than 130 rpm
$45 * n^{-0.2}$ g/kWh when n is 130 or more but less than 2000 rpm
9.8 g/kWh when n is 2000 or more

where n = rated engine speed (crankshaft revolutions per minute).

Swedish national regulations

In January 1998, the Swedish government introduced national regulations based on the fairway fee structure for vessels depending on their emissions. Vessels with nitrogen oxides emissions below 2 g/kWh pay $0.33 per gross tonne, while vessels emitting over 12 g/kWh are charged $0.54 per gross tonne. Between 2 and 12 g/kWh there is a linear scale of charges in 1 g/kWh increments. In addition, ship owners who fit devices to lower nitrogen oxides emissions by the year 2002 may have up to 40% of the investment costs reimbursed.

C8.1.3 Volatile organic compounds and carbon monoxide

US Environmental Protection Agency and California Air Resources Board

In 1996 the United States Environmental Protection Agency adopted exhaust emission standards for gasoline spark-ignition marine engines with the goal to reduce the emissions of hydrocarbons from outboard and personal watercraft engines by 75 percent from baseline levels by 2025 [C20].

Exhaust emissions from new, nonroad spark-ignition engines at or below 19 kW, effective from the 1997 model year, shall not exceed the following levels.

[43] For the purpose of the regulation, major conversion means the replacement of an engine by a new engine built on or after 1 January 2000, any substantial modification to the engine or the increase of the maximum continuous rating of the engine by more than 10%.

Engine class		Carbon monoxide
Engine < 225 cc displacement	16.1	519
Engine 225 cc in displacement	13.4	519

The California Air Resource Board has recently proposed exhaust emission standards that will reduce emissions of hydrocarbons and oxides of nitrogen from personal watercraft by 50% beyond the federal program by 2010 [C21]. The proposed regulation establishes the following corporate average exhaust emission standards.

Category	Model year 2001	Model year 2004	Model year 2007
Outboards less than or equal to 75 kW	20 (40)	17 (40)	13(27)
Outboards greater than 75 kW	40(134)	27 (80)	13 (40)
Personal watercraft	40 (134)	27 (80)	13 (40)

The numbers listed in parentheses are the upper limit to which manufacturers may certify engine families as part of the corporate averaging program.

C8.2. Emissions control technology

There are a number of ways to reduce nitrogen oxide and sulphur oxide emissions from marine diesel engines. The emissions control technology can be classified as primary or secondary, depending whether the method controls pollutant formation during the combustion process or uses after treatment systems to remove them from the exhaust.

C8.2.1 Sulphur oxides

Primary methods

The primary method of reducing sulphur oxide emissions is by reducing fuel sulphur content.

Secondary methods

Sulphur oxide emissions can also be reduced by scrubbing the exhaust with seawater. Because of the natural alkalinity of seawater, SO_2 in the exhaust can be dissolved in seawater then discharged into the sea. The first prototype exhaust gas seawater washing system was installed on the ferry M/S Kronprins Harald in early 1991. After about 1700 hrs operation trial, up to 92% of sulphur oxides reduction was claimed. There is some public concern that the discharge of spent water may in turn pollute the sea. However, the sulphate that is produced by scrubbing is also one of the major dissolved constituents of natural seawater [C22].

C8.2.2 Nitrogen oxides and other pollutants

Primary methods

Primary methods reduce NO_X emissions by reducing the peak combustion temperature and pressure. This, however, generally increases the formation of other species (particulate, CO, HC) and the fuel consumption due to the decreased thermal efficiency of the engine (generally, 10% nitrogen oxides reduction causes 1% increase in consumption). Techniques for NO_X control are discussed in detail in MEET Deliverable 25 [C2], and include:

- injection timing retard
- modified fuel injectors
- turbocharging with aftercooling
- exhaust gas recirculation
- ammonia injection
- water injection or use of emulsified diesel fuel
- improved and/or alternative fuels
- improved hydrodynamic design of the ship

Secondary methods

Selective catalytic reduction (SCR) systems have been successfully used onboard ships and have demonstrated a reduction rate for nitrogen oxides of more than 95%. In an SCR, a reactor is included in the exhaust system, where ammonia or urea is introduced to react with NO and NO_2 in the exhaust to produce water and nitrogen [C22].

The use of low sulphur content fuel is of substantial benefit to the application of SCR systems. In an SCR some of the SO_2 in the exhaust is oxidised to SO_3, which later will form sulphurous or sulphuric acid when in contact with the water in the exhaust system. Sulphuric acid causes rapid corrosion of SCR system and other components in the exhaust system. Also when the acids combine with ammonia, salts with a high melting point are formed, resulting in an increase in particulate emissions.

As well as reducing emissions of SO_2 a seawater scrubber also functions as a filter, so that soot emission can be reduced by 99% and nitrogen oxides by 40%.

C8.3. MEET methodology for estimating future emissions from ships

The methodology for future emission estimates is a modification of the simplified methodology discussed in section C3. Because small, gasoline engines are not included in the simplified methodology, emission reduction scenarios are only introduced only for sulphur oxides and nitrogen oxides. Some ideas on possible reductions of other pollutants from these types of ship are given in section C8.1.3.

As presented in section C3, emissions are calculated as:

$$E_i = \sum_{j,k,l} E_{i,j,k,l} \tag{C7}$$

with, for future estimates:

$$E_{i,j,k,l} = S_{j,k}(GT) \times t_{j,k,l} \times F*_{i,j,l,s} \tag{C8}$$

where:

$$F*_{i,j,l,s} = F_{i,j,l} \times f_{i,s} \tag{C9}$$

where:

i	is the pollutant (see Table C1)
j	is the fuel (see Table C4)
k	is the ship class (see Table C2);
l	is the engines type class (see Table C3);
s	is the reference emission reduction scenario
E_i	is the total emissions of pollutant i
$E_{i,j,k,l}$	is the total emission of pollutant i from use of fuel j on ship class k with engine type l
$S_{j,k}(GT)$	is the daily consumption of fuel j in ship class k as a function of gross tonnage
$t_{j,k,l}$	is the number of days in navigation of ships of class k with engine type l using fuel j
$F^*_{i,j,l,s}$	is the average reduced emission factor for pollutant i from fuel j in engine type l
$F_{i,j,l}$	is the current average emission factor for pollutant i from fuel j in engines type l
$f_{i,s}$	is the reduction factor for pollutant i in the scenario s (see Tables C22 to C24)

For short passage ferry traffic, in order to take into account hotelling and manoeuvring emissions, the days in navigation must be increased to allow for these modes. In these modes, fuel consumption is about half of the cruising rate, so in this case t_{jkl} is equal to the sum of the days in cruising and half of the days in hotelling and manoeuvring.

C8.4. Proposed reduction factors

The default basic emission factors (kg/ton of fuel) for use in the simplified methodology are given in Table C15. Because the SO_X emission factors are proportional to the sulphur content of the fuel, it is necessary also to assume the following default values in order to determine absolute emission rates:

- 3% by weight for bunker fuel oil
- 1% by weight for marine diesel oil
- 0.2% by weight for marine gas oil

In Table C22 to C24, the reduction factors proposed for use in simplified methodology for the three different emission scenarios are reported. The following assumptions have been made:

- all marine diesel oil and marine gas oil sold in the EC in all future scenarios will have a maximum sulphur content of 0.2%

- heavy fuel oil will have an average sulphur content of 2% in the low reduction scenario, 1.5% in the intermediate reduction scenario and 1% in the high reduction scenario

- For the nitrogen oxides will be assumed reductions only for diesel engines and particularly:

  . an emission reduction of 10% in the low reduction scenario
  . an emission reduction of 30% in the intermediate reduction scenario
  . an emission reduction of 80% in the high reduction scenario

Table C22. Proposed reduction factors for use in the low reduction scenario

Engine types	NO_X	CO	CO_2	VOC	PM	SO_X
Steam turbines - BFO	1	1	1	1	1	0.667
Steam turbines - MDO engines	1	1	1	1	1	0.2
High speed diesel engines - BFO	0.9	1	1	1	1	0.667
Medium speed diesel engines - BFO	0.9	1	1	1	1	0.667
Slow speed diesel engines - BFO	0.9	1	1	1	1	0.667
High speed diesel engines - MDO	0.9	1	1	1	1	0.2
Medium speed diesel engines - MDO	0.9	1	1	1	1	0.2
Slow speed diesel engines - MDO	0.9	1	1	1	1	0.2
Gas turbines	1	1	1	1	1	0.2

Table C23. Proposed reduction factors for use in the intermediate reduction scenario

Engine types	NO_X	CO	CO_2	VOC	PM	SO_X
Steam turbines - BFO	1	1	1	1	1	0.5
Steam turbines - MDO engines	1	1	1	1	1	0.2
High speed diesel engines - BFO	0.7	1	1	1	1	0.5
Medium speed diesel engines - BFO	0.7	1	1	1	1	0.5
Slow speed diesel engines - BFO	0.7	1	1	1	1	0.5
High speed diesel engines - MDO	0.7	1	1	1	1	0.2
Medium speed diesel engines - MDO	0.7	1	1	1	1	0.2
Slow speed diesel engines - MDO	0.7	1	1	1	1	0.2
Gas turbines	1	1	1	1	1	0.2

Table C24. Proposed reduction factors for use in the high reduction scenario

Engine types	NO_X	CO	CO_2	VOC	PM	SO_X
Steam turbines - BFO engines	1	1	1	1	1	0.333
Steam turbines - MDO engines	1	1	1	1	1	0.2
High speed diesel engines - BFO	0.2	1	1	1	1	0.333
Medium speed diesel engines - BFO	0.2	1	1	1	1	0.333
Slow speed diesel engines - BFO	0.2	1	1	1	1	0.333
High speed diesel engines - MDO	0.2	1	1	1	1	0.2
Medium speed diesel engines - MDO	0.2	1	1	1	1	0.2
Slow speed diesel engines - MDO	0.2	1	1	1	1	0.2
Gas turbines	1	1	1	1	1	0.2

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Part D. AIR TRANSPORT

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D1. INTRODUCTION

Three main classes of air transport can be distinguished when analysing its operational and emission related characteristics:

- flights performed under Instrument Flight Rules (IFR),
- military operational air traffic,
- flights performed under Visual Flight Rules (VFR).

There are some minor overlaps between the classes. However, each category has its own typical data set available for traffic characteristics and engine emissions, so it makes sense to base the methodology for estimating exhaust emissions on these three classes.

Accuracy of data input is different for the three categories, but so is their contribution to total air transport emissions. About sixty to eighty percent of emissions originate from IFR flights so great attention must be paid to this class. Normally IFR flights are operated as flights controlled by Air Traffic Services (ATS) within controlled airspace only. That means that detailed information on aircraft type and route is available, either from the flight plan (FP) or the ATS which reports all flights to the Central Route Charging Office (CRCO) of Eurocontrol. IFR flights are generally flights with civil aircraft. Only those military flights which belong to general air traffic (GAT) are included in IFR data. Jets, turbofans and turboprops generally represent this sort of traffic, which typically involves big commercial aircraft flying long distances using fixed operational routines.

Flights performed under VFR generally are not operated as controlled flights so neither a FP nor detailed information on the route flown is available. However, VFR flights represent less than 5 % of fuel consumption and pollution caused by air traffic. Operational military air traffic represents another group of aviation on which limited or inaccurate information is available.

Figure D1 shows a schematic diagram of these types of air traffic together with the types of engine most often used for the various purposes and the location of the most important impacts of their emissions.

In common with the other MEET methodologies for emission calculations, that for air traffic combines an estimate of the amount of transport activity with emission factors per unit of activity to derive total emissions. And, also as for the other modes, there needs to be a classification of the transport activity to take into account the differences between types of aircraft/engine combination, their different operating modes, the different pollutants and so on. In detail, the method follows those for the other non-road modes: an initial estimate is made of the fuel consumed during an air transport operation and pollutant emissions are calculated using fuel-specific emission factors.

For IFR flights, emission indices (EI), i.e. the mass of pollutant produced per mass of fuel used, are provided for eight typical operational conditions, which may be combined to cover most of an aircraft's operation during a flight. For ground operations while aircraft is standing (refuelling, use of auxiliary power units, engine start) just few data exist for three aircraft/engine combinations. The standard operating conditions are:

- taxi out
- take off
- climb
- cruise
- descent
- landing
- taxi in.

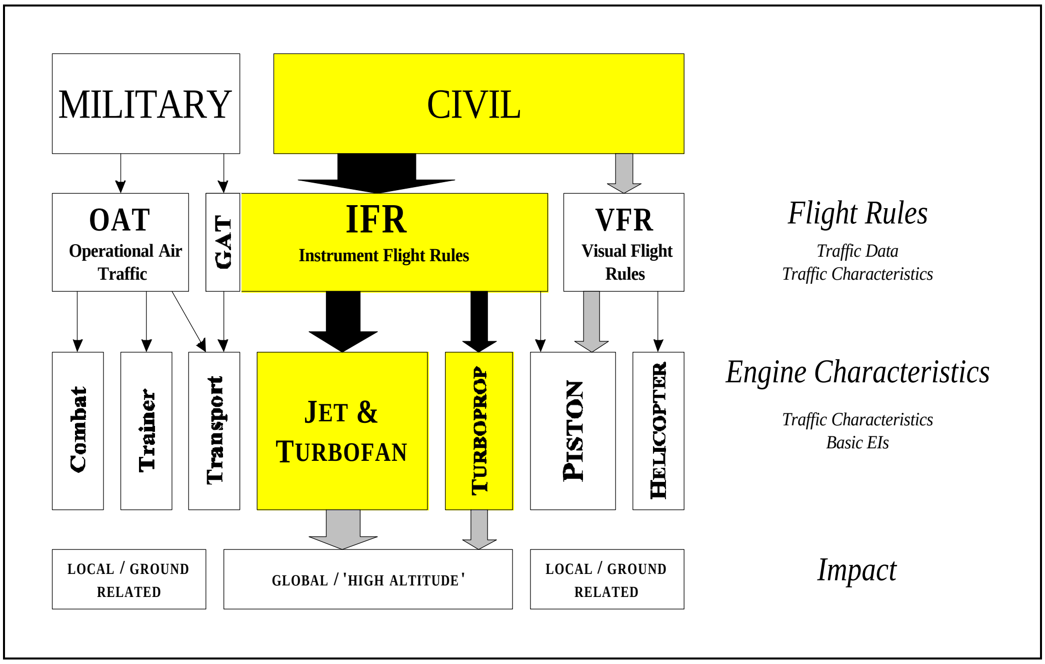

Figure D1. Air traffic categories, operational modes and aircraft/engine types

Emission factors are based on engine certification data in the ICAO (International Civil Aviation Organisation) Engine Exhaust Emission Databank [D1]. It contains data sets of thrust (engine performance), fuel flow and emissions of components CO, NO_X and VOC which apply to four different power settings, Mach number 0 and altitude 0 m. Using also information on the aircraft performance during the flight from the emission simulation model ATEMIS [D2] leads to average emission indices. They are independent of the flight altitude with the exception of $EINO_X$ (the EI for NO_X) which strongly depends on combustion temperature.

Component included in this exercise are fuel burnt, H_2O, CO_2, CO, NO_X, VOC and SO_2. There is a great uncertainty about other pollutants such as particulates, PAH, CH_4, NO_2 or NH_3 so these cannot be included at the moment.

The methodology and data set provided will enable users:

- to build air traffic emission inventories for a region (spatial resolution > 10 km)
- to assess the impact of changes in the number of aircraft movements
- to assess impacts from changing the distance flown (e.g. reducing time spent in holding patterns)

The EI contain aggregated data for average aircraft/engine combinations and average performance. This may lead to errors, wrong results and wrong conclusions in applications such as:

- assessing the impact of changes in engine technology of an aircraft type. That is only possible if additional information on the new aircraft/engine combination is available
- assessing the impact of changing the average cruise altitude
- using the results as input for local dispersion modelling

EI for military flights are based on hours of operation and average fuel consumption per hour because of limitations in the nature of military data available. Components included are H_2O, CO_2, CO, NO_X, VOC and SO_2.

Data availability for VFR flights is very similar to that of military air traffic. That means no detailed information on flight path and specific emissions is available, and EI for VFR are based again on hours of operation and average fuel consumption per hour. Components included are H_2O, CO_2, CO, NO_X, VOC and SO_2.

D2. METHODOLOGY

D2.1. IFR Flights

The methodology for IFR flights is based on standard flight profiles for about 35 aircraft/engine combinations, which represent about three quarters of European air traffic (see Figure D2). Dividing each flight profile into several sectors of constant performance and emission characteristics allows the algorithm to be adapted to different user requirements (e.g. airport or in flight emissions) and can increase the resolution of the results. Emissions are estimated as follows:

$$TE_p = \sum_r \sum_p SE_{j,p,r} \times N_{j,r} \qquad \text{(D1)}$$

$$SE_{j,p,r} = \int_{D_1(A)}^{D_2(A)} FC_j\,(Dr) \times EI_{j,p}\,(Dr)\,dDr \qquad \text{(D2)}$$

where:

TE_p	is the total emission of pollutant *p* (kg per period)
$SE_{j,p,r}$	is the specific emission of pollutant *p*, from aircraft/engine combination *j* on route *r* (kg per aircraft)
$N_{j,r}$	is the number of aircraft of category *j* on route *r* per period
$FC_j(Dr)$	is the fuel consumption of aircraft category *j* per km (kg_{fuel}/km)
$EI_{j,p}(Dr)$	is the emission index for pollutant *p* ($kg_{emissions}/kg_{fuel}$)
Dr	is the distance between city pair (route *r*) (km)
$D_2(A) - D_1(A)$	is the distance flown within the area *A* (km)
j	is the aircraft/engine category
p	is the pollutant
r	is the route from airport to airport

The $SE_{j,p,r}$ were generated using the ATEMIS engine model (*ATEMIS* - *A*ir *T*raffic *Emi*ssion *S*imulation) which was developed for calculating the fuel consumption, and NO_X, CO and VOC emitted from civil IFR air traffic over Austria. An engine model of 12 parameters is used which allows estimates to be made of engine performance, thrust and from that the instantaneous fuel flow ff_i for an aircraft/engine combination.

The ANCAT/EC inventory also provides a database containing EI for different aircraft/engine combinations, flight profiles and engine conditions. However, fuel consumption and NO_X are the only components included in the ANCAT/EC inventory. Therefore, the results for NO_X, distances flown and fuel burned from ANCAT/EC were used to verify the MEET approach.

D2.1.1 Principles of ATEMIS

Instantaneous fuel flow is a function of thrust and specific fuel consumption:

$$ff_i = th_j\,(M,a,\lambda,ps) \times SFC_j\,(M,a,\lambda,ps) \qquad \text{(D3)}$$

where:

ff_j	is the instantaneous fuel flow of engine *j* (kg/h)
th_j	is the thrust of engine *j* (N)
M	is the Mach number
a	is the altitude (km)
l	is the bypass ratio
SFC_j	is the specific fuel consumption.

A model using six parameters describes the performance graph of both the thrust and SFC:

$$th_j\,(M,a,\lambda,ps) = th_0 \times ps \times \sum_{k=0}^{2}\left[ak_k\,(\lambda) + d_k\,(\lambda)\right] \times M^{(2-k)} \qquad \text{(D4)}$$

$$SFC(M,a,\lambda,ps) = th_0 \times ps \times \sum_{m=0}^{2}\left[ag_m\,(\lambda) + b_m\,(\lambda)\right] \times M^{(2-m)} \qquad \text{(D5)}$$

where:

th_j	is the thrust of engine *j*
th_0	is the thrust of the engine for M = 0 and a = 0
M	is the Mach number
SFC_0	is the SFC for M = 0 and a = 0
l	is the bypass ratio
ps	is the power setting (0 - 1)
a	is the altitude (km)

$k_k(l)$, $d_k(l)$, $g_m(l)$, $b_m(l)$ are coefficients as a function of the bypass ratio

Since NO_X production strongly depends on combustion temperature, which decreases with outside temperature (engine take in temperature), the specific emission index for NO_X is corrected for altitude using the results from Lipfert [D3]:

$$\eta_{NO_X}\,(M,a) = \frac{e_{NO_X}\,(M,a)}{e_{NO_X}\,(M=0,a=0)} \qquad \text{(D6)}$$

This concept guarantees high flexibility. Depending on the available data on aircraft and engine types, power settings and engine performances, ATEMIS can be used for simulating a single aircraft's flight as well as for nation-wide surveys on air traffic emissions.

Four kinds of input data are used for ATEMIS:

Air traffic data

Each civil IFR flight within, into, from and over the territory of Austria is stored digitally by Austro Control, the former Federal Office of Civil Aviation (Table D1). Each line represents one aircraft movement with its features:

- flight number, aircraft type designator (ATD), wake turbulence category, true air speed (TAS), flight level (FL), time, airport from, airport to, route point codes.

Airport data

The airport data file contains information on the airport itself such as:

- airport code, airport name, latitude, longitude, elevation,

as well as basic aircraft performance features like:

- initial climb altitude (ICALT), final approach distance (FAD) and taxi times.

Route points

The route points are used to provide a regional distribution of the emissions and specified by:

- route point code, name, latitude, longitude.

Aircraft (engines) data

The aircraft data represent the engine performance and the specific emission factors, including:

- aircraft code, name, maximum take off weight (MTOW), engine type, number of engines, bypass ratio, compression, thrust, fuel flows for take off, climb, approach and descent/taxi, emission index for VOC, CO, NO_X and for take off, climb, approach and descent/taxi, power setting for take off, two levels of climb and cruise, approach and descent, cruise levels, climb rate and speeds, approach speeds, descent rates and six coefficients each determining thrust and specific fuel consumption.

Table D1. Air traffic data [D4]

Flight Number	Aircraft Type	Wake Turbul. Cat.	True Air Speed	Flight Level	Time	Airport from	Airport to	Route Point #1	Route Point #2	Route Point #3	. . . .	Route Point #n
AOE298	B73S	M	442	330	0	EGCC	LGKR	BRE				
TRA124	B73S	M	420	350	5	LTAI	EHAM	MUR	GRZ	PET	VEL	GRO
AMM362	B757	M	471	370	31	EGCC	LGIR	LOF	VIW	TEL		
AOE268	B757	M	468	370	32	EGCC	LGKR	BRE				
AEF862	MD80	M	447	330	34	EDDF	LTAC	KIR	LNZ	LIM	GRZ	MUR

D2.2. Military Flights

Because of the entirely different nature of military data available, the methodology for military flights is based on hours of operation and average fuel consumption per hour. This approach has already been used for military flights in the ECAC/ANCAT 2 inventory [D5]:

$$TME_p = \sum_m EI_{m,p} \times FC_m \times H_m \qquad \text{(D7)}$$

where:

- TME_p is the total military emission of pollutant p (kg per period)
- H_m is the number of hours of operation of aircraft class m per period (hours per period)
- FC_m is the fuel consumption of aircraft class m per hour (kg_{fuel}/hour)
- $EI_{m,p}$ is the emission index for pollutant p ($kg_{emissions}/kg_{fuel}$)
- m is the military aircraft class
- p is the pollutant

Depending on the reference used and the country concerned military air traffic uses about 13 to 43 % of total aviation fuel and contributes 2 to 35 % to NO_X from aircraft (see Table D2).

Table D2. Fuel consumption and emissions of military and total air traffic (from [D6], [D7], [D8], [D9])

Reference	Base year	Fuel burnt (Mt/yr)			NO_X emissions (Mt/yr)		
		military	total	% military	military	total	% military
ANCAT	1992	17.1	132.5	12.9	0.21	10.82	1.9
CH	1990	69.7	420.5	16.6	0.34	6.57	5.2
D	1984	1205.9	2802.4	43.0	10.16	28.89	35.2
NL	1992	98.0	628.0	15.6	1.50	8.10	18.5

D2.3. VFR Flights

Data availability for VFR flights is very similar to that for military air traffic. That means no detailed information on flight path and specific emissions is available so an algorithm is used which is the same as for military flights.

$$TVE_p = \sum_m EI_{v,p} \times FC_v \times H_v \qquad \text{(D8)}$$

where:

- TVE_p is the total VFR flight emission of pollutant p (kg per period)
- H_v is the number of hours of operation of aircraft class v per period (hours per period)
- FC_v is the fuel consumption of aircraft class v per hour (kg_{FUEL}/hour)
- $EI_{v,p}$ is the emission index for pollutant p ($kg_{EMISSIONS}/kg_{FUEL}$)
- v is the VFR aircraft class
- p is the pollutant

D3. RELEVANT ACTIVITY STATISTICS

D3.1. Movement data

The European organisation for safety of air navigation in Brussels (Eurocontrol) is responsible for:

- Management of the European ATC Harmonisation and Integration Programme (EATCHIP) for 33 ECAC states

- Establishment of a single European Air Traffic Flow Management Unit (CFMU) covering 31 European states

- R & D work aimed at increasing ATC capacity in Europe (EATMS)

- Collection of route charges on behalf of 20 states

- Management of an International Air traffic Control Centre in Maastricht.

A department of Eurocontrol collects and provides air traffic statistics and forecast data for the whole of Europe. Statistics prepared show the time history of the actual air traffic situation whereas forecasts are based on economic scenarios and give a feeling for the future trends in air traffic over Europe.

Each IFR flight is controlled and recorded by the Central Route Charge Office of Eurocontrol (CRCO). So CRCO data contain information on each flight as it is actually performed. CRCO data are considered to be very comprehensive including 20 European countries in 1996, which means about 5.5 million flights in that year. For each flight a data set is recorded containing:

- date of flight
- departure/arrival aerodromes
- aircraft type
- operator
- distance flown by country

The main limitations of the CRCO data are that distance by country does not take into account the actual route but just the average or usual route for a particular destination, and no information is available on flight levels, time and numbers of passengers. They are presented in monthly routine statistics.

VFR flights and military air traffic generally are not operated as controlled flights so there does not exist detailed information on flight route and performance.

In order to obtain access to nationally held statistics, a questionnaire was distributed during the MEET project to get information on existing and planned inventories, methodology and movement databases used. No general trend on data availability was found from the answers. There is a lot of detailed information on air traffic movements in some European countries, but access to these data is sometimes difficult or impossible due to legal restriction. Availability of air traffic data in those countries which replied to the questionnaire is summarised in Tables D3 to D5.

D3.2. Fleet data

The Eurocontrol CRCO database also contains information on aircraft types used over Europe. Figure D2 shows the contribution of different aircraft types to total air traffic (domestic and intercontinental departures and landings and overflights) in 1995.

Table D3. Availability of air traffic control data in Europe - answers from the questionnaire

Country	Availability			From	Medium				Free	Priced
	All	Consultants	Restricted		Paper	Tape		E-mail		
						PC format	Other			
Switzerland	Not available									
Switzerland	Data available from Eurocontrol									
Czech Rep.			Gov. Org.		X					
Denmark			CAA							
Denmark	Not available									
EE	Depends on political decision			EANS						
EU	Not available									
France	Not available									
Germany			Gov. Org.	DFS			X			X
Germany			TÜV	CAA						X
Iceland	X			CAA	X			X	X	
Monaco	X			SATS	X					
Norway										
Norway		X								
Netherlands	Not available									
Romania	X			ATS	X	X			X	
Sweden			FFA	LFV, SAS	X				X	
UK				Eurocontrol						

Table D4. Availability of simple movement data (number of movements) in Europe

Country	By airport	By destination	By aircraft	By period	Available for			From	Medium				Cost
					All	Consultants	Restricted		Paper	Tape		E-mail	
										PC	Other		
Switzerland	X		X	X	Not available								
Switzerland	Not available												
Czech Rep.	X			X			Gov. Org.		X				
Denmark	X			X	X			CAA	X				Priced
Denmark	X			X	X			CAA	X				Priced
EE	X	X	X	X	Depends on political decision			EANS					
EU	Not available												
France	Not available												
Germany				X			Gov. Org.	DFS			X		Priced
Germany	X	X	X	X			TÜV	CAA		X			Priced
Iceland	X	X	X	X	X			CAA	X			X	Free
Monaco	X	X	X	X				ATS	X				
Norway	X			X	X			CAA	X				Free
Norway	X			X		X		Airports	Data have to be collected				Free
Netherlands	Not available												
Romania	X	X	X	X			Int. and Gov. Org.	CAA	X	X			Free
Sweden	X	X	X	X			FFA	LFV,SAS	X				Free
UK	X			X	X			DETR	X				Free

Table D5. Availability of flight distances in Europe - answers from the questionnaire

Country	By aircraft type	By route	By period	Available for			From	Medium				Free	Priced
				All	Consultants	Restricted		Paper	Tape		E-mail		
									PC	Other			
Switzerland	X	X	X	Not available									
Switzerland	Not available												
Czech Rep.	Restricted by operators												
Denmark	Not available												
Denmark	Not available												
EE	X	X	X	Depends on political decision			EANS						
EU	Not available												
France	Not available												
Germany	Not available												
Germany		X				TÜV	CAA		X				X
Iceland	Not available												
Monaco		X	X	X			ATS	X					
Norway	Not available												
Norway		X			X							X	
Netherlands	Not available												
Romania	X	X	X	X			ATS		X			X	
Sweden	X	X	X			FFA	LFV, SAS					X	
UK	X						CAA						

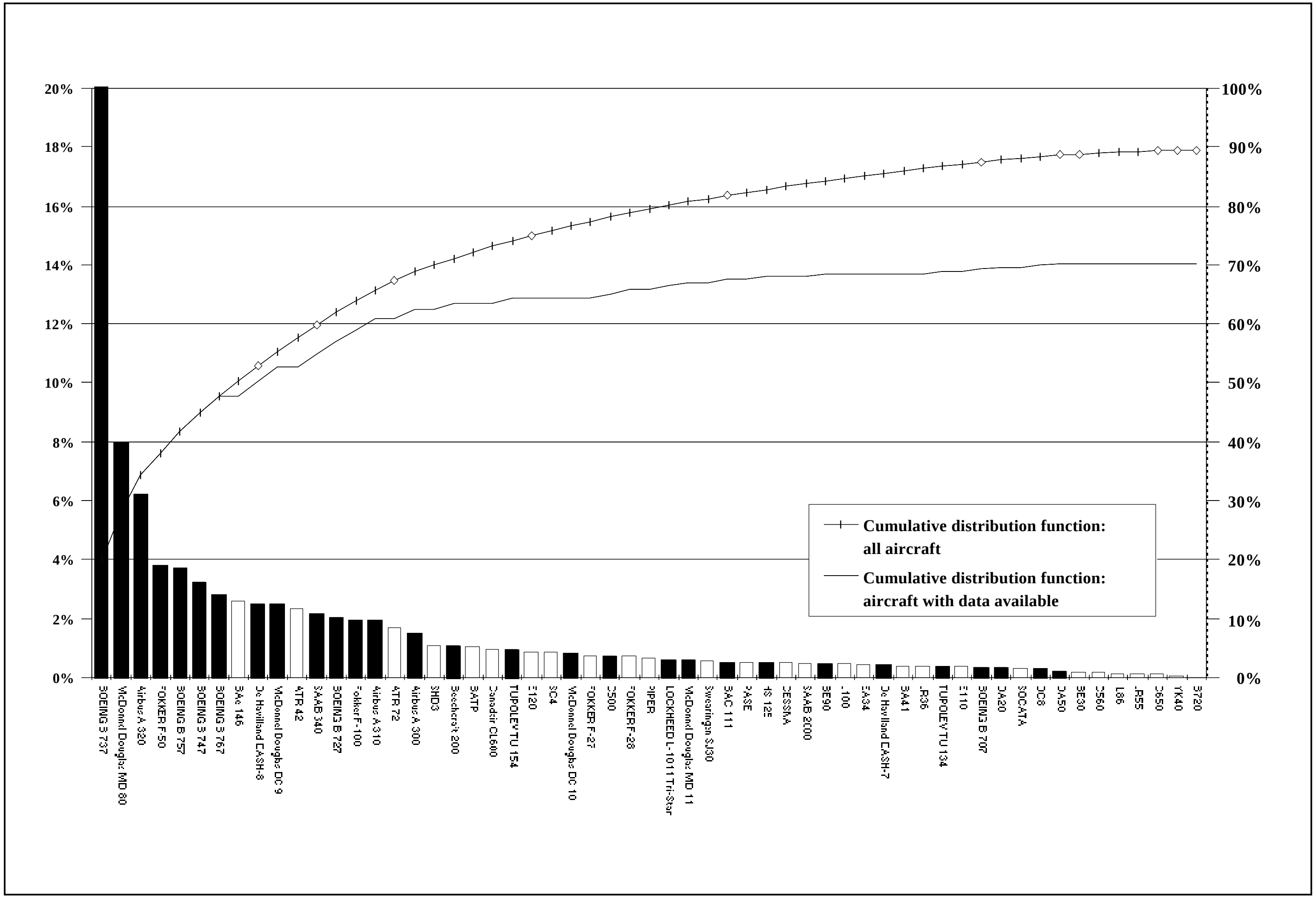

Figure D2. The 57 most frequently used aircraft types in Europe 1995 [D10]

D4. EMISSION FACTORS

D4.1. IFR flights

The ICAO Engine Exhaust Emission Databank [D1] contains basic engine emission data which originate from the ICAO engine certification. They are based on measurements under normalised conditions using the LTO-cycle (Landing Take-Off cycle) as a standard procedure. This cycle represents take-off, cruise, landing and idle of the engine under ground conditions. The LTO- cycle does not include emissions caused by:

- ageing of the engine
- maintenance
- inflight condition
- refuelling of the aircraft
- auxiliary power units to produce energy on board
- engine starting and warming up, with unburnt or incompletely burned kerosene.

Table D6 shows an example of an ICAO data sheet for one engine. Each data sheet is divided into three main sections:

- engine identification and relevant performance data, which include pressure ratio, rated output and data type and data source
- emission data - in this table power settings and time in each mode of the LTO-cycle are described. Results of measurement for fuel flow, emission indices and smoke number are registered as well as the number of engines tested and the number of tests on each engine.
- ancillary data - in this part accessory loads, atmospheric conditions and fuel specification are summarised, the date, location and organisation performing the test are given, and possible additional remarks are noted.

CO_2, H_2O, SO_2

As well as the pollutants included in the ICAO database, there are some other components of interest like CO_2, H_2O and SO_2. The amounts of these emissions strongly depends on the fuel composition, so the emission index is almost independent of the engine performance. Table D7 gives a summary of emission factors for CO_2, H_2O and SO_2 from a number of sources.

Table D7. Emission factors (g/kg) for CO_2, H_2O, SO_2 from national inventories and studies

Reference	**CO_2**	**H_2O**	**SO_2**
ECAC [D11]	3100	1240	-
TÜV [D9]	-	-	0.9789
Olivier [D12]	3220	1250	1.0000
Switzerland [D6], [D13]	-	-	0.9844
Netherlands [D8]	3168	1242	0.2070
Guidebook [D7]	3133	1266	1.0000
Norway [D12]	-	-	0.3200

ICAO ENGINE EXHAUST EMISSIONS DATA BANK ISSUE 1 - OCTOBER 1993
Note : Dp/Foo and SN values are NOT the characteristic levels

UNIQUE ID NUMBER :	JT9D-70A	BY-PASS RATIO	4.9
ENGINE IDENTIFICATION :	1PW034	PRESSURE RATIO	24.5
ENGINE TYPE :	TF	RATED OUTPUT	235.8

<u>DATA TYPE</u>
- x PRE-REGULATION
- \- CERTIFICATION
- \- REVISED (SEE REMARKS)

<u>DATA SOURCE</u>
- x NEWLY MANUFACTURED ENGINE
- \- IN-SERVICE ENGINES
  - BEFORE OVERHAUL
  - AFTER OVERHAUL
- \- DEDICATED TEST ENGINES TO PRODUCTION STANDARDS

<u>EMISSIONS DATA</u>
- \- UNCORRECTED
- x CORRECTED FOR AMBIENT EFFECTS

MODE	POWER SETTING (%Foo)	TIME mins	FUEL FLOW Kg/s	EMISSIONS INDICES g/Kg HC	CO	NOx	SMOKE NUMBER
TAKE-OFF	100	0.7	2.4419	0.2	0.2	31.6	-
CLIMB OUT	85	2.2	1.9996	0.2	0.2	25.6	-
APPROACH	30	4.0	0.6804	0.3	1.7	7.8	-
IDLE	7	26.0	0.2370	12.0	53.0	3.0	-
NUMBER OF TESTS				2	-	-	-
NUMBER OF ENGINES				2	-	-	-
Dp/Foo (AVERAGE) (g/kN) OR SN (MAX)				20.0	87.7	54.4	8
Dp/Foo (g/kN) OR SN (SIGMA)				2.4	5.9	3.0	1
Dp/Foo (g/kN) OR SN RANGE				-	-	-	-

<u>ACCESSORY LOADS</u>

POWER EXTRACTION	0 (kW)	AT :	- POWER SETTINGS
STAGE BLEED	0 % CORE FLOW	AT :	- POWER SETTING

ATMOSPHERIC CONDITIONS

PRESSURE	kPa	97 - 100
TEMPERATURE	°C	7 to 12
ABS. HYMIDITY	Kg/Kg	0.0029 - 0.0050

FUEL

SPEC	**H/C**	**AROM (%)**
JET A	1.89	-

MANUFACTURER	Pratt & Whitney
TEST ORGANIZATION	P&WA
TEST LOCATION	E Hartford, CT, USA
TEST DATES	FROM April 76 TO April 76

<u>REMARKS</u>

Table D6. ICAO certification data sheet of a JT90-70a Engine

A simulation based on ATEMIS profiles was made for the 30 aircraft listed in Table D8. Results (fuel consumption, distances, time, NO_X) were compared with those from ANCAT/EC inventory (see D5). Figure D3 gives a typical example of a flight profile together with the cumulative emissions and fuel consumption.

The next step was to find the best analytic curve for the different flight states, the fuel consumption and pollutants to provide a data set for fuel burnt and EI for each pollutant. The results for each of the aircraft types are tabulated in Annex D1.

Table D8. Types of aircraft for which simulations were carried out

Aircraft type		**Sheet number (Annex D1)**
BOEING	B707	1
	B727	2
	B737	3
	B747	4
	B757	5
	B767	6
British Aerospace	BAC 111	7
Beechcraft King Air	BE 20	8
	BE 90	9
Cessna	C500	10
Dassault Falcon	DA 20	11
	DA 50	12
De Havilland	DASH 8	13
Douglas	DC 8	14
	DC 9	15
	DC 10	16
Airbus	EA 30	17
	EA 31	18
	EA 32	19
Fokker	F 28	20
	F 50	21
	F 100	22
Hawker Siddeley	HS 25	23
Lockheed	L 101	24
McDonnel Douglas	MD 11	25
	MD 80	26
	MD 82	27
SAAB	SF 340	28
Tupolev	TU 34	29
	TU 54	30

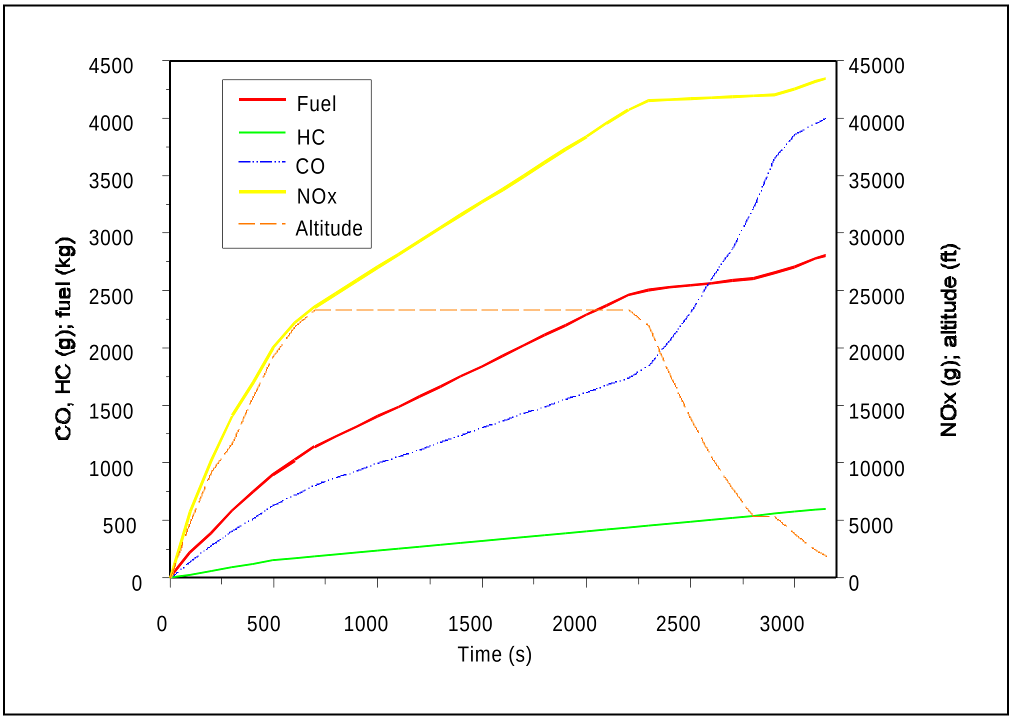

Figure D3. Flight profile and emissions for cruise altitude flight level 240

D4.1.1. Emissions during ground operations

For the Zürich-Kloten airport emissions from aircraft engine starts, auxiliary power units (APU) and aircraft refuelling were measured by Scherer (Table D9) [D14]. Emissions of aircraft refuelling and APU are not covered by the LTO cycle. The study shows that the LTO cycle covers only about 1/8 of the VOC emissions during a stay at the airport (Table D10).

Table D9. VOC emissions per engine during engine start and warming-up (total VOC) and VOC emissions registered in the LTO-cycle (LTO-VOC)

Aircraft (number of engines)	Engine type	Date of measure	Total VOC	Time of initial engine start	LTO-VOC
MD-11 (3)	PW 4460	6 - 1992	1100 g	4.5 s	280 g
MD-11 (3)	PW 4460	6 - 1992	1500 g	4.9 s	310 g
Airbus A 340 (4)	CF M56-5C2	8 - 1993	1500 g	3.9 s	110 g
Airbus A 340 (4)	CF M56-5C2	8 - 1993	1500 g	3.8 s	360 g
Airbus A 310 (2)	JT 9D-7R 4E1	8 - 1993	1800 g	4.7 s	510 g

Table D10. Ground VOC emissions of a McDonnel Douglas MD-11

Engine start of 3 PW-4460 engines	2600 g	Sum of the VOC emissions of the LTO-cycle
Refuelling (of the complete tank) at 19 °C	3800 g	
Engine start of auxiliary power units (APU)	150 g	
Operation of APU for 10 minutes	15 g	
Sum of the additional VOC emissions	6565 g	880 g

Hüttig et al [D15] prepared a similar study for Frankfurt airport on emissions from APU (Table D11). EI were derived from this report as well as a specific fuel consumption per operating hour.

Table D11. Emission rates of auxiliary power units

	CO_2 g/kg	SO_2 g/kg	NO_X g/kg	VOC g/kg	CO g/kg
APU - start	3149.86	1.00	2.24	0.18	3.01
APU - idle	3149.74	1.01	7.96	1.70	21.12
APU (A/C)	3150.00	1.00	8.47	0.60	9.17

Emissions from refuelling are described in a study by Olivier [D12]. Total annual VOC emissions from fuel handling are reported to be about 0.6 kg per aircraft. The turn over factor, which is the amount of evaporated fuel per unit of transferred fuel is given as:

0.5 m^3VOC/m^3 fuel for buffer tanks
0.2 m^3VOC/m^3 fuel for underground storage
1 m^3VOC/m^3 fuel for others

D4.2. Military Flights

The quality of publicly available data on aircraft/engine performance, on specific fuel consumption and on specific emission factors for military flights is relatively poor. The ICAO engine exhaust emission databank does not provide any information since there is no ICAO certification for military engines.

Average emission indices are given in Table D12. They are based on data from national air traffic inventories ([D9], [D6], [D13], [D7]) and from the ANCAT/EC project. It should be noted that the figures are based on the special national situation or on a global average. Applying them to another country where different aircraft types are used, e.g. Eastern European countries with Soviet made planes, may cause errors.

Table D12. Emission rates for military flights in different countries

	Nature of flight	CO	VOC	NO_X	SO_2	H_2O	CO_2
Germany	LTO-cycle	39.3	10.9	8.3	1.1		
	Helicopter cruise	38.8	8.0	2.6	1.0		
	Combat jet	10.0	1.2	10.9	0.9		
	Cruise 0.46-3 km	12.4	1.6	10.7	0.9		
	Cruise >3 km	8.2	1.1	8.5	0.9		
Netherlands	Total	126	4.0	15.8	0.2	1250	2942
	F-16	102	3.36	15.3	0.2	1224	2959
Switzerland	LTO-Cycle	33.9	2.59	4.631	1.025		
	cruise	14.95	0.67	5.034	0.999		

D4.3. VFR Flights

A set of emission indices for VFR flights is given in Tables D13 to D15 using data from different national inventories.

Table D13. Emission rates for VFR flights - Germany [D9]

	CO (g/kg)	VOC (g/kg)	NO_X (g/kg)	SO_2 (g/kg)
VFR-flight	798	18.867	3.140	0.420

Table D14. Emission rates for helicopters - Germany [D9], the Netherlands [D16], and Switzerland [D6], [D13]

	VOC g/kg	CO g/kg	NO_X g/kg	CO_2 g/kg	SO_2 g/kg	H_2O g/kg
Germany - cruise	7.99	38.79	2.65		0.99	
Netherlands - cruise	3.65	11.06	3.14	3.14	0.20	1.25
Switzerland	0.26	1.10	13.31		0.97	

Table D15. Emission rates for VFR flights - the Netherlands [D8], [D16]

	VOC g/kg	CO g/kg	NO_X g/kg	CO_2 g/kg	H_2O g/kg	SO_2 g/kg
Flight level 0 - 30						
Light Propellers	20.09	1054.07	2.70	0.21	1255.81	0.21
Light Turbo Jets	18.30	35.10	7.30	0.20	1300.00	0.20
Medium Turbo Jets	7.05	21.84	7.19	0.19	1245.61	0.19
Flight level 30 - 180						
Light Propellers	12.50	1080.00	4.00	0.17	1333.33	0.17
Light Turbo Jets	0.89	2.89	13.05	0.21	1263.16	0.21
Medium Turbo Jets	1.04	5.13	8.04	0.20	1254.10	0.20
Flight level 180 - 360						
Medium Turbo Jets	0.79	4.59	7.64	0.21	1256.41	0.21

D5. VERIFICATION

The ANCAT/EC emission inventory group produced an aircraft NO_X emission inventory in support of the AERONOX aircraft emissions research project. The AERONOX project was set up to determine, among other things, the emissions of NO_X from aircraft engines and global air traffic at cruise altitudes, and was supported by the CEC as well as national institutions. The ANCAT/EC inventory is based on emission profiles calculated with models similar to ATEMIS.

Four different input data sets are used by ANCAT/EC:

Flight profile

- take off length
- climb rate
- flight altitude
- cruise Mach number
- cruise range
- glide path descent

Aircraft type

- take off weight
- gross wing area
- lift over drag function
- standard atmosphere

Engine type

- thrust (SLS, SFC)
- overall pressure ratio
- bypass ratio, mass flow

Emission correlation

- combustor inlet condition (temperature, pressure, airflow, fuel flow)
- measured point of reference (at least one e.g., ICAO data)

Comprehensive data on length and time of climb, cruise and descent and on fuel consumption and NO_X emissions were available, so a comparison between results from the MEET method and ANCAT/EC profiles was carried out for four aircraft types (B727, B737, A310, A320) on a 1000 km flight. The results are given in Table D16.

There is a fairly good agreement of specific fuel consumption in the two methodologies. However, some trends are evident:

- The ANCAT/EC profiles tend to have lower fuel consumption than the MEET profiles. That is due to different assumptions in the model parameters on:
  - take off weight (ATEMIS uses maximum take off weight, ANCAT only 70 % of pay load),
  - engine performance (ATEMIS uses different climb rate) and
  - the engine mix used for the aircraft type (Boeing B 737).

Table D16. Comparison of results from MEET and ANCAT/EC

		MEET		ANCAT/EC		DIFFERENCE	
Aircraft type	**Operational state**	**Fuel/distance [kg/NM]**	**Fuel/time [kg/s]**	**Fuel/distance [kg/NM]**	**Fuel/time [kg/s]**	**Fuel/distance [%]**	**Fuel/time [%]**
Boeing B727	Climb	17.131	1.801	17.359	1.991	+ 1 %	+ 11 %
	Cruise	7.899	0.839	7.340	0.933	- 7 %	+ 11 %
	Descent	3.262	0.324	1.439	0.140	- 56 %	- 57 %
	Trip Total	9.295	0.979	8.020	0.984	- 14 %	+ 0 %
Boeing B737	Climb	12.743	1.3450	10.520	1.060	- 17 %	- 21 %
	Cruise	6.724	0.7154	4.635	0.534	- 31 %	- 25 %
	Descent	2.491	0.2436	1.581	0.151	- 37 %	- 38 %
	Trip Total	14.590	0.798	5.119	0.569	- 65 %	- 29 %
Airbus A-310	Climb	17.556	2.048	25.039	2.883	+ 43 %	+ 41 %
	Cruise	10.787	1.149	8.159	1.052	- 24 %	- 9 %
	Descent	3.103	0.312	3.089	0.320	- 0 %	+ 3 %
	Trip Total	11.801	1.278	8.865	1.104	- 25 %	- 14 %
Airbus A-320	Climb	11.601	1.262	9.881	1.047	- 15 %	- 17 %
	Cruise	6.151	0.653	4.510	0.564	- 27 %	- 14 %
	Descent	1.782	0.178	1.414	0.138	- 21 %	- 23 %
	Trip Total	6.689	0.709	5.016	0.592	- 25 %	- 16 %

This comparison shows the limits for accuracy and resolution of such a top down approach. A comparison for the area of Austria had been carried out using results from the ANCAT/EC inventory and the ATEMIS calculation [D17] which on this level of resolution lead to a difference of about 10 % between these two inventories.

D6. FUTURE EMISSIONS

D6.1. Introduction

Like most industries, airlines face a growing number of environmental regulations that are having a major impact on their business decisions. Fuel is their second biggest expense, exceeded only by labour. The major US airlines spend more than $10 billion a year on fuel, which is about 15% of total operating costs [D18]. As a result, increased fuel efficiency has been a top priority for many years, and US airlines have increased fuel efficiency nearly 50% over the past two decades. Greater fuel efficiency leads in turn to a decrease in aircraft emissions.

A study by the General Accounting Office [D19] found that aircraft emissions of HC and CO declined 85% and 70% respectively between 1976 and 1988, as more efficient aircraft entered the fleet. Emissions of NO_X rose by about 12% because of the higher engine temperatures needed to increase fuel efficiency. While the increase in NO_X is a concern, aircraft emit small amounts relative to other sources (about 2-4% of total man-made emissions).

Future emissions from aviation will depend on the balance between improvements in technology, producing more efficient and less polluting aircraft, and the growth in air transport. In this section, new and improved technologies are briefly reviewed and predictions of future levels of traffic are examined. On the basis of this information, a number of future scenarios for aircraft emissions are presented.

D6.2. New technologies

D6.2.1 Anticipated advancements in engine design

At least conceptually the reduction of CO, HC and smoke is straightforward: the combustion should be prolonged for as long as possible at high temperature in the presence of excess oxygen. This also has the effect of increasing the combustion efficiency. Unfortunately the long residence time that would reduce these pollutants would favour the formation of NO_X. The solution will probably lie with some form of staged combustor, where different injectors and different regions of the combustor are used for low and high thrust.

Other methods of achieving low levels of emissions also exist. One such method is known as "rich burn, quick quench, lean burn". The improved combustor burns fuel more efficiently and cleanly, reducing hydrocarbon emissions to 12 percent, CO emissions to 22 percent and NO_X emissions to 49 percent of International Civil Aviation Organisation (ICAO) standards [D20]. Another method is known as "lean premix prevapourised". This concept has demonstrated potential (in laboratory conditions) for NO_X emissions of 10% less than those of rich burn, quick quench, lean burn.

The technology required to reduce aircraft engine emissions is an area that is being constantly researched and advanced. The technology mentioned above, while providing a reduction, has not been accepted as the solution. Manufacturers will continue to add to the advances already made, and these continuing advancements will lead to greater reductions in aircraft emissions.

D6.2.2 Anticipated advancements in aircraft design

Aerodynamic improvements

For a fuel efficient aircraft, it is important to minimise its aerodynamic resistance. The target is to develop an aircraft geometry and surface that give a smooth and laminar flow.

Over the past decade, winglets have been a common addition to aircraft wings. Winglets provide additional lift while not contributing to drag as much as conventional wings. Another area of aerodynamic performance that may benefit commercial aviation is laminar flow control (LFC). LFC is an active boundary-layer flow control technique (usually steady suction) employed to maintain a laminar flow state. A significant advancement made in the development of LFC technology is the concept of hybrid laminar flow control, which integrates the concepts of natural laminar flow with LFC to reduce suction requirements and reduce system complexity [D21]. By using LFC and hybrid LFC, fuel savings between 5 and 30% have been reported [D22].

The Blended Wing Body (BWB)

A revolutionary configuration, the blended wing body (BWB) was conceived by the McDonnell Douglas Corporation and is being studied by a team comprising McDonnell Douglas, Stanford University, the University of Southern California, Clark Atlanta University, the University of Florida, and NASA Langley and Lewis Research Centers [D23]. The idea behind this design approach is to maximise overall efficiency by integrating the engines, wings, and the body into a single lifting surface. Preliminary analyses indicate that the BWB would outperform all conventional aircraft. It is conceived to carry 800 passengers over 7000 miles at a cruise speed of approximately 560 mph. This is almost twice the passenger capacity of the Boeing 747-400. It would reduce fuel burn and harmful emissions per passenger mile by almost a third in comparison to today's aircraft. Other potential benefits of the BWB include increased aerodynamic performance, lower operating cost and reduced community noise levels. However, many challenges still exist that will involve complex solutions requiring a multidisciplinary design approach.

Aircraft Materials

Lightweight composite materials have the potential to reduce airframe weight by 30% with equal or better structural strength. Today’s aircraft are 97% metallic, with composites used for a very limited number of components, such as vertical fins and horizontal surfaces of tailplanes [11]. In the next century, some foresee advances that could enable aircraft to be 80% composite and 30% lighter. Weight reductions will come in both engines and airframes, and the two are synergistic. Lighter aircraft require smaller engines, smaller engines require less fuel and less fuel leads to a reduction in aircraft emissions.

D6.2.3 Anticipated advancements in alternative fuels

Hydrogen

Liquid hydrogen has a certain appeal as an alternative to fossil–based aircraft fuels. Generated from water, it is a renewable resource that is essentially non-polluting and its energy density (by mass) is three times that of kerosene. However, the problem of sustainable and environmentally friendly hydrogen generation is still unsolved.

There are still some technical problems to overcome, including the storage of the fuel (the -235^{o}C storage requirement, makes the use of integral wing tanks impossible), and a lack of infrastructure to deliver the fuel. No fundamental barriers prohibit the use of cryogenic gases in existing turbine engines and the conversion does not involve changes to basic engine configuration. Necessary modifications are confined to the combustion chamber, the fuel pump and an additional heat exchanger necessary to vaporise the liquid hydrogen.

Natural gas

Liquid natural gas technology is very similar to cryogenic hydrogen applications. Like kerosene, however, natural gas is a non-renewable resource and can only be regarded as an interim solution.

Renewable fuel sources

The possibility of the use of renewable fuel sources for civil aviation has been considered by the environment committee of the International Civil Aviation Organisation. The potential of 4 bio-fuels was assessed: corn oil, rapeseed oil, soybean oil and ethanol/methanol. Compared with kerosene the vegetable oils had the advantage of superior lubricity which would be of benefit in engine fuel systems. However, high freeze point and low temperature viscosity problems would raise major safety issues, as would their low volatility and atomization levels. Their use would result in high emissions at low power, and possibly visible smoke emissions at higher power settings. Their oxygen content would reduce net heat output, necessitating a greater fuel load for a given flight, and resulting in greater emissions.

Ethanol and methanol have unacceptably low lubricity properties, and its greater corrosivity could seriously affect fuel system components. Its combustion would result in high concentrations of the toxic compounds formaldehyde and acrolein in hydrocarbon emissions. Its lower heating values compared to kerosene would reduce aircraft range significantly for a given fuel load.

It is apparent that the main contender to replace conventional aviation fuel is hydrogen, and even hydrogen has a long way to go until it is in commercial use. Table D17 provides a comparison of alternative fuels with kerosene.

Table D17. Alternative fuels for aviation

	Kerosene fossil (reference)	Kerosene biomass	Liquid natural gas	Liquid hydrogen	Liquid ethane propane butane	MeOH biomass	EtOH biomass
Not relying on fossil fuel		*		*	*	*	*
Universally available		*		*	*	*	*
No specific energy basis				*			
No competition to other basic needs	*		*	*			
Energy density by mass	*	*	*	**	*		
Energy density by volume	*	*					
Easy operation	*	*				*	*
Safety	*	*	*	*	*	*	*
No increase of CO2 in atmosphere		*		*	*	*	*
No/little harmful emission/waste			*	*	*	*	*
Low cost	*		*				

D6.2.4 Anticipated improvements in aircraft operations

Efficiency of an aircraft is not limited to the manner in which fuel is consumed or an aircraft's aerodynamic effectiveness, it is also a function of the manner in which the aircraft is operated. Significant reductions in aviation emissions could be achieved through improved operational efficiencies using improved communications, navigation and air traffic management procedures. The Centre for Advanced Aviation System Development (CAASD) of the MITRE corporation reviewed enhancements currently planned or under development by civil aviation authorities to determine their potential for reducing emissions through their impact on aircraft fuel burn. It was estimated that aviation emissions could be reduced by approximately 12 percent worldwide [D25].

D6.3. Future fleet

D6.3.1 The world's fleet

Air travel is growing more quickly than any other transport mode. In 1996, the growth rate was 6.8% and in 1997, influenced by a dramatic slowdown in Asia in the second half of the year, it was 6.1% [D26]. Worldwide air travel is projected to average 5% per year over the next 10 years. Air travel growth and airline profitability have led to more aircraft orders. Orders during 1996 and 1997 were equivalent to 8% and 9% of the world airline fleet, respectively. Table D18 shows what the Boeing Company anticipates the composition of the world fleet to be over the next twenty years, and suggests that the fleet size will more than double.

Table D18. Forecast fleet size and composition (Boeing Company)

Seat capacity/size	1997	2002	2007	2012	2017
Single aisle					
50-90	613	870	1,085	1,502	1,941
91-121	2,489	2,492	2,857	3,010	3,345
121-170	4,031	4,837	5,602	6,664	7,726
171-240	793	1,280	1,944	2,805	3,782
Twin aisle					
Small	1,194	1597	1,987	2,368	2,759
Intermediate	885	1,098	1,511	2,045	2,675
747 and larger	840	835	929	1,065	1,264
Total passenger	10,845	13,009	15,915	19,459	23,492
Freighter					
Small	637	722	773	820	983
Medium standard	420	417	332	234	260
Medium wide	123	173	259	409	659
Large	254	335	416	582	804
Total Freighter	1,434	1,647	1,780	2,045	2,706
Total Fleet	12,279	14,656	17,695	21,504	26,198

The UK's Department of Trade and Industry (DTI) have also made a forecast of the world fleet. This forecast is more conservative than that from Boeing, suggesting an increase to around 17500 aircraft by 2020[44]. Despite the inconsistencies between different forecasts, they are indicative of the future: new aircraft will be added to the fleet to replace retired aircraft and to provide the extra capacity needed.

D6.3.2 Predicted European traffic levels

EUROCONTROL have produced forecasts of air traffic up to and including 2015, based on three different growth scenarios [D27]. The forecasts are for the geographical area known as EURO 88, made up of, Belgium, Luxembourg, Germany, France, United Kingdom, Netherlands, Ireland, Spain, Canary Islands, Lisboa FIR, Santa Maria FIR, Switzerland and Austria. Although the data does not include all the current EU Member States it is indicative of the likely rate of change throughout Europe. These scenarios have been adopted for use in deriving future emissions, and extrapolated from 2015 to 2020.

The main assumptions in the Eurocontrol scenarios concern economic performance (both nationally and of the airlines), the availability of alternative modes of transport (high speed trains), the penetration of videoconferencing (avoiding the need for travel) and the degree of congestion at European airports. The assumptions are varied from the base case to provide both high and low growth scenarios. Figure D4 displays the resulting estimates of the number of flights in the EUROCONTROL area between 1974 and 2020.

[44] It should be noted that these figures only include aircraft of eighty seats or more and do not include freight aircraft.

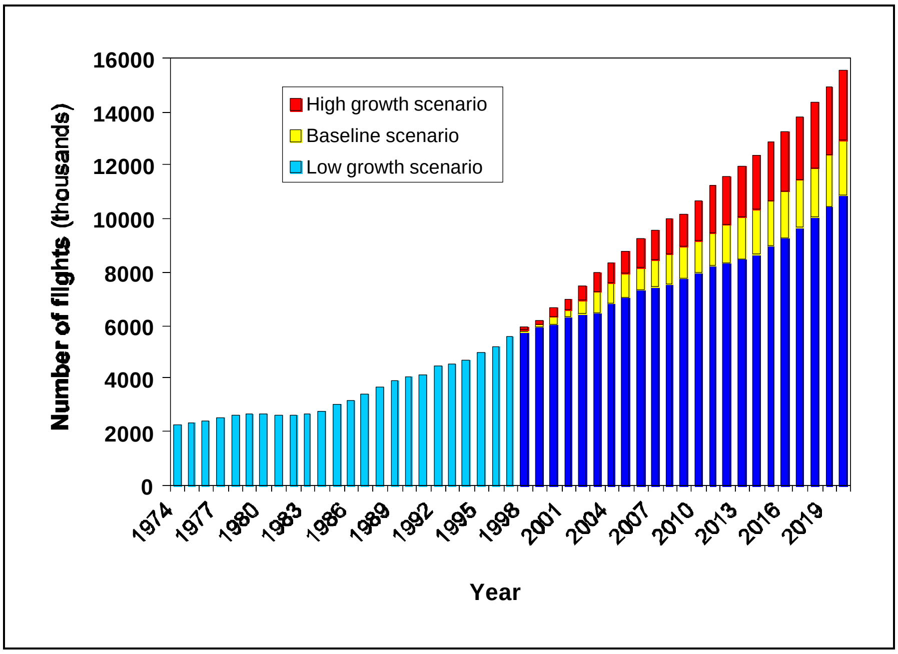

Figure D4. Air traffic forecasts for the EUROCONTROL area

D6.4. Development of emission scenarios

The EUROCONTROL traffic scenarios were combined with assumptions concerning the size and technology of the aircraft fleet in order to develop three scenarios for future emissions: high emission, low emission and baseline scenarios. The main points of these scenarios are listed below.

D6.4.1 Baseline emission scenario

- Economic growth in the period leading up to the dates of interest is normal.
- Airlines purchase aircraft at the rate expected and retire aircraft as expected.
- Manufactures develop technology as forecast.
- Due to normal economic growth, traffic levels are as expected.
  . Infrastructure was developed for the level of traffic that it handles, thus airlines achieve the same operational efficiency as forecast.
- Concern for the environment does not increase significantly, so emission regulations are developed as expected.
- High speed trains compete for air traffic as expected.
- Internet technology (videoconferencing, data transmittal etc.) remains a complementary tool of business and does not divert more passengers than forecast

D6.4.2 Low emission scenario

- Poor economic growth in the period leading up to the dates of interest.
    - . Airlines have less money, thus counteract this low economic period by purchasing more fuel efficient aircraft to reduce their expenses.
- Manufactures budget increasing amounts towards R&D of more fuel efficient engines, alternative fuels and aircraft.
- Due to the poor economic growth, traffic levels are lower than expected.
    - . This has a direct impact. Less aircraft produce less emissions.
    - . The infrastructure was developed to handle more traffic, and because of the lower traffic, aircraft spend less time, taxiing, waiting, holding etc. Thus there is an emission reduction due to operational efficiency.
- Increasing awareness of the environment promotes more stringent emission standards than are currently expected.
- High speed trains increase more than expected in popularity, they thus divert air passengers, reducing demand and reducing the frequency of flights.
- Internet technology reduces the need for business travel.

D6.4.3 High emission scenario

- Rapid economic growth in the period leading up to the dates of interest.
    - . Oil prices are reduced.
    - . Airlines cannot retire older aircraft as they need to handle more traffic than expected.
- Manufactures are put under pressure to increase production rates and place less emphasises on R&D. Thus less efficient aircraft and engines are being developed than was expected.
- Due to the rapid economic growth, traffic levels are higher than expected.
    - . This has a direct impact, more aircraft produce increasing emissions.
    - . The infrastructure was developed to handle less traffic, and because of the higher traffic, aircraft spend more time, taxiing, waiting, holding etc. Thus there is an emission increase due to operational inefficiency.
- A reduced awareness of the environment leads to a situation where authorities are not overly concerned with exhaust emission standards.
- High speed trains increase less than expected in popularity, rail traffic is diverted to air.
- Internet technology is used less and there is an increase in business travel.

D6.5. Forecast of reduction in aircraft emissions

D6.5.1 Baseline emission scenario - 2010

It was stated earlier (D6.2.4) that the expected reduction of emissions from improved aircraft operations was about 12% at today's traffic levels. Allowing for the projected doubling of traffic, the expected reduction will be in the region of 6%.

Considering the age distribution of the fleet (50% of the fleet in 2010 will be 12 years old and younger), it is estimated that the benefit derived from engine design improvements will be in the region of 7.5%, and that from aircraft design improvements will be about 4.5%.

Allowing for the slow introduction of hydrogen as an aircraft fuel, and the fact that the necessary infrastructure changes are quite large, a reduction of around 1% in emissions is expected from the use of hydrogen fuel.

The total expected reduction in aircraft emissions is therefore be in the region of 19%. This figure represents the emission reduction attributable to improvements in fuel efficiency. However, efforts are also being made to reduce emission indices (EI), thus additional benefits may come from that area. Table D19 shows the baseline reduction in EI for NO_X, CO and HC. These figures represent global fleet averages and are based on work conducted for ICAO in association with the International Co-ordinating Council of Aerospace Industries Associations (ICCAIA) [D28]. Figures for the base year are extracted from NASA inventories [D29].

Table D19. Emission indices - baseline scenario 2010 (global fleet averages)

	NO_X **kg NO_X/1000ASK**[45]	**CO** **kg CO/1000ASK**	**HC** **kg HC/1000ASK**
Current EI	0.40	101	63
Baseline EI 2010	0.36	95	59

D6.5.2 Low emission scenario - 2010

Because the air traffic management system would be well able to cope with the amount of traffic in this scenario, the expected benefit derived from improvements in aircraft operations would be greater than expected, at approximately 8%.

More than 50% of the fleet in 2010 in this scenario will be 12 years old and younger. It is estimated that the benefit derived from engine design improvements will be in the region of 8.5%, and from improved aircraft design, 5.5%.

In this scenario, it is expected that hydrogen fuel will be phased into service more quickly than expected, thus it is expected that the benefit from alternative fuels is in the region of 3%.

[45] ASK - available seat.km

The total expected reduction in aircraft emissions would therefore be in the region of 24%.

Table D20 shows the low emissions scenario reduction in EI for NO_X, CO and HC.

Table D20. Emission indices - low emission scenario 2010 (global fleet averages)

	NO_X kg NO_X/1000ASK	**CO kg CO/1000ASK**	**HC kg HC/1000ASK**
Current EI	0.40	101	63
Low Scenario EI 2010	0.34	92	56

D6.5.3 High emission scenario – 2010

The air traffic management system would be under pressure to cope with the amount of traffic in this scenario, the expected benefit derived from improvements in aircraft operations would be less than expected and estimated in the region of 4%.

Less than 50% of the fleet in 2010 in this scenario will be 12 years old and younger. It is estimated that the benefit derived from engine design improvements will be in the region of 4.5%, and from improvements in aircraft design, 4%.

In this scenario, there will be very little penetration of aircraft using alternative fuels, thus there is no expected benefit.

The total expected reduction in aircraft emissions would therefore be in the region of 12.5%.

Table D21 shows the reduction in EI for NO_X, CO and HC for the high emission scenario.

Table D21. Emission indices - high emissions scenario 2010 (global fleet averages)

	NO_X kg NO_X/1000ASK	**CO kg CO/1000ASK**	**HC kg HC/1000ASK**
Current EI	0.40	101	63
High Scenario EI 2010	0.38	98	62

D6.5.4 Baseline emission scenario - 2020

Following the procedures in the previous paragraphs, the following reductions have been determined:

- improved aircraft operations 10%.
- engine design improvements 11%.
- aircraft design improvements 8%.
- alternative fuels 4.5%.

The total expected reduction in aircraft emissions would therefore be in the region of 33.5%.

Table D22 shows the EI for NO_X, CO and HC for the baseline emission scenario.

Table D22. Emission indices - baseline scenario 2020 (global fleet averages)

	NO_X kg NO_X/1000ASK	**CO kg CO/1000ASK**	**HC kg HC/1000ASK**
Current EI	0.40	101	63
Baseline EI 2020	0.32	74	48

D6.5.5 Low emission scenario - 2020

- improvements in aircraft operations 12%.
- engine design improvements 12.5%.
- aircraft design improvements 9.5%.
- alternative fuels 4.75%.

The total expected reduction in aircraft emissions would therefore be in the region of 39.75%.

Table D23 shows the EI for NO_X, CO and HC in the low emission scenario.

Table D23. Emission indices - low emission scenario 2020 (global fleet averages)

	NO_X kg NO_X/1000ASK	**CO kg CO/1000ASK**	**HC kg HC/1000ASK**
Current EI	0.40	101	63
Baseline EI 2010	0.30	70	45

D6.5.6 High emission scenario – 2020

- improvements in aircraft operations 7%.
- engine design improvements 6.25%.
- aircraft design improvements 5.5%.
- alternative fuels 2%.

The total expected reduction in aircraft emissions would therefore be in the region of 21.5%.

Table D24 shows the EI for NO_X, CO and HC in the high emission scenario.

Table D24. Emission indices - high emission scenario 2020 (global fleet averages)

	NO_X kg NO_X/1000ASK	**CO kg CO/1000ASK**	**HC kg HC/1000ASK**
Current EI	0.40	101	63
Baseline EI 2010	0.34	78	49

D6.5.7 Summary

Table D25 summarises the emission reduction scenarios described above. The data are presented as percentage changes from a base year fleet of 1995. However, it should be emphasised that any long range projections of aircraft technology are extremely speculative and that the trends presented here, although based on the best sources of data available at this time, are still subject to many uncertainties.

Table D25. Aircraft efficiency increases and reduction factors for emission indices

Scenario	**Aircraft efficiency (%)**			**EI NO_X (%)**			**EI CO (%)**			**EI HC (%)**		
	low	**base**	**high**	**low**	**base**	**high**	**low**	**base**	**high**	**low**	**base**	**high**
Base year 1995	100	100	100	100	100	100	100	100	100	100	100	100
2010	124	119	115	85	90	95	91	94	97	88	93	98
2020	140	134	122	75	80	85	69	73	77	71	76	78

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Annex D1

B707										Boeing 707

Category includes: Boeing 707
Engine category: turbofan
Standard engine types: P&W JT3D
Engine of category: engine mix
European traffic: 0.35% (share in European air traffic movements 1995)

Max. cruising speed:	545	mph	1010	km/h
Av. cruising speed:	540	mph	1001	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	55,589	66,408	kg	
Max. take off:	116,575	151,318	kg	
Cruise altitude	short	long	range (defaults if no data available)	
			FL(=100ft)	

Equations for usage coefficients:
Variable x = CRALT

Operation state (OS)	Index	Coefficient	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO_X	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		258.82	(kg/s) 0.53921	2.5000	111.997	97.999
OS 3 take off	tff		45		211.32	(kg/s) 4.69600	12.1000	0.399	1.500
OS 4 climb	cl	b0		-1.353E+01	-1.923E+02		1.217E+01	a0 1.958E+00	a0 2.800E+00
		b1		6.676E-03	1.841E-01		-4.250E-04	a1 3.722E+01	a1 -2.279E+01
		b2		-2.182E-07	-3.009E-06		1.680E-08		
		b3		1.016E-11	6.742E-11		-2.722E-13		
OS 5 cruise	cr	b0				(kg/km) 1.116E+01	1.279E+01	2.000	2.800
		b1				(kg/km) 1.307E-02	-4.299E-02		
		b2				(kg/km) -7.815E-05	4.280E-05		
OS 6 descent	dsc	b0		1.391E+00	1.218E+01		2.861E+00	c0 -1.225E+02	c0 -1.049E+02
		b1		5.234E-03	7.511E-03		-2.690E-04	c1 2.271E+01	c1 1.966E+01
		b2		-4.674E-08	-1.605E-07		1.590E-08		
		b3		1.458E-12	1.138E-11		-2.759E-13		
OS 7 landing	ld		15		70.44	(kg/s) 4.69600	12.0950	4.003	1.505
OS 8 taxi in	txi		360		194.11	(kg/s) 0.53919	2.4990	112.004	98.001
OS 9 ground operations	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

B727 **Boeing 727**

Category includes: Boeing 727 -100, -200
Engine category: turbofan
Standard engine types: P&W JT8D
Engine of category: engine mix
European traffic: 2.02% (share in European air traffic movements 1995)

Max. cruising speed:	518	mph	960	km/h
Av. cruising speed:	495	mph	917	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	36,560	45,360	kg	
Max. take off:	75,570	95,030	kg	
Cruise altitude	short	long	range (defaults if no data available)	
	330	350	FL(=100ft)	

Equations for usage coefficients:
Variable x = CRALT

Operation state (OS)	Index	Coefficient	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO_X	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		199.30	(kg/s) 0.41521	10.0500	10.798	35.549
OS 3 take off	tff		45		146.29	(kg/s) 3.25089	10.9030	0.328	1.101
OS 4 climb	cl	b0		-1.246E+01	-1.043E+02		1.108E+01	a0 3.743E-01	a0 1.507E+00
		b1		6.233E-03	1.142E-01		-1.990E-04	a1 -8.899E-01	a1 -7.732E+00
		b2		-1.642E-07	-1.566E-06		5.198E-09		
		b3		8.114E-12	3.083E-11		-8.617E-14		
OS 5 cruise	cr	b0				(kg/km) 1.507E+00	1.332E+01	0.375	1.500
		b1				(kg/km) 4.035E-02	-4.497E-02		
		b2				(kg/km) -9.321E-	4.506E-05		
OS 6 descent	dsc	b0		-8.197E-01	-3.926E+00		3.119E+00	c0 1.063E+01	c0 3.509E+01
		b1		5.203E-03	5.445E-03		5.617E-05	c1 1.796E-02	c1 4.693E-02
		b2		-3.793E-08	-1.112E-07		3.014E-09		
		b3		1.099E-12	7.520E-12		-4.686E-14		
OS 7 landing	ld		15		48.76	(kg/s) 3.25067	10.9110	0.328	1.107
OS 8 taxi in	txi		360		149.47	(kg/s) 0.41519	10.0490	10.798	35.552
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

B737 **Boeing 737**

Category includes: Boeing 737 -100, -200, -300, -400, -500, -600, -700, -800

Engine category: turbofan

Standard engine types: CFM56-3B-2, P&W JT8D

Engine of category: engine mix

European traffic: 20.04% (share in European air traffic movements 1995)

Max. cruising speed:	509	mph	943	km/h
Av. cruising speed:	411	mph	761	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	25,878	34,270	kg	
Max. take off:	49,940	76,430	kg	
Cruise altitude	short	long	range (defaults if no data available)	
	330	350	FL(=100ft)	

Equations for usage coefficients:

Variable x = CRALT

$$Y = b_0 + b_1x + b_2x^2 + b_3x^3$$

$$Y = a_0 + a_1/x$$

$$Y = c_0 + c_1\ln(x)$$

Operation state (OS)	Index	Coefficient	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO_X	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		141.41	(kg/s) 0.29460	3.1470	10.600	33.300
OS 3 take off	tff		45		109.03	(kg/s) 2.42289	19.1510	0.468	0.725
OS 4 climb	cl	b0		-1.926E+01	-9.020E+01		1.938E+01	a0 5.235E-01	a0 1.006E+00
		b1		8.645E-03	8.386E-02		-6.940E-04	a1 -1.115E+00	a1 -5.412E+00
		b2		-4.317E-07	-1.929E-06		2.511E-08		
		b3		1.398E-11	4.656E-11		-3.831E-13		
OS 5 cruise	cr	b0				(kg/km) 1.943E+00	1.960E+01	0.520	1.000
		b1				(kg/km) 2.345E-02	-6.625E-02		
		b2				(kg/km) -5.318E-	6.648E-05		
OS 6 descent	dsc	b0		-1.321E-01	4.061E+00		3.702E+00	c0 -8.772E+00	c0 -2.874E+01
		b1		5.479E-03	4.426E-04		-3.710E-04	c1 1.881E+00	c1 6.026E+00
		b2		-5.835E-08	-9.164E-08		2.071E-08		
		b3		1.346E-12	5.344E-12		-3.388E-13		
OS 7 landing	ld		15		36.34	(kg/s) 2.42267	19.1520	0.468	0.715
OS 8 taxi in	txi		360		106.06	(kg/s) 0.29461	3.1490	10.598	33.302
OS 9 ground	go								
							EI-CO_2	3150 g/kg	
							EI-SO_2	1.00 g/kg	
							EI-H_2O	1240 g/kg	

B747	**Boeing 747**

Category includes: Boeing 747 -100, -200, -300, -400, SP
Engine category: turbofan
Standard engine types: GE CF6-50, CF6-80
Engine of category: engine mix
European traffic: 3.24% (share in European air traffic movements 1995)

Max. cruising speed:	507	mph	939	km/h
Av. cruising speed:	490	mph	908	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	147,420	182,255	kg	
Max. take off:	272,155	394,625	kg	
Cruise altitude	short	long	range (defaults if no data available)	
	390	390	FL(=100ft)	

Equations for usage coefficients:
Variable x = CRALT

$$Y = b_0 + b_1x + b_2x^2 + b_3x^3$$

$$Y = a_0 + a_1/x$$

$$Y = c_0 + c_1\ln(x)$$

Operation state (OS)	**Index**	**Coefficient**	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO_X	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		410.30	(kg/s) 0.85479	3.5290	19.181	44.541
OS 3 take off	tff		45		404.71	(kg/s) 8.99356	38.3900	0.185	0.613
OS 4 climb	cl	b0		-3.829E+01	-7.101E+02		4.035E+01	a0 0.190E+00	a0 6.531E-01
		b1		1.608E-02	4.404E-01		-1.729E-03	a1 0.000E+00	a1 -8.396E-01
		b2		-1.031E-06	-1.801E-05		7.142E-08		
		b3		2.995E-11	4.629E-10		-1.168E-12		
OS 5 cruise	cr	b0				(kg/km) 1.795E+01	3.831E+01	0.186	0.650
		b1				(kg/km) 1.172E-02	-1.284E-01		
		b2				(kg/km) -6.348E-	1.280E-04		
OS 6 descent	dsc	b0		1.478E+00	2.355E+01		8.120E+00	c0 -1.926E+01	c0 -4.432E+01
		b1		5.181E-03	1.380E-02		-9.4400E-04	c1 3.704E+00	c1 8.562E+00
		b2		-3.878E-08	-3.133E-07		5.251E-08		
		b3		1.299E-12	1.697E-11		-9.267E-13		
OS 7 landing	ld		15		134.90	(kg/s) 8.99333	38.3910	0.185	0.615
OS 8 taxi in	txi		360		307.73	(kg/s) 0.85481	3.5290	19.179	44.539
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

B757	**Boeing 757**

Category includes: Boeing 757 -200
Engine category: turbofan
Standard engine types: RB211-535, P&W PW2037
Engine of category: engine mix
European traffic: 3.69% (share in European air traffic movements 1995)

Max. cruising speed:	493	mph	914	km/h
Av. cruising speed:	460	mph	850	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	57,039	57,180	kg	
Max. take off:	104,325	113,395	kg	
Cruise altitude	short	long	range (defaults if no data available)	
	370	390	FL(=100ft)	

Equations for usage coefficients:
Variable x = CRALT

$$Y = b_0 + b_1x + b_2x^2 + b_3x^3$$

$$Y = a_0 + a_1/x$$

$$Y = c_0 + c_1\ln(x)$$

Operation state (OS)	**Index**	**Coefficient**	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO_X	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		182.40	(kg/s) 0.38000	4.2980	2.851	15.439
OS 3 take off	tff		45		167.40	(kg/s) 3.72000	52.7000	0.693	1.010
OS 4 climb	cl	b0		-7.212E+01	-4.545E+02		5.513E+01	a0 9.462E-01	a0 1.235E+00
		b1		2.604E-02	2.279E-01		-2.678E-03	a1 -5.034E+00	a1 -4.419E+00
		b2		-1.649E-06	-1.016E-05		1.034E-07		
		b3		3.922E-11	2.239E-10		-1.509E-12		
OS 5 cruise	cr	b0				(kg/km) 7.253E+00	4.635E+01	0.940	1.230
		b1				(kg/km) 1.131E-02	-1.545E-01		
		b2				(kg/km) -4.062E-	1.520E-04		
OS 6 descent	dsc	b0		9.223E-01	8.301E+00		8.117E+00	c0 -1.070E+00	c0 -1.321E+01
		b1		5.022E-03	5.645E-03		-8.540E-04	c1 3.752E-01	c1 2.743E+00
		b2		-1.923E-08	-1.199E-07		4.257E-08		
		b3		7.177E-13	5.767E-12		-6.563E-13		
OS 7 landing	ld		15		55.80	(kg/s) 3.72000	52.7060	0.699	1.004
OS 8 taxi in	txi		360		136.80	(kg/s) 0.38000	4.2980	2.851	15.439
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

B767 **Boeing 767**

Category includes:	Boeing 767 -200, 300			
Engine category:	turbofan			
Standard engine types:	GE CF6-80C2, P&W JT9D			
Engine of category:	engine mix			
European traffic:	2.79%	(share in European air traffic movements 1995)		
Max. cruising speed:	493	mph	914	km/h
Av. cruising speed:	461	mph	855	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	80,510	89,900	kg	
Max. take off:	136,078	181,440	kg	
Cruise altitude	short	long	range (defaults if no data available)	
	390	390	FL(=100ft)	

Equations for usage coefficients:
Variable x = CRALT

$$Y = b_0 + b_1x + b_2x^2 + b_3x^3$$

$$Y = a_0 + a_1/x$$

$$Y = c_0 + c_1\ln(x)$$

Operation state (OS)	Index	Coefficient	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO_X	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		180.48	(kg/s) 0.37600	3.9450	4.915	24.762
OS 3 take off	tff		45		204.48	(kg/s) 4.54400	31.9880	0.166	0.621
OS 4 climb	cl	b0		-1.909E+01	-2.422E+02		3.270E+01	a0 1.720E-01	a0 6.618E-01
		b1		8.479E-03	1.798E-01		-1.212E-03	a1 -9.130E-02	a1 -7.222E-01
		b2		-4.292E-07	-5.444E-06		4.923E-08		
		b3		1.441E-11	1.218E-10		-8.074E-13		
OS 5 cruise	cr	b0				(kg/km) 7.195E+00	3.332E+01	0.520	1.000
		b1				(kg/km) 2.165E-02	-1.112E-01		
		b2				(kg/km) -6.322E-	1.100E-04		
OS 6 descent	dsc	b0		-1.783E+00	-2.853E+00		1.171E+00	c0 5.377E+00	c0 2.447E+01
		b1		5.308E-03	5.973E-03		6.011E-05	c1 -4.778E-02	c1 2.975E-02
		b2		-5.060E-08	-1.417E-07		-8.275E-10		
		b3		1.509E-12	7.905E-12		2.554E-14		
OS 7 landing	ld		15		68.16	(kg/s) 4.54400	31.9840	0.161	0.616
OS 8 taxi in	txi		360		135.36	(kg/s) 0.37600	3.9450	4.913	24.764
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

B111									**British Aerospace 111**

Category includes: British Aerospace 111
Engine category: turbofan
Standard engine types: SPEY MK 506, SPEY MK 511s.Srs500, SPEY MK 512-14DWs
Engine of category: engine mix
European traffic: 0.50% (share in European air traffic movements 1995)

Max. cruising speed:	470	mph	870	km/h
Av. cruising speed:	400	mph	742	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	21,049	24,758	kg	
Max. take off:	35,833	47,400	kg	
Cruise altitude	short	long	range (defaults if no data available)	
			FL(=100ft)	

Equations for usage coefficients:
Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	Index	Coefficient	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO$_X$	EI-HC	EI-CO
			DUR	D	FC	SFC	SE$_{NOx}$	SE$_{HC}$	SE$_{CO}$
OS 1 engine start	es								
OS 2 taxi out	txo		480		121.92	(kg/s) 0.25400	3.6010	3.691	31.767
OS 3 take off	tff		45		80.19	(kg/s) 1.78200	22.6960	0.087	0.125
OS 4 climb	cl	b0		-1.805E+01	-8.697E+01		2.278E+01	a0 1.205E-01	a0 6.383E-01
		b1		8.305E-03	7.584E-02		-9.700E-04	a1 -5.333E+00	a1 -9.065E+00
		b2		-3.704E-07	-1.694E-06		4.096E-08		
		b3		1.403E-11	3.611E-11		-6.632E-13		
OS 5 cruise	cr	b0				(kg/km) 2.605E+00	2.229E+01	0.120	0.630
		b1				(kg/km) 1.143E-02	-7.485E-02		
		b2				(kg/km) -3.835E-	7.442E-05		
OS 6 descent	dsc	b0		1.384E+00	2.861E+00		4.558E+00	c0 -2.797E+00	c0 -2.508E+01
		b1		4.901E-03	3.034E-03		-5.150E-04	c1 6.386E-01	c1 5.594E+00
		b2		-1.564E-08	-4.916E-08		3.165E-08		
		b3		8.787E-13	4.988E-12		-5.691E-13		
OS 7 landing	ld		15		26.73	(kg/s) 1.78200	22.7090	0.075	0.112
OS 8 taxi in	txi		360		91.44	(kg/s) 0.25400	3.5980	3.685	31.769
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

BE200	**Beechcraft Super King Air 200**

Category includes: Beechcraft Super King Air 200
Engine category: turboprop
Standard engine types: P&WC PT6A-41, PT6A-42s
Engine of category: engine mix
European traffic: 1.10% (share in European air traffic movements 1995)

Max. cruising speed:	289	mph	536	km/h
Av. cruising speed:	278	mph	515	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	3,318	3,675	kg	
Max. take off:	5,670	5,670	kg	
Cruise altitude	short	long	range (defaults if no data available)	
			FL(=100ft)	

Equations for usage coefficients:
Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	Index	Coefficient	Duration of OS (s) DUR	Distance of OS (km) D	Fuel consumption total (kg) FC	Fuel consumption specific SFC	Specific emission parameters (g/kg) EI-NO_X SE_{NOx}	EI-HC SE_{HC}	EI-CO SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		14.40	(kg/s) 0.03000	4.0970	14.028	35.972
OS 3 take off	tff		45		5.67	(kg/s) 0.12600	9.5240	0.000	1.235
OS 4 climb	cl	b0		-4.453E+01	-9.213E+00		9.583E+00	a0 2.050E-02	a0 1.399E+00
		b1		1.821E-02	6.662E-03		-2.680E-04	a1 -3.254E-01	a1 -3.064E+00
		b2		-1.319E-06	-2.704E-07		6.874E-09		
		b3		3.399E-11	6.699E-12		-1.100E-13		
OS 5 cruise	cr	b0				(kg/km) 4.139E-01	1.154E+01	0.023	1.403
		b1				(kg/km) 2.595E-07	-3.895E-02		
		b2				(kg/km) -2.145E-	3.892E-05		
OS 6 descent	dsc	b0		2.482E+00	3.048E-01		2.182E+00	c0 -8.576E+00	c0 -1.957E+01
		b1		5.324E-03	3.660E-04		-1.370E-04	c1 2.236E+00	c1 5.509E+00
		b2		-6.503E-08	-5.207E-10		9.103E-09		
		b3		9.166E-13	3.620E-13		-1.443E-13		
OS 7 landing	ld		15		1.89	(kg/s) 0.12600	9.5240	0.000	1.058
OS 8 taxi in	txi		360		10.80	(kg/s) 0.03000	4.0740	13.981	36.019
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

BE90	**Beechcraft King Air 90**

Category includes: Beechcraft King Air 90
Engine category: turboprop
Standard engine types: P&WC PT6A-6, PT6A-135s
Engine of category: engine mix
European traffic: 0.50% (share in European air traffic movements 1995)

Max. cruising speed:	267	mph	494	km/h
Av. cruising speed:	235	mph	435	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	2,412	3,212	kg	
Max. take off:	4,218	5,352	kg	
Cruise altitude	short	long	range (defaults if no data available)	
		240	FL(=100ft)	

Equations for usage coefficients:
Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	**Index**	**Coefficient**	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO$_X$	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		9.60	(kg/s) 0.02000	4.0630	13.958	36.042
OS 3 take off	tff		45		3.69	(kg/s) 0.08200	9.4485	0.000	1.084
OS 4 climb	cl	b0		-1.493E+01	-4.921E+00		9.775E+00	a0 2.030E-01	a0 1.404E+00
		b1		8.930E-03	4.633E-03		-3.380E-04	a1 -3.466E-01	a1 -3.633E+00
		b2		-7.423E-07	-2.326E-07		1.274E-08		
		b3		2.995E-11	8.619E-12		-2.883E-13		
OS 5 cruise	cr	b0				(kg/km)		0.019	1.400
		b1				(kg/km)			
		b2				(kg/km)			
OS 6 descent	dsc	b0		7.227E-01	1.585E-01		2.687E+00	c0 -2.841E+00	c0 -5.010E+00
		b1		3.890E-03	3.760E-04		-3.230E-04	c1 1.743E+00	c1 4.245E+00
		b2		-5.123E-08	7.786E-10		3.331E-08		
		b3		1.247E-12	-3.917E-13		-9.153E-13		
OS 7 landing	ld		15		1.23	(kg/s) 0.08200	9.7560	0.000	0.813
OS 8 taxi in	txi		360		7.20	(kg/s) 0.02000	4.1670	14.028	35.972
OS 9 ground	go								
							EI-CO_2	3150 g/kg	
							EI-SO_2	1.00 g/kg	
							EI-H_2O	1240 g/kg	

C500	Cessna Citation C 500

Category includes: Cessna Citation I, II, V
Engine category: turbofan
Standard engine types: P&W JT15-D
Engine of category: engine mix
European traffic: 0.70% (share in European air traffic movements 1995)

Max. cruising speed:	427	mph	790	km/h
Av. cruising speed:	384	mph	711	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	2,455	4,004	kg	
Max. take off:	4,920	7,212	kg	
Cruise altitude	short	long	range (defaults if no data available)	
			FL(=100ft)	

Equations for usage coefficients:
Variable x = CRALT

$$Y = b_0 + b_1x + b_2x^2 + b_3x^3$$

$$Y = a_0 + a_1/x$$

$$Y = c_0 + c_1\ln(x)$$

Operation state (OS)	Index	Coefficient	Duration of OS (s) DUR	Distance of OS (km) D	Fuel consumption total (kg) FC	Fuel consumption specific SFC	Specific emission parameters (g/kg) EI-NO_X SE_{NOx}	EI-HC SE_{HC}	EI-CO SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		22.08	(kg/s) 0.04600	1.7660	50.498	132.020
OS 3 take off	tff		45		13.32	(kg/s) 0.29600	7.5830	0.000	2.628
OS 4 climb	cl	b0		-1.067E+01	-8.476E+00		7.421E+00	a0 1.180E-02	a0 3.517E+00
		b1		5.348E-03	9.233E-03		-1.540E-04	a1 -3.505E-01	a1 -1.595E+01
		b2		-1.804E-07	-1.866E-07		4.243E-09		
		b3		8.089E-12	5.083E-12		-7.967E-14		
OS 5 cruise	cr	b0				(kg/km) 1.041E+00	8.876E+00	3.498	2.230
		b1				(kg/km) 1.380E-03	-3.035E-02		
		b2				(kg/km) -5.362E-	3.000E-05		
OS 6 descent	dsc	b0		4.718E-01	8.033E-01		1.780E+00	c0 -4.703E+01	c0 -1.449E+02
		b1		5.709E-03	7.600E-04		-1.740E-04	c1 9.487E+00	c1 2.402E+01
		b2		-9.149E-08	-1.724E-08		1.069E-08		
		b3		2.134E-12	9.169E-13		-1.891E-13		
OS 7 landing	ld		15		4.44	(kg/s) 0.29600	7.6580	0.000	2.703
OS 8 taxi in	txi		360		106.06	(kg/s) 0.29461	1.7510	50.483	132.005
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

DA20 **Dassault Mystère / Falcon 10**

Category includes:	Dassault Mystère / Falcon 10, 100			
Engine category:	turbofan			
Standard engine types:	Garrett TFE731-2			
Engine of category:	engine mix			
European traffic:	0.30%	(share in European air traffic movements 1995)		
Max. cruising speed:	492	mph	912	km/h
Av. cruising speed:		mph		km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	4,880	5,055	kg	
Max. take off:	8,500	8,755	kg	
Cruise altitude	short	long	range (defaults if no data available)	
			FL(=100ft)	

Equations for usage coefficients:

Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	Index	Coefficient	Duration of OS (s) DUR	Distance of OS (km) D	Fuel consumption total (kg) FC	Fuel consumption specific SFC	Specific emission parameters (g/kg) EI-NO_X SE_{NOx}	EI-HC SE_{HC}	EI-CO SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		23.04	(kg/s) 0.04800	2.8210	20.052	58.594
OS 3 take off	tff		45		18.45	(kg/s) 0.41000	15.2300	0.108	1.409
OS 4 climb	cl	b0		-1.008E+01	-1.098E+01		1.553E+01	a0 1.282E-01	a0 2.042E+00
		b1		5.079E-03	1.092E-02		-4.510E-04	a1 -2.508E-01	a1 -1.188E+01
		b2		-1.868E-07	-1.897E-07		1.624E-08		
		b3		8.209E-12	5.075E-12		-2.698E-13		
OS 5 cruise	cr	b0				(kg/km) 9.023E-01	1.698E+01	0.127	2.030
		b1				(kg/km) 1.563E-03	-5.751E-02		
		b2				(kg/km) -6.703E-	5.791E-05		
OS 6 descent	dsc	b0		3.023E+00	1.335E+00		3.537E+00	c0 -2.259E+01	c0 -6.098E+01
		b1		4.905E-03	6.790E-04		-3.500E-04	c1 4.118E+00	c1 1.155E+01
		b2		-2.029E-08	-1.211E-08		2.066E-08		
		b3		1.025E-12	9.493E-13		-3.636E-13		
OS 7 landing	ld		15		6.15	(kg/s) 0.41000	15.2850	0.163	1.463
OS 8 taxi in	txi		360		17.28	(kg/s) 0.04800	2.8360	20.023	58.623
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

DA50 **Dassault Falcon 50**

Category includes:	Dassault Falcon 50			
Engine category:	turbofan			
Standard engine types:	Garrett TFE731-3			
Engine of category:	engine mix			
European traffic:	0.20%	(share in European air traffic movements 1995)		
Max. cruising speed:	475	mph	880	km/h
Av. cruising speed:	430	mph	797	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	9,150		kg	
Max. take off:	17,600	18500	kg	
Cruise altitude	short	long	range (defaults if no data available)	
			FL(=100ft)	

Equations for usage coefficients:

Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	Index	Coefficient	Duration of OS (s) DUR	Distance of OS (km) D	Fuel consumption total (kg) FC	Fuel consumption specific SFC	Specific emission parameters (g/kg) EI-NO_X SE_{NOx}	EI-HC SE_{HC}	EI-CO SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		34.56	(kg/s) 0.07200	2.8070	20.052	58.594
OS 3 take off	tff		45		27.67	(kg/s) 0.61489	15.2510	0.108	1.409
OS 4 climb	cl	b0		-6.592E+00	-1.340E+01		1.554E+01	a0 1.283E-01	a0 2.044E+00
		b1		3.592E-03	1.444E-02		-4.630E-04	a1 -2.770E-01	a1 -1.227E+01
		b2		-6.732E-08	-1.793E-07		1.695E-08		
		b3		4.662E-12	4.204E-12		-2.754E-13		
OS 5 cruise	cr	b0				(kg/km) 1.606E+00	1.693E+01	0.129	2.030
		b1				(kg/km) 3.830E-04	-5.711E-02		
		b2				(kg/km) -6.552E-	5.713E-05		
OS 6 descent	dsc	b0		3.023E+00	1.952E+00		3.865E+00	c0 -2.224E+01	c0 -6.088E+01
		b1		4.905E-03	1.019E-03		-3.890E-04	c1 4.086E+00	c1 1.155E+01
		b2		-2.029E-08	-1.818E-08		2.242E-08		
		b3		1.025E-12	1.424E-12		-3.905E-13		
OS 7 landing	ld		15		9.22	(kg/s) 0.61467	15.2930	0.108	1.410
OS 8 taxi in	txi		360		25.92	(kg/s) 0.07200	2.8160	20.023	58.603
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

DASH 8	**De Havilland Dash 8**

Category includes:	De Havilland Dash 8 -100, -200, -300			
Engine category:	turboprop			
Standard engine types:	P&W PW120A, 121As, 123, 123Bs, 123Cs, 123Ds			
Engine of category:	engine mix			
European traffic:	2.50%	(share in European air traffic movements 1995)		
Max. cruising speed:	287	mph	532	km/h
Av. cruising speed:	237	mph	440	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	10,250	11,657	kg	
Max. take off:	15,650	19,504	kg	
Cruise altitude	short	long	range (defaults if no data available)	
		270	FL(=100ft)	

Equations for usage coefficients:

Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	Index	Coefficient	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO_X	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		33.60	(kg/s) 0.07000	4.1070	36.012	4.107
OS 3 take off	tff		45		13.23	(kg/s) 0.29400	9.5990	1.209	9.599
OS 4 climb	cl	b0		-7.461E+01	-6.493E+01		9.658E+00	a0 2.110E-02	a0 1.407E+00
		b1		3.367E-02	3.628E-02		-3.220E-04	a1 -3.477E-01	a1 -7.058E+00
		b2		-3.029E-06	-2.632E-06		1.259E-08		
		b3		8.763E-11	7.533E-11		-2.908E-13		
OS 5 cruise	cr	b0				(kg/km)		0.037	1.378
		b1				(kg/km)			
		b2				(kg/km)			
OS 6 descent	dsc	b0		1.281E+00	4.492E-01		2.825E+00	c0 -3.222E+00	c0 -5.102E+00
		b1		4.708E-03	1.139E-03		-2.870E-04	c1 1.762E+00	c1 4.204E+00
		b2		-5.828E-08	-3.033E-09		2.472E-08		
		b3		1.260E-12	1.392E-12		-5.710E-13		
OS 7 landing	ld		15		4.41	(kg/s) 0.29400	9.5240	0.000	1.134
OS 8 taxi in	txi		360		25.20	(kg/s) 0.07000	4.0870	14.008	35.992
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

DC8 **Douglas DC8**

Category includes: Douglas DC8 -10, -20, -30, -40, -50
Engine category: turbofan
Standard engine types: P&W JT3D
Engine of category: engine mix
European traffic: 0.30% (share in European air traffic movements 1995)

Max. cruising speed:	504	mph	933	km/h
Av. cruising speed:		mph		km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	60,020		kg	
Max. take off:	147,415		kg	
Cruise altitude	short	long	range (defaults if no data available)	
			FL(=100ft)	

Equations for usage coefficients:
Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	Index	Coefficient	Duration of OS (s)	Distance of OS (km)	Fuel consumption		Specific emission parameters (g/kg)		
					total (kg)	specific	EI-NO_X	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		249.60	(kg/s) 0.52000	3.5020	4.030	14.099
OS 3 take off	tff		45		214.38	(kg/s) 4.76400	22.8010	0.350	1.031
OS 4 climb	cl	b0		-2.969E+01	-2.932E+02		2.327E+01	a0 5.037E-01	a0 1.409E+00
		b1		1.287E-02	2.200E-01		-7.780E-04	a1 -2.913E+00	a1 -7.185E+00
		b2		-7.410E-07	-6.198E-06		3.059E-08		
		b3		2.369E-11	1.597E-10		-5.077E-13		
OS 5 cruise	cr	b0				(kg/km) 8.726E+01	2.429E+01	0.500	1.400
		b1				(kg/km) -4.942E-	-8.073E-02		
		b2				(kg/km) 7.640E-04	7.912E-05		
OS 6 descent	dsc	b0		1.971E+00	1.080E+01		5.221E+00	c0 -3.102E+00	c0 -1.152E+01
		b1		4.948E-03	7.202E-03		-5.730E-04	c1 6.938E-01	c1 2.492E+00
		b2		-2.369E-08	-1.339E-07		3.355E-08		
		b3		1.099E-12	1.053E-11		-5.951E-13		
OS 7 landing	ld		15		71.46	(kg/s) 4.76400	22.7960	0.350	1.036
OS 8 taxi in	txi		360		187.20	(kg/s) 0.52000	3.4990	4.028	14.103
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

DC9	**McDonnel Douglas DC9**

Category includes:	McDonnel Douglas DC9 -10, -20, -30, -40, -50			
Engine category:	turbofan			
Standard engine types:	P&W JT8D			
Engine of category:	engine mix			
European traffic:	2.50%	(share in European air traffic movements 1995)		
Max. cruising speed:	490	mph	907	km/h
Av. cruising speed:	478	mph	885	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	22,635	28,068	kg	
Max. take off:	41,140	54,885	kg	
Cruise altitude	short	long	range (defaults if no data available)	
	330	350	FL(=100ft)	

Equations for usage coefficients:

Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	Index	Coefficient	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO$_X$	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		133.44	(kg/s) 0.27800	3.8290	6.422	23.958
OS 3 take off	tff		45		101.88	(kg/s) 2.26400	18.3940	0.324	1.129
OS 4 climb	cl	b0		-8.143E+00	-7.241E+01		1.869E+01	a0 3.838E-01	a0 1.425E+00
		b1		4.358E-03	7.248E-02		-7.790E-04	a1 -9.984E-01	a1 -5.193E+00
		b2		-8.355E-08	-1.273E-06		3.237E-08		
		b3		5.584E-12	2.325E-11		-5.156E-13		
OS 5 cruise	cr	b0				(kg/km) 2.042E+00	1.838E+01	0.520	1.000
		b1				(kg/km) 2.200E-02	-6.208E-02		
		b2				(kg/km) -5.643E-	6.221E-05		
OS 6 descent	dsc	b0		1.589E+00	4.002E+00		3.893E+00	c0 -5.232E+00	c0 -1.936E+01
		b1		5.125E-03	3.914E-03		-3.770E-04	c1 1.139E+00	c1 4.237E+00
		b2		-4.107E-08	-8.284E-08		2.344E-08		
		b3		1.349E-12	5.820E-12		-4.150E-13		
OS 7 landing	ld		15		33.96	(kg/s) 2.26400	18.4040	0.324	1.119
OS 8 taxi in	txi		360		100.08	(kg/s) 0.27800	3.8270	6.425	23.961
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

DC10	McDonnel Douglas DC10

Category includes:	McDonnel Douglas DC10			
Engine category:	turbofan			
Standard engine types:	GE CF6-50			
Engine of category:	engine mix			
European traffic:	0.83%	(share in European air traffic movements 1995)		
Max. cruising speed:	530	mph	982	km/h
Av. cruising speed:	490	mph	908	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	121,198	122,951	kg	
Max. take off:	259,450	263,085	kg	
Cruise altitude	short	long	range (defaults if no data available)	
			FL(=100ft)	

Equations for usage coefficients:

Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	Index	Coefficient	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO_X	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		265.39	(kg/s) 0.55290	3.6320	33.532	64.200
OS 3 take off	tff		45		294.30	(kg/s) 6.54000	36.7990	0.333	0.632
OS 4 climb	cl	b0		-1.759E+01	-2.809E+02		3.898E+01	a0 3.668E+00	a0 7.017E-01
		b1		8.322E-03	2.328E-01		-1.442E-03	a1 -6.559E-01	a1 -1.331E+00
		b2		-3.545E-07	-4.619E-06		5.640E-08		
		b3		1.354E-11	1.221E-10		-8.960E-13		
OS 5 cruise	cr	b0				(kg/km) 1.079E+01	3.865E+01	0.366	0.700
		b1				(kg/km) 2.925E-02	-1.276E-01		
		b2				(kg/km) -9.546E-	1.240E-04		
OS 6 descent	dsc	b0		1.780E+00	1.661E+01		8.553E+00	c0 -3.694E+01	c0 -7.064E+01
		b1		5.039E-03	8.024E-03		-9.770E-04	c1 6.789E+00	c1 1.299E+01
		b2		-2.685E-08	-1.493E-07		5.381E-08		
		b3		1.139E-12	1.068E-11		-9.462E-13		
OS 7 landing	ld		15		98.10	(kg/s) 6.54000	36.7990	0.336	0.632
OS 8 taxi in	txi		360		199.04	(kg/s) 0.55289	3.6320	33.531	64.203
OS 9 ground	go								
							EI-CO_2	3150 g/kg	
							EI-SO_2	1.00 g/kg	
							EI-H_2O	1240 g/kg	

A300 **Airbus 300**

Category includes: Airbus 300 -B2, -B4, -600, -600ST
Engine category: turbofan
Standard engine types: GE CF6-50, GE CF6-80
Engine of category: engine mix
European traffic: 1.52% (share in European air traffic movements 1995)

Max. cruising speed:	495	mph	917	km/h
Av. cruising speed:	457	mph	847	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	78,854	89,699	kg	
Max. take off:	142,000	171,700	kg	
Cruise altitude	short	long	range (defaults if no data available)	
		290	FL(=100ft)	

Equations for usage coefficients:
Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	Index	Coefficient	Duration of OS (s) DUR	Distance of OS (km) D	Fuel consumption total (kg) FC	Fuel consumption specific SFC	Specific emission parameters (g/kg) EI-NO_X SE_{NOx}	EI-HC SE_{HC}	EI-CO SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		180.00	(kg/s) 0.37500	3.0940	29.139	61.472
OS 3 take off	tff		45		225.00	(kg/s) 5.00000	33.6690	0.337	0.510
OS 4 climb	cl	b0		-1.077E+01	-1.476E+02		3.421E+01	a0 3.913E-01	a0 5.100E-01
		b1		5.020E-03	1.330E-01		-1.360E-03	a1 -1.073E+00	a1 -4.800E-03
		b2		-1.233E-07	-1.888E-06		5.337E-08		
		b3		6.064E-12	3.736E-11		-8.008E-13		
OS 5 cruise	cr	b0				(kg/km) 5.714E+00	3.469E+01	0.389	0.510
		b1				(kg/km) 2.087E-02	-1.201E-01		
		b2				(kg/km) -5.333E-	1.250E-04		
OS 6 descent	dsc	b0		4.733E+00	2.306E+01		7.352E+00	c0 -4.083E+01	c0 -8.695E+01
		b1		4.939E-03	5.013E-03		-6.030E-04	c1 6.502E+00	c1 1.379E+01
		b2		-1.479E-08	-9.456E-08		2.678E-08		
		b3		7.361E-13	6.338E-12		-3.990E-13		
OS 7 landing	ld		15		75.13	(kg/s) 5.00867	33.6750	0.333	0.506
OS 8 taxi in	txi		360		135.00	(kg/s) 0.37500	3.0960	29.141	61.467
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

A310	**Airbus 310**

Category includes: Airbus 310
Engine category: turbofan
Standard engine types: GE CF6-80, P & W JT9D
Engine of category: engine mix
European traffic: 1.93% (share in European air traffic movements 1995)

Max. cruising speed:	484	mph	897	km/h
Av. cruising speed:	459	mph	850	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	80,142	80,329	kg	
Max. take off:	142,000	164,000	kg	
Cruise altitude	short	long	range (defaults if no data available)	
	350	**370**	FL(=100ft)	

Equations for usage coefficients:
Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	**Index**	**Coefficient**	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO_X	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		204.67	(kg/s) 0.42640	4.0990	1.182	9.137
OS 3 take off	tff		45		187.79	(kg/s) 4.17311	40.0500	0.154	0.538
OS 4 climb	cl	b0		-1.379E+01	-1.513E+02		4.150E+01	a0 1.244E-01	a0 5.043E-01
		b1		6.308E-03	1.202E-01		-1.531E-03	a1 5.675E+00	a1 6.623E-01
		b2		-2.433E-07	-2.515E-06		6.182E-08		
		b3		9.680E-12	6.037E-11		-9.972E-13		
OS 5 cruise	cr	b0				(kg/km) 8.173E+00	4.237E+01	0.125	0.507
		b1				(kg/km) 4.789E-03	-1.413E-01		
		b2				(kg/km) -3.008E-	1.390E-04		
OS 6 descent	dsc	b0		1.769E+00	1.026E+01		8.921E+00	c0 -8.667E-01	c0 -8.207E+00
		b1		5.034E-03	6.278E-03		-1.049E-03	c1 1.981E-01	c1 1.678E+00
		b2		-2.464E-08	-1.363E-07		5.914E-08		
		b3		1.046E-12	8.272E-12		-1.049E-12		
OS 7 landing	ld		15		62.60	(kg/s) 4.17333	40.0480	0.160	0.543
OS 8 taxi in	txi		360		153.50	(kg/s) 0.42639	4.0980	1.179	9.134
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

A320	**Airbus 320**

Category includes:	Airbus 320			
Engine category:	turbofan			
Standard engine types:	CFM56-5			
Engine of category:	engine mix			
European traffic:	6.22%	(share in European air traffic movements 1995)		
Max. cruising speed:	487	mph	903	km/h
Av. cruising speed:	454	mph	847	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	41,583	41,870	kg	
Max. take off:	73,500	77,000	kg	
Cruise altitude	short	long	range (defaults if no data available)	
	370	**390**	FL(=100ft)	

Equations for usage coefficients:

Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	**Index**	**Coefficient**	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO_X	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		117.12	(kg/s) 0.24400	5.1310	0.871	12.884
OS 3 take off	tff		45		105.93	(kg/s) 2.35400	32.5780	0.160	0.689
OS 4 climb	cl	b0		-9.233E+00	-6.428E+01		3.288E+01	a0 1.701E-01	a0 7.104E-01
		b1		4.474E-03	6.045E-02		-1.033E-03	a1 -8.950E-02	a1 -3.973E-01
		b2		-9.910E-08	-9.614E-07		3.559E-08		
		b3		4.917E-12	1.921E-11		-5.197E-13		
OS 5 cruise	cr	b0				(kg/km) 3.694E+00	3.556E+01	0.172	0.661
		b1				(kg/km) 1.008E-02	-1.225E-01		
		b2				(kg/km) -2.916E-	1.260E-04		
OS 6 descent	dsc	b0		5.027E-01	5.745E+00		6.326E+00	c0 -6.055E-01	c0 -1.292E+01
		b1		5.394E-03	3.541E-03		-5.690E-04	c1 1.411E-01	c1 2.460E+00
		b2		-4.600E-08	-7.306E-08		2.860E-08		
		b3		9.871E-13	3.493E-12		-4.279E-13		
OS 7 landing	ld		15		35.31	(kg/s) 2.35400	32.5690	0.170	0.680
OS 8 taxi in	txi		360		87.84	(kg/s) 0.24400	5.1340	0.877	12.876
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

F28	**Fokker 28**

Category includes:	Fokker 28			
Engine category:	turbofan			
Standard engine types:	Spey 555			
Engine of category:	engine mix			
European traffic:	0.73%	(share in European air traffic movements 1995)		
Max. cruising speed:	455	mph	843	km/h
Av. cruising speed:	366	mph	678	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	16,965	17,645	kg	
Max. take off:	33,110	33,110	kg	
Cruise altitude	short	long	range (defaults if no data available)	
	290	310	FL(=100ft)	

Equations for usage coefficients:

Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	Index	Coefficient	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO_X	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		101.76	(kg/s) 0.21200	2.7610	47.298	58.756
OS 3 take off	tff		45		65.52	(kg/s) 1.45600	20.4060	0.580	0.366
OS 4 climb	cl	b0		-7.909E+00	-3.523E+01		2.046E+01	a0 8.772E-01	a0 3.498E-01
		b1		4.488E-03	4.372E-02		-8.030E-04	a1 -5.038E+00	a1 3.637E-01
		b2		-1.241E-07	-7.507E-07		3.105E-08		
		b3		6.645E-12	1.574E-11		-4.882E-13		
OS 5 cruise	cr	b0				(kg/km) 1.544E+00	2.022E+01	0.875	0.350
		b1				(kg/km) 1.267E-02	-6.844E-02		
		b2				(kg/km) -3.448E-	6.877E-05		
OS 6 descent	dsc	b0		1.724E+00	3.564E+00		4.214E+00	c0 -4.213E+01	c0 -5.388E+01
		b1		5.095E-03	2.681E-03		-4.820E-04	c1 8.749E+00	c1 1.102E+01
		b2		-3.435E-08	-4.290E-08		2.823E-08		
		b3		8.689E-13	4.132E-12		-5.055E-13		
OS 7 landing	ld		15		21.84	(kg/s) 1.45600	20.4210	0.595	0.366
OS 8 taxi in	txi		360		76.32	(kg/s) 0.21200	2.7650	47.301	58.766
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

F50 **Fokker 50**

Category includes: Fokker 50
Engine category: turboprop
Standard engine types: Spey 555
Engine of category: engine mix
European traffic: 3.80% (share in European air traffic movements 1995)

Max. cruising speed:	287	mph	532	km/h
Av. cruising speed:	245	mph	454	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	12,520		kg	
Max. take off:	19,950	20,820	kg	
Cruise altitude	short	long	range (defaults if no data available)	
		240	FL(=100ft)	

Equations for usage coefficients:
Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	Index	Coefficient	Duration of OS (s) DUR	Distance of OS (km) D	Fuel consumption total (kg) FC	Fuel consumption specific SFC	Specific emission parameters (g/kg) EI-NO_X SE_{NOx}	EI-HC SE_{HC}	EI-CO SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		40.32	(kg/s) 0.08400	4.0920	13.988	36.012
OS 3 take off	tff		45		16.02	(kg/s) 0.35600	9.6130	0.000	1.186
OS 4 climb	cl	b0		-1.350E+02	-1.424E+02		9.779E+00	a0 2.060E-02	a0 1.405E+00
		b1		5.901E-02	7.182E-02		-3.680E-04	a1 -2.411E-01	a1 -3.947E+00
		b2		-5.417E-06	-5.716E-06		1.690E-08		
		b3		1.515E-10	1.584E-10		-4.041E-13		
OS 5 cruise	cr	b0				(kg/km)		0.016	1.400
		b1				(kg/km)			
		b2				(kg/km)			
OS 6 descent	dsc	b0		-4.950E-03	-3.751E-01		1.601E+00	c0 -1.003E+00	c0 -1.553E+00
		b1		5.451E-03	9.960E-04		-3.824E-05	c1 1.497E+00	c1 3.748E+00
		b2		-1.072E-07	-2.076E-08		3.114E-09		
		b3		2.024E-12	1.316E-12		-2.912E-14		
OS 7 landing	ld		15		5.34	(kg/s) 0.35600	9.5510	0.000	1.124
OS 8 taxi in	txi		360		30.24	(kg/s) 0.08400	4.1010	13.988	36.012
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

F100 **Fokker 100**

Category includes:	Fokker 100			
Engine category:	turbofan			
Standard engine types:	TAY MK650			
Engine of category:	engine mix			
European traffic:	1.94%	(share in European air traffic movements 1995)		
Max. cruising speed:	456	mph	745	km/h
Av. cruising speed:	453	mph	737	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	24,375	24,541	kg	
Max. take off:	43,090	45,810	kg	
Cruise altitude	short	long	range (defaults if no data available)	
	350	350	FL(=100ft)	

Equations for usage coefficients:

Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	Index	Coefficient	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO_X	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		105.60	(kg/s) 0.22000	2.5000	3.400	24.100
OS 3 take off	tff		45		68.40	(kg/s) 1.52000	21.0960	0.804	0.702
OS 4 climb	cl	b0		-1.633E+01	-6.910E+01		2.087E+01	a0 2.878E-01	a0 8.025E-01
		b1		7.764E-03	6.095E-02		-7.410E-04	a1 9.245E+00	a1 -1.845E+00
		b2		-3.788E-07	-1.659E-06		2.831E-08		
		b3		1.368E-11	4.428E-11		-4.730E-13		
OS 5 cruise	cr	b0				(kg/km) 9.941E-01	2.185E+01	0.300	0.800
		b1				(kg/km) 2.017E-02	-7.405E-02		
		b2				(kg/km) -4.521E-	7.457E-05		
OS 6 descent	dsc	b0		5.712E-01	3.160E-00		4.184E+00	c0 -2.241E+00	c0 -1.784E+01
		b1		5.662E-03	3.907E-03		-4.990E-04	c1 5.513E-01	c1 4.102E+00
		b2		-8.942E-08	-7.655E-08		2.908E-08		
		b3		2.113E-12	4.247E-12		-5.175E-13		
OS 7 landing	ld		15		22.80	(kg/s) 1.52000	21.0960	0.789	0.702
OS 8 taxi in	txi		360		79.20	(kg/s) 0.22000	2.5000	3.396	24.104
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

HS 125 **Hawker Siddeley HS 125**

Category includes: Hawker Siddeley HS 125
Engine category: turbojet, turbofan
Standard engine types: Rolls Royce Viper 522, Viper 601, PW 305
Engine of category: engine mix
European traffic: 0.50% (share in European air traffic movements 1995)

Max. cruising speed:	427	mph	810	km/h	
Av. cruising speed:	409	mph	767	km/h (used here)	
Weights	from	to	(depending on exact type)		
Operational empty:	5,557		kg		
Max. take off:	10,569	11,340	kg		
Cruise altitude	short	long	range (defaults if no data available)		
			FL(=100ft)		

Equations for usage coefficients:
Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	Index	Coefficient	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO_X	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		23.04	(kg/s) 0.04800	2.8210	20.052	58.594
OS 3 take off	tff		45		18.45	(kg/s) 0.41000	15.2300	0.108	1.409
OS 4 climb	cl	b0		-8.122E+00	-1.046E+01		1.552E+01	a0 1.282E-01	a0 2.043E+00
		b1		4.349E-03	1.112E-02		-4.560E-04	a1 -2.582E-01	a1 -1.205E+01
		b2		-9.892E-08	-1.500E-07		1.658E-08		
		b3		5.997E-12	3.748E-12		-2.739E-13		
OS 5 cruise	cr	b0				(kg/km) 1.077E+00	1.697E+01	0.128	2.030
		b1				(kg/km) -6.201E-	-5.741E-02		
		b2				(kg/km) -4.022E-	5.768E-05		
OS 6 descent	dsc	b0		3.023E+00	1.172E+00		3.872E+00	c0 -2.114E+01	c0 -5.805E+01
		b1		4.905E-03	6.790E-04		-4.030E-04	c1 3.992E+00	c1 1.131E+01
		b2		-2.029E-08	-1.210E-08		2.358E-08		
		b3		1.025E-12	9.491E-13		-4.158E-13		
OS 7 landing	ld		15		6.15	(kg/s) 0.41000	15.2850	0.163	1.463
OS 8 taxi in	txi		360		17.28	(kg/s) 0.04800	2.8360	20.023	58.623
OS 9 ground	go								
							EI-CO_2	3150 g/kg	
							EI-SO_2	1.00 g/kg	
							EI-H_2O	1240 g/kg	

L1101	**Lockheed L1101**

Category includes: Lockheed L 1101 TriStar
Engine category: turbofan
Standard engine types: RB211-524B, -22B
Engine of category: engine mix
European traffic: 0.62% (share in European air traffic movements 1995)

Max. cruising speed:	526	mph	973	km/h
Av. cruising speed:	483	mph	894	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	109,045	112,670	kg	
Max. take off:	195,045	231,330	kg	
Cruise altitude	short	long	range (defaults if no data available)	
			FL(=100ft)	

Equations for usage coefficients:
Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	Index	Coefficient	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO_X	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		359.28	(kg/s) 0.74850	3.1150	57.980	87.681
OS 3 take off	tff		45		286.81	(kg/s) 6.37356	40.6610	0.439	2.155
OS 4 climb	cl	b0		-2.648E+01	-3.752E+02		4.152E+01	a0 3.940E-01	a0 3.510E+00
		b1		1.147E-02	2.532E-01		-1.977E-03	a1 8.594E-01	a1 -2.548E+01
		b2		-6.575E-07	-8.775E-06		8.411E-08		
		b3		2.104E-11	2.279E-10		-1.356E-12		
OS 5 cruise	cr	b0				(kg/km) 8.986E+00	3.747E+01	0.395	3.480
		b1				(kg/km) 2.703E-02	-1.247E-01		
		b2				(kg/km) -6.845E-	1.230E-04		
OS 6 descent	dsc	b0		2.320E+00	1.720E+01		7.667E+00	c0 -5.252E+01	c0 -7.385E+01
		b1		4.761E-03	1.099E-02		-9.520E-04	c1 1.072E+01	c1 1.566E+01
		b2		-1.550E-09	-2.266E-07		5.430E-08		
		b3		6.819E-13	1.398E-11		-9.760E-13		
OS 7 landing	ld		15		95.40	(kg/s) 6.36000	40.6590	0.439	2.155
OS 8 taxi in	txi		360		269.46	(kg/s) 0.74850	3.1140	57.979	87.679
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

MD 11 **McDonnel Douglas MD 11**

Category includes:	McDonnel Douglas MD 11				
Engine category:	turbofan				
Standard engine types:	PW 4460				
Engine of category:	engine mix				
European traffic:	0.59%	(share in European air traffic movements 1995)			
Max. cruising speed:	510	mph	945	km/h	
Av. cruising speed:	473	mph	876	km/h (used here)	
Weights	from	to	(depending on exact type)		
Operational empty:	129,590	131,035	kg		
Max. take off:	155,620	286,250	kg		
Cruise altitude	short	long	range (defaults if no data available)		
			FL(=100ft)		

Equations for usage coefficients:

Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	Index	Coefficient	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO_X	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		250.56	(kg/s) 0.52200	3.5160	18.119	44.121
OS 3 take off	tff		45		300.37	(kg/s) 6.67489	32.4200	0.236	0.536
OS 4 climb	cl	b0		-1.748E+01	-2.854E+02		3.434E+01	a0 2.554E-01	a0 5.841E-01
		b1		8.295E-03	2.376E-01		-1.189E-03	a1 -3.343E-01	a1 -9.046E-01
		b2		-3.551E-07	-4.722E-06		4.558E-08		
		b3		1.375E-11	1.256E-10		-7.282E-13		
OS 5 cruise	cr	b0				(kg/km) 1.228E+01	3.515E+01	0.255	0.583
		b1				(kg/km) 2.170E-02	-1.173E-01		
		b2				(kg/km) -8.363E-	1.160E-04		
OS 6 descent	dsc	b0		1.780E+00	1.738E+01		7.856E+00	c0 -2.065E+01	c0 -5.045E+01
		b1		5.390E-03	7.575E-03		-8.650E-04	c1 3.723E+00	c1 9.081E+00
		b2		-2.685E-08	-1.409E-07		4.717E-08		
		b3		1.139E-12	1.008E-11		-8.233E-13		
OS 7 landing	ld		15		100.12	(kg/s) 6.67467	32.4210	0.240	0.539
OS 8 taxi in	txi		360		187.92	(kg/s) 0.52200	3.5170	18.119	44.120
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

MD 80	**McDonnel Douglas MD 80**

Category includes:	McDonnel Douglas MD 80			
Engine category:	turbofan			
Standard engine types:	P&W JT8D			
Engine of category:	engine mix			
European traffic:	7.99%	(share in European air traffic movements 1995)		
Max. cruising speed:	500	mph	925	km/h
Av. cruising speed:	440	mph	814	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	35,239	35,369	kg	
Max. take off:	63,503	67,810	kg	
Cruise altitude	short	long	range (defaults if no data available)	
	330	350	FL(=100ft)	

Equations for usage coefficients:

Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	Index	Coefficient	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO_X	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		124.80	(kg/s) 0.26000	3.5020	4.030	14.103
OS 3 take off	tff		45		107.19	(kg/s) 2.38200	22.8010	0.355	0.725
OS 4 climb	cl	b0		-1.354E+01	-8.164E+01		2.323E+01	a0 5.030E-01	a0 1.407E+00
		b1		6.593E-03	7.819E-02		-7.700E-04	a1 -2.849E+00	a1 -7.039E-
		b2		-2.603E-07	-1.408E-06		2.957E-08		
		b3		1.073E-11	3.504E-11		-4.852E-13		
OS 5 cruise	cr	b0				(kg/km) 2.415E+00	2.449E+01	0.500	1.400
		b1				(kg/km) 2.182E-02	-8.224E-02		
		b2				(kg/km) -5.628E-	8.177E-05		
OS 6 descent	dsc	b0		1.407E+00	4.822E+00		5.251E+00	c0 -2.997E+00	c0 -1.159E+01
		b1		5.223E-03	3.647E-03		-5.730E-04	c1 6.836E-01	c1 2.500E+00
		b2		-4.620E-08	-7.566E-08		3.320E-08		
		b3		1.425E-12	5.321E-12		-5.842E-13		
OS 7 landing	ld		15		35.73	(kg/s) 2.38200	22.8100	0.364	1.036
OS 8 taxi in	txi		360		93.60	(kg/s) 0.26000	3.5040	4.028	14.103
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

MD 82 **McDonnel Douglas MD 82**

Category includes:	McDonnel Douglas MD 82				
Engine category:	turbofan				
Standard engine types:	P&W JT8D				
Engine of category:	engine mix				
European traffic:	7.99%	(share in European air traffic movements 1995)			
Max. cruising speed:	500	mph	925	km/h	
Av. cruising speed:	440	mph	814	km/h (used here)	
Weights	from	to	(depending on exact type)		
Operational empty:	35,239	35,369	kg		
Max. take off:	63,503	67,810	kg		
Cruise altitude	short	long	range (defaults if no data available)		
	330	350	FL(=100ft)		

Equations for usage coefficients:

Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	Index	Coefficient	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO_X	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		128.64	(kg/s) 0.26800	3.5990	3.483	12.632
OS 3 take off	tff		45		121.86	(kg/s) 2.70800	26.9980	0.271	0.730
OS 4 climb	cl	b0		-2.501E+02	-1.039E+03		2.846E+01	a0 4.236E-01	a0 1.211E+00
		b1		9.166E-02	4.338E-01		-1.359E-03	a1 -3.048E+00	a1 -9.559E-
		b2		-7.105E-06	-2.948E-05		6.496E-08		
		b3		1.638E-10	6.707E-10		-1.208E-12		
OS 5 cruise	cr	b0				(kg/km) 6.800E+00	3.054E+01	0.421	1.199
		b1				(kg/km) 1.967E-02	-1.194E-01		
		b2				(kg/km) 3.333E-05	1.470E-04		
OS 6 descent	dsc	b0		3.584E-01	6.653E-01		4.349E+00	c0 -1.107E+00	c0 -4.902E+00
		b1		5.157E-03	3.420E-03		-5.030E-04	c1 4.527E-01	c1 1.729E+00
		b2		-3.663E-08	-6.697E-08		2.964E-08		
		b3		1.078E-12	4.646E-12		-5.041E-13		
OS 7 landing	ld		15		40.62	(kg/s) 2.70800	27.0060	0.271	0.739
OS 8 taxi in	txi		360		96.48	(kg/s) 0.26800	3.5970	3.483	12.635
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

SAAB 340 **SAAB 340**

Category includes:	Saab 340			
Engine category:	turboprop			
Standard engine types:	GE CT17-5A2, CT7-9B			
Engine of category:	engine mix			
European traffic:	2.10%	(share in European air traffic movements 1995)		
Max. cruising speed:	282	mph	523	km/h
Av. cruising speed:	260	mph	484	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	7,810	8,140	kg	
Max. take off:	12,370	13,155	kg	
Cruise altitude	short	long	range (defaults if no data available)	
		240	FL(=100ft)	

Equations for usage coefficients:

Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	Index	Coefficient	Duration of OS (s)	Distance of OS (km)	Fuel consumption total (kg)	Fuel consumption specific	Specific emission parameters (g/kg) EI-NO$_X$	EI-HC	EI-CO
			DUR	D	FC	SFC	SE_{NOx}	SE_{HC}	SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		33.30	(kg/s) 0.06938	4.1070	13.988	36.012
OS 3 take off	tff		45		13.23	(kg/s) 0.29400	9.5990	0.000	1.209
OS 4 climb	cl	b0		-1.109E+01	-1.284E+01		9.563E+00	a0 2.140E-02	a0 1.406E+00
		b1		6.915E-03	1.424E-02		-2.760E-04	a1 -3.660E-01	a1 -3.964E+00
		b2		-4.964E-07	-5.320E-07		7.956E-09		
		b3		2.238E-11	2.223E-11		-1.717E-13		
OS 5 cruise	cr	b0				(kg/km)		0.029	1.433
		b1				(kg/km)			
		b2				(kg/km)			
OS 6 descent	dsc	b0		2.796E-01	-1.281E-01		2.561E+00	c0 1.601E+01	c0 3.607E+01
		b1		4.187E-03	1.203E-04		-2.730E-04	c1 -2.133E-01	c1 -8.446E-03
		b2		-5.334E-08	-5.143E-09		3.070E-08		
		b3		1.811E-12	2.001E-12		-8.740E-13		
OS 7 landing	ld		15		70.44	(kg/s) 0.29400	9.5240	0.000	1.134
OS 8 taxi in	txi		360		194.11	(kg/s) 0.07000	4.0870	14.0080	35.992
OS 9 ground	go								
							EI-CO_2	3150 g/kg	
							EI-SO_2	1.00 g/kg	
							EI-H_2O	1240 g/kg	

TU 134 **Tupolev 134**

Category includes:	Tupolev 134			
Engine category:	turbofan			
Standard engine types:	Soloviev D-30			
Engine of category:	engine mix			
European traffic:	0.94%	(share in European air traffic movements 1995)		
Max. cruising speed:	485	mph	1010	km/h
Av. cruising speed:	405	mph	1001	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	27,500	29,050	kg	
Max. take off:	44,500	47,000	kg	
Cruise altitude	short	long	range (defaults if no data available)	
			FL(=100ft)	

Equations for usage coefficients:

Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	Index	Coefficient	Duration of OS (s) DUR	Distance of OS (km) D	Fuel consumption total (kg) FC	Fuel consumption specific SFC	Specific emission parameters (g/kg) EI-NO$_X$ SE$_{NOx}$	EI-HC SE$_{HC}$	EI-CO SE$_{CO}$
OS 1 engine start	es								
OS 2 taxi out	txo		480		141.79	(kg/s) 0.29540	2.9970	11.002	35.602
OS 3 take off	tff		45		106.02	(kg/s) 2.35600	19.1000	0.255	0.698
OS 4 climb	cl	b0		-1.543E+01	-1.013E+02		1.955E+01	a0 2.500E-01	a0 1.007E+00
		b1		7.162E-03	8.103E-02		-7.940E-04	a1 -2.300E-03	a1 -5.839E+00
		b2		-2.860E-07	-2.103E-06		3.349E-08		
		b3		1.168E-11	5.629E-11		-5.604E-13		
OS 5 cruise	cr	b0				(kg/km) 4.384E+00	1.940E+01	0.250	1.000
		b1				(kg/km) 7.031E-03	-6.536E-02		
		b2				(kg/km) -2.192E-	6.524E-05		
OS 6 descent	dsc	b0		1.591E+00	6.489E+00		4.006E+00	c0 -9.394E+00	c0 -2.978E+01
		b1		5.134E-03	4.908E-03		-4.260E-04	c1 1.978E+00	c1 6.342E+00
		b2		-3.703E-08	-1.094E-07		2.527E-08		
		b3		1.287E-12	5.862E-12		-4.489E-13		
OS 7 landing	ld		15		35.34	(kg/s) 2.35600	19.1000	0.255	0.707
OS 8 taxi in	txi		360		106.34	(kg/s) 0.29539	3.0000	11.002	35.603
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

TU 154 **Tupolev 154**

Category includes: Tupolev 154
Engine category: turbofan
Standard engine types: KKBM NK-8
Engine of category: engine mix
European traffic: 0.94% (share in European air traffic movements 1995)

Max. cruising speed:	527	mph	975	km/h
Av. cruising speed:	486	mph	900	km/h (used here)
Weights	from	to	(depending on exact type)	
Operational empty:	43,500	55,300	kg	
Max. take off:	90,000	100,000	kg	
Cruise altitude	short	long	range (defaults if no data available)	
			FL(=100ft)	

Equations for usage coefficients:

Variable x = CRALT

$Y = b_0 + b_1x + b_2x^2 + b_3x^3$

$Y = a_0 + a_1/x$

$Y = c_0 + c_1\ln(x)$

Operation state (OS)	Index	Coefficient	Duration of OS (s) DUR	Distance of OS (km) D	Fuel consumption total (kg) FC	Fuel consumption specific SFC	Specific emission parameters (g/kg) EI-NO_X SE_{NOx}	EI-HC SE_{HC}	EI-CO SE_{CO}
OS 1 engine start	es								
OS 2 taxi out	txo		480		226.94	(kg/s) 0.47279	2.4980	112.003	98.004
OS 3 take off	tff		45		215.06	(kg/s) 4.77911	12.0990	3.999	1.502
OS 4 climb	cl	b0		-8.571E+00	-1.305E+02		1.237E+01	a0 1.965E+00	a0 2.823E+00
		b1		4.574E-03	1.440E-01		-4.370E-04	a1 3.875E+01	a1 -2.518E+01
		b2		-6.646E-08	-1.725E-06		1.747E-08		
		b3		5.774E-12	3.643E-11		-2.831E-13		
OS 5 cruise	cr	b0				(kg/km) 4.684E+00	1.289E+01	2.000	2.800
		b1				(kg/km) 3.950E-02	-4.370E-02		
		b2				(kg/km) -1.020E-	4.403E-05		
OS 6 descent	dsc	b0		1.591E+00	9.524E+00		2.799E+00	c0 -1.113E+02	c0 -9.533E+01
		b1		5.134E-03	6.675E-03		-2.690E-04	c1 2.171E+01	c1 1.880E+01
		b2		-3.703E-08	-1.321E-07		1.623E-08		
		b3		1.287E-12	9.792E-12		-2.840E-13		
OS 7 landing	ld		15		71.69	(kg/s) 4.77933	12.0940	4.003	1.506
OS 8 taxi in	txi		360		170.21	(kg/s) 0.47281	2.5030	111.997	97.997
OS 9 ground	go								

EI-CO_2	3150 g/kg
EI-SO_2	1.00 g/kg
EI-H_2O	1240 g/kg

Part E. FUEL AND ENERGY PRODUCTION

Contributors to this section

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E1. INTRODUCTION

This part presents an analysis of the air pollutant emissions from the production of a range of fuels for use in the transportation sector [E1]. The fuels considered are gasoline, diesel, liquefied petroleum gas (LPG), kerosene, heavy fuel oil (HFO), compressed natural gas (CNG), electricity and rapeseed methyl ester (RME). In combination with the other parts of this report the information presented here will enable the calculation of life-cycle emissions for the majority of transport applications. Emissions have been quantified in terms of mass of pollutant per GJ of useful energy output in order to facilitate comparison between the fuels.

Comparison of the various fuels suggests that natural gas production gives the lowest emissions per unit of useful energy output, due to the low processing requirement. The liquid crude oil based fuels all have similar production emissions, with small variations due to the amount of processing required at the refinery, and due to the different specific energy contents of the various grades of fuel. The emissions from RME production are higher than for the crude oil based fuels because of the significant agricultural input as well as the processing of the rapeseed oil into RME. The highest emissions are associated with electricity production from non-renewable energy sources. However, in this case it should be remembered that, unlike for all the other fuels, there are zero emissions at the point of use.

E2. CRUDE OIL BASED FUELS

The crude oil based fuels, namely gasoline, diesel, LPG, kerosene and heavy fuel oil are considered together due to their similar production routes. The production route for these fuels consists of extraction, transportation of the crude oil, refining and distribution of the refined fuel. Additionally for LPG there is a parallel route as some low molecular weight compounds do not require further processing and can be transported directly to the distribution terminal. The emissions that result at each stage of the production process have been considered separately, before summation to give a final value for each fuel. Refinery emissions are based on the process energy used for each of the individual streams within the refinery. A linear optimisation refinery model has been used to model the three most common types of refinery in Europe, with calculations being based on the characteristics of the oil refineries that are situated in each country.

The overall results are shown in Tables E1 to E5. Each table relates to one of the crude oil based fuels, and shows the emission factors for each country.

The results show that the emissions associated with the high value products such as gasoline tend to be greater than from low value products such as HFO. This is related to the greater profits associated with high value products, which result in it being financially worthwhile to introduce extra processing stages to increase the yield. Small variations were observed between the results for different countries. The variations relate primarily to the types of refinery that are used in each country, as certain types of refinery are more suited to certain products than others. No account has been taken of trading of refined products between countries, as this would necessitate a level of demand modelling that would be beyond the scope of this project.

Table E1. Total fuel production emissions for gasoline, by country

Country	CO_2 kg/GJ	CO g/GJ	NO_X g/GJ	NMVOC g/GJ	SO_2 g/GJ	CH_4 g/GJ	PM g/GJ
Austria	9.4	5.4	45.7	213.0	62.7	17.4	2.7
Belgium	9.2	5.1	42.2	211.5	65.6	17.4	2.4
Denmark	9.0	5.1	43.2	203.5	93.3	17.2	1.8
Finland	9.3	5.6	45.6	208.7	77.7	17.3	2.4
France	9.3	5.1	42.2	212.3	62.7	17.3	2.5
Germany	9.2	5.1	43.2	208.3	78.1	17.3	2.2
Greece	9.5	5.8	49.3	208.9	79.5	17.3	2.4
Ireland	8.9	5.0	42.5	203.5	93.1	17.0	1.8
Italy	9.3	5.4	46.0	208.8	77.9	17.2	2.3
Netherlands	9.2	5.1	42.4	209.8	72.2	17.4	2.3
Portugal	9.3	5.4	45.2	210.2	72.2	17.3	2.4
Spain	9.3	5.4	45.2	210.0	73.3	17.3	2.4
Sweden	9.2	5.5	44.7	208.0	78.4	17.1	2.3
Switzerland	9.0	5.4	45.8	203.5	95.1	16.9	1.9
UK	9.3	5.1	42.4	211.4	66.9	17.4	2.4

Table E2. Total fuel production emissions for diesel, by country

Country	CO_2 kg/GJ	CO g/GJ	NO_X g/GJ	NMVOC g/GJ	SO_2 g/GJ	CH_4 g/GJ	PM g/GJ
Austria	6.8	5.0	39.1	87.9	45.1	15.7	1.1
Belgium	6.8	4.6	36.0	87.6	48.4	15.7	1.0
Denmark	7.2	4.6	38.0	86.1	77.7	15.6	1.4
Finland	7.0	5.1	39.4	87.4	57.5	15.6	1.3
France	6.7	4.6	35.8	87.8	44.9	15.7	1.0
Germany	6.9	4.6	37.1	87.3	57.8	15.7	1.2
Greece	7.2	5.3	43.2	87.2	62.7	15.7	1.4
Ireland	7.2	4.5	37.4	86.2	77.5	15.5	1.4
Italy	7.0	4.9	39.9	87.3	59.0	15.6	1.2
Netherlands	6.8	4.6	36.2	87.6	51.8	15.7	1.1
Portugal	6.9	4.9	39.0	87.4	55.2	15.7	1.2
Spain	6.9	4.9	39.0	87.5	54.5	15.7	1.2
Sweden	7.0	5.0	38.8	87.0	61.8	15.5	1.3
Switzerland	7.2	4.8	40.5	86.1	79.4	15.3	1.4
UK	6.8	4.6	36.1	87.8	47.6	15.8	1.1

Table E3. Total fuel production emissions for LPG, by country

Country	CO_2 kg/GJ	CO g/GJ	NO_X g/GJ	NMVOC g/GJ	SO_2 g/GJ	CH_4 g/GJ	PM g/GJ
Austria	6.0	4.2	33.3	56.8	30.1	15.7	1.6
Belgium	6.0	4.1	32.3	56.3	31.7	16.1	1.5
Denmark	6.2	4.2	33.8	53.8	39.5	18.0	1.2
Finland	6.2	4.7	34.8	55.4	34.5	16.3	1.5
France	5.8	4.1	31.7	56.6	30.1	15.5	1.5
Germany	6.2	4.2	32.6	55.3	36.7	16.8	1.4
Greece	6.6	4.5	35.5	55.6	37.3	17.2	1.5
Ireland	6.0	4.1	33.1	53.8	41.6	16.7	1.2
Italy	6.2	4.3	34.6	55.7	36.9	15.7	1.4
Netherlands	6.2	4.2	32.4	55.8	32.9	16.6	1.4
Portugal	6.2	4.3	34.2	56.0	35.9	16.5	1.6
Spain	6.1	4.2	33.9	55.8	36.4	16.3	1.5
Sweden	5.7	4.6	33.5	55.2	33.4	15.4	1.4
Switzerland	5.4	4.2	32.5	53.7	37.5	15.2	1.0
UK	6.2	4.1	33.5	56.3	35.2	16.8	1.6

Table E4. Total fuel production emissions for kerosene, by country

Country	CO_2 kg/GJ	CO g/GJ	NO_X g/GJ	NMVOC g/GJ	SO_2 g/GJ	CH_4 g/GJ	PM g/GJ
Austria	6.9	4.9	40.8	91.4	63.5	16.1	1.4
Belgium	6.4	4.5	36.3	82.9	53.5	16.0	1.2
Denmark	4.4	4.0	31.4	39.1	14.7	15.7	0.7
Finland	6.4	5.0	38.8	80.8	52.4	16.0	1.3
France	6.7	4.5	37.0	89.5	59.2	16.0	1.2
Germany	6.3	4.5	36.3	80.0	50.9	16.0	1.1
Greece	6.1	5.0	41.4	68.6	45.8	16.0	1.2
Ireland	4.4	3.9	30.7	39.1	14.5	15.6	0.7
Italy	6.2	4.7	38.8	76.8	50.3	15.9	1.2
Netherlands	6.6	4.5	36.6	87.5	57.0	16.1	1.2
Portugal	6.2	4.7	38.2	75.9	49.4	16.0	1.2
Spain	6.4	4.7	38.9	81.9	54.6	16.0	1.2
Sweden	5.6	4.7	36.1	63.6	36.9	15.8	1.1
Switzerland	4.4	4.3	33.9	39.1	16.4	15.5	0.8
UK	6.7	4.5	37.2	90.4	60.2	16.1	1.3

Table E5. Total fuel production emissions for heavy fuel oil, by country

Country	CO_2 kg/GJ	CO g/GJ	NO_X g/GJ	NMVOC g/GJ	SO_2 g/GJ	CH_4 g/GJ	PM g/GJ
Austria	5.7	4.9	40.8	91.3	63.5	16.1	1.4
Belgium	5.5	4.0	31.8	78.8	27.9	14.8	1.2
Denmark	5.1	3.9	31.5	78.2	31.5	14.7	0.9
Finland	5.5	4.4	34.3	77.3	30.3	14.7	1.2
France	5.5	4.0	31.9	78.7	27.5	14.8	1.2
Germany	5.4	4.0	32.1	77.2	29.8	14.8	1.1
Greece	5.6	4.6	37.9	78.6	33.6	14.8	1.3
Ireland	5.1	3.9	30.9	78.2	31.3	14.5	0.9
Italy	5.5	4.3	34.8	77.8	31.4	14.7	1.2
Netherlands	5.4	3.9	31.7	77.4	28.6	14.8	1.1
Portugal	5.5	4.2	34.3	78.7	30.5	14.8	1.2
Spain	5.5	4.2	34.3	78.0	30.6	14.8	1.2
Sweden	5.4	4.3	33.4	78.6	30.0	14.6	1.2
Switzerland	5.1	4.2	33.8	78.2	33.1	14.4	1.0
UK	5.5	4.0	31.9	78.0	28.3	14.9	1.2

E3. NATURAL GAS BASED FUELS

Compressed natural gas is different to the other fuels in that the final product requires much less processing than the other alternatives considered here. The processing is limited to removal of impurities, including water. Transportation is via pipeline which is assumed to be powered by electricity. A much higher proportion of the emissions come from the distribution stage for CNG compared to the other fuels. This is due to its gaseous nature, which gives rise to a greater potential for fugitive hydrocarbon emissions. By combining the energy use and emissions from the extraction, gas separation, processing, transmission and distribution of natural gas, the overall non-vehicle energy use and emissions have been calculated. The results are shown in Table E6. The emissions data supplied for CNG should be considered as generic values for all countries in Europe, as few data are available on the differences between the fuel supply networks in different countries.

Table E6. Emissions for the production and distribution of natural gas

	CO_2 kg/GJ	CO g/GJ	CH_4 g/GJ	NMVOC g/GJ	NO_X g/GJ	SO_2 g/GJ	PM g/GJ
Extraction and processing	1.6	1.0	20.0	11.0	4.1	2.0	0.0
Distribution	0.0	0.0	198.0	16.0	0.0	0.0	0.0
Filling station	2.5	0.4	5.7	0.5	6.5	14.9	0.8
Total	4.1	1.4	223.7	27.5	10.6	16.9	0.8

E4. ELECTRICITY

The emissions from the production of electricity are much greater than for the production of other fuels. However, electric vehicles produce no emissions at the point of use, so the actual environmental impact of electricity production emissions (usually in rural areas) may be substantially lower than the impact of equivalent internal combustion engine emissions in more densely populated areas. The data show wide variations in the emissions per unit of useful energy output between the countries considered. This is because a wide range of energy sources are used for the production of electricity depending on local conditions. Furthermore, even for one fuel type, there are variations in the emissions abatement technologies used in different locations. The variations in emissions from electricity production between the different countries will have significant implications for the environmental benefit that can be ascribed to the use of electric vehicles from country to country. The overall air pollutant emissions factors for electricity production in each country are shown in Table E7.

Table E7. Total electricity production emissions by country

Country	CO_2 kg/GJ	CO g/GJ	NO_X g/GJ	NMVOC g/GJ	SO_2 g/GJ	CH_4 g/GJ	PM g/GJ
Austria	62.9	14.5	92.7	16.0	74.2	80.3	6.9
Belgium	94.3	16.7	289.4	12.2	533.5	240.3	27.2
Denmark	257.3	43.0	811.6	24.7	912.9	902.7	62.7
Finland	155.1	38.6	307.3	15.6	198.0	310.9	23.4
France	17.6	3.2	61.0	3.2	183.9	36.1	7.9
Germany	189.7	27.3	306.3	9.4	931.5	465.1	56.2
Greece	296.4	38.7	393.6	38.9	979.2	604.0	62.4
Ireland	212.9	33.8	672.0	44.6	1639.5	466.7	74.3
Italy	162.5	33.4	551.7	105.3	977.2	111.8	41.1
Luxembourg	101.9	16.2	90.1	16.9	71.1	27.3	3.7
Netherlands	175.7	31.6	281.8	32.0	185.2	392.5	19.0
Norway	1.7	0.6	2.8	0.2	3.7	0.6	0.2
Portugal	170.4	34.0	507.1	53.7	1260.7	359.0	59.4
Spain	126.8	19.4	414.2	16.0	1235.8	306.8	57.8
Sweden	20.6	6.0	42.2	6.6	34.7	22.2	3.1
Switzerland	6.6	2.5	12.9	1.4	21.5	0.7	1.1
UK	167.8	27.4	631.8	20.2	1445.8	458.9	69.9
European Average	127.4	21.3	325.9	22.6	744.9	282.6	39.1

E5. BIOFUELS

Several studies on the production of the biofuel rapeseed methyl ester have been reviewed. Wide variations were found between the results in the individual reports, especially in terms of the energy input to fuel production.

Table E8 summarises the energy use and emissions associated with agriculture, transport, processing and distribution of RME using natural gas as the fuel for the esterification process. It shows that the energy input per GJ of RME produced is 870 MJ for winter rape, allowing an energy credit for the by-product cattle cake. The energy input is reduced to 664 MJ/GJ_{RME} if straw is used as the process fuel (Table E9). If natural gas is used as the process fuel, and replacement energy credits are given for cattle cake and all the straw produced as a by-product from winter rape, the energy balance could be reduced to around 15 MJ/GJ_{RME}, assuming that technology for biomass combustion is developed such that there is a power generation market for the straw. However, it is not realistic at present to assume such a market.

Table E8. Energy use and emissions from the production, transport and distribution of biodiesel from oilseed rape (natural gas used for process energy)

	Energy	**Emissions (g/GJ_{RME})**					
	MJ/GJ_{RME}	**CO_2**	**CO**	**VOC**	**NO_X**	**SO_2**	**PM**
Agriculture							
Winter rape	413	10430	44.6	20.4	110.8	2.3	16.7
Oil extraction	230	29278	4.9	70.1	74.9	171.2	9.0
By-product cattle cake	[85]	[10826]					
Processing							
Natural gas	297	11954	1.1	98.9	12.7	0.5	-
Transport							
Seed & oil	10	703	3.2	0.4	10.8	0.2	0.9
Distribution of RME	5	357	1.6	0.2	5.5	0.1	0.4
Totals: winter rape							
Natural gas (cattle cake MJ & CO_2 credits)	870	41896	55.5	190.0	214.6	174.3	27.0

Figures in square brackets are credits.

Table E9. Energy use and emissions from the production, transport and distribution of biodiesel from oilseed rape (rape straw used for process energy)

	Energy	**Emissions (g/GJ_{RME})**					
	MJ/GJ_{RME}	**CO_2**	**CO**	**VOC**	**NO_X**	**SO_2**	**PM**
Agriculture							
Winter rape	413	10430	44.6	20.4	110.8	2.3	16.7
Oil extraction:	230	29278	4.9	70.1	74.9	171.2	9.0
By-product cattle cake	[85]	[10826]					
Processing							
Straw	89	(21348)	35.6	16.6	19.0	5.9	6.4
Transport							
Straw	2	123	0.56	0.1	1.9	0.0	0.2
Seed & oil	10	703	3.2	0.4	10.8	0.2	0.9
Distribution of RME	5	357	1.6	0.2	5.5	0.1	0.4
Totals: winter rape							
Straw (cattle cake MJ & CO_2 credits)	664	30070	90.6	107.8	222.8	179.8	33.6

Figures in square brackets are credits, round brackets indicate CO_2 from biomass.

The data in Tables E8 and E9 reflect the position in the UK. However, several other studies have been carried out into the production of rapeseed methyl ester for use as a transport fuel. These studies have produced results that imply a lower energy input per useful output of biodiesel.

E6. REFERENCE

E1. **Lewis C A (1997)** Fuel and energy production emission factors. Deliverable 20 of the MEET project. AEA Technology, Harwell, UK.

Part F. APPLICATIONS OF THE MEET METHODOLOGY

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F1. INTRODUCTION

In parts A to E of this report, methodologies are given for the estimation of the pollutant emissions and energy consumption of transport in the EU. Taken overall, the procedures that have been developed are complex and detailed. Default data are given for each of the many variables involved in the calculations, their precision and completeness depending on the amount of information available. This part includes examples of applications of the methodology. It is provided for two main reasons:

- To show potential users how the methods should be used in a number of concrete examples, rather than in the generalised way discussed elsewhere in the report.

- To illustrate some of the applications for which the methodology is appropriate.

Although every effort has been made to ensure that the MEET methodology is as up-to-date and comprehensive as possible, it is inevitable that it will not provide all of the information needed for all possible applications. A further purpose of this part of the report is, by working through realistic types of calculation, to show where the procedures must be supplemented - either by the provision of additional data or by assumptions about aspects of a problem that are not explicitly answered in the MEET methodology. In this context, some estimates of the uncertainties inherent in the results produced by the MEET method are also made and discussed.

Three basic types of application are considered. The first is a demonstration of how some of the disaggregated data on transport activity and emissions may be combined. In many cases, users may not wish to perform the extensive calculations needed when starting from the basic principles and data sets. They may not need detailed results or they may not have access to data sources offering any improvement over the basic MEET default values. In those circumstances, it is possible to use pre-calculated emission factors aggregated, for example by country, by transport mode and so on. Here, examples of aggregation are shown for hot and evaporative emissions from road transport.

The second type of example includes calculations of emissions from specific transport operations. Emissions from rail transport are calculated for four different routes chosen to cover a variety of types of railway operation.

The third set of examples again considers specific journeys, and in this case compares the emissions and energy consumption associated with different modes of travel.

The data used in these examples were taken mainly from MEET Deliverable 21 [F1]. It should be noted that some of these data differ from those in this report and in the final versions of the detailed MEET Deliverables because they have been supplemented or improved. The final versions were not available at the time these calculations were made. While this means that there may be numerical differences between the results given here and those that would be obtained using the final data sets, the principles would be unaffected. More detailed discussion of these examples is contained in MEET Deliverables 23 [F2] and 24 [F3].

F2. AGGREGATED ROAD TRANSPORT EMISSION FACTORS

F2.1 Hot emissions

In Part A, it was shown that the emissions from road vehicles depend on many parameters, and the calculation procedure that is given enables emissions estimates to be made for many vehicle categories and operating conditions. The estimates may be combined in various ways: to give, for example, emissions from all vehicles of a certain type, all traffic in a defined area or all traffic on a particular type of road. The numbers and types of possible permutation depend on the variables by which the emission factors and functions are classified. In the examples given here, only emissions from vehicles with hot engines are considered (evaporative and start emissions are included in deliverable 23 [F2]), and the parameters involved are given in Tables F1 to F5. As well as those in the tables, another variable is the year for which the estimates are made. This has a strong influence on the numbers and types of vehicles in the fleet and, hence, on their emissions. In these examples, the fleet composition is for the 1995, and annual mileages are based on 1990 (1995 data were not available when the example was calculated).

Table F1. Countries included in the calculations[46]

Country					
Belgium	France	Greece	Italy	Netherlands	Spain
Denmark	Germany	Ireland	Luxembourg	Portugal	UK

Table F2. Road types included in the calculations

Road type		
Urban	Rural	Highway

Table F3. Fuel types included in the calculation

Fuel type		
Gasoline	Diesel	LPG

Table F4. Pollutants included in the calculations[47]

Pollutant	Vehicle type
Carbon monoxide	All vehicles
Nitrogen oxides	All vehicles
Volatile organic compounds	All vehicles
Particulates	All diesel vehicles
Carbon dioxide	All vehicles except gasoline HGVs and motorcycles
Fuel consumption	Gasoline HGVs and motorcycles

[46] Data for Austria, Finland and Sweden were not available at the time of the calculations.

[47] When the calculations were carried out, emission functions for CO_2 and fuel consumption were not yet available for all types of vehicle. The combinations considered are noted in the table.

Table F5. Categories of vehicles included in the calculations[48]

<table>
<tr><th colspan="5">Passenger cars</th></tr>
<tr><th>Fuel</th><th>Emission standard</th><th>< 1.4 l</th><th>1.4 - 2.0 l</th><th>> 2.0 l</th></tr>
<tr><td>Gasoline</td><td>pre ECE</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td></td><td>ECE 15-00/01</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td></td><td>ECE 15-02</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td></td><td>ECE 15-03</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td></td><td>ECE 15-04</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td></td><td>Improved conventional</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td></td><td>Open loop catalyst</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td></td><td>Early closed loop catalyst</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td></td><td>EURO I</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Diesel</td><td>Uncontrolled</td><td colspan="2">✓</td><td>✓</td></tr>
<tr><td></td><td>EURO I</td><td colspan="2">✓</td><td>✓</td></tr>
<tr><td>LPG</td><td>Uncontrolled</td><td colspan="3">✓</td></tr>
<tr><td></td><td>EURO I</td><td colspan="3">✓</td></tr>
</table>

<table>
<tr><th colspan="3">Light duty vehicles</th></tr>
<tr><th>Fuel</th><th>Emission standard</th><th></th></tr>
<tr><td>Gasoline</td><td>Conventional</td><td>✓</td></tr>
<tr><td></td><td>93/59 EEC</td><td>✓</td></tr>
<tr><td>Diesel</td><td>Conventional</td><td>✓</td></tr>
<tr><td></td><td>93/59 EEC</td><td>✓</td></tr>
</table>

<table>
<tr><th colspan="6">Heavy duty vehicles</th></tr>
<tr><th>Fuel</th><th>Emission standard</th><th>HGV <16 t</th><th>HGV > 16 t</th><th>Urban bus</th><th>Coach</th></tr>
<tr><td>Gasoline</td><td>Conventional</td><td colspan="2">✓</td><td></td><td></td></tr>
<tr><td>Diesel</td><td>Conventional</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td></td><td>EEC Stage I</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
</table>

<table>
<tr><th colspan="5">Motorcycles</th></tr>
<tr><th>Fuel</th><th>Emission standard</th><th>< 50 cc</th><th>> 50 cc 2-stroke</th><th>> 50 cc 4-stroke</th></tr>
<tr><td>Gasoline</td><td>Uncontrolled</td><td>✓</td><td>✓</td><td>✓</td></tr>
</table>

[48] The calculation is for 1995, therefore some of the vehicle categories in the full MEET classification are not included because they were not manufactured until later. There are also some differences between this classification and that finally adopted (see Table A5), such as the inclusion of 'early catalyst cars'. This is because the calculations were done before the availability of the definitive data structure.

F2.2 Aggregation procedure

Aggregated emission factors were calculated in several stages, as outlined below:

Stage 1 - aggregation according to the vehicle sub-category (see Table F6), for each country and road type; using equation F1

$$e_{av_c,j,k,s} = \frac{\sum_{i=1}^{i=categories} n_i \times l_i \times p_{i,j} \times e_{i,j,k}}{n_i \times l_i \times p_{i,j}} \qquad \text{(F1)}$$

where:

$e_{av_c,j,k,s}$ is the average hot emission factor (g/km) for country *c*, road type *j*, pollutant *k* and vehicle sub-category *s*
$e_{i,j,k}$ is the emission factor (g/km) for pollutant *k*, for a vehicle of type *i* corresponding to the average speed on road type *j*
n_i is the number of vehicles of type *i*
l_i is the annual mileage (km/year) of vehicles of type *i*
$p_{i,j}$ is the fraction of the annual mileage of vehicle type *i* on road type *j*

Stage 2 - aggregation according to the vehicle sub-category for each country, independent of road type; using equation F2

$$e_{av_c,k,s} = \frac{\sum_{j=1}^{j=3} e_{av_c,j,k,s} \times l_{c,j,s}}{l_{c,s}} \qquad \text{(F2)}$$

where:

$e_{av_c,k,s}$ is the average hot emission factor (g/km) for country *c*, pollutant *k* and vehicle sub-category *s*
$l_{c,j,s}$ is the annual distance travelled (km) by vehicle sub-category *s* on road type *j* in country *c*
$l_{c,s}$ is the total annual distance travelled (km) by vehicle sub-category *s* in country *c*

Stage 3 - aggregation according to the vehicle sub-category for each road type for Europe; using equation F3

$$e_{av_{eu},j,k,s} = \frac{\sum_{c=1}^{c=all} e_{av_c,j,k,s} \times l_{c,j,s}}{l_{eu,j,s}} \qquad \text{(F3)}$$

where:

$e_{av_{eu},j,k,s}$ is the average hot emission factor (g/km) for Europe, pollutant *k*, vehicle sub-category *s* and road type *j*

$l_{eu,\,j,\,s}$ is the total annual distance travelled (km) by vehicle sub-category *s* on road type *j* in Europe

Stage 4 - aggregation according to the vehicle sub-category for Europe, independent of road type; using equation F4

$$e_{av_{eu},k,s} = \frac{\sum_{j=1}^{j=3} e_{av_{eu},j,k,s} \times l_{eu,j,s}}{l_{eu,s}} \qquad \text{(F4)}$$

where:

$e_{av_{eu},k,s}$ is the average hot emission factor (g/km) for Europe, pollutant *k* and vehicle sub-category *s*

$l_{eu,\,j,\,s}$ is the total annual distance travelled (km) by vehicle sub-category *s* in Europe

Stage 5 - aggregation for Europe according to the vehicle class (Table F6) for each road type; using equation F5

$$e_{av_{eu},v,k,j} = \frac{\sum_{s=1}^{s=sub-categories} e_{av_{eu},j,k,s} \times l_{eu,j,s}}{l_{eu,v}} \qquad \text{(F5)}$$

where:

$e_{av_{eu},v,k,j}$ is the average hot emission factor (g/km) for Europe, pollutant *k*, road type *j* and vehicle class *v*

$l_{eu,\,v}$ is the total annual distance travelled (km) by vehicle class *v* in Europe

Stage 6 - aggregation for Europe according to the vehicle class, independent of road type; using equation F6

$$e_{av_{eu},v,k} = \frac{\sum_{j=1}^{j=3} e_{av_{eu},v,k,j} \times l_{eu,v,j}}{l_{eu,v}} \qquad \text{(F6)}$$

where:

$e_{av_{eu},v,k}$ is the average hot emission factor (g/km) for Europe, pollutant *k* and vehicle class *v*

$l_{eu,\,v,\,j}$ is the total annual distance travelled (km) by vehicle class *v* on road type *j* in Europe

Stage 7 - aggregation for Europe for all vehicles for each road type; using equation F7

$$e_{av_{eu},k,j} = \frac{\sum_{v=1}^{v=classes} e_{av_{eu},v,k,j} \times l_{eu,v,j}}{l_{eu,j}} \qquad \text{(F7)}$$

where:

$e_{av_{eu},k,j}$ is the average hot emission factor (g/km) for Europe, pollutant *k* and road type *j*
$l_{eu,j}$ is the total annual distance travelled (km) on road type *j* in Europe

Stage 8 - aggregation for Europe for all vehicles, independent of road type; using equation F8

$$e_{av_{eu},k} = \frac{\sum_{j=1}^{j=3} e_{av_{eu},k,j} \times l_{eu,j}}{l_{eu}} \qquad \text{(F8)}$$

where:

$e_{av_{eu},k}$ is the average hot emission factor (g/km) for Europe, pollutant *k*
l_{eu} is the total annual distance travelled (km) in Europe

Table F6. Vehicle classes and sub-categories for emission factor aggregation

Vehicle class	Sub-categories	Road type		
		Urban	Rural	Highway
Passenger car	Conventional gasoline	✓	✓	✓
	Catalyst gasoline	✓	✓	✓
	Conventional diesel	✓	✓	✓
	EURO I diesel	✓	✓	✓
	Conventional LPG	✓	✓	✓
	EURO I LPG	✓	✓	✓
Light duty vehicle	Conventional gasoline	✓	✓	✓
	Catalyst gasoline	✓	✓	✓
	Conventional diesel	✓	✓	✓
	EURO I diesel	✓	✓	✓
Heavy duty vehicle	HGV conventional gasoline	✓	✓	✓
	HGV conventional diesel	✓	✓	✓
	Stage I diesel	✓	✓	✓
	Urban bus conventional diesel	✓	✕	✕
	Urban bus Stage I diesel	✓	✕	✕
	Coach conventional diesel	✕	✓	✓
	Coach Stage I diesel	✕	✓	✓
Motorcycle	< 50 cc conventional	✓	✓	✕
	> 50 cc conventional	✓	✓	✓

F2.3 Data sources

With a few exceptions, the data used in the calculations were taken from the MEET deliverables available at the time.

F2.3.1 Traffic statistics

Vehicle fleet composition The numbers of vehicles in each category, for the reference year 1995 were from deliverable 4 [F4].

Annual mileage This was also taken from deliverable 4 [F4], for the reference year 1990, and with the following exception:

- no annual mileage was given for EURO I diesel cars in the UK; the same mileage as the uncontrolled diesel cars was assumed.

Mileage distribution Data from deliverable 21 [F1] were used, with the following exceptions:

- data in deliverable 21 were given separately for West Germany and the former East Germany. For passenger cars, the data from COPERT II [F5], which are for the whole of Germany, were used instead; the data were for gasoline cars only, so the same distribution was assumed for diesels. For heavy duty vehicles, the data for West Germany (from deliverable 21) were assumed to apply to the whole of Germany.

- for Italy, data were missing for EURO I gasoline passenger cars; the distribution was assumed to be equal to that for ECE 15-04 vehicles.

- for all countries, there were no data for EURO I diesel cars; the distribution was assumed to be equal to that of uncontrolled diesel cars.

- no distribution was given for gasoline heavy duty vehicles; it was assumed to be equal to that for 3.5 - 16 tonne diesel HGVs.

Vehicle speeds Speed data were also taken from deliverable 21, with the following exceptions:

- data for Germany were taken from COPERT II.

- for Italy, data were missing for EURO I gasoline passenger cars; the speeds were assumed to be equal to those for ECE 15-04 vehicles.

- for all countries, there were no data for EURO I diesel cars; the speeds were assumed to be equal to those of uncontrolled diesel cars.

- where data for speeds of light duty vehicles were missing, they were assumed to be the same as for passenger cars.

- no data were given for heavy duty vehicles. UK data[49] were used for all countries [F6].
- no data were given for motorcycles. UK data[49] were used for all countries [F7].

F2.3.2 Emission functions

Emission functions from deliverable 21 were used with the following exception and modification:

- no data were given for gasoline heavy duty vehicles. Factors from COPERT II were used.
- traffic statistics were available for diesel heavy goods vehicles in two weight categories while emission functions were provided for four categories. The emission functions were combined to correspond with the traffic data classification.

F2.4 Results

Deliverable 23 [F2] contains a complete set of results from all stages of the aggregation procedure described above. Some examples are presented in Figures F1 - F3.

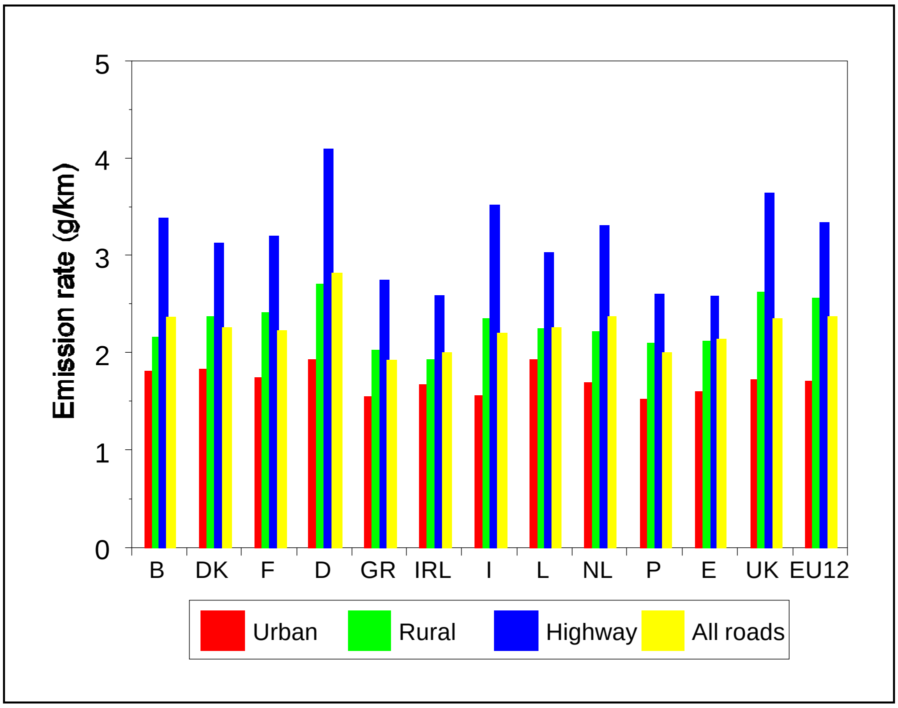

Figure F1. Nitrogen oxides emissions from conventional gasoline cars by road type and country

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[49] For urban, rural and highway roads respectively:

Heavy goods vehicles - 51 km/h, 80 km/h, 90 km/h; Buses and coaches - 48 km/h, 80 km/h, 100 km/h; Motorcycles - 51 km/h, 96 km/h, 101 km/h

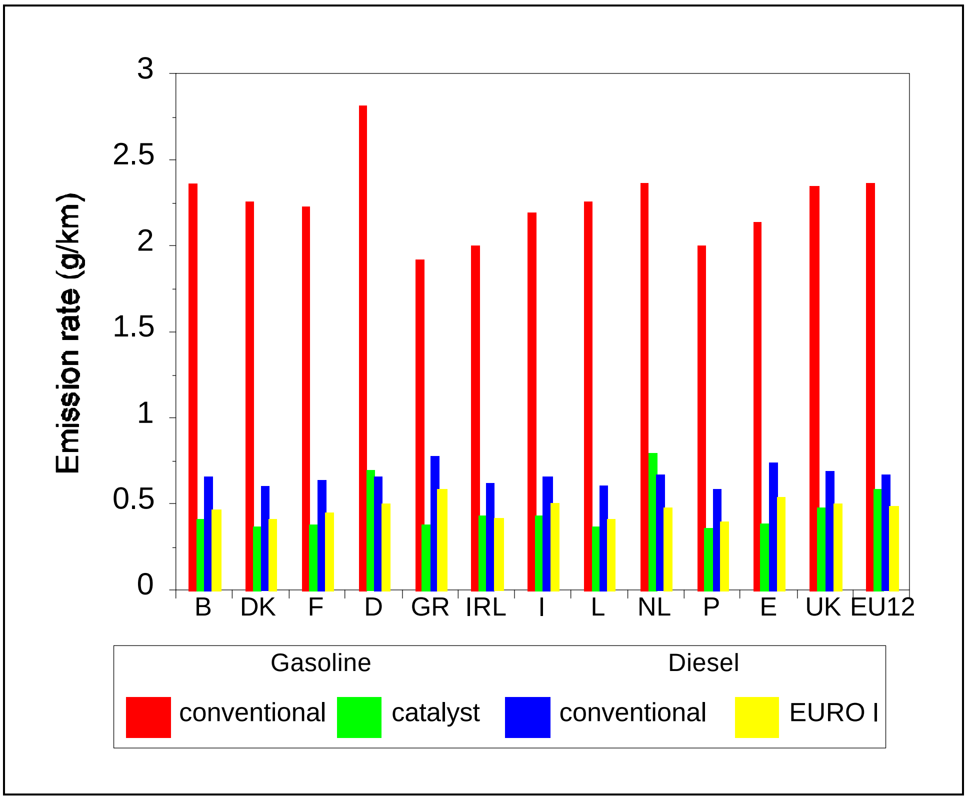

Figure F2. Nitrogen oxides emissions from different types of car for all roads, by country

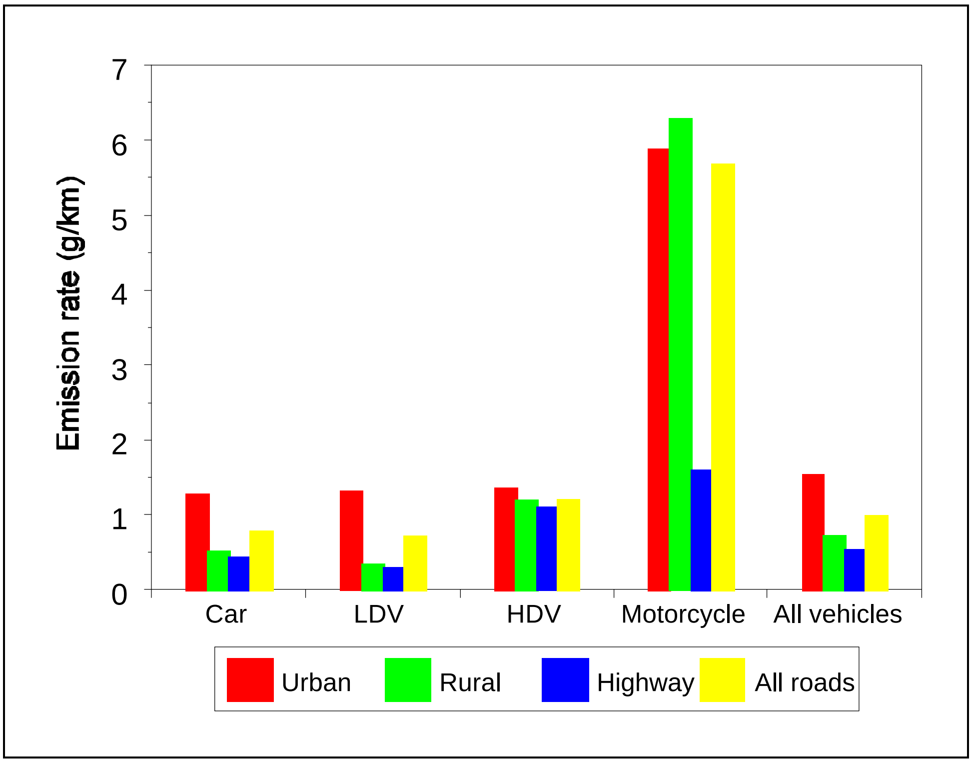

Figure F3. VOC emissions for different vehicle classes by road type, European average

F3. TYPICAL RAIL EMISSION FACTORS

Estimates of the emissions from a few typical rail journeys have been calculated to demonstrate the MEET methodology. The procedure used is that given in Deliverable 17 [F8]. It is described in outline in part B of this report, and summarised below.

The emissions are calculated from the energy consumption, using energy-specific emission factors, according to equation F9:

$$E_i = F \times ESEF_i \qquad \text{(F9)}$$

where:

E_i	is the total emission of pollutant *i* corresponding to the railway activity considered
F	is the fuel (or energy) consumed in carrying out that activity
$ESEF_i$	is the fuel- (g/kg of fuel) or energy-specific (g/kW.h) emission factor for pollutant *i*

The energy consumption may be calculated using equation F10:

$$E' \cong \frac{(N_{stops}+1)}{L} \times \frac{v_{max}^2}{2} + B_0 + B_1 v_{ave} + B_2 v_{ave}^2 + g\frac{\Delta h}{L} \qquad \text{(F10)}$$

where:

E'	is the energy consumption (kJ/tonne.km)
N_{stops}	is the number of intermediate stops
L	is the trip length (km)
v_{max}	is the maximum speed during the trip (m/s)
v_{ave}	is the average speed of the trip (m/s)
B_0, B_1 and B_2	are coefficients
g	is the gravitational constant
Δh	is the change in altitude over the trip

F3.1 Input data and data sources

Calculations were carried out for four train journeys originating in the UK. Journey details and train specifications were taken from timetables and other published information. They are given in Table F7.

The coefficient used in the energy calculation (B_0, B_1, B_2) and the energy-specific emission factors for diesel trains are from deliverable 17 [F8], while those for electric trains are the averages for the production of electricity in the UK given in Deliverable 20 [F9] (see also part E of this report). These data are given in Tables F8 and F9.

Table F7. Details of the routes and trains for the example calculations

Route	Journey details					Train details			
	Journey	**Distance (km)**	**Stops**	v_{max} **(m/s)**	v_{ave} **(m/s)**	**Type**	**Fuel**	**Weight (t)**	**No. of seats**
1	Lichfield to Reddich	53.1	22	40	11.7	Class 323	Electric	120	284
2	Manchester to Sheffield	68.8	13	33.3	14.4	Class 101 Class 142	Diesel	58 51	124 121
3	Sheffield to London	269.6	5	55.6	31.9	Class 43 standard Class 43 pullman	Diesel	420 420	468 442
4	London to Brussels	350.0	2	83.3	36.1		Diesel	800	766

Table F8. Coefficients used in the energy calculation

Route	B_0	B_1	B_2
1	16.0	0.366	0.0260
2	15.5	0.292	0.0574
3	15.5	0.292	0.0574
4	16.0	0.366	0.0260

Table F9. Energy-specific emission factors

	CO_2	CO	NO_X	HC	SO_2	PM
Diesel (g/kW.h)	640	3.9	10.7	2.0	0.8	0.4
Electricity (g/GJ)	167800	27.4	631.8	20.2	1445.8	69.9

F3.2 Results

In order that the emissions from these railway journeys may be compared with those for other modes, the results have been expressed in units of g/passenger.km. Clearly, this depends on the train occupancy rate, and values were calculated for four levels of occupancy (25%, 50%, 75% and 100%). The results are given in full in deliverable 23 [F2], and those for 50% occupancy are given in Table F10. They are compared with the results obtained for European passenger travel by car (assuming the car carries 2 people) in Figure F4.

Table F10. Emissions calculated for the four example rail journeys (50% occupancy)

Route	Train	Emission rate (g/passenger.km)					
		CO_2	CO	NO_X	HC	SO_2	PM
1	Class 323	39.8	0.01	0.10	0.10	0.23	0.012
2a	Class 101	24.1	0.15	0.40	0.08	0.03	0.015
2b	Class 142	21.7	0.13	0.36	0.07	0.03	0.014
3a	Class 43 standard	37.5	0.23	0.63	0.12	0.05	0.023
3b	Class 43 pullman	39.7	0.24	0.66	0.12	0.05	0.025
4		24.7	0.005	0.06	0.06	0.15	0.008

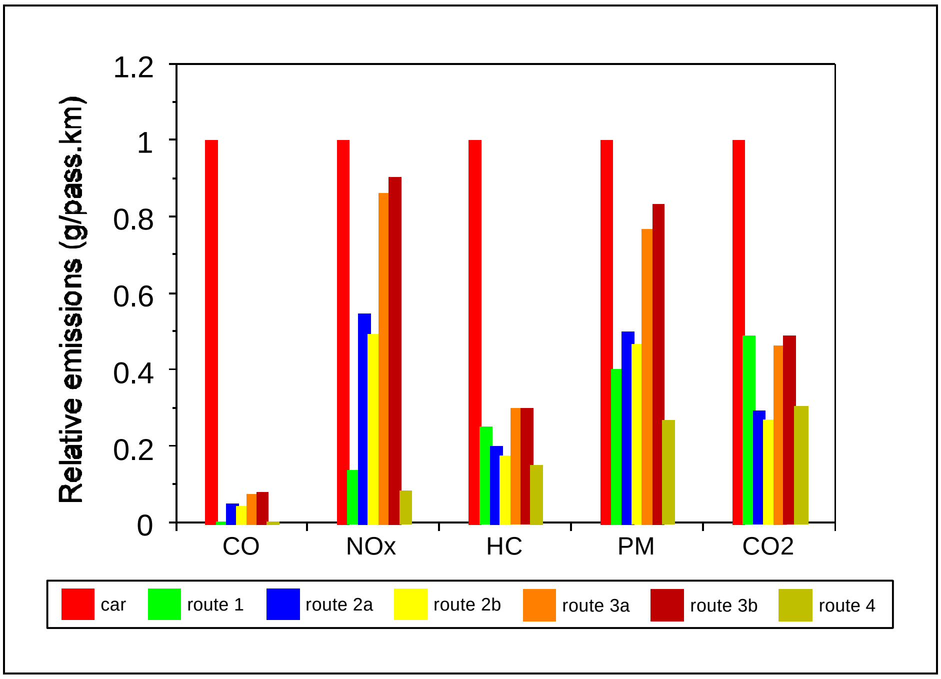

Figure F4. Emissions from car passenger transport compared with those from selected rail journeys

F4. INTERMODAL COMPARISONS

F4.1 Introduction

Personal mobility and the transport of goods are increasing every year, as are the associated environmental impacts, and policies to encourage means of transport with lower environmental impacts are becoming more important than ever. A prerequisite to the reduction of adverse effects is an understanding of the eco-efficiency of different transport modes. This section reports on a number of intermodal comparisons in which the emissions and energy consumption of alternative transport modes are assessed. To enable these comparisons to be made on the basis of equivalent transport services, the environmental loads are expressed per unit of transport unit (i.e. per passenger.km or per tonne-km).

Intermodal comparisons are important in the context of policies which aim to cause a general change to modal split, when environmental indicators based on average values (of a total fleet, region etc.) are relevant. If individuals have to decide which mode to choose for a particular transport purpose, or if, for example, an operator has to replace old vehicles by new ones, it is better to apply a marginal approach, i.e. to base the comparison on the details of that situation.

F4.2 Methodological aspects

F4.2.1 Modes considered

In the examples considered, comparisons have been made between the main transport modes currently in use for passengers and goods. Some means of transport were ignored, for example passenger transport by boat (which is not relevant in Central Europe, but of major importance and in direct competition to aircraft travel in Scandinavia and toward the British Isles), gas transport by pipe line, and transport modes with low market shares (pleasure boats, small aircraft, etc.). Assumptions regarding the transport modes investigated were as follows:

Road traffic Only conventional passenger cars are included; new car concepts (LEV, hybrid cars, etc.) have been ignored. Public road transport is by diesel powered buses only. For goods transport, heavy duty vehicles have been assumed to have a gross weight limit of 40t.

Rail traffic The main characteristic differentiating between passenger trains is their travel speed and the corresponding stop-to-stop distance. For cargo trains, the main factor is average travel speed.

Air traffic Most scheduled aircrafts combine passenger and goods transport at the same time. For the purpose of intermodal comparisons for either passenger or goods transport, emissions and power consumption have to be split according to the proportional load.

Water traffic Only goods transport by ship has been considered. From the Central European perspective, only inland cargo is relevant, although for most European countries with shore lines, coastal transport should be taken into account as well.

F4.2.2 Units of transport

In order to perform intermodal comparisons, a unit of activity (transport) has to be derived that is common for all modes. The same units might not be the most suitable for all comparisons. There are different units of transport which could be considered and for which the environmental impacts could be assessed. Two possibilities are

Transport activity Passenger.kilometres (pkm) or tonne.kilometres (tkm). Emissions and energy consumption rates based on these units can be produced for all modes, resulting in units such as g/pkm or g/tkm. However, they require additional information or assumptions about load factors since the emissions in general are calculated per vehicle.km. Furthermore, these indicators are independent of the distance over which people travel or goods are transported.

Transport product Transport distances vary inherently between modes. In general, for example, air cargo is transported over longer distances than road cargo, and passenger flights are longer than car trips. Therefore, it would sometimes be more meaningful to base the comparison on the result or product of a certain transport activity rather than the amount of activity itself. Examples where this may be appropriate include comparing the ecological impact of transporting wine from Europe with that of transporting wine from California, the most adequate comparison is not per tonne.kilometre, but, on a product basis, total transport related emissions per bottle of wine; similarly, vacation trips by air are generally longer than those by car or by rail, therefore a comparison on a product basis (total emissions per day of vacation) would produce more appropriate results than a comparison on a transport activity basis.

Despite these shortcomings, all impacts of traffic given here are expressed per passenger.km or tonne.km, mainly for practical reasons.

F4.2.3 Load factors

Load factors are necessary to convert emission factors per vehicle.kilometre to emissions per unit of transport, which are then comparable between different modes. Load factors influence the results of any intermodal comparison directly. However, the available statistical data is very sparse, and this introduces an additional uncertainty to intermodal comparisons. Load factors also exhibit a strong dependence on the time of day. Public transport load factors are considerably higher during peak hours than on the average, while the opposite is true for passenger cars. These differences in load factors are considerable and are a very sensitive parameter with respect to the resulting emission indicators.

F4.2.4 Future technologies

Another main influencing factor for emission calculations is technology, and a main determinant for the emission levels of each technology is legislation. While for road vehicles there is some sort of reduction plan for pollutant emissions (EURO-1, -2, -3, -4 etc.), no comparable concepts for the other modes have been identified.

Table F11 provides an overview of future developments likely to have impact on the emission levels of atmospheric pollutants.

Table F11. Summary of future technological developments likely to have effects on the average emissions from different transport modes

Mode	Future development	Effect on emissions
Rail	High speed train traffic Reduction of specific weight per seat Low-cost light-weight trains for regional transport	higher power consumption lower power consumption lower power consumption
Water	Higher efficiency of propulsion engine Reduction of maritime diesel sulphur content Legislation on emission levels of NO_X, CO	lower power consumption lower SO_2 lower NO_X, CO
Air	Legislation on emission levels of NO_X, CO Increased share of turboprop instead of turbofan on short distances Improved air traffic management	lower NO_X, CO higher NO_X, fuel consumption; lower CO, HC lowers all emissions
Road	EURO3 legislation (year 2000) EURO4 legislation (year 2005) Reduction of gasoline sulphur and benzene content	lower NO_X, CO, HC further lowers NO_X, CO, HC lower SO_2, benzene
Electricity production	Decrease of share of coal fired power plants Decrease of transmission losses Cleaning of exhaust gases (fossil powered plants)	lower CO_2, SO_2, etc. higher efficiency (=> lower emissions) higher CO_2; lower SO_2 etc.
Fossil fuel production	Reduction of gasoline sulphur content to 0.05%S Reduction of benzene content	higher CO_2 higher CO_2

F4.2.5 Pollutants considered

The pollutants covered by the MEET methodology differ for each mode, i.e., emission estimates are not available for all modes for all pollutants. Table F12 gives an overview of the available combinations.

Table F12. Emission estimation methodologies available within MEET

Mode	CO_2	CO	NO_X	VOC	SO_2	PM_{10}	CH_4	Pb
Road	✓	✓	✓	✓	✓	✓	×	✓
Rail	✓	✓	✓	✓	✓	✓	×	×
Ship	✓	✓	✓	✓	✓	✓	×	×
Air	✓	✓	✓	✓	✓	×	×	×
Energy production	✓	✓	✓	✓	✓	✓	✓	×

In these examples, only a few representative pollutants have been considered:

- NO_X as an indicator of the group of pollutants with impacts on a local scale (NO_X, VOC, PM_{10}, etc.). In the first example, PM_{10} is also included

- CO_2 is included to represent the emissions which act on a global level.

F4.3 Examples

The purpose of these examples is to illustrate the application of the MEET database for intermodal comparisons. Calculations have been performed using the procedures given in earlier parts of this report. For all examples, a wide variety of assumptions had to be made, concerning the current fleet compositions, the technology mix to be used for the emissions from fuel and electricity production, average load factors, developments to take place in the near future, etc. All of these assumptions influence the resulting emission estimates. Though care has been taken to provide reasonable assumptions, the illustrations presented here use generalised, typical numbers, emission factors, and fleet compositions, and not those for the very specific examples themselves. Therefore, the results are meant as an illustration only; their precision for any given intermodal comparison could be further improved by using more specific information.

F4.3.1 Commuting in big cities - Brussels

Definition

The effect of changes in the modal split and of improvements in vehicle technology (different for each mode) are illustrated for a hypothetical commuter transport system in a big city. The modes considered are urban trains, buses, and passenger cars. Two possible modal split scenarios are investigated in combination with three different stages of vehicle technology: the current fleet, and the future fleet (2010), and today's best available technologies.

The present modal split situation is assumed to have the majority of commuters using passenger cars (60%), with the rest using the public transport system. Usage of the urban train system and the bus network is assumed to be equal.

The alternative modal split scenario is an attempt to depict the possible outcome of a green commuter plan adopted for parts of the workforce of the European Commission in Brussels. It consists of several measures, aimed partly at influencing the modal split (between public and private passenger transport), and partly to increase the load factor of the individual means of transport. The goals and measures affecting the mobility of Commission employees, as proposed in the Green Housekeeping Action Plan 1997 - 2000[50], can be summarised as follows:

[50] In order to include an assessment of the 2010 fleet in this example, it has been assumed that these measures will continue unchanged beyond 2000.

- Increase by 50% of the use of sustainable means of transport (public transport, bicycles, walking) by the staff of the Commission.
- Implement pull/push measures to increase the uses of sustainable means of transport.
- Administrative and financial provisions for the extension of a car-pooling system.
- Financial incentives for the use of public transport and bicycle; and disincentives for car-use and parking.

It has been assumed that the above actions will have effects in two directions:

- The promotion of the use of public transport leads to a shift in the modal split.
- Due to the higher share of public transport, there will be an efficiency increase for the public transport system as a whole, allowing for somewhat higher load factors.
- The car pooling measures will lead to higher average load occupancies of the passenger car commuter fleet.

Note that the non-emitting transport means (bicycles and walking) are neglected here. The definitions of the two modal split scenarios - the 'traditional' and 'green commute' scenarios - are summarised in Table F13.

Table F13. Modal split definitions

Scenario	Transport mode	Modal share (%)
Traditional	Urban trains	20
	Buses	20
	Private cars	60
Green Commute	Urban trains	30
	Buses	25
	Private cars	45

Combining these with the three stages of vehicle technology leads to the definition of six scenarios, which are given in Table F14.

Table F14. Definition of scenarios

	Current fleet (1995)	Best available technology (1995)	Future fleet (2010)
Modal split traditional	Scenario A	Scenario B	Scenario C
Modal split green commute	Scenario D	Scenario E	Scenario F

Load factors

Peak-hour load factors are considered to depend on the modal split. It has been assumed that the load factor for public transport during the peak hour is already high in the traditional scenarios. The increase in the market share in the green commute scenarios will largely be absorbed by increasing the frequencies of trains and buses. However, an additional gain in overall efficiency has been assumed, and the current load factors of 75% (assumed identical for trains and buses) show a modest increase to 77% in the green commute scenarios.

The occupancy rate of passenger cars in the traditional scenarios is estimated as 1.1 passengers (including the driver, except for taxis, where the driver is not taken into account). The implementation of the measures to promote car pooling are assumed to have the effect that 33% of all currently non-pooling car commuters will join in car pooling. This leads to an increase in the average occupancy per car to 1.3 passengers.

Present, best and future technologies

For the train system, emission factors for traditional urban trains are used for the current fleet. For the fleet in 2010, a 50:50 ratio of these, and newer lightweight trains has been assumed, and for the best available technology it has been assumed that all trains are of the newer type.

To characterise the current urban bus fleet, emission factors for buses built and operated in the 1980s and early 1990s are used. For the best currently available technology, buses are assumed to conform with the EURO II legislation. Further reductions are underway, however. The EURO III legislation calls for additional significant reductions of emission levels. In 2010, it is possible that buses will be in use which meet the limit values of EURO IV, a standard currently being discussed in the European Parliament. To reflect these changes, it is assumed that the 2010 fleet consists of 33.3% EURO II, 33.3% EURO III and 33.3% EURO IV vehicles.

The commuter car fleet is characterised by the different shares of EURO I, II, III, and IV vehicles. The current fleet consists of pre EURO and EURO I cars. The fleet in 2010 will contain cars up to the EURO IV standard. EURO II is adopted as the best currently available technology. The detailed composition of the car fleet is based on statistics for Belgium given in MEET deliverable 15 [F10].

Table F15 provides an overview of the different fleet assumptions for the different modes.

Table F15. Fleet compositions and assumed best current technology for each mode

	Current fleet	Best available technology	Future fleet
Urban trains	urban train	light weight	50:50 mix
Bus fleet	1995 fleet	EURO-2	EURO-2, -3, -4 mix
Passenger cars			
Share of diesel	42.3%	43%	44.0%
Share of pre-EURO	47.0%		0.0%
Share of EURO 1	43.0%		0.1%
Share of EURO 2		100%	6.9%
Share of EURO 3			27.5%
Share of EURO 4			65.5%

Results

For the three pollutants and the six scenarios considered, the resulting emissions per passenger.kilometre are shown in Figure F5, averaged over all three transport modes.

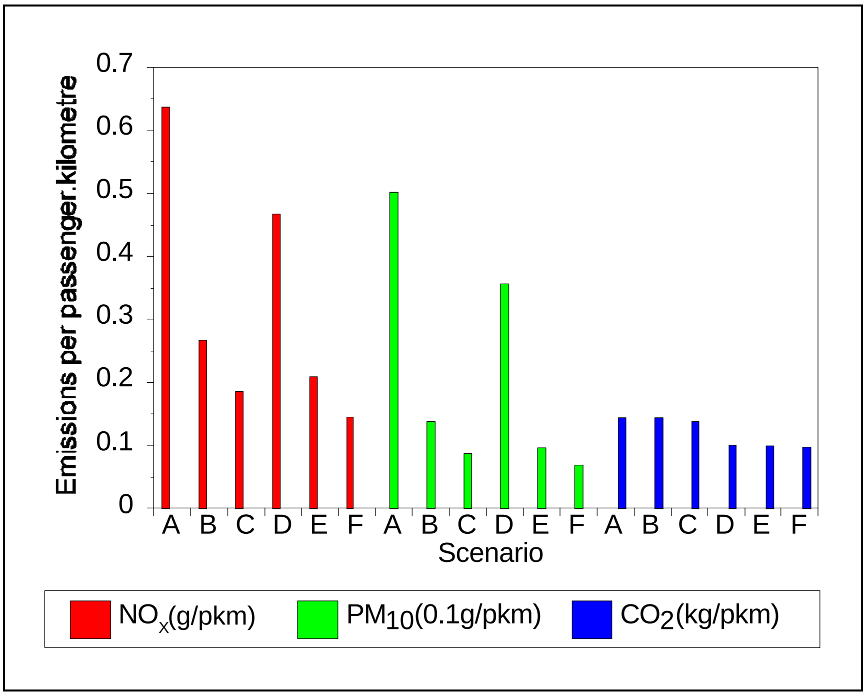

Figure F5. Overall average emissions per motorised commuter

The NO_X emissions fall significantly in the future, largely because of technology improvements to road vehicles. While currently the total NO_X emissions in the traditional scenario (A) are clearly higher than for the green commute scenario (D), this advantage will be reduced in the future (regarding atmospheric pollutants; of course, there are many other reasons in favour of public transport).

Similar trends are shown for PM_{10}, with a sharp drop in emissions in the future, due to the EURO legislation both for buses and for passenger cars. Differences according to the different modal splits are small, and mainly reflect the assumed share of diesel vehicles in the passenger car fleet.

The CO_2 emissions per passenger.kilometre will not change significantly over the next decades. However, because of the higher energy efficiency of public transport systems, emissions are significantly lower for the green commute scenarios.

Figure F6 again shows emissions per passenger kilometre, but this time separately for each mode of transport.

Current passenger cars show the highest NO_X emission level, but by 2010, they will be slightly less polluting than buses. This is because the EURO legislation on heavy duty vehicles will be implemented some years later than for passenger cars.

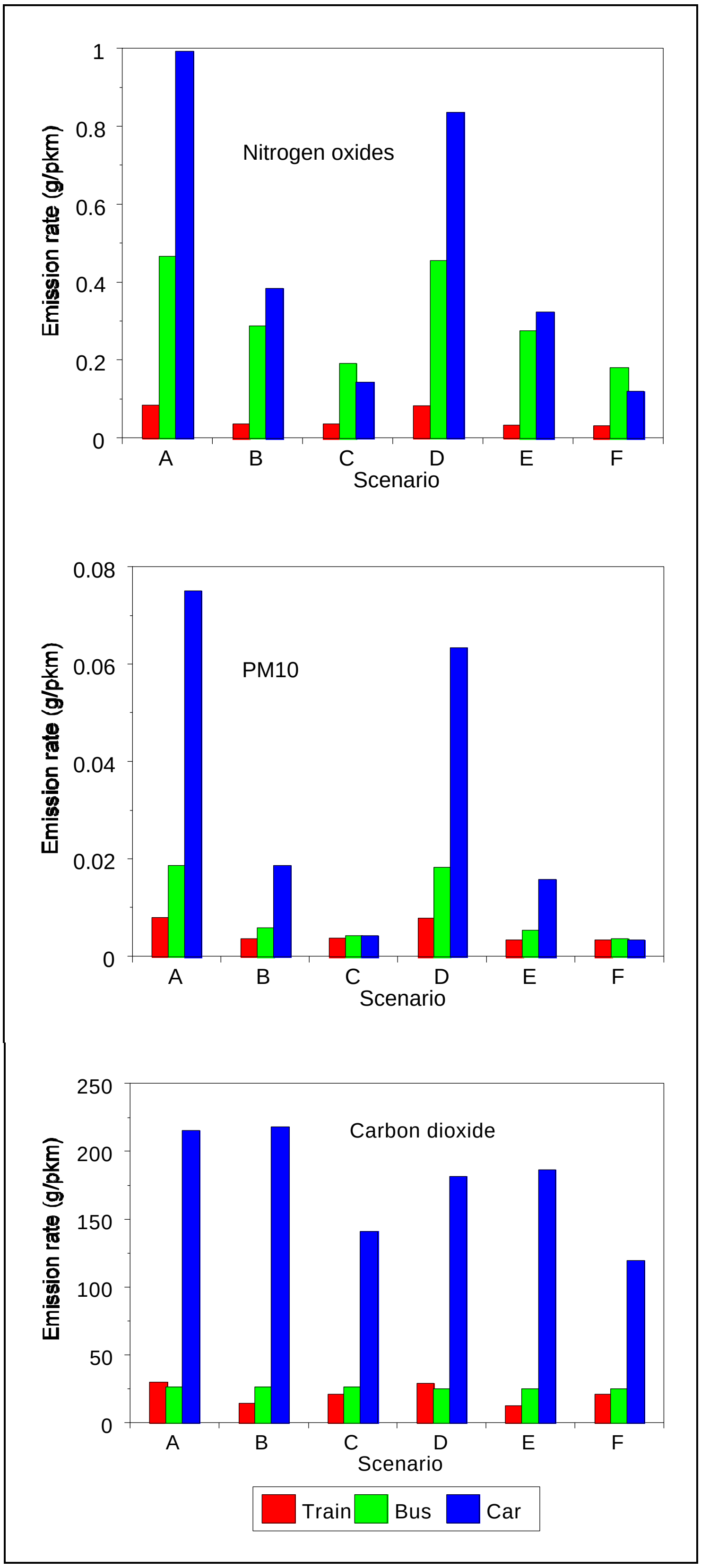

Figure F6. NO_X, PM_{10} and CO_2 emission rates for each mode and scenario

Current PM_{10} emissions are clearly dominated by the emissions from passenger cars. Again, however, EURO legislation will reduce this disadvantage within the next 20 years.

The only pollutant where public transport clearly outperforms individual transport, now and in the future, and not depending on the modal split, is CO_2. Passenger cars emit 4 to 6 times more, and will continue to do so.

F4.3.2 A trip to Rome

Definition

To illustrate long distance passenger transport with different means of transportation, a trip between two capitals, Vienna and Rome, is investigated, and transport by car, aircraft and international train considered. This is initially done for the present day transport situations (load factors and technology), and additionally, the sensitivity to changes in load factors and technology are investigated. CO_2 and NO_X emissions are compared.

The trip to Rome is defined as follows:

- Start of the trip: Vienna city centre, near St Stephen's dome
- Destination: Rome city centre
- Means of transport: passenger car, using highways whenever possible

  high speed train (TGV type), using taxis to go from Vienna city centre to the station, and to go from Roma Termini to centre

  aircraft: from Vienna Airport to Rome Fiumicino, using taxis to travel to and from the airports.

The transport distance is different for each mode, but to compare emissions per passenger.kilometre, the same reference distance has been used for all modes.

Two different sets of load factors, and three different sets of technology are distinguished. These sets are combined to yield the six scenarios shown in Table F16, for which the relative emissions for NO_X and CO_2 have been estimated.

Table F16. Definition of scenarios

	Current technology (1995)	**Best available technology (1995)**	**Future technology (2010)**
Maximum load factors	Scenario A	Scenario B	Scenario C
Average load factors	Scenario D	Scenario E	Scenario F

Load factors, current and best technology

The assumptions for the load factors and technology mixes for each mode are listed in Table F17.

Table F17. Definition of load factors and technology mixes

Parameter set	Mode	Value
Current technology emission factors	road	Austrian average highway fleet composition (1995)
	rail	TGV Est
	air	Average fleet on route London - Paris 1993
Best available technology emission factors	road	EURO-2
	rail	TGV Duplex
	air	Airbus 320
Future technology emission factors	road	Austrian average highway fleet composition (2010)
	rail	33:33:33 mix of TGV Est, TGV Duplex and future TGV
	air	1994 - 2010 reduction factors applied to London - Paris fleet
Average load factors	road	2.3 passengers per car
	rail	load factor 0.70
	air	load factor 0.65
Maximum load factor (100%)	road	4 passengers per car
	rail	load factor 1.00
	air	load factor 1.00

Results

Figures F7 and F8 show the main results of the comparison.

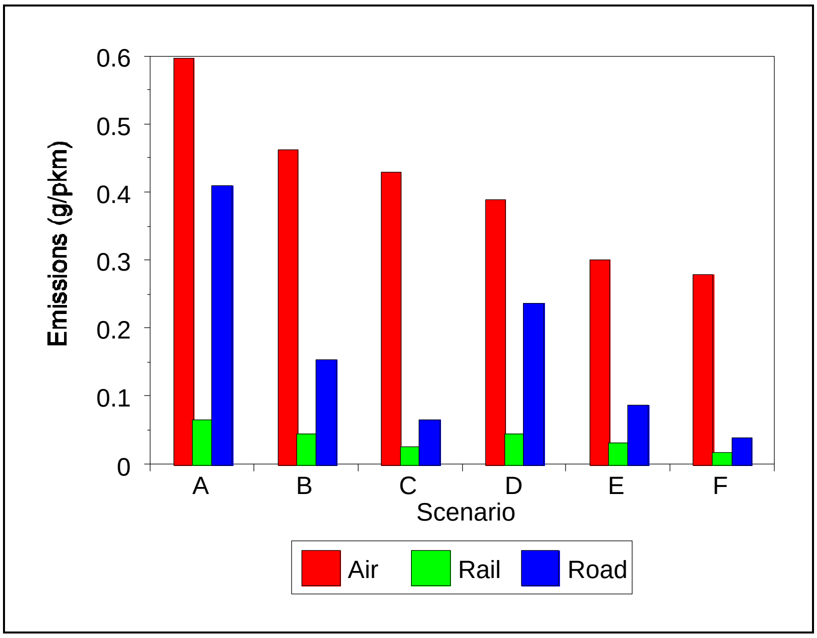

Figure F7. Comparison of nitrogen oxide emissions for the six scenarios

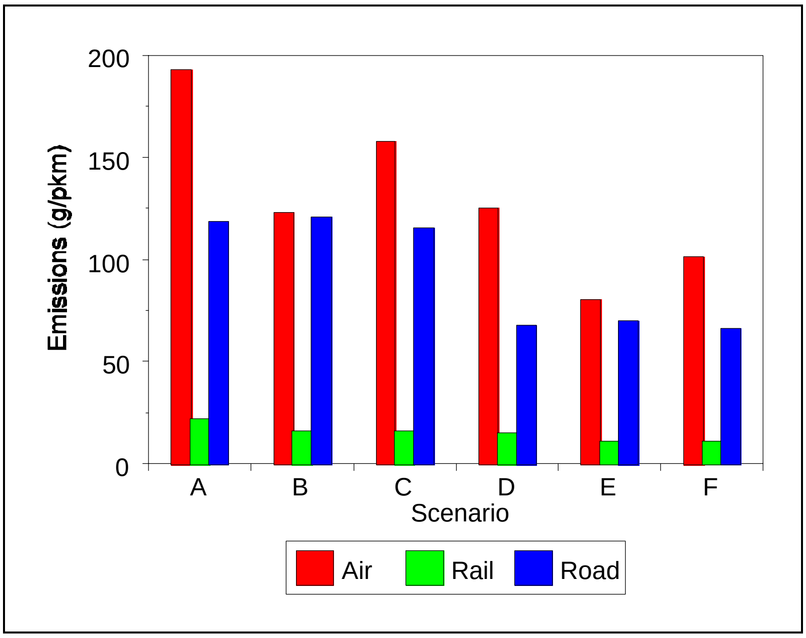

Figure F8. Comparison of carbon dioxide emissions for the six scenarios

Emission levels are highest for air transport, both for NO_X and CO_2. Taking the train is clearly the least polluting way to travel from Vienna to Rome. Using the car instead causes NO_X emissions which are a factor of 5 higher for the current average fleet composition. Using the best vehicle technology currently available, this disadvantage is still a factor of 3. For the 2010 fleet, the advantage of the train with respect to the car is only a factor of 2, and this is mainly because no reduction rates for the 2010 emissions from the production of crude oil based fuels are available, whereas reduction factors have been used for the production of electricity. Within the current example, and using an Austrian/Italian fuel production emission mix, this source contributes more than 50% of the NO_X emissions.

Comparing the current fleet with the future fleet (scenarios A and C), NO_X emission reductions amount to roughly 25% for aircraft, but are much higher (75%) for passenger cars. This tendency will alter the present rough equivalence of car and air travel over long distances in favour of car travel. Load factors are also a very significant parameter: when the passenger car is used by 4 instead of 2.3 people, the emission levels per passenger.kilometre obviously reduce by almost 50%.

F4.3.3 Cargo transport Rotterdam - Zurich

Definition

This comparison involves goods transport by ship, by train and by road. The route differs depending on the mode:

- ship: Rotterdam Europort to Basle on the River Rhine, Basle - Zurich by road

- train: Rotterdam - Arnheim - Germany - Basle - Zurich; an additional 20 km on road to reach the final destination is assumed

- road: fastest route between Rotterdam Europort and the final destination

The type of goods is not specified, but because high load factors have been assumed, this example is valid only for goods whose transport is limited by their weight, and not their volume. Four different scenarios are considered, with two sets of load factors, and two different fleet technologies, as outlined in Table F18.

Table F18. Definition of scenarios

	Current technology (1995)	**Future technology (2010)**
Maximum load factors	Scenario A	Scenario B
Moderate load factors	Scenario C	Scenario D

Load factors

Because of the weight limited type of goods considered in this example, it has been assumed that a load factor of 100% is technically possible and this is used for all modes in one pair of scenarios. Load factors of 50% are used for the other scenarios. The load factor of the delivery to the final destination point of goods transported by rail or water is always assumed to be 50%.

All emissions are given per tonne.kilometre with respect to the same reference distance, despite the fact that for each mode, the effective transport distance might be different.

Present and future technology

For heavy duty vehicles, the fleet used on long-distance goods transport usually consists of new vehicles. As they become older, they are sold, or used for shorter distance transport within the same company. The heavy duty vehicle fleet on long distance routes is assumed to consist of EURO-I vehicles only in 1995, and of EURO-3 vehicles only in 2010.

For the current fleet of inland cargo ships, the emission factors as provided in part C of this report have been applied. For the future fleet, reduction factors have been proposed in Deliverable 25 for NO_X and SO_2 (see also part C of this report). For NO_X, which was calculated in this example, a reduction of 15% was assumed by 2010.

Since no significant developments are assumed to take place for freight trains in the near future (constant weight and load per axle, constant energy consumption), the only difference between emissions from the current and the future freight train fleet is caused by the reduction of electricity production emission factors.

Results

Figures F9 and F10 give the aggregate emission factors for NO_X and CO_2 for the different scenarios.

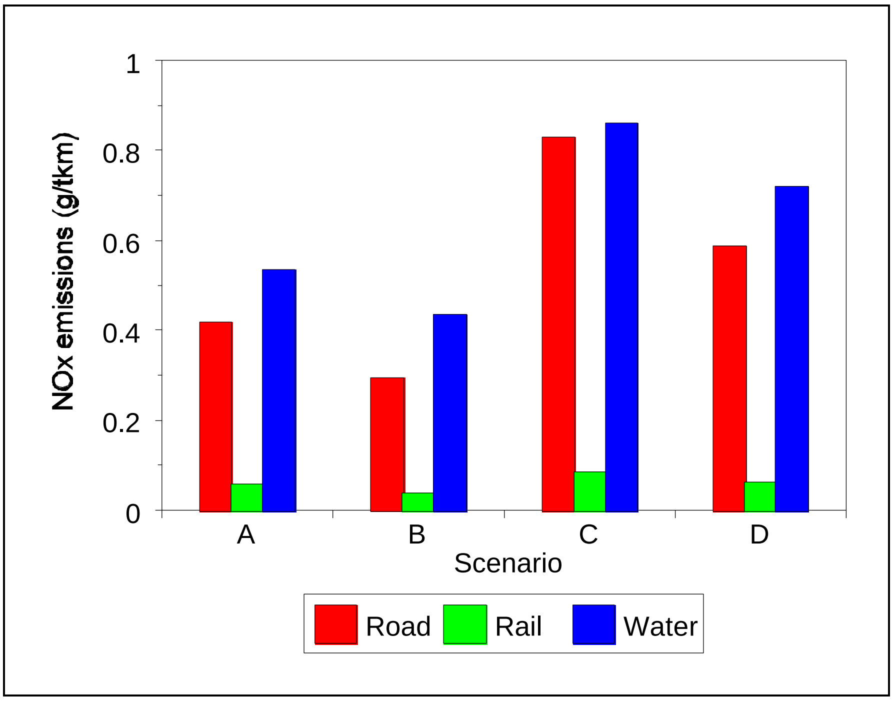

Figure F9. Comparison of nitrogen oxides emissions for the four scenarios

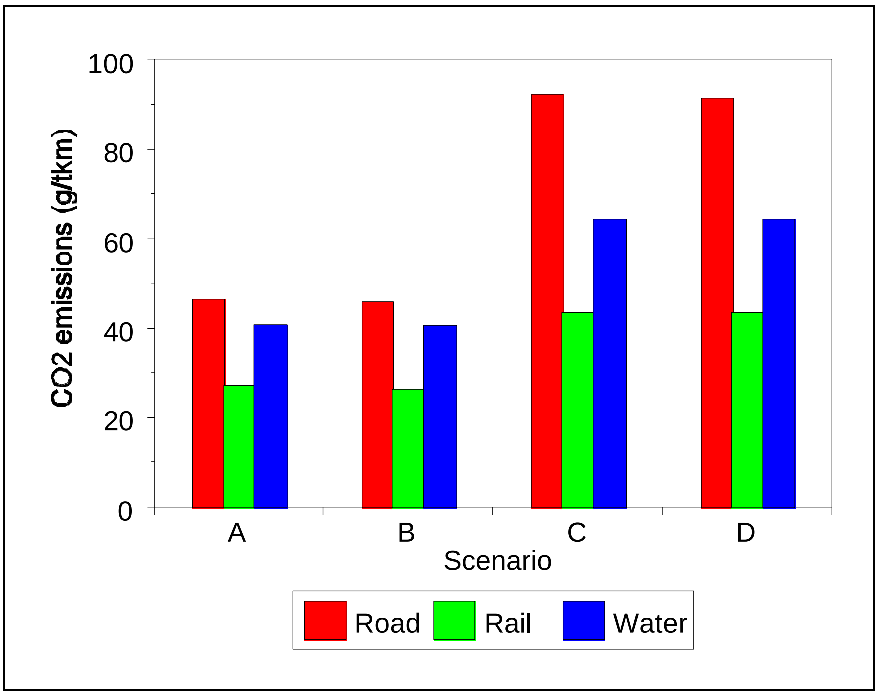

Figure F10. Comparison of carbon dioxide emissions for the four scenarios

For both NO_X and CO_2 emissions, the train clearly is the least polluting form of transport. The amount of pollution caused by inland cargo ships is remarkable. The main reasons for this are that no legislative action has yet been undertaken on ship emissions, whereas tough restrictions have already been applied to lorries. Also, the fuel used (maritime diesel for ships) causes the emission indices per amount of energy consumed to be higher.

Comparing the medium and the high load factor results, the higher gain in efficiency for HDV is evident, as compared to both trains and ships. This is probably partly due to the methodology (whereas the emission factors for heavy duty vehicles and, indirectly, freight trains, depend on the load, such a correction does not exist for cargo ships), but also to the relatively high empty weight of lorries.

F5. REFERENCES

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