SNAP CODES: **070100**
070200
070300
070400
070500

SOURCE ACTIVITY TITLE: **ROAD TRANSPORT**
Passenger Cars
Light Duty Vehicles < 3.5t
Heavy Duty Vehicles > 3.5t and buses
Mopeds and Motorcycles < 50cm^3
Motorcycles > 50cm^3

NOSE CODES: **201.01**
201.02
201.03
201.04
201.05

NFR CODES: **1 A 3 b i**
1 A 3 b ii
1 A 3 b iii
1 A 3 b iv

1 ACTIVITIES INCLUDED

This chapter provides the methodology, emission factors and relevant activity data to calculate emissions produced by the exhaust systems of road vehicles (SNAP codes 0701 to 0705). It does not cover non-exhaust emissions such as fuel evaporation from vehicles (SNAP code 0706) and component attrition (SNAP code 0707). Table 1-1 provides all the SNAP codes included in this chapter according to the EMEP/CORINAIR nomenclature.

The vehicle category split presented in Table 1-1 may serve as a basis to report emissions from road transport to international bodies. However, from a technical point of view, it does not provide the level of detail considered necessary to collect emissions from road vehicles in a systematic way. This is because road vehicle powertrains make use of a great range of fuels, engine technologies and aftertreatment devices. Thus, a more detailed vehicle category split is necessary and has been developed, as quoted in Table 1-2. On the one hand, this vehicle split attempts to introduce the level of detail necessary for vehicle technology distinction and on the other to preserve the spatial resolution for the three major driving classes (urban, rural and highway).

Pollutants covered include all major emission contributions from road transportation: Ozone precursors (CO, NO_x, NMVOC), greenhouse gases (CO_2, CH_4, N_2O), acidifying substances (NH_3, SO_2), particulate matter (PM), carcinogenic species (PAHs & POPs), toxic substances (dioxins and furans) and heavy metals. PM information is also distinguished to different particle sizes and further to mass, the particle number and surface concentration are reported.

All PM emission factors reported in this chapter refer to $PM_{2.5}$, as the coarse fraction ($PM_{2.5-10}$) is negligible in vehicle exhaust. Also, fuel (energy) consumption figures can be calculated. For NMVOC, a speciation to 68 substances is provided.

Table 1-1: Activities covered in this chapter according to EMEP/CORINAIR nomenclature

SNAP	2002 NFR	Name of SNAP/CORINAIR Activity
0701	1A3b i	PASSENGER CARS
070101		Highway Driving
070102		Rural Driving
070103		Urban Driving
0702	1A3b ii	LIGHT DUTY VEHICLES <3.5 t
070201		Highway Driving
070202		Rural Driving
070203		Urban Driving
0703	1A3b iii	HEAVY DUTY VEHICLES >3.5 t and buses
070301		Highway Driving
070302		Rural Driving
070303		Urban Driving
0704	1A3b iv	MOPEDS & MOTORCYCLES < 50 cm³
0705		MOTORCYCLES > 50 cm³
070501		Highway Driving
070502		Rural Driving
070503		Urban Driving

The methodology presented is the fourth update of the initial attempt for the CORINAIR 1985 emissions inventory (Eggleston et al., 1989) and firstly updated in 1991 for the CORINAIR 1990 inventory (Eggleston et al., 1993). This was included in the first version of the Emission Inventory Guidebook. The second update of the methodology (Ahlvik et al., 1997) was introduced in the software tool COPERT II (Ntziachristos and Samaras, 1997) and a further update of the Guidebook was prepared. The previous methodology version was fully embodied in the COPERT III tool (Ntziachristos and Samaras, 2000). The present methodology is fully incorporated in the software tool COPERT 4 which is available at http://lat.eng.auth.gr/copert/.

Several sources have been used as input to the methodology presented. The fundamental elements date back to the first version and several emission factors from older vehicles still remain unmodified since this first version. The previous version of this chapter introduced several methodological revisions, including extended vehicle classification and pollutant coverage, emission factors and corrections for road gradient and vehicle load, etc. The present version introduces both additional refinements and new calculation elements. Those revisions and extensions mainly originate from the following sources:

- The European Commission (DG Transport) *ARTEMIS* project, which was funded to develop a new database of emission factors of gaseous pollutants from transport (http://www.trl.co.uk/artemis)

- The European Commission (DG Transport) *PARTICULATES* project, which was funded to develop a new database of PM emission factors and particle characteristics of exhaust emissions from road transport (http://lat.eng.auth.gr/particulates)

- Aristotle University specific studies and literature reviews, aiming at developing new information for N_2O and NH_3 emissions and emissions from hybrid vehicles

- A European Commission (DG Enterprise) study on potential options for emission standards of Euro 3 mopeds (http://ec.europa.eu/enterprise/automotive/ mveg_meetings/meeting96/ptw_final_report.pdf)

The following major revisions have been made since previous version of the methodology:

- Updated hot emission factors and consumption factors for Euro I and later gasoline and diesel passenger cars and light duty vehicles
- PM emission factors, including conventional gasoline vehicles, vehicles with direct injection gasoline engines and diesel vehicles equipped with particle filters
- PM number and surface concentration, distinguished in particle size classes
- New emission factors for hybrid vehicles, i.e. vehicles combining an electrical motor and a thermal engine
- New emission factors of greenhouse gases (N2O, CH4), and NH3, including fuel and deterioration effects
- New emission factors for Euro 2 and later motorcycles and mopeds, including PM emissions from 2-stroke ones and an updated evaporation loss calculation
- New hot emission factors for Euro 2 and later heavy duty vehicles

The study team is also working on the following issues, which will soon be available and will be included in the COPERT 4 software:

- A new cold start calculation methodology, which includes more detailed calculations for late technology vehicles
- A new evaporation calculation which takes into account fuels of different volatility

Table 1-2: Vehicle category split adopted for description of road transportation

SNAP-like code	Activity	Driving Mode		
		Highway	**Rural**	**Urban**
07 01	PASSENGER CARS			
07 01 01	Gasoline <1.4 l	07 01 01 01	07 01 01 02	07 01 01 03
07 01 02	Gasoline 1.4 – 2.0l	07 01 02 01	07 01 02 02	07 01 02 03
07 01 03	Gasoline >1.4 l	07 01 03 01	07 01 03 02	07 01 03 03
07 01 04	Diesel <2.0 l	07 01 04 01	07 01 04 02	07 01 04 03
07 01 05	Diesel >2.0 l	07 01 05 01	07 01 05 02	07 01 05 03
07 01 06	LPG	07 01 06 01	07 01 06 02	07 01 06 03
07 01 07	Two Stroke Gasoline	07 01 07 01	07 01 07 02	07 01 07 03
07 01 08	Hybrids	07 01 08 01	07 01 08 02	07 01 08 03
07 02	LIGHT DUTY VEHICLES <3.5 t			
07 02 01	Gasoline	07 02 01 01	07 02 01 02	07 02 01 03
07 02 02	Diesel	07 02 02 01	07 02 02 02	07 02 02 03
07 03	HEAVY DUTY VEHICLES			
07 03 01	Gasoline	07 03 01 01	07 03 01 02	07 03 01 03
07 03 02	Diesel <7.5 t	07 03 02 01	07 03 02 02	07 03 02 03
07 03 03	Diesel 7.5 – 16 t	07 03 03 01	07 03 03 02	07 03 03 03
07 03 04	Diesel 16 – 32 t	07 03 04 01	07 03 04 02	07 03 04 03
07 03 05	Diesel >32 t	07 03 05 01	07 03 05 02	07 03 05 03
07 03 06	Urban Buses	-	-	07 03 06 00
07 03 07	Coaches	07 03 07 01	07 03 07 02	07 03 07 03
07 04	MOPEDS & MOTORCYCLES < 50cm³	-	-	07 04 01 00
07 05	MOTORCYCLES			
07 05 01	Two stroke >50 cm³	07 05 01 01	07 05 01 02	07 05 01 03
07 05 02	Four stroke >50 cm³	07 05 02 01	07 05 02 02	07 05 02 03
07 05 03	Four stroke 50 – 250 cm³	07 05 03 01	07 05 03 02	07 05 03 03
07 05 04	Four stroke 250 – 750 cm³	07 05 04 01	07 05 04 02	07 05 04 03
07 05 05	Four stroke >750 cm³	07 05 05 01	07 05 05 02	07 05 05 03

2 CONTRIBUTION TO TOTAL EMISSIONS

Road transport poses significant environmental pressures (EEA, 2006). Until lately, air quality was the major issue of concern for road transport emissions but significant technology improvements have effectively alleviated the risks. Today, greenhouse gases (and energy consumption) from road vehicles arise as the main concern for sustainable road transport development. Available data show that in 2005, transport (excluding international aviation and maritime transport) contributed to about 21% of total GHG emissions in EU-15 and 56% of total NO_x. However the trends in those two pollutants are opposite, with ~23% increase and ~40% decrease of CO_2 and NO_x in 2005 respectively, compared to 1990 levels. Road transport is the main source of these shares, with a contribution of over 70% to GHG gases and 75% to NO_x. Table 2-1 and Table 2-2 show the contribution of road transport to total anthropogenic emissions of main pollutants in different European territories.

Table 2-1: Contribution of road transport to national total (ETC/ACC, 2005)

Country Group	Road transport emissions - Year 2003								
	CO_2 (Mt)	CH_4 (kt)	N_2O (kt)	NO_x (kt)	CO (kt)	NMVOC (kt)	SO_2 (kt)	NH_3 (kt)	PM_{10} (kt)
AC2 & CC2	24.3	4.2	0.75	529	2092	401	90.4	0.72	0.53
BC				22	76.3		1.0		0
EEA32	971	138	90.1	5069	16455	2964	201	87.5	343
EFTA4	29.9	4.2	3.2	96.6	523	67	1.96	3.39	8.42
EU10	76.4	14.2	7.7	581	1790	619	48.8	3.87	48.1
EU15	845	117	79.0	3890	12200	1902	65.6	80.0	287
EU25	922	131	86.7	4472	13990	2521	114	83.9	335
NIS				1226	10975	2148	407	0.55	0.43

Note: Country group definitions, as used by the European Environment Agency (http://www.eea.europa.eu)

Table 2-2: Contribution of road transport [%] to national total (ETC/ACC, 2005).

Country	Road transport contribution [%] to total emissions - Year 2003								
	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	NH_3	PM_{10}
AC2 & CC2	12.9	0.24	1.38	33.5	34.8	28.4	2.8	0.2	7.2
BC				21.6	55.0		0.18		
EEA32	22.4	0.65	6.8	39.8	42.7	26.0	1.81	2.1	16.2
EFTA4	33.0	0.96	11.2	28.6	56.8	15.9	2.89	4.5	10.2
EU10	12.3	0.41	4.5	36.0	30.4	47.8	1.94	0.6	10.0
EU15	24.5	0.74	7.3	41.9	46.9	22.8	1.21	2.4	18.4
EU25	22.6	0.68	6.92	41.0	43.8	26.2	1.44	2.1	16.4
NIS				37.4	71.8	62.0	11.4	0.05	4.6

The relevant contribution of each vehicle category to total emissions of each of the main pollutants is shown in Table 2-3. It is shown that the relevant share is pollutant specific.

Table 2-3: Emissions of different vehicle categories as percentage of the EU Totals for road transport. In parentheses the range of dispersion of the countries (Estimates for Year 2002)

Category	CO	NOx	NMVOC	CH_4	PM	FC	CO_2
Gasoline PC	79.15 (90.8 - 58.0)	28.23 (44.5 - 15.5)	58.69 (78.2 - 36.9)	77.29 (87.8 - 59.9)	0.00 (0.0 - 0.0)	46.61 (65.4 - 28.1)	45.43 (64.7 - 27.3)
Diesel PC	1.00 (3.9 - 0.1)	6.20 (20.0 - 0.4)	1.86 (5.8 - 0.1)	1.34 (4.6 - 0.1)	17.89 (35.7 - 1.8)	8.37 (23.6 - 0.7)	8.68 (24.2 - 0.8)
Gasoline LDV	9.57 (27.8 - 0.9)	3.84 (9.6 - 0.2)	7.72 (23.2 - 0.6)	4.32 (11.3 - 0.3)	0.00 (0.0 - 0.0)	3.55 (8.6 - 0.2)	3.26 (8.1 - 0.2)
Diesel LDV	1.17 (3.9 - 0.1)	7.65 (19.7 - 1.1)	1.54 (5.7 - 0.3)	0.73 (2.3 - 0.1)	21.65 (45.9 - 4.4)	7.51 (20.5 - 0.8)	7.81 (21.0 - 0.9)
Diesel HDV	3.75 (7.6 - 1.3)	47.07 (71.4 - 28.9)	16.81 (30.8 - 7.2)	8.94 (15.7 - 3.1)	55.83 (76.7 - 37.6)	30.46 (48.1 - 17.4)	31.56 (49.4 - 18.5)
Buses	0.43 (0.9 - 0.1)	6.70 (12.2 - 2.1)	1.18 (2.5 - 0.3)	1.19 (2.5 - 0.6)	5.39 (12.6 - 1.2)	2.80 (6.4 - 0.9)	2.91 (6.6 - 1.0)
Coaches	0.04 (0.1 - 0.0)	0.85 (1.5 - 0.0)	0.18 (0.3 - 0.0)	0.16 (0.3 - 0.0)	0.69 (1.4 - 0.0)	0.49 (1.0 - 0.0)	0.52 (1.0 - 0.0)
Mopeds	1.91 (6.9 - 0.1)	0.02 (0.1 - 0.0)	8.80 (26.0 - 0.7)	2.76 (11.4 - 0.2)	0.00 (0.0 - 0.0)	0.37 (1.6 - 0.0)	0.20 (0.8 - 0.0)
Motrocycles	3.69 (11.2 - 0.4)	0.20 (0.7 - 0.0)	3.86 (10.8 - 0.7)	3.61 (13.5 - 0.3)	0.00 (0.0 - 0.0)	0.57 (2.3 - 0.0)	0.38 (1.5 - 0.0)

3 GENERAL

3.1 Description

In order to help identifying the vehicle categories, Table 3-1 gives the classification of vehicles according to the UN-ECE. The main vehicle categories can be allocated to the UN-ECE classification as follows:

Passenger Cars	M1
Light Duty Vehicles	N1
Heavy Duty Vehicles	N2, N3
Urban Buses & Coaches	M2, M3
Two Wheelers	L1, L2, L3, L4, L5

3.2 Definitions

Significant definitions will be described and explained in the relevant chapters.

3.3 Techniques

Traditionally, road vehicles have been powered by internal combustion engines which operate on fossil fuels combustion (gasoline, diesel, LPG, etc.). The combustion process produces CO_2 and harmless H_2O as the main products. Unfortunately, combustion also produces several by-products which either originate from incomplete fuel oxidation (CO, hydrocarbons, particulate matter) or from the oxidation of non-combustible species present in the combustion chamber (NO_x from N_2 in the air, SO_x from S in the fuel and lubricant, etc.). In order to comply with emission legislation, vehicle manufacturers have been installing aftertreatment devices, such as catalytic converters, to suppress by-product emission. However, such devices may also produce small quantities of pollutants such as NH_3 and N_2O.

Table 3-1: Vehicle classification categories according to UN-ECE

Category L:	Motor vehicles with less than four wheels
Category L1:	Two-wheeled vehicles with an engine cylinder capacity not exceeding 50 cm³ and a maximum design speed not exceeding 40 km/h.
Category L2:	Three-wheeled vehicles with an engine cylinder capacity not exceeding 50 cm³ and a maximum design speed not exceeding 40 km/h.
Category L3:	Two-wheeled vehicles with an engine cylinder capacity exceeding 50 cm³ or a design speed exceeding 40 km/h.
Category L4:	Vehicles with three wheels asymmetrically arranged in relation to the longitudinal median axis, with an engine cylinder capacity exceeding 50 cm³ or a design speed exceeding 40 km/h (motor cycles with sidecar).
Category L5:	Vehicles with three wheels symmetrically arranged in relation to the longitudinal median axis, with a maximum weight not exceeding 1,000 kg and either an engine cylinder capacity exceeding 50 cm³ or a design speed exceeding 40 km/h (motor cycles with sidecar).
Category M:	Power driven vehicles having at least four wheels or having three wheels when the maximum weight exceeds 1 metric ton, and used for the carriage of passengers
Category M1:	Vehicles used for the carriage of passengers and comprising not more than eight seats in addition to the driver's seat.
Category 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 metric tonnes.
Category 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 metric tonnes.
Category N:	Power-driven vehicles having at least four wheels or having three wheels when the maximum weight exceeds 1 metric ton, and used for the carriage of goods
Category N1:	Vehicles used for the carriage of goods and having a maximum weight not exceeding 3.5 metric tonnes.
Category N2:	Vehicles used for the carriage of goods and having a maximum weight exceeding 3.5 but not exceeding 12 metric tonnes.
Category N3:	Vehicles used for the carriage of goods and having a maximum weight exceeding 12 metric tonnes.

Gasoline powered (also spark-ignition) engines are used in small vehicles (up to 3.5 t GVW) because of their superior power/weight ratio and their wider operation range compared to diesel engines. Some less important reasons have also been responsible for this, such as lower noise output and more refined operation. For very small vehicles (mopeds and motorcycles), two stroke engines have been favourable, especially in the past, because they provide the highest power/size ratio of all concepts. Diesel engines (also compression-ignition) on the other hand dominate in large vehicle applications because of their improved fuel efficiency and torque characteristics over gasoline engines. Lately though, an increasing shift to diesel engines is observed also for passenger cars, which now correspond to the highest share of new passenger car registrations in several European countries. The ACEA (2006) statistics show that 48.3% of passenger cars sold in Europe in 2005 were diesel ones, with shares reaching as high as 70% for countries like Austria, Belgium and France. This is an outcome of the higher fuel efficiency of diesel engines and technology improvements which increase the power output density for given engine size.

There are currently new technologies available, which aim at decreasing both energy consumption and pollutant emissions. Those technologies include new combustion processes for internal combustion engines (Gasoline Direct Injection (GDI), Controlled Auto-Ignition, Homogeneous Charge Compression Ignition), new fuels (CNG, Reformulated grades, eventually H_2) and alternative powertrains (hybrids – meaning a combination of internal combustion engine and electric motor, fuel cell vehicles, etc.). Some of these technologies (e.g. GDI, hybrids) become quite popular nowadays while others are still in the development phase.

Given the diversity in propulsion concepts, the calculation of emissions from road vehicles is a complicated and demanding procedure, which requires availability of good quality activity data and emission rates. This report aims at covering emissions from all widespread technologies today in a systematic manner that will allow the production of high quality emission inventories.

3.4 Emissions

The methodology covers exhaust emissions of CO, NO_x, NMVOC, CH_4, CO_2, N_2O, NH_3, SO_x, diesel exhaust particulates (PM), PAHs and POPs, Dioxins and Furans and heavy metals contained in the fuel (Lead, Cadmium, Copper, Chromium, Nickel, Selenium and Zinc). A detailed NMVOC split is also included to distinguish hydrocarbon emissions as alkanes, alkenes, alkines, aldehydes, ketones and aromatics. Particulate emissions in the vehicle exhaust mainly fall in the $PM_{2.5}$ size range. Therefore, all PM mass emission factors correspond to $PM_{2.5}$. Also PM emissions are distinguished in different particle sizes.

According to the detail of information available and the approach adopted by the methodology to calculate emissions, the above mentioned pollutants can be arbitrarily distinguished into four groups:

Group 1: Pollutants for which a detailed methodology exists, based on specific emission factors and covering different traffic situations and engine conditions. The pollutants included in this group are given in Table 3-2.

Group 2: Emissions dependent on fuel consumption. Fuel consumption is calculated with specific consumption factors and calculations are of the same quality as of pollutants of Group 1. Emissions of pollutants of this Group are produced as a fraction of fuel consumption. These substances are quoted in Table 3-3.

Group 3: Pollutants for which a simplified methodology is applied mainly due to the absence of detailed data. This Group contains the pollutants given in Table 3-4.

Group 4: NMVOC profiles which are derived as a fraction of total NMVOC emissions. A small fraction of NMVOC remaining is considered to be PAHs. Speciation includes the categories given in Table 3-5.

Table 3-2: Pollutants included in Group 1 and methodology equivalencies

Pollutant	**Equivalent**
Carbon Monoxide (CO)	Given as CO
Nitrogen Oxides (NO_x: NO and NO_2)	Given as NO_2 equivalent
Volatile Organic Compounds (VOC)	Given as $CH_{1,85}$ equivalent (Also given as HC in emission standards)
Methane (CH_4)	Given as CH_4
Non Methane VOC (NMVOC)	Given as the remainder of VOC minus CH_4
Nitrous Oxide (N_2O)	Given as N_2O
Ammonia (NH_3)	Given as NH_3
Particulate Matter (PM)	Given as the mass of collected on a filter below 52°C in CVS-type of measurements. This corresponds to $PM_{2.5}$. Coarse exhaust PM is considered negligible, hence $PM_{2.5}$=PM_{10}.
PM Number and Surface	Given as particle number and particle active surface per kilometer, respectively

Table 3-3: Pollutants included in Group 2 and methodology equivalencies

Pollutant	**Equivalent**
Carbon Dioxide (CO_2)	Given as CO_2
Sulphur Dioxide (SO_2)	Given as SO_2
Lead (Pb)	Given as Pb
Cadmium (Cd)	Given as Cd
Chromium (Cr)	Given as Cr
Copper (Cu)	Given as Cu
Nickel (Ni)	Given as Ni
Selenium (Se)	Given as Se
Zinc (Zn)	Given as Zn

Table 3-4: Pollutants included in Group 3 and methodology equivalencies

Pollutant	**Equivalent**
Polyaromatic Hydrocarbons (PAHs) and Persistent Organic Pollutants (POPs)	Detailed speciation including indeno(1,2,3-cd)pyrene, benzo(k)fluoranthene, benzo(b)fluoranthene, benzo(ghi)perylene, fluoranthene, benzo(a)pyrene
Polychlorinated Dibenzo Dioxins (PCDDs) and Polychlorinated Dibenzo Furans (PCDFs)	Given as Dioxins and Furans respectively

Table 3-5: Pollutants included in Group 4 and methodology equivalencies

Pollutant	**Equivalent**
Alkanes (C_nH_{2n+2}):	Given in Alkanes speciation
Alkenes (C_nH_{2n}):	Given in Alkenes speciation
Alkines (C_nH_{2n-2}):	Given in Alkines speciation
Aldehydes ($C_nH_{2n}O$)	Given in Aldehydes speciation
Ketones ($C_nH_{2n}O$)	Given in Ketones speciation
Cycloalkanes (C_nH_{2n})	Given as Cycloalkanes
Aromatics	Given in Aromatics speciation

3.5 Controls

The control of emissions from vehicles has been the target of relevant European legislation since the 70s. In order to fulfil those requirements, vehicle manufacturers have been improving the technology of their engines and introducing emission control systems. As a result, today's vehicles are more than an order of magnitude cleaner than vehicles two decades ago as regards conventional pollutants (CO, NO_x, VOC). Emission legislation becomes increasingly stringent and, as a result, further improvement of the emission levels are being established.

The classification of vehicles according to their emission control technologies is made on the basis of the legislation they comply with which, by turn, consists a critical point in the application of the present methodology. The following paragraphs discuss the relevant legislation for each vehicle category.

3.5.1 Legislation classes of gasoline passenger cars

The production year of vehicles in this category has been taken into account by introducing different classes, which either reflect legislative steps (ECE, Euro) or technology steps ("Improved Conventional", "Open Loop").

From 1970 and until 1985 all EC member states followed the UN ECE R15 (United Nations Economic Committee for Europe Regulation 15) amendments as regards the emissions of pollutants from vehicles lighter than 3.5 tonnes (gross vehicle weight – GVW). According to the relevant EC Directives, the implementation dates of these regulations were as follows:

pre ECE vehicles	up to 1971
ECE 15 00 & 01	1972 to 1977
ECE 15 02	1978 to 1980
ECE 15 03	1981 to 1985
ECE 15 04	1985 to 1992

The above implementation dates correspond to an "average" for the EU 15 member states. They are different from one member state to another as the directives had to be ratified by the national parliaments. Even more important, these regulations were applicable on the vehicles registered in the member state - either produced in the member state or imported from elsewhere in the world.

After 1985, new technologies appeared, imposed by the EC legislation and national schemes applying to vehicles <2.5 t. Those technologies are described in the following paragraphs.

<u>Gasoline Passenger Cars <1.4l</u>

a. Improved Conventional: It takes into account German and Dutch incentive programmes:

Anl.XXIVC (relevant for Germany). Effective date: 1.7.1985

NLG 850 (relevant for the Netherlands). Effective date: 1.1.1986

It is assumed that the required emission standards can be met by applying improved but conventional engine technology, that is without the use of a catalytic converter. This type of emission control technology also started to appear in Denmark from 1.1.1988.

b. Open Loop: It takes into account German, Danish, Greek and Dutch incentive programmes. It is assumed that the required emission standards can be met by applying open loop three way catalysts. Effective dates: Denmark 1.1.1989, Germany 1.7.1985, Greece 1.1.1990, the Netherlands 1.1.1987.

c. Euro I: As early Euro I vehicles are considered those complying to (e.g. voluntary programmes in Germany carried out after 1.7.1985), where compliance with US 83 limits is required. However, directive 91/441/EEC introduced this emission standard at a European level for all vehicles introduced in the market for the period 1992 to 1996. This was also the first emission legislation which required unleaded fuel use.

<u>Gasoline Passenger Cars 1.4-2.0 l</u>

a. Improved conventional. It takes into account vehicles which meet the limit values of Directive 88/76/EEC by means of open loop catalysts. In practice, relevant only for national incentive programmes. Effective dates of implementation are: Denmark 1.1.1987, Germany 1.7.1985, the Netherlands 1.1.1987.

b. Open Loop. It takes into account vehicles which meet the limit values of Directive 88/76/EEC by means of open loop catalysts (three-way but no lambda controlled catalytic converters). In practice relevant only to the national incentive programmes. Effective dates of implementation are: Denmark 1.1.1987, Germany 1.7.1985, Greece 1.1.1990, the Netherlands 1.1.1986.

c. Euro I: Similar to < 1.4 l, It takes into account national incentive programmes where compliance with US 83 limits is required. However, directive 91/441/EEC introduced this emission standard for all vehicles sold between 1992 and 1996. The use of unleaded fuel was mandatory.

<u>Gasoline Passenger Cars >2.0 l</u>
a. Euro I. It takes into account EC legislation and national incentive programmes:
88/76/EEC (relevant for all countries). Effective date for new vehicles: 1.1.1990. US 83 (only relevant for Denmark, Germany, Greece, the Netherlands). Effective date: Denmark 1.1.1987, Germany 1.7.1985, Greece 1.1.1989, the Netherlands 1.1.1987. It is assumed that the required emission standards can be met by applying closed loop three way catalysts. Directive 91/441/EEC introduced this emission standard for all vehicles launched in the market between 1992 and 1996.

<u>Recent, current and future legislation steps</u>
After Euro I emission standards, all member states adopted directive 94/12/EC (Euro II) for type approval in the period 1996 - 2000. Compared to 91/441/EEC, 94/12/EC imposed a 30% and 55% reduction in CO and HC+NOx respectively, while the Euro III step (Directive 98/69/EC implemented in 2000) imposed reductions of 30%, 40% and 40%, respectively, for CO, HC and NO_x over Euro II. The current Euro IV regulation (Directive 98/69/EC Stage 2005) brought an additional reduction of 57% for CO and 47% for HC and NO_x. Such reductions bring emission levels of 2005 vehicles to the 1/5 of what it used to be in 1995. This is achieved with the use of closed-loop three way catalytic converters and additional measures such as installation of oxidation pre-catalysts, accurate control of the lambda value, use of on-board diagnostics systems and even the installation of NO_x-storage systems. Recently (Dec. 2005) a following regulatory step was announced (Euro V – COM(2005)683) which will target an additional 25% reduction of NO_x and HC for gasoline cars, compared to Euro IV. No gasoline Euro V vehicles have been available in Europe while this chapter was in preparation. However, it could be expected that the actual emission factors of this new technology will also be ~25% less than the Euro IV (similar to their emission standard) because a similar technology between Euro IV and Euro V is expected.

3.5.2 Legislation classes of diesel passenger cars

<u>Conventional vehicles</u>
The "Conventional" vehicle class applies to diesel passenger cars of all capacities and includes vehicles prior to the introduction of the "Consolidated Emissions Directive" 91/441/EEC. Therefore, cases included are non regulated vehicles launched prior to 1985 and vehicles complying with directive ECE 15/04 (up to 1992). In principle diesel vehicles of this class are equipped with indirect injection engines and no exhaust aftertreatment.

<u>Current and future diesel technologies</u>
Improved diesel technologies include vehicles complying with directives 91/441/EEC (Euro I, 1992-1996), 94/12/EC (Euro II, valid from 1996 for indirect injection and 1997 for direct injection up to 2000), regulation 98/69/EC Stage 2000 (Euro III), and the current regulation 98/69/EC Stage 2005 (Euro IV). Euro I were the first vehicles to be regulated for all four main pollutants CO, HC+NOx and PM. Few of those vehicles were equipped with oxidation catalysts. Directive 94/12/EC brought reductions over the former Directive of 68% for CO, 38% for HC+NOx and 55% for PM and oxidation catalysts were used in almost all vehicles. Euro III vehicles targeted an additional 40%, 60%, 14% and 37.5% less CO, NOx, HCs and PM than Euro II vehicles. The significant reductions were achieved with exhaust gas recirculation (NO_x reduction) and optimisation of fuel injection with use of common rail

systems (PM reduction). Also fuel refinements (mainly sulphur content reduction) played an important role in PM emission improvement. In addition, due to national incentives and manufacturers' competition, some Euro III vehicles were equipped with original diesel particle filters to reduce the PM emissions to levels much below the emission standard. Therefore, a special PM emission factor needs to be provided for these vehicles. The current Euro IV vehicles further improve emission levels by 22% on CO and 50% to all other pollutants. Further to the voluntary introduction of the particle filter to some vehicles, such significant reductions have been made possible with advanced engine technology and aftertreatment measures, such as cooled EGRs, and NOx reduction - PM oxidation techniques. As in the case of gasoline vehicles, a Euro V proposal is currently in consideration, which calls for 25% reduction in NOx and 80% reduction in PM over Euro IV. Such low levels are expected to become reachable only with the mandatory use of a diesel particle filter.

3.5.3 Legislation classes of LPG passenger cars

LPG vehicles constitute a small and constantly decreasing fraction of the European fleet. Legislation classes provided for LPG passenger cars, as in the case of diesel passenger ones, include a "Conventional" class where vehicles up to 91/441/EEC are grouped together. After this, legislation classes are introduced according to the Directives as adopted in the case of gasoline and diesel passenger cars.

3.5.4 Legislation classes of 2-stroke passenger cars

This type of vehicles is relevant mainly for some Eastern European countries (and to some extent for Germany). A very limited fleet of such vehicles is still in circulation and no particular emission standards are applicable. Therefore all such vehicles are grouped in a common "Conventional" class.

3.5.5 Legislation classes of gasoline light duty vehicles <3.5 t

In EU, the emissions of these vehicles were covered by the different ECE steps up to 1993 and all such vehicles are covered by the term "Conventional". From 1993 to 1997 new emission standards have been applied (Euro I - Directive 93/59/EEC), which ask for catalytic converters on gasoline powered vehicles. Directive 96/69/EC (Euro II) introduced stricter emission standards for light duty trucks in 1997 and was valid up to 2001. Two more legislation steps have been introduced since then, namely Euro III - 98/69/EC (valid 2001-2006) and Euro IV - 98/69/EC (valid 2006 onwards) which introduce even stricter emission standards. Finally, the Euro V proposal of passenger cars covers this vehicle category as well, with somehow differentiated emission standards. It is expected that the emission control technology of light duty vehicles generally follows the technology of passenger cars with a delay of 1-2 years.

3.5.6 Legislation classes of diesel light duty vehicles <3.5 t

Legislation classes valid for gasoline light duty vehicles are also applicable in the case of diesel ones (with different emission standards level plus PM emission standard). In general, engine technology of diesel light duty vehicles follows the one of respective diesel passenger cars with 1-2 years delay.

3.5.7 Legislation classes of gasoline heavy duty vehicles >3.5 t

Heavy duty gasoline vehicles >3.5 t play a negligible role in European emissions from road traffic. Any such vehicles are included in the "Conventional" class without further distinction to legislation steps because no specific emission standards have been set for such vehicles.

3.5.8 Legislation classes of diesel heavy duty vehicles >3.5 t

Emissions from diesel engines used in vehicles of gross weight over 3.5 t were first regulated in 1988 with the introduction of the original ECE 49 Regulation. Vehicles (or, better, engines) complying with ECE 49 and earlier are all classified as "Conventional". Directive 91/542/EEC, implemented in two stages, brought two standards of reduced emission limits valid from 1992 to 1995 (Stage 1) and 1996 up to 2000 (Stage 2). Directive 1999/96/EC Step 1 (Euro III) was valid since 2000 and introduced a 30% reduction of all pollutants over the Euro II case. The same directive included an intermediate step in 2005 (Euro IV) and a final step in 2008 (Euro V). Standards for 2008 are very strict, targeting an over 70% reduction of NOx and over 85% decrease of PM compared to 1996 standards.

3.5.9 Legislation classes for 2 stroke mopeds <50 cm³

No EU-wide emission standards were agreed until lately for emissions of two wheelers but only national legislation was valid in a few countries. In June 1999, multi-directive 97/24/EC (Step 1 – Euro I) introduced emission standards, which for the case of two-stroke mopeds <50cm³, were applied to CO (6 g/km) and HC+NO_x (3 g/km). An additional stage of the legislation came into force in June 2002 (Euro II) with emission levels of 1 g/km CO and 1.2 g/km HC+NO_x. New Euro 3 emission standards for such small vehicles are currently under preparation in the European Commission to be proposed to the European Council, which will not introduce arithmetic differences to the Euro II emission step, but will introduce a certification test initiated from ambient temperature conditions (as opposed to hot engine start currently in the regulations). Due to the very strict emission limits, it is expected that very few 2-stroke mopeds will be available after the new step becomes mandatory (possibly 2008) and those that will conform with the regulations will need to be equipped with precise air-fuel metering devices, possible direct injection and secondary air injection in the exhaust line.

3.5.10 Legislation classes for 2-stroke and 4-stroke motorcycles >50 cm³

Emissions from two and four stroke motorcycles >50 cm³ were first introduced in June 1999 (Euro 1) when directive 97/24/EC came into force. The directive imposes different emission standards for two and four stroke vehicles respectively, and separate limits are set for HC and NO_x to allow for a better distinction in the different technologies (2-stroke : CO 8 g/km, HC 4 g/km, NO_x 0.1 g/km; 4-stroke : CO 13 g/km, HC 3 g/km, NO_x 0.3 g/km). In 2002, regulation 2002/51/EC introduced the Euro 2 (2003) and the Euro 3 (2006) steps for motorcycles with differentiated emission standards depending on the engine size. No other emission standards have been planned for the future. However, it is soon expected that the World Motorcycle Test Cycle (WMTC) will be used worldwide as a certification test and this may bring some changes in the emission standards.

3.5.11 Future emission standards

At present, there are only discussions how future emission standards (post Euro V) should formulate and whether current form of measuring and controlling emissions will be applicable for the very low emission levels of future vehicles. Hence, the discussion is mainly widened in scope to include parameters such as emission levels durability, on-board diagnostics and measurement systems and alternative fuels production. The discussion is expected to generate useful results after 2008 when the efficiency of present measures to relax environmental pressures will have been examined.

3.5.12 Summary of vehicle technologies / control measures utilised

Table 3-6 provides a summary of all vehicle categories and technologies (emission standards) covered by the present methodology.

Table 3-6: Summary of all vehicle classes covered by the methodology

<table>
<tr><th>Vehicle Type</th><th>Class</th><th>Legislation</th></tr>
<tr><td rowspan="8">Passenger Cars</td><td>Gasoline
<1.4l</td><td rowspan="3">PRE ECE
ECE 15/00-01
ECE 15/02
ECE 15/03
ECE 15/04
Improved Conventional
Open Loop
Euro I - 91/441/EEC
Euro II - 94/12/EC
Euro III - 98/69/EC Stage 2000
Euro IV - 98/69/EC Stage 2005</td></tr>
<tr><td>Gasoline
1.4 - 2.0l</td></tr>
<tr><td>Gasoline
>2.0l</td></tr>
<tr><td>Diesel
<2.0l</td><td rowspan="2">Conventional
Euro I - 91/441/EEC
Euro II - 94/12/EC
Euro III - 98/69/EC Stage 2000
Euro IV - 98/69/EC Stage 2005</td></tr>
<tr><td>Diesel
>2.0l</td></tr>
<tr><td>LPG</td><td>Conventional
Euro I - 91/441/EEC
Euro II - 94/12/EC
Euro III - 98/69/EC Stage 2000
Euro IV - 98/69/EC Stage 2005</td></tr>
<tr><td>2 Stroke</td><td>Conventional</td></tr>
<tr><td>Hybrids <1.6l</td><td>Euro IV - 98/69/EC Stage 2005</td></tr>
</table>

table continues in next page

Table 3-6(cont.): Summary of all vehicle classes covered by the methodology

Vehicle Type	Class	Legislation
Light Duty	Gasoline	Conventional

Vehicles	<3.5t	Euro I - 93/59/EEC Euro II - 96/69/EC Euro III - 98/69/EC Stage 2000 Euro IV - 98/69/EC Stage 2005
	Diesel <3.5t	Conventional Euro I - 93/59/EEC Euro II - 96/69/EC Euro III - 98/69/EC Stage 2000 Euro IV - 98/69/EC Stage 2005
Heavy Duty Vehicles	Gasoline >3.5t	Conventional
	Rigid <=7.5t	Conventional Euro I - 91/542/EEC Stage I Euro II - 91/542/EEC Stage II Euro III - 1999/96/EC Stage I Euro IV – 1999/96/EC Stage II Euro V – 1999/96/EC Stage III
	Rigid 7.5-12t	
	Rigid 12-14t	
	Rigid 14-20t	
	Rigid 20-26t	
	Rigid 26-28t	
	Rigid 28-32t	
	Rigid >32t	
	Articulated 14-20t	
	Articulated 20-28t	
	Articulated 28-34t	
	Articulated 34-40t	
	Articulated 40-50t	
	Articulated 50-60t	
Buses	Urban <=15t	Conventional Euro I - 91/542/EEC Stage I Euro II - 91/542/EEC Stage II Euro III - 1999/96/EC Stage I Euro IV – 1999/96/EC Stage II Euro V – 1999/96/EC Stage III
	Urban 15-18t	
	Urban >18t	
	Coaches standard <=18t	
	Coaches articulated >18t	
Mopeds	<50cm^3	Conventional 97/24/EC Stage I 97/24/EC Stage II Euro III proposal
Motorcycles	2 Stroke >50cm^3	Conventional
	4 stroke 50 - 250cm^3	97/24/EC
	4 stroke 250 - 750cm^3	2002/51/EC Stage I
	4 stroke >750cm^3	2002/51/EC Stage II

Due to the technological developments that occurred for heavy duty engines, but also their use in a wide range of vehicle types, in order to cover as many uses as possible, a more detailed classification of Heavy Duty Vehicles and Busses is required, than the one presented in Table 1-2. Table 3-6 includes this new categorization. In order however not to deviate with the CORINAIR classification, Figure 3-1 shows the correspondence of the more detailed HDV classes with the old ones.

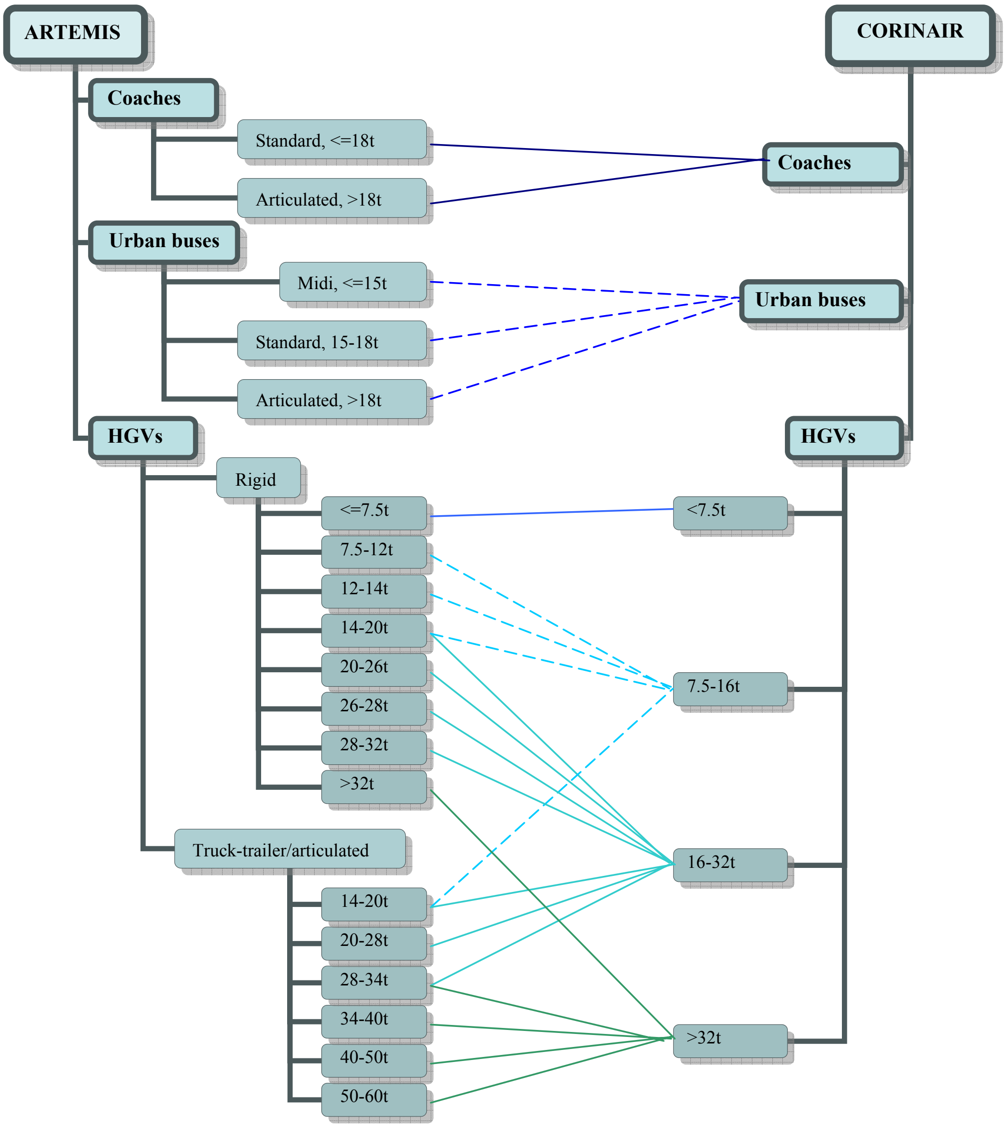

Figure 3-1: Correspondence between the CORINAIR and new HDV and Bus categorization, adopted in the framework of the ARTEMIS (2006) project

4 SIMPLER METHODOLOGY

The methodology proposed in the following paragraphs is actually the application of the detailed methodology presented in next section at a national level (NUTS 0), followed by derivation of relevant emission factors. This means that we have a-priori introduced a large number of data and estimates required to apply the methodology for calculating emissions and we have come up with aggregated emission factors.

Based on this approach, total emission estimates for a country can be calculated using the simple equation:

$$E_{i,j} = \Sigma_j(FC_j \times EF_{i,j}) \quad (1)$$

where,
$E_{i,j}$: emission of pollutant i from vehicles of category j [g pollutant],
FC_j : fuel consumption of vehicle category j [kg fuel],
$EF_{i,j}$: fuel consumption specific emission factor of pollutant i for vehicle category j [g/kg fuel].

In principle, any energy consumption related figure can substitute FC_j value. One may choose to use total vehicle-kilometres or passenger-kilometres, etc. However, we have chosen fuel consumption because it is a widely reported figure and one, which even the occasional user of the methodology has a perception of. Also, we propose to lump vehicle categories of Table 1-2 to come up with simplified emission factors. The split adopted is seen in Table 4-1 together with the range of SNAP-like codes included in each vehicle category j. The simplified methodology does not deal with LPGs, 2-stroke and gasoline heavy-duty vehicles because of their small contribution to a national inventory.

Table 4-1: Vehicle categories for application of the simplified methodology and respective SNAP-like ranges from Table 1-2.

Vehicle category - j	SNAP-like code ranges included from Table 1-2
Gasoline passenger cars <2.5 t	07 01 01 01 – 07 01 03 03
Diesel passenger cars <2.5 t	07 01 04 01 – 07 01 05 03
Gasoline light duty vehicles <3.5 t	07 02 01 01 – 07 02 01 03
Diesel light duty vehicles <3.5 t	07 02 02 01 – 07 02 02 03
Diesel heavy duty vehicles >7.5 t	07 03 02 01 – 07 03 05 03
Buses	07 03 06 00
Coaches	07 03 07 01 – 07 03 07 03
Powered two-wheeled vehicles	07 04 01 00 – 07 05 05 03

Table 4-2 to Table 4-16 provide fuel consumption specific emission factors for main pollutants and for each EU-15 country and countries classified as CC4, BC and NIS. These emission factors should be combined with fuel consumption for specific vehicle category to provide total emission estimates. In particular for CO_2, the emission factor corresponds to the end-of-pipe and not ultimate CO_2 emissions. For definition and conversion between the two, please refer to section 5.6.1. The emission factor production is based on a large number of assumptions concerning vehicle technology mix (e.g. share of passenger cars to different ECE and Euro standards), driving conditions (travelling speeds, etc.) and even climatic conditions (temperature). Such assumptions as well as the methodology to produce vehicle fleet compositions is described in detail in relevant literature (e.g. Zachariadis et al., 2001). There are a number of clarifications which need to be made for the relevance and range of application of those emission factors (most of these shortcomings are thoroughly discussed by Ntziachristos et. al. (2002):

- They have not been calculated on the basis of national submitted data but following a uniform methodology across all countries. Hence, combination with the activity data proposed also in this report (section 6) should not be expected to necessarily provide consistent results with the official data presented in Table 2-1.
- They correspond to a fleet composition estimated for year 2002. Their accuracy deteriorates as time distance increases from this point because new technologies appear and the contribution of older technologies decreases.
- They correspond to national-wide applications including mixed conditions driving (urban congestion to free flow highway).

Their range of application can cover:

- Simplified inventories where rough estimates of the road transport contribution are required.
- Calculation of emissions when a particular vehicle type is artificially promoted or discouraged from circulation (e.g. dieselisation, 2-wheelers promotions in urban areas, etc).
- Demonstrations of the emission reduction potential when shifting the balance with other modes of transport

Table 4-2: Bulk emission factors (g/kg fuel) for Austria, year 2002.

Category	Austria					
	CO	NOx	NMVOC	CH_4	PM	CO_2 [kg/kg fuel]
Gasoline PC	131.64	10.69	9.61	1.68	0.00	2.94
Diesel PC	7.98	11.80	1.82	0.14	2.36	3.12
Gasoline LDV	257.94	20.36	24.70	1.18	0.00	2.70
Diesel LDV	12.17	18.67	2.03	0.08	3.45	3.11
Diesel HDV	7.27	28.69	3.68	0.27	1.76	3.11
Buses	14.15	43.72	4.44	0.42	1.93	3.10
Coaches	7.39	32.98	3.95	0.32	1.54	3.11
Mopeds	500.80	1.20	310.80	7.60	0.00	1.38
Motrocycles	628.75	5.46	94.33	5.76	0.00	1.88

Table 4-3: Bulk emission factors (g/kg fuel) for Belgium, year 2002.

Category	Belgium					
	CO	NOx	NMVOC	CH4	PM	CO_2 [kg/kg fuel]
Gasoline PC	109.37	6.81	7.86	1.31	0.00	3.01
Diesel PC	9.24	12.84	1.77	0.13	1.86	3.12
Gasoline LDV	202.93	18.27	20.75	0.99	0.00	2.78
Diesel LDV	10.77	16.87	1.81	0.07	2.93	3.11
Diesel HDV	7.72	19.14	4.51	0.18	1.44	3.10
Buses	13.65	42.53	4.36	0.42	1.87	3.10
Coaches	7.17	31.95	3.87	0.31	0.00	3.11
Mopeds	535.60	1.20	328.00	8.00	0.00	1.27
Motorcycles	636.64	6.37	56.72	6.07	0.00	2.00

Table 4-4: Bulk emission factors (g/kg fuel) for Denmark, year 2002.

Category	Denmark					
	CO	NOx	NMVOC	CH4	PM	CO_2 [kg/kg fuel]
Gasoline PC	116.72	11.47	13.13	1.50	0.00	2.93
Diesel PC	7.06	11.07	1.62	0.12	1.94	3.12
Gasoline LDV	226.08	15.50	22.11	1.14	0.00	2.79
Diesel LDV	10.45	18.33	2.03	0.08	2.76	3.11
Diesel HDV	7.21	24.29	4.03	0.25	1.56	3.11
Buses	10.79	36.02	3.93	0.38	1.52	3.11
Coaches	6.13	26.07	3.38	0.28	1.14	3.12
Mopeds	306.80	0.84	210.00	5.20	0.00	2.02
Motorcycles	470.12	6.07	80.98	5.76	0.00	2.10

Table 4-5: Bulk emission factors (g/kg fuel) for Finland, year 2002.

Category	Finland					
	CO	NOx	NMVOC	CH_4	PM	CO_2 [kg/kg fuel]
Gasoline PC	138.78	12.99	12.20	1.41	0.00	2.92
Diesel PC	7.93	12.05	1.90	0.14	2.41	3.12
Gasoline LDV	219.47	18.54	22.74	1.05	0.00	2.76
Diesel LDV	11.53	18.74	2.10	0.08	3.31	3.11
Diesel HDV	10.63	27.37	6.33	0.27	2.17	3.10
Buses	13.63	42.52	4.36	0.42	1.87	3.10
Coaches	7.20	31.92	3.86	0.31	1.47	3.11
Mopeds	273.60	0.80	188.00	4.40	0.00	2.14
Motorcycles	542.80	4.76	142.66	5.77	0.00	1.86

Table 4-6: Bulk emission factors (g/kg fuel) for France, year 2002.

Category	France					
	CO	NOx	NMVOC	CH4	PM	CO_2 [kg/kg fuel]
Gasoline PC	146.75	13.01	17.31	1.66	0.00	2.93
Diesel PC	9.27	12.57	1.99	0.13	2.16	3.12
Gasoline LDV	267.54	18.87	30.11	1.31	0.00	2.72
Diesel LDV	12.81	20.87	2.19	0.08	3.38	3.11
Diesel HDV	11.25	24.32	6.78	0.26	1.97	3.09
Buses	12.94	40.84	4.25	0.41	1.78	3.10
Coaches	6.93	30.46	3.74	0.30	1.39	3.11
Mopeds	289.60	0.80	199.60	4.80	0.00	2.08
Motorcycles	486.41	7.47	69.63	6.79	0.00	2.23

Table 4-7: Bulk emission factors (g/kg fuel) for Germany, year 2002.

Category	Germany					
	CO	NOx	NMVOC	CH4	PM	CO_2 [kg/kg fuel]
Gasoline PC	190.86	11.76	13.54	2.29	0.00	2.90
Diesel PC	9.76	13.95	2.32	0.19	3.14	3.12
Gasoline LDV	257.77	24.03	22.12	1.52	0.00	2.69
Diesel LDV	13.82	18.87	2.40	0.10	4.60	3.11
Diesel HDV	10.99	23.81	6.54	0.24	1.99	3.09
Buses	14.36	44.37	4.48	0.43	1.97	3.10
Coaches	7.47	33.47	3.99	0.32	1.57	3.11
Mopeds	569.60	1.20	344.00	8.80	0.00	1.17
Motorcycles	750.34	7.13	62.50	6.79	0.00	1.97

Table 4-8: Bulk emission factors (g/kg fuel) for Greece, year 2002.

Category	Greece					
	CO	NOx	NMVOC	CH4	PM	CO_2 [kg/kg fuel]
Gasoline PC	172.92	14.51	23.91	1.33	0.00	2.83
Diesel PC	11.46	11.43	2.53	0.08	2.56	3.11
Gasoline LDV	216.89	21.38	28.92	1.00	0.00	2.75
Diesel LDV	11.97	20.24	1.62	0.06	2.90	3.11
Diesel HDV	9.69	30.04	5.27	0.28	2.18	3.10
Buses	13.16	41.61	4.30	0.41	1.82	3.10
Coaches	7.02	30.98	3.79	0.31	1.43	3.11
Mopeds	438.80	1.20	280.40	6.80	0.00	1.58
Motorcycles	585.22	5.90	98.42	5.90	0.00	1.93

Table 4-9: Bulk emission factors (g/kg fuel) for Ireland, year 2002.

Category	Ireland					
	CO	NOx	NMVOC	CH4	PM	CO_2 [kg/kg fuel]
Gasoline PC	115.53	11.63	18.20	1.14	0.00	2.91
Diesel PC	6.25	8.59	1.36	0.08	1.46	3.12
Gasoline LDV	224.34	19.64	29.04	1.03	0.00	2.73
Diesel LDV	11.30	18.40	1.82	0.07	3.03	3.11
Diesel HDV	7.81	25.31	4.05	0.24	1.62	3.11
Buses	12.91	41.00	4.26	0.41	1.79	3.10
Coaches	6.93	30.46	3.74	0.30	1.40	3.11
Mopeds	337.60	0.80	231.20	5.20	0.00	1.90
Motorcycles	476.56	7.14	56.50	6.21	0.00	2.22

Table 4-10: Bulk emission factors (g/kg fuel) for Italy, year 2002.

Category	Italy					
	CO	NOx	NMVOC	CH4	PM	CO_2 [kg/kg fuel]
Gasoline PC	155.50	13.77	18.97	1.32	0.00	2.86
Diesel PC	6.27	9.16	1.35	0.11	1.77	3.12
Gasoline LDV	225.26	18.46	23.45	1.03	0.00	2.76
Diesel LDV	11.13	18.18	1.79	0.07	2.90	3.11
Diesel HDV	8.72	22.59	5.02	0.23	1.64	3.10
Buses	12.83	40.67	4.24	0.41	1.77	3.10
Coaches	6.90	30.26	3.73	0.30	1.38	3.11
Mopeds	456.00	1.04	286.00	7.20	0.00	1.54
Motorcycles	573.73	6.83	54.64	6.21	0.00	2.11

Table 4-11: Bulk emission factors (g/kg fuel) for Luxembourg, year 2002.

Category	Luxembourg					
	CO	NOx	NMVOC	CH_4	PM	CO_2 [kg/kg fuel]
Gasoline PC	120.39	3.70	6.21	1.45	0.00	2.97
Diesel PC	7.33	11.41	1.77	0.14	1.55	3.12
Gasoline LDV	208.28	22.85	18.59	1.39	0.00	2.79
Diesel LDV	11.78	15.80	2.30	0.11	4.00	3.11
Diesel HDV	8.46	25.25	4.63	0.24	1.65	3.11
Buses	11.50	37.59	4.04	0.39	1.60	3.11
Coaches	6.40	27.52	3.50	0.28	1.22	3.12
Mopeds	375.20	0.80	241.60	6.00	0.00	1.81
Motorcycles	597.79	4.56	152.62	5.56	0.00	1.74

Table 4-12: Bulk emission factors (g/kg fuel) for Netherlands, year 2002.

Category	Netherlands					
	CO	NOx	NMVOC	CH4	PM	CO_2 [kg/kg fuel]
Gasoline PC	155.82	7.37	10.65	2.01	0.00	2.92
Diesel PC	11.74	13.88	2.93	0.16	3.13	3.11
Gasoline LDV	315.75	18.49	23.72	1.63	0.00	2.73
Diesel LDV	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Diesel HDV	8.60	27.42	4.87	0.26	1.84	3.11
Buses	10.85	36.19	3.94	0.38	1.53	3.11
Coaches	6.15	26.19	3.39	0.28	1.15	3.12
Mopeds	376.80	1.20	231.20	5.60	0.00	1.84
Motorcycles	508.95	6.83	71.59	6.18	0.00	2.15

Table 4-13: Bulk emission factors (g/kg fuel) for Portugal, year 2002.

Category	Portugal					
	CO	NOx	NMVOC	CH4	PM	CO_2 [kg/kg fuel]
Gasoline PC	165.17	11.51	16.09	1.86	0.00	2.85
Diesel PC	8.68	11.69	2.43	0.15	2.66	3.12
Gasoline LDV	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Diesel LDV	14.02	16.92	2.56	0.11	4.68	3.11
Diesel HDV	10.24	20.38	5.95	0.20	1.74	3.09
Buses	12.92	41.01	4.26	0.41	1.79	3.10
Coaches	6.93	30.48	3.75	0.30	1.40	3.11
Mopeds	422.40	1.04	259.60	6.40	0.00	1.67
Motorcycles	613.08	4.07	168.56	5.53	0.00	1.66

Table 4-14: Bulk emission factors (g/kg fuel) for Spain, year 2002.

Category	Spain					
	CO	NOx	NMVOC	CH_4	PM	CO_2 [kg/kg fuel]
Gasoline PC	220.75	13.01	22.12	2.01	0.00	2.76
Diesel PC	12.60	12.17	3.32	0.12	3.38	3.11
Gasoline LDV	301.60	16.83	24.86	1.37	0.00	2.63
Diesel LDV	11.82	22.23	2.39	0.08	3.29	3.11
Diesel HDV	10.99	26.58	6.55	0.28	2.02	3.10
Buses	13.31	41.80	4.31	0.41	1.83	3.10
Coaches	7.08	31.25	3.81	0.31	1.44	3.11
Mopeds	357.20	1.20	220.40	5.60	0.00	1.90
Motorcycles	592.76	3.76	178.00	5.81	0.00	1.67

Table 4-15: Bulk emission factors (g/kg fuel) for Sweden, year 2002.

Category	Sweden					
	CO	NOx	NMVOC	CH4	PM	CO_2 [kg/kg fuel]
Gasoline PC	175.65	10.89	16.01	2.12	0.00	2.89
Diesel PC	8.90	10.43	2.34	0.12	2.65	3.11
Gasoline LDV	269.36	17.72	24.40	1.27	0.00	2.65
Diesel LDV	10.81	16.54	2.09	0.08	3.37	3.11
Diesel HDV	10.26	27.66	5.89	0.26	2.07	3.10
Buses	14.04	43.30	4.42	0.42	1.91	3.10
Coaches	7.35	32.72	3.92	0.32	1.51	3.11
Mopeds	418.00	0.80	264.80	6.40	0.00	1.66
Motorcycles	604.37	7.52	54.32	6.83	0.00	2.15

Table 4-16: Bulk emission factors (g/kg fuel) for UK, year 2002.

Category	UK					
	CO	NOx	NMVOC	CH4	PM	CO_2 [kg/kg fuel]
Gasoline PC	167.87	9.44	15.78	1.85	0.00	2.90
Diesel PC	9.02	10.72	2.18	0.13	2.34	3.11
Gasoline LDV	212.31	11.12	17.07	1.22	0.00	2.80
Diesel LDV	8.92	15.55	2.11	0.08	2.57	3.11
Diesel HDV	8.47	25.70	5.17	0.25	1.74	3.11
Buses	9.63	33.37	3.76	0.36	1.38	3.11
Coaches	5.70	23.68	3.19	0.26	1.00	3.12
Mopeds	274.80	0.80	193.60	4.80	0.00	2.12
Motorcycles	482.75	7.52	77.55	6.49	0.00	2.21

Table 4-17: Suggested bulk emission factors (g/kg fuel) for BC, NIS and CC4 countries, year 2002.

Category	BC, NIS and CC4 countries					
	CO	NOx	NMVOC	CH4	PM	CO2 [kg/kg fuel]
Gasoline PC	221.70	28.39	34.41	1.99	0.00	2.72
Diesel PC	12.66	11.68	3.73	0.12	4.95	3.09
Gasoline LDV	305.63	26.58	32.61	1.51	0.00	2.59
Diesel LDV	15.94	20.06	2.08	0.08	4.67	3.09
Diesel HDV	11.54	38.34	6.05	0.34	2.64	3.09
Buses	15.71	49.18	4.13	0.51	2.15	3.09
Coaches	10.61	42.02	5.75	0.44	2.24	3.09
Mopeds	600.00	1.20	357.70	8.76	0.00	1.07
Motorcycles	691.76	4.82	114.71	5.26	0.00	1.71

5 DETAILED METHODOLOGY

Total emission estimates are calculated with combination of firm technical data (e.g. emission factors) and activity data (e.g. total vehicle kilometres). All technical data depend on control variables which may be tuned, to provide an accurate estimate depending on the type of application of the methodology.

5.1 Types of emission

In principle, total emissions are calculated by summing emissions from three different sources, namely the thermally stabilised engine operation (hot), the warming-up phase (cold start) and due to evaporation. Evaporation is dealt with in the next chapter. It is also clarified that the word "engine" is used in place of the actual "engine and any exhaust aftertreatment devices". Distinction in emissions during the stabilised and warming-up phase is necessary because of the substantial difference in vehicle emission performance during those two conditions. Concentrations of most pollutants during the warming-up period are many times higher than during hot operation and a different methodological approach is required to estimate over-emissions during this period. In that respect, total emissions can be calculated by means of the equation:

$$E_{TOTAL} = E_{HOT} + E_{COLD} \qquad (2)$$

where,

E_{TOTAL}: total emissions (g) of any pollutant for the spatial and temporal resolution of the application,

E_{HOT}: emissions (g) during stabilised (hot) engine operation,

E_{COLD}: emissions (g) during transient thermal engine operation (cold start).

5.2 Emissions under different driving conditions

Vehicle emissions are heavily dependent on the engine operation conditions. Different driving situations impose different engine operation conditions and therefore a distinct emission performance. In that respect, a distinction is made in urban, rural and highway driving to account for variations in driving performance.

As will be later demonstrated, different activity data and emission factors are attributed to each driving situation. Also, by definition, cold start emissions are attributed to urban driving because the assumption is made that the large majority of vehicles starts any trip in urban areas. Therefore, as far as driving conditions are concerned (spatial desegregation), total emissions can be calculated by means of the equation:

$$E_{TOTAL} = E_{URBAN} + E_{RURAL} + E_{HIGHWAY} \qquad (3)$$

where,

E_{URBAN}, E_{RURAL}, $E_{HIGHWAY}$: total emissions (g) of any pollutant for the respective driving situation.

5.3 Calculation outline

Calculation of total emissions is made by combining activity data for each vehicle category with appropriate emission factors. Those emission factors vary according to input data (driving situations, climatic conditions). Also, information on fuel consumption and specifications is required to maintain a fuel balance between user provided figures and calculations. A summary of the variables required and the intermediate calculated values is given in the flow chart of Figure 5.1.

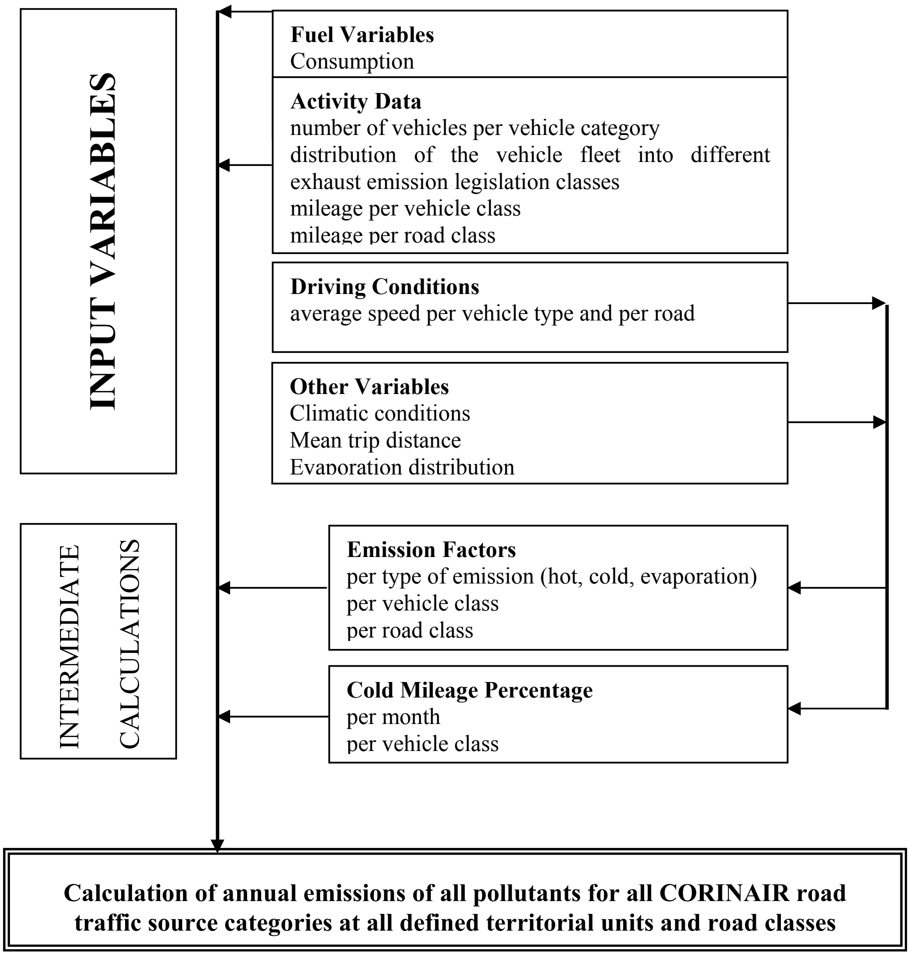

Figure 5.1: Flow chart of the application of the baseline methodology

5.4 Hot emissions

By "Hot Emissions" we mean by convention the emissions occurring under thermally stabilised engine and exhaust aftertreatment conditions. These emissions depend on a variety of factors including the distance that each vehicle travels, its speed (or road type), its age, engine size and weight. As will be later explained, many countries do not have solid estimates of these data. Therefore a method to estimate the emissions from available solid data has been proposed. However, it is important that each country uses the best data they have available. This is an issue to be resolved by each individual country.

The basic formula for estimating hot emissions, using experimentally obtained emission factors is:

Emissions per Period of Time [g] = Emission Factor [g/km] × Number of Vehicles [veh.]× Mileage per Vehicle per Period of Time [km/veh.]

Different emission factors, number of vehicles and mileage per vehicle need to be introduced for each vehicle category and class. The assumption is made that hot emission factors, i.e. emission factors corresponding to thermally stabilised engine operation, depend only on average speed. The dependency of hot emission factors with speed is given by the functions quoted in tables of section 8 of this chapter for each vehicle category and class. The period of time depends on the application (month, year, etc.)

Therefore, the formula to be applied for the calculation of hot emissions of pollutants in Groups 1 and 3 and in the case of an annual emission estimation, yields (Note: the same formula is also applied for the calculation of the total fuel consumed by vehicles of the specific class. But, in the case of fuel consumption, an additional distinction needs to be made for different fuel types):

$$E_{HOT;\, i,\, j,\, k} = N_j \times M_{j,k} \times e_{HOT;\, i,\, j,\, k} \qquad (4)$$

where,

$E_{HOT;\, i,\, j,\, k}$: emissions of the pollutant i in [g], produced in the reference year by vehicles of class j driven on roads of type k with thermally stabilised engine and exhaust aftertreatment system

N_j: number of vehicles [veh.] of class j in circulation at the reference year

$M_{j,k}$: mileage per vehicle [km/veh.] driven on roads of type k by vehicles of class j

$e_{HOT;\, i,\, j,\, k}$: average fleet representative baseline emission factor in [g/km] for the pollutant i, relevant for the vehicle class j, operated on roads of type k, with thermally stabilised engine and exhaust aftertreatment system

and,

i (pollutants): 1-36 for the pollutants of Group 1 and Group 3 (Section 3.4)

j (vehicle class): 1-105 for the vehicle classes defined in the vehicle split (Table 3-6)

k (road class): 1-3 for "urban", "rural", and "highway" driving.

5.4.1 Accounting for vehicle speed

Vehicle speed, which is introduced into the calculation via the three driving modes, has a major influence on the emissions of the vehicles. Different approaches have been developed to take into account the driving patterns. With the emission factors presented in this chapter, the authors propose two alternative methods:

to select one single average speed, representative of each of the road types "urban", "rural" and "highway" (e.g. 20 km/h, 60 km/h and 100 km/h, respectively) and to apply the emission factors taken from the graphs or calculated with the help of the equations, or

to define mean speed distribution curves $f_{j,\, k}(V)$ and to integrate over the emission curves, i.e.

$$e_{HOT;\,i,\,j,\,k} = \int [e(V) \times f_{j,\,k}(V)]\, dV \qquad (5)$$

where,

V: speed of vehicles on road classes "rural", "urban", "highway",

e(V): mathematical expression of the speed-dependency of $e_{HOT;\,i,\,j,\,k}$

$f_{j,\,k}(V)$: equation (e.g. formula of "best fit" curve) of the frequency distribution of the mean speeds which corresponds to the driving patterns of vehicles on road classes "rural", "urban" and "highway". $f_{j,k}(V)$ depends on vehicle class j and road type k.

It is evident that the first approach mentioned above is much easier and most likely the one to be chosen by most of the countries. Additionally, given the uncertainty in the estimation of the emission factors (see section 11), the improvement brought by the second approach cannot really be substantiated.

5.5 Cold start emissions

Cold starts, compared with the "hot emissions", result in additional emissions. They take place under all three driving conditions, however, they seem to be most likely for urban driving. In principle they occur for all vehicle categories. However, emission factors are only available or can be reasonably estimated for gasoline, diesel and LPG passenger cars and - assuming that these vehicles behave like passenger cars - light duty vehicles, so that just these categories are covered by the methodology. Moreover, they are considered not to be a function of vehicle age.

These emissions are calculated as an extra emission over the emissions that would be expected if all vehicles were only operated with hot engines and warmed-up catalysts. A relevant factor, corresponding to the ratio of cold over hot emissions, is used and applied to the fraction of kilometres driven with cold engines. This factor varies from country to country. Driving behaviour (varying trip lengths), as well as climate conditions affect the time required to warm up the engine and/or the catalyst and hence the fraction of a trip driven with cold engine. These factors can be taken into account, but again information may not be available to do this thoroughly in all countries, so that estimates have to close identified gaps.

The cold emissions are introduced into the calculation as additional emissions per km by using the following formula:

$$E_{COLD;\,i,\,j} = \beta_{i,\,j} \times N_j \times M_j \times e_{HOT;\,i,\,j} \times (e^{COLD} / e^{HOT}|_{i,j} - 1) \qquad (6)$$

where,

$E_{COLD;\,i,\,j}$: cold start emissions of the pollutant i (for the reference year), caused by vehicle class j,

$\beta_{i,\,j}$: fraction of mileage driven with cold engines or catalyst operated below the light-off temperature,

N_j : number of vehicles [veh.] of class j in circulation,

M_j : total mileage per vehicle [km/veh.] in vehicle class j,

$e^{COLD} / e^{HOT}|_{i,j}$: cold over hot ratio of pollutant i emissions, relevant to vehicles of class j.

The β-parameter depends on ambient temperature t_a (for practical reasons the average monthly temperature is proposed to be used) and pattern of vehicle use, in particular the average trip length l_{trip}. However, since information on l_{trip} is not available in many countries for all vehicle classes, simplifications have been introduced for some vehicle categories. According to available statistical data (André et al., 1998) a European value of 12.4 km has been established for the l_{trip} value. Moreover, according to a relevant analysis, the value of l_{trip} for annual vehicle circulation should be found in the range of 8 to 15 km. Therefore it is proposed to use the value of 12.4 km unless firm national estimates are available. Table 6-3 presents the l_{trip} values used in the COPERT 1990 inventories by different member states.

The introduction of more stringent emission standards for catalyst gasoline vehicles has imposed shorter periods for the catalyst to reach the light-off temperature. This is reflected to less mileage driven under warming-up conditions. Therefore, the β-parameter is also a function of the level of legislation conformity for gasoline catalyst vehicles. Table 8-12 presents the fraction of the original β-parameter to be used for current and future catalyst vehicles and for the main pollutants.

The over-emission ratio e^{COLD}/e^{HOT} also depends on the ambient temperature and pollutant considered. Although the model introduced in the initial version of this methodology is still used for the calculation of emissions during the cold start phase, updated over-emission ratios were introduced for catalyst equipped gasoline vehicles in the previous update of this chapter. These ratios were based on the MEET project (MEET, 1999. However, the proposed approach still cannot fully describe the cold-start emission behaviour of recent vehicle technologies and a revision is scheduled for the next update of this chapter.
As has already been discussed, cold start over-emission is attributed to urban driving only because the valid assumption is made that the majority of trips start in urban areas. However, a portion of cold start over-emissions may also be attributed to rural conditions, in cases where the mileage fraction driven with non-thermally stabilised engine conditions (β-parameter) exceeds the mileage share attributed to urban conditions (S_{URBAN}). This case requires a transformation of equation (6), which then yields:

If $\beta_{i,\,j} > S_{URBAN}$,

$$E_{COLD;\,i,\,j,\,URBAN} = S_{URBAN;\,i,\,j} \times N_j \times M_j \times e_{HOT;\,i,\,j,\,URBAN} \times (e^{COLD} / e^{HOT}|_{i,j} - 1)$$
$$E_{COLD;\,i,\,j,\,RURAL} = (\beta_{i,\,j} - S_{URBAN;\,i,\,j}) \times N_j \times M_j \times e_{HOT;\,i,\,j,\,URBAN} \times (e^{COLD} / e^{HOT}|_{i,j} - 1) \qquad (7)$$

In this case, it is considered that the total mileage driven under urban conditions corresponds to warming-up conditions, while the remaining over-emissions are attributed to urban conditions. The case demonstrated by equation (7) is rather extreme for a national inventory and can only happen in cases where a very small value has been provided for l_{trip}. Note also that the urban hot emission factor is used in both forms of equation (7). This is because total cold start related emissions should not be differentiated according to place of emission.

It is important to note that VOC values proposed for the β-parameter and the e^{COLD}/e^{HOT} over-emission ratio are applied to calculate over-emissions of both NMVOC and CH_4 during cold start.

5.6 Fuel consumption dependent emissions

In principle, total emission estimates for pollutants depending on fuel consumption should be derived on the basis of the statistical (true) fuel consumption which is generally known by statistical sources. However, the necessity to allocate emissions to different vehicle categories (and classes) cannot be covered solely by means of the statistical consumption which is not separately provided for each vehicle class. In order to achieve both aims, first fuel dependent pollutants should be calculated on the basis of the calculated fuel consumption (per vehicle class) and then a correction should be applied based on the true consumption. In mathematical terms, this correction can be expressed:

$$E_{i,jm}^{CORR} = E_{i,jm}^{CALC} \times \frac{FC_m^{STAT}}{\sum_{jm} FC_{jm}^{CALC}} \quad (8)$$

where,

j_m: class j from Table 3-6 operating on fuel type m,

$E_{i,jm}^{CORR}$: the corrected emission of fuel dependent pollutant i (CO_2, SO_2, Pb, HM) for vehicle class j_m,

$E_{i,jm}^{CALC}$: the emission of fuel dependent pollutant i estimated on the basis of the calculated fuel consumption of vehicle class j_m,

FC_m^{STAT}: the statistical (true) total consumption of fuel type m (leaded gas unleaded gasoline, diesel, LPG)

$\sum_{jm} FC_{jm}^{CALC}$: the total calculated fuel consumption of all vehicle classes operating on fuel type m.

In that respect, total emission estimates for any emission dependent pollutant equals that derived by the statistical fuel consumption while there is still information provided for the allocation of emissions to different vehicle classes. The calculation of value $E^{CALC}_{i,jm}$ is demonstrated in the following paragraphs.

5.6.1 Carbon dioxide (CO_2) emissions

Ultimate CO_2 emissions are estimated on the basis of fuel consumption only, assuming that the carbon content of the fuel is fully oxidised into CO_2**.** The following formula should be applied:

$$E_{CO_2,j}^{CALC} = 44.011 \times \frac{FC_{jm}^{CALC}}{12.011 + 1.008 r_{H:C,m}} \quad (9)$$

where,

$r_{H:C,m}$ the ratio of hydrogen to carbon atoms in the fuel (~1.8 for gasoline and ~2.0 for diesel).

If **end-of-pipe CO_2** emissions are to be calculated, then other emissions of C atoms in the form of CO, VOC and particulate emissions have to be taken into account. Then the following formula is applied:

$$E_{CO_2,j}^{CALC} = 44.011 \times \left(\frac{FC_{jm}^{CALC}}{12.011 + 1.008 r_{H:C,m}} - \frac{E_{jm}^{CO}}{28.011} - \frac{E_{jm}^{VOC}}{13.85} - \frac{E_{jm}^{PM}}{12.011} \right) \quad (10)$$

5.6.2 Sulphur dioxide (SO_2) emissions

The emissions of SO_2 are estimated by assuming that all sulphur in the fuel is transformed completely into SO_2 using the formula:

$$E_{SO_2,j}^{CALC} = 2 \times k_{S,m} \times FC_{jm}^{CALC} \quad (11)$$

where,

$k_{S,m}$: weight related sulphur content in fuel of type m [kg/kg fuel].

5.6.3 Lead (Pb) and other heavy metals emissions

Emissions of lead are estimated by assuming that 75% of lead contained in the fuel is emitted into air (Hassel et al., 1987). The formula used is:

$$E_{Pb,j}^{CALC} = 0.75 \times k_{Pb,m} \times FC_{jm}^{CALC} \quad (12)$$

where,

$k_{Pb,m}$: weight related lead content of gasoline (type m) in [kg/kg fuel].

With regard to the emission of other heavy metal species, emission factors provided correspond both to fuel and lubricant content and engine wear. Therefore it is considered that the total quantity is emitted to the atmosphere (no losses in the engine). Therefore, emissions of heavy metals included in Group 2 are calculated by means of:

$$E_{i,j}^{CALC} = k_{i,m} \times FC_{jm}^{CALC} \quad (13)$$

where,

$k_{i,m}$: weight related content of i- heavy metal in fuel type m [kg/kg fuel].

Values are proposed for fuel content in heavy metals, as provided by the Expert Panel on Heavy Metals and POPs of the UNECE Task Force on Emission Inventories. However, these emission factors have to be considered as preliminary estimates only. More measurements are needed in order to confirm these values.

5.7 Emission corrections

Corrections can be applied to the emission methodology, as it has been described by the baseline equations (4) - (5), to accommodate variation of emissions according to various environmental and technology effects. Specifically, the effect on emissions of the following parameters can be tackled:

a. Vehicle age (mileage). Baseline emission factors to be used in equation (4) correspond to a fleet of average mileage (30-60 Mm) and an inherent degradation factor is implemented. Further emission degradation due to increased mileage should be modelled by additional degradation factors. However, for the sake of consistency between the Member States, it is proposed not to introduce such corrections when compiling a baseline inventory up to the year 2000 because of the relatively young fleet age. However, when inventories and forecasts for future years need to be made, it is advised to correct emission factors according to mileage to introduce the effect of vehicle age in the calculations.

b. Improved fuels. Improved fuel qualities have become mandatory in the European Union since year 2000. The effect on the emissions of current and older vehicles can be quantified again by means of relevant correction factors. Those corrections should only be applied in inventories compiled for years after the introduction of the improved fuels.

c. Road gradient and vehicle load on heavy duty vehicles emissions. Corrections need to be made to heavy duty vehicles emissions in cases of driving on non-flat roads. The corrections should only be applied in national inventories by those Member States where statistical data allow for a distinction of heavy duty vehicle mileage on roads of positive or negative gradient. Also, by default, a factor of 50% is considered for the load of heavy duty vehicles. In cases where significant deviations exist for the mean load factor of the heavy duty vehicle fleet, respective corrections should be brought by means of respective emission factors functions.

5.7.1 Emission degradation due to vehicle age

Correction factors need to be applied to the baseline emission factor to account for different vehicle age. This correction factor which is given by equation:

$$MC_{C,i} = A_M \times M_{MEAN} + B_M \quad (14)$$

where,

M_{MEAN}: the mean fleet mileage of vehicles for which correction is applied
$MC_{C,i}$: the mileage correction factor for a given mileage (M_{av}), pollutant i and a specific cycle
A_M: the degradation of the emission performance per kilometre
B_M: the emission level of a fleet of brand new vehicles

B_M is lower than 1 because the correction factors are determined using vehicle fleets with mileages ranging from 16,000 to 50,000 km. Therefore, brand new vehicles are expected to emit less than the sample vehicles. It is assumed that emissions do not further degrade above 120,000 km for Euro I and II vehicles and 160,000 km for Euro III and IV vehicles.

The effect of average speed on emission degradation is taken into account by combining the observed degradation lines over the two driving modes (urban, road). It is assumed that for speeds outside the region defined by the average speed of urban driving (19 km/h) and road driving (63 km/h), the degradation is independent of speed. Linear interpolation between the two values provides the emission degradation in the intermediate speed region. Table 8-67 presents the methodology parameters and the application of the scheme that are being discussed later on this document.

5.7.2 Fuel effects

Fuels of improved specifications become mandatory in Europe in two steps, January 2000 (Fuel 2000[1]) and January 2005 (Fuel 2005) respectively. The specifications of those fuels are displayed in Table 5-1 (Gasoline) and
Table 5-2 (Diesel). Because of their improved properties, the fuels result in lower emissions from vehicles. Therefore, the stringent emission standards of Euro III technology (introduced ~2000) are achieved with fuel quality "Fuel 2000" and the more stringent emission standards of Euro IV and V with fuel quality "Fuel 2005". Table 5-3 shows the base emission fuel considered for each vehicle class.

Table 5-1: Gasoline fuel specifications

Property	**1996 Base Fuel (market average)**	**Fuel 2000**	**Fuel 2005**
Sulphur [ppm]	165	130	40
RVP [kPa]	68 (summer) 81 (winter)	60 (summer) 70 (winter)	60 (summer) 70 (winter)
Aromatics [vol. %]	39	37	33
Benzene [vol. %]	2.1	0.8	0.8
Oxygen [wt %]	0.4	1.0	1.5
Olefins [vol. %]	10	10	10
E100 [%]	52	52	52
E150 [%]	86	86	86
Trace Lead [g/l]	0.005	0.003	0.003

Table 5-2: Diesel fuel specifications

Property	**1996 Base Fuel (market average)**	**Fuel 2000**	**Fuel 2005**
Cetane Number [-]	51	53	53
Density at 15°C [kg/m^3]	840	840	835
T_{95} [°C]	350	330	320
PAH [%]	9	7	5
Sulphur [ppm]	400	300	40
Total Aromatics [%]	28	26	24

Table 5-3: Base fuels for each vehicle class

Vehicle Class	**Base Fuel**	**Available Improved Fuel Qualities**
Pre- Euro III	1996 Base Fuel	Fuel 2000 , Fuel 2005
Euro III	Fuel 2000	Fuel 2005
Euro IV	Fuel 2005	-

[1] By convention

However use of such fuels results in reduced emissions also from pre-Euro III vehicle technologies, for which the 1996 market average fuel is considered as a basis (Table 5-3). Those reductions are equally applied to hot and cold start emissions. To correct the hot emission factors proposed, equations derived in the framework of the EPEFE programme (ACEA and EUROPIA, 1996) are applied. Table 8-68, Table 8-69 and Table 8-70 display the equations for different vehicle categories and classes.

The hot emission factors are corrected according to the equation:

$$FCe_{HOT;\,I,\,j,\,k} = FCorr_{i,\,j,\,Fuel} / FCorr_{i,\,j,\,Base} \times e_{HOT;\,i,\,j,\,k} \qquad (15)$$

where,

$FCe_{HOT;\,i,\,j,\,k}$: the hot emission factor corrected for the use of improved fuel for pollutant I of vehicle class j driven on road types k

$FCorr_{i,\,j,\,Fuel}$: the fuel correction for pollutant i, vehicle category j, calculated with equations given in Table 8-68, Table 8-69 and Table 8-70 for the available improved fuel qualities (Table 5-3)

$FCorr_{i,\,j,\,Base}$: the fuel correction for pollutant i, vehicle category j, calculated with equations given in Table 8-68, Table 8-69 and Table 8-70 for the base fuel quality of vehicle class j (Table 5-3)

It is mentioned that equation (15) should not be used to provide the deterioration of emissions in case that an older fuel is used in a newer technology (e.g. use of Fuel 2000 in Euro IV vehicles by inversion of FC coefficients). The emission factor calculated via equation (15) should be introduced in equations (4) and (6) or (7) respectively to estimate hot and cold start emissions.

6 RELEVANT ACTIVITY STATISTICS

In principle, vehicle statistics are readily available in the national statistical offices of all countries and in international statistical organisations and institutes (e.g. EUROSTAT, International Road Federation - IRF). However, it must be stressed that these statistics are almost exclusively vehicle oriented (i.e. comprising fleet data), with information about general aggregate categories only (e.g. passenger cars, trucks, buses, motorcycles). In addition, only little information referring to age and technology distribution can be found in a consistent form, while very little information is available as regards activity data (with the exception of fuel statistics). In addition more detailed traffic data required for the calculations (such as average trip length for cold start emissions) are available only in a few countries.

Despite the lack of direct data in the national and international statistics as regards transport activity, and age and technology distribution of the vehicles, such data can be produced in an indirect way. The following hints may be helpful:

- *Age and technology distribution*: The (generally available) time series on fleet evolution and annual new registrations can be used in order to come up with estimates of appropriate scrappage rates. By combining the above with implementation dates of certain technologies, a relatively good picture of the fleet composition at specific years can be reached.

- *Mileage driven and mileage split*: Calculated fuel consumption on the basis of appropriate assumptions for annual mileage of the different vehicle categories can be balanced with available fuel statistics, following the methodology presented in chapter 5.1, using representative fuel consumption factors. By applying a trial-and-error approach, it is possible to reach acceptable estimates of mileage activity data.

Activity statistics presented in this methodology correspond to the central estimates provided by EEA in their relevant report (Ntziachristos et al., 2002). They have been produced with application of an approach as the one mentioned before to older official data. Table 6-1 provides the European fleet per vehicle category and Table 6-2 the mean mileage driven by each vehicle in each category.

Table 6-1: 2002 Vehicle fleet in the EU 15 countries

Country	Gasoline PC	Diesel PC	Gasoline LDV	Diesel LDV	Diesel HDV	Buses & Coaches	Two Wheelers
Austria	3 152 165	941 556	30 055	73 154	243 316	10 477	566 232
Belgium	3 207 878	1 468 450	88 760	172 729	188 435	14 090	444 676
Denmark	1 722 938	85 361	71 295	118 507	146 989	14 314	136 908
Finland	2 211 212	194 109	71 630	194 300	65 606	8 805	114 087
France	21 403 436	4 683 885	1 030 207	2 557 828	700 509	86 088	1 486 539
Germany	40 382 437	6 339 589	518 270	1 251 392	1 458 545	96 811	4 694 988
Greece	2 729 040	38 277	425 712	385 195	202 764	27 459	1 312 322
Ireland	906 757	138 014	11 334	66 404	112 920	5 737	16 980
Italy	30 688 296	4 892 337	503 066	1 633 541	1 290 050	84 616	7 137 278
Luxembourg	225 394	47 886	2 265	974	12 209	960	28 243
Netherlands	5 136 112	687 316	5 702	n.a.	674 734	13 089	368 959
Portugal	2 807 226	311 914	n.a.	613 933	552 177	17 003	794 687
Spain	13 418 202	3 379 900	862 828	2 142 255	586 696	48 976	2 074 002
Sweden	4 004 703	119 605	253 971	40 436	103 520	14 636	280 384
UK	24 342 193	1 999 321	1 238 713	1 120 819	589 992	72 178	644 677

Table 6-2: 2002 Mileage driven by each vehicle category in EU15 countries

Country	Gasoline PC	Diesel PC	Gasoline LDV	Diesel LDV	Diesel HDV	Buses & Coaches	Two Wheelers
Austria	16 641	18 156	25 000	25 000	67 891	41 573	4 881
Belgium	14 319	22 774	20 000	35 000	63 275	23 210	7 800
Denmark	20 410	21 413	18 253	15 000	38 714	60 040	3 846
Finland	19 256	31 165	8 500	16 000	55 000	70 000	3 260
France	9 950	15 059	16 500	25 000	59 719	39 550	4 359
Germany	11 596	15 353	17 500	22 000	70 340	47 000	2 420
Greece	16 689	16 054	13 000	20 000	40 225	16 904	5 975
Ireland	20 388	14 977	25 000	27 000	35 989	48 136	11 955
Italy	9 273	15 760	20 000	17 000	38 742	41 000	5 088
Luxembourg	13 920	20 174	40 000	40 000	40 000	47 730	2 189
Netherlands	10 841	15 087	35 000	n.a.	26 180	35 000	3 980
Portugal	12 267	12 267	n.a.	15 000	26 683	30 220	477
Spain	9 578	14 362	22 500	30 000	60 281	28 000	2 428
Sweden	15 005	23 579	20 000	35 000	56 930	60 000	5 995
UK	13 729	15 644	17 000	16 500	60 000	60 000	3 815

n.a.: not available

For the calculation of cold –start related emissions, the mean trip length is necessary. Table 6-3 provides the figures submitted by national experts in a previous COPERT exercise. Despite these data refer to a decade ago circulation conditions, they can still be rather safely used because mean trip is a highly aggregate value which little varies from year to year.

Table 6-3: Examples of average estimated trip length values- l_{trip} - as taken by COPERT 1990 updated run

Country	Trip Length [km]	Country	Trip Length [km]
Austria	12	Hungary	12
Belgium	12	Ireland	14
Denmark	9	Italy	12
Germany	14	Luxembourg	15
Spain	12	Netherlands	13.1
France	12	Portugal	10
Finland	17	UK	10
Greece	12		

7 POINT SOURCE CRITERIA

There are no relevant point sources, which fall under the source activities dealt within this chapter.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

Emission factors corresponding to non-catalyst gasoline passenger cars were jointly worked out by the members of the CORINAIR Working Group (Eggleston et al. 1993), taking into account the results of comprehensive studies carried out in France, Germany, Greece, Italy, the Netherlands and the United Kingdom. In addition, some data measured in Austria, Sweden and Switzerland were incorporated. For catalyst equipped and improved diesel passenger cars (91/441/EEC and on), light duty vehicles, diesel heavy duty vehicles and power two wheelers, the emission factors incorporated are the outcome of the MEET project. Emission and consumption factors for passenger cars and light duty vehicles originate from a large number of measurements conducted in several European countries (Samaras et al., 1998). The emission factors proposed in a joint German - Swiss research project (Keller et al., 1995) were adopted for diesel heavy duty vehicles and two-wheelers.

The emission factors proposed can be distinguished into two classes: those for which detailed evaluations are necessary and possible, and those for which more simple "bulk" emission factors or equations can be provided. The pollutants CO, VOC and NO_x, PM together with fuel consumption factors fall under the first category, while SO_2, NH_3, Pb, CO_2, N_2O and partly CH_4 fall under the second one. Therefore this chapter is organised as follows:

First the exhaust emission factors of CO, VOC and NO_x, PM (called "regulated" pollutants because they have been regulated by relevant legislation) as well as fuel consumption factors of the individual SNAP activities are presented and discussed.

Secondly the "bulk" emission factors for SO_2, NH_3, Pb, CO_2, N_2O and CH_4 follow.

Table 8-1: Coding explanation used for the methodological approaches adopted for each vehicle category

Method	Hot Emissions	Cold Start Overemission	Evaporation Losses*
A	the total annual kilometres driven per vehicle the share of kilometres driven under the driving modes 'urban', 'rural', 'highway' A1: the average speed of the vehicles under the driving modes 'urban', 'rural', 'highway' A1: speed-dependent hot emission factors A2: driving mode dependent emission factors	the average trip length per vehicle trip the average monthly temperature temperature, trip length and catalyst technology dependent cold start correction factor	the fuel volatility (RVP) the average monthly temperature and temperature variation fuel volatility and temperature dependent emission factor
B	the total annual kilometres driven per vehicle the share of kilometres driven under the driving modes 'urban', 'rural', 'highway' B1: the average speed of the vehicles under the driving modes 'urban', 'rural', 'highway' B1: speed-dependent hot emission factors B2: driving mode dependent emission factors	*No Cold Start Overemission Calculations*	the fuel volatility (RVP) the average monthly temperature and temperature variation fuel volatility and temperature dependent emission factor
C	the total annual kilometres driven per vehicle the share of kilometres driven under the driving modes 'urban', 'rural', 'highway' driving mode dependent emission factors	*No Cold Start Overemission Calculations*	*No Evaporation Calculations*
D	the total annual fuel consumption of the vehicle category fuel consumption related emission factors	*No Cold Start Overemission Calculations*	*No Evaporation Calculations*

*Attributed only to NMVOC emissions from gasoline powered vehicles

Analytical description of the methodology application for each vehicle category follows. However, Table 8-1 and Table 8-2 show the level of detail which is necessary for the calculation of emissions from each vehicle technology.

Table 8-2: Summary of calculation methods applied for the different vehicle classes and pollutants

Vehicle Category	NO_x	CO	NMVOC	CH_4	PM	N_2O	NH_3	SO_2	CO_2	Pb	HM	FC
Gasoline Passenger Cars												
Pre-ECE	A1	A1	A1	A2	-	A2	A2	D	D	D	D	A1
ECE 15/00-01	A1	A1	A1	A2	-	A2	A2	D	D	D	D	A1
ECE 15/02	A1	A1	A1	A2	-	A2	A2	D	D	D	D	A1
ECE 15/03	A1	A1	A1	A2	-	A2	A2	D	D	D	D	A1
ECE 15/04	A1	A1	A1	A2	-	A2	A2	D	D	D	D	A1
Improved Conventional	A1	A1	A1	A2	-	A2	A2	D	D	D	D	A1
Open Loop	A1	A1	A1	A2	-	A2	A2	D	D	D	D	A1
Euro I to Euro IV	A1	A1	A1	A1	-	A2	A2	D	D	D	D	A1
Diesel Passenger Cars												
Conventional	A1	A1	A1	A1	A1	C	C	D	D	D	D	A1
Euro I to Euro IV	A1	A1	A1	A1	A1	C	Ψ	D	D	D	D	A1
LPG Passenger Cars	A1	A1	A1	A2	-	C	-	-	D	-	-	A1
2 Stroke Passenger Cars	C	C	C	C	-	C	C	D	D	D	D	C
Light Duty Vehicles												
Gasoline <3.5t Conv.	A1	A1	A1	A2	-	A2	A2	D	D	D	D	A1
Gasoline <3.5t Euro I to Euro IV	A1	A1	A1	A1	-	A2	A2	D	D	D	D	A1
Diesel <3.5t Conventional	A1	A1	A1	A2	A1	A2	A2	D	D	D	D	A1
Diesel <3.5t Euro I to Euro IV	A1	A1	A1	A2	A1	A2	A2	D	D	D	D	A1
Heavy Duty Vehicles >3.5 t												
Gasoline Conventional	C	C	C	C	-	C	C	D	D	D	D	C
Diesel Conventional	B1	B1	B1	C	B1	C	C	D	D	D	D	B1
Diesel Euro I to Euro V	B1	B1	B1	C	B1	C	C	D	D	D	D	B1
Buses & Coaches Conventional	B1	B1	B1	C	B1	C	C	D	D	D	D	B1
Buses & Coaches Euro I to Euro V	B1	B1	B1	C	B1	C	C	D	D	D	D	B1
Two Wheelers												
Mopeds <50cm³	B2	B2	B2	C	-	C	C	D	D	D	D	B2
Motorcycles 2-st >50cm³	B1	B1	B1	C	-	C	C	D	D	D	D	B1
Motorcycles 4-st 50-250 cm³	B1	B1	B1	C	-	C	C	D	D	D	D	B1
Motorcycles 4-st 250-750cm³	B1	B1	B1	C	-	C	C	D	D	D	D	B1
Motorcycles 4-st >750cm³	B1	B1	B1	C	-	C	C	D	D	D	D	B1

8.1 Gasoline passenger cars

8.1.1 Pre Euro I – "Conventional"

Hot Emissions

Hot emission factors for conventional vehicles are given in Table 8-3, Table 8-4 and Table 8-5 for different pollutants and Table 8-6 provides fuel consumption factors for the same vehicles. Those emission factors have been developed in the framework of older COPERT exercises (Eggleston et al., 1989). Separate equations are valid for different speed ranges and engine capacity classes.

Table 8-3: Speed dependency of CO emission factors for gasoline passenger cars

Vehicle Class	Engine Capacity	Speed Range (km/h)	CO Emission Factor (g/km)	R^2
PRE ECE	All capacities All capacities	10-100 100-130	$281V^{-0.630}$ $0.112V + 4.32$	0.924 -
ECE 15-00/01	All capacities All capacities	10-50 50-130	$313V^{-0.760}$ $27.22 - 0.406V + 0.0032V^2$	0.898 0.158
ECE 15-02	All capacities All capacities	10-60 60-130	$300V^{-0.797}$ $26.260 - 0.440V + 0.0026V^2$	0.747 0.102
ECE 15-03	All capacities All capacities	10-20 20-130	$161.36 - 45.62\ln(V)$ $37.92 - 0.680V + 0.00377V^2$	0.790 0.247
ECE 15-04	All capacities All capacities	10-60 60-130	$260.788 \cdot V^{-0.910}$ $14.653 - 0.220V + 0.001163V^2$	0.825 0.613
Improved Conventional	CC < 1.4 l 1.4 l < CC < 2.0 l	10-130 10-130	$14.577 - 0.294V + 0.002478V^2$ $8.273 - 0.151V + 0.000957V^2$	0.781 0.767
Open Loop	CC < 1.4 l 1.4 l < CC < 2.0 l	10-130 10-130	$17.882 - 0.377V + 0.002825V^2$ $9.446 - 0.230V + 0.002029V^2$	0.656 0.719

Table 8-4: Speed dependency of VOC emission factors for gasoline passenger cars

Vehicle Class	Engine Capacity	Speed Range (km/h)	VOC Emission Factor (g/km)	R^2
PRE ECE	All capacities All capacities	10-100 100-130	$30.34V^{-0.693}$ 1.247	0.980 -
ECE 15-00/01	All capacities All capacities	10-50 50-130	$24.99V^{-0.704}$ $4.85V^{-0.318}$	0.901 0.095
ECE 15-02/03	All capacities All capacities	10-60 60-130	$25.75V^{-0.714}$ $1.95 - 0.019V + 0.00009V^2$	0.895 0.198
ECE 15-04	All capacities All capacities	10-60 60-130	$19.079V^{-0.693}$ $2.608 - 0.037V + 0.000179V^2$	0.838 0.341
Improved Conventional	CC < 1.4 l 1.4 l < CC < 2.0 l	10-130 10-130	$2.189 - 0.034V + 0.000201V^2$ $1.999 - 0.034V + 0.000214V^2$	0.766 0.447
Open Loop	CC < 1.4 l 1.4 l < CC < 2.0 l	10-130 10-130	$2.185 - 0.0423V + 0.000256V^2$ $0.808 - 0.016V + 0.000099V^2$	0.636 0.49

Cold start emissions

Table 8-7 provides e^{COLD}/e^{HOT} over-emission ratios for pollutants of Group 1. The β-parameter is calculated by means of equation provided in Table 8-8. Introduction of those values in equation (6), together with the hot emission factors quoted previously provides estimates of cold start emissions. Again, those ratios have been produced during older COPERT versions.

Table 8-5: Speed dependency of NO_x emission factors for gasoline passenger cars

Vehicle Class	Engine Capacity	Speed Range (km/h)	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	$1.29e^{0.0099V}$	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	$1.484+0.013 \cdot V+0.000074V^2$	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

Table 8-6: Speed dependency

of fuel consumption factors for gasoline passenger cars

Vehicle Class	Cylinder Capacity	Speed Range (km/h)	Fuel Consumption Factor (g/km)	R^2
PRE ECE	CC < 1.4 l	10-60	$521V^{-0.554}$	0.941
		60-80	55	-
		80-130	$0.386V + 24.143$	-
	1.4 l < CC < 2.0 l	10-60	$681V^{-0.583}$	0.936
		60-80	67	-
		80-130	$0.471V + 29.286$	-
	CC > 2.0 l	10-60	$979V^{-0.628}$	0.918
		60-80	80	-
		80-130	$0.414V + 46.867$	-
ECE 15-00/01	CC < 1.4 l	10-60	$595V^{-0.63}$	0.951
		60-130	$95 - 1.324V + 0.0086V^2$	0.289
	1.4 l < CC < 2.0 l	10-60	$864V^{-0.69}$	0.974
		60-130	$59 - 0.407V + 0.0042V^2$	0.647
	CC > 2.0 l	10-60	$1236V^{-0.764}$	0.976
		60-130	$65 - 0.407V + 0.0042V^2$	-

continued in next page

Table 8-6(cont.): Speed dependency of fuel consumption factors for gasoline passenger cars

Vehicle Class	Cylinder Capacity	Speed Range (km/h)	Fuel Consumption Factor (g/km)	R^2
ECE 15-02/03	CC < 1.4 l	10-50 50-130	$544V^{-0.63}$ $85 - 1.108V + 0.0077V^2$	0.929 0.641
	1.4 l < CC < 2.0 l	10-50 50-130	$879V^{-0.72}$ $71 - 0.7032V + 0.0059V^2$	0.950 0.830
	CC > 2.0 l	10-50 50-130	$1224V^{-0.756}$ $111 - 1.333V + 0.0093V^2$	0.961 0.847
ECE 15-04	CC < 1.4 l	10-17.9 17.9-130	$296.7 - 80.21\ln(V)$ $81.1 - 1.014V + 0.0068V^2$	0.518 0.760
	1.4 l < CC < 2.0 l	10-22.3 22.3-130	$606.1V^{-0.667}$ $102.5 - 1.364V + 0.0086V^2$	0.907 0.927
	CC > 2.0 l	10-60 60-130	$819.9V^{-0.663}$ $41.7 + 0.122V + 0.0016V^2$	0.966 0.650
Improved Conventional	CC < 1.4 l 1.4 l < CC < 2.0 l	10-130 10-130	$80.52 - 1.41V + 0.013V^2$ $111.0 - 2.031V + 0.017V^2$	0.954 0.994
Open Loop	CC < 1.4 l 1.4 l < CC < 2.0 l	10-130 10-130	$85.55 - 1.383V + 0.0117V^2$ $109.6 - 1.98V + 0.0168V^2$	0.997 0.997

Table 8-7: Over-emission ratios e^{COLD} / e^{HOT} for conventional gasoline vehicles (temperature range of –10°C to 30°C)

Conventional Gasoline Powered Vehicles	e^{COLD} / e^{HOT}
CO	$3.7 - 0.09\ t_a$
NO_x	$1.14 - 0.006\ t_a$
VOC	$2.8 - 0.06\ t_a$
Fuel Consumption	$1.47 - 0.009\ t_a$

Table 8-8: Cold mileage percentage β

Calculations based on	β-parameter (Beta parameter)
Estimated l_{trip}	$0.6474 - 0.02545 \times l_{trip} - (0.00974 - 0.000385 \times l_{trip}) \times t_a$

8.1.2 Euro I and later

Hot emissions

Hot emissions estimates for Euro I and post-Euro I vehicles are calculated as a function of speed. They have been developed in the framework of the *Artemis* project. Table 8-9 provides the factors of the function used to calculate the emission factors. The generic function used in this case is:

$$EF = (a + c \times V + e \times V^2)/(1 + b \times V + d \times V^2) \quad (16)$$

Table 8-9: Values for eq.(16) to calculate emissions from Euro 1 and later gasoline passenger cars

Pollutant	Emission Standard	Engine capacity	Speed Range (km/h)	R^2	a	b	c	d	e
CO	Euro I	All capacities	10-130	0.87	1.12E+01	1.29E-01	-1.02E-01	-9.47E-04	6.77E-04
	Euro II	All capacities	10-130	0.97	6.05E+01	3.50E+00	1.52E-01	-2.52E-02	-1.68E-04
	Euro III	All capacities	10-130	0.97	7.17E+01	3.54E+01	1.14E+01	-2.48E-01	
	Euro IV	All capacities	10-130	0.93	1.36E-01	-1.41E-02	-8.91E-04	4.99E-05	
HC	Euro I	All capacities	10-130	0.82	1.35E+00	1.78E-01	-6.77E-03	-1.27E-03	
	Euro II	All capacities	10-130	0.95	4.11E+06	1.66E+06	-1.45E+04	-1.03E+04	
	Euro III	All capacities	10-130	0.88	5.57E-02	3.65E-02	-1.10E-03	-1.88E-04	1.25E-05
	Euro IV	All capacities	10-130	0.10	1.18E-02		-3.47E-05		8.84E-07
NO_x	Euro I	All capacities	10-130	0.86	5.25E-01		-1.00E-02		9.36E-05
	Euro II	All capacities	10-130	0.52	2.84E-01	-2.34E-02	-8.69E-03	4.43E-04	1.14E-04
	Euro III	All capacities	10-130	0.80	9.29E-02	-1.22E-02	-1.49E-03	3.97E-05	6.53E-06
	Euro IV	All capacities	10-130	0.71	1.06E-01		-1.58E-03		7.10E-06
FC	Euro I	<1.4	10-130	0.99	1.91E+02	1.29E-01	1.17E+00	-7.23E-04	
		1.4-2.0	10-130	0.98	1.99E+02	8.92E-02	3.46E-01	-5.38E-04	
		>2.0	10-130	0.93	2.30E+02	6.94E-02	-4.26E-02	-4.46E-04	
	Euro II	<1.4	10-130	0.99	2.08E+02	1.07E-01	-5.65E-01	-5.00E-04	1.43E-02
		1.4-2.0	10-130	0.98	3.47E+02	2.17E-01	2.73E+00	-9.11E-04	4.28E-03
		>2.0	10-130	0.98	1.54E+03	8.69E-01	1.91E+01	-3.63E-03	
	Euro III	<1.4	10-130	0.99	1.70E+02	9.28E-02	4.18E-01	-4.52E-04	4.99E-03
		1.4-2.0	10-130	0.99	2.17E+02	9.60E-02	2.53E-01	-4.21E-04	9.65E-03
		>2.0	10-130	0.99	2.53E+02	9.02E-02	5.02E-01	-4.69E-04	
	Euro IV	<1.4	10-130	0.95	1.36E+02	2.60E-02	-1.65E+00	2.28E-04	3.12E-02
		1.4-2.0	10-130	0.96	1.74E+02	6.85E-02	3.64E-01	-2.47E-04	8.74E-03
		>2.0	10-130	0.98	2.85E+02	7.28E-02	-1.37E-01	-4.16E-04	

Table 8-10 also presents simplified emission factors to be used for PM emission calculation from gasoline passenger cars of Euro 1 and later technologies. A separate emission factor is proposed for direct injection gasoline vehicles (GDI) due to the different combustion process of these engines.

Table 8-10: PM emission factors for Euro I and later gasoline passenger cars

Pollutant	Emission Standard	Fuel specs (EN590)	Urban [g/km]	Rural [g/km]	Highway [g/km]
PM	EURO I & II	2000-2009	3.22E-03	1.84E-03	1.90E-03
	EURO III & IV	2000-2009	1.28E-03	8.36E-04	1.19E-03
	EURO III GDI	2000-2009	6.60E-03	2.96E-03	6.95E-03

Cold start emissions

Emissions of catalyst equipped vehicles during the warming up phase are significantly higher than during stabilised thermal conditions due to the reduced efficiency of the catalytic converter at temperatures below the light-off. Therefore, the effect of cold start has to be modelled in detail in the case of Euro I and later vehicles. Table 8-11 provides e^{COLD}/e^{HOT} over-emission ratios for three main pollutants (and fuel consumption). The values proposed are a result of fitting the existing COPERT methodology to the results published by MEET and are a function of ambient temperature and average travelling speed. Two speed regions have been introduced (5-25 km/h and 25-45 km/h). As in the case of hot emission factors, the value introduced for speed should correspond to the mean speed during travelling and not to the instantaneous speed. The speed range proposed is sufficient to cover most applications because cold start over-emissions are in principle allocated to urban driving only.

Table 8-11: Over-emission ratios e^{COLD} / e^{HOT} for Euro I and later gasoline vehicles (V: speed in km/h, t_a: temperature in °C)

Case	**Category**	**Speed [km/h]**	**Temp [°C]**	**$e^{COLD}/e^{HOT} = A \times V + B \times t_a + C$** A	**B**	**C**
CO	CC<1.4 l	5 - 25	-20 : 15	0.156	-0.155	3.519
		26 - 45	-20 : 15	0.538	-0.373	-6.24
		5 - 45	>15	8.032E-02	-0.444	9.826
	1.4 l < CC < 2.0 l	5 - 25	-20 : 15	0.121	-0.146	3.766
		26 - 45	-20 : 15	0.299	-0.286	-0.58
		5 - 45	>15	5.03E-02	-0.363	8.604
	CC>2.0 l	5 - 25	-20 : 15	7.82E-02	-0.105	3.116
		26 - 45	-20 : 15	0.193	-0.194	0.305
		5 - 45	>15	3.21E-02	-0.252	6.332
NOx	CC<1.4 l	5 - 25	> -20	4.61E-02	7.38E-03	0.755
		26 - 45	> -20	5.13E-02	2.34E-02	0.616
	1.4 l < CC < 2.0 l	5 - 25	> -20	4.58E-02	7.47E-03	0.764
		26 - 45	> -20	4.84E-02	2.28E-02	0.685
	CC>2.0 l	5 - 25	> -20	3.43E-02	5.66E-03	0.827
		26 - 45	> -20	3.75E-02	1.72E-02	0.728
VOC	CC<1.4 l	5 - 25	-20 : 15	0.154	-0.134	4.937
		26 - 45	-20 : 15	0.323	-0.240	0.301
		5 - 45	>15	9.92E-02	-0.355	8.967
	1.4 l < CC < 2.0 l	5 - 25	-20 : 15	0.157	-0.207	7.009
		26 - 45	-20 : 15	0.282	-0.338	4.098
		5 - 45	>15	4.76E-02	-0.477	13.44
	CC>2.0 l	5 - 25	-20 : 15	8.14E-02	-0.165	6.464
		26 - 45	-20 : 15	0.116	-0.229	5.739
		5 - 45	>15	1.75E-02	-0.346	10.462
FC	All Classes	-	-10 : 30	0	-0.009	1.47

Note: e^{COLD} /e^{HOT} should be replaced with unit when it is calculated less than unit within the temperature and speed application limits

In the cases of CO and VOC over-emission occurs not only because of the low catalyst conversion efficiency but also because of the fuel enrichment during cold start conditions which allows for better drivability of a cold engine. The enrichment depends on the engine temperature during cold start. Therefore, over-emission of those pollutants during cold starts is not only higher than NO_x (which is generally not sensitive to fuel enrichment) but it also has a stronger dependence on temperature. This is why two different temperature ranges have to be distinguished for those pollutants.

The proposed functions receive values less than unit at relatively high temperatures. Results should be replaced by unit in this case. Generally, cold start effect becomes negligible in the region of 25°C in the case of CO and 30°C in the case of VOC. This is not only because over-emission under such ambient conditions is limited but also because actual engine start-up temperature can still be high after several hours of parking at these high ambient temperatures.

The mileage fraction driven during the warming up phase is calculated by means of the formula provided in Table 8-8. After calculating the β-parameter and the e^{COLD}/e^{HOT} over-emission ratios, the application of equations (6) or (7) is straightforward.

Emission reduction compared to Euro I during the warming up phase of post-Euro I vehicle technologies mainly comes from the reduced time which is required from new catalytic systems to reach the light-off temperature. This time reduction is further reflected to a decrease in the distance travelled with a partial warmed engine and/or exhaust aftertreatment devices. Therefore, reduced cold start emissions are simulated with a respective decrease of the β-parameter, which stands for the mileage fraction driven with a cold or partially warmed engine. Table 8-12 provides reduction factors ($bc_{i,j}$) to be applied on the β-parameter according to pollutant and vehicle class.

Table 8-12: β-parameter reduction factors (bc) in case of post-Euro I gasoline vehicles for three main pollutants

Emission legislation	**CO**	**NO_x**	**VOC**
Euro II - 94/12/EC	0.72	0.72	0.56
Euro III - 98/69/EC Stage 2000	0.62	0.32	0.32
Euro IV - 98/69/EC Stage 2005	0.18	0.18	0.18

On the other hand, there is no particular reason for over-emission rate (i.e. emission in g/s) differentiation between vehicle classes[2]. This means that the e^{COLD}/e^{HOT} value calculated for Euro I vehicles can be also applied in the case of later vehicle classes without further reductions. In the same respect, even the hot emission factor involved in the equation of cold start over-emission of post-Euro I vehicles should keep the Euro I calculated value. This is valid because, as mentioned before, there is no evidence for significant reduction of the rate of over-emission for later than Euro I vehicle classes.

[2] However this statement probably fails to predict the additional emission reduction which might be brought by the cold start testing (-7°C) for Euro III and later vehicles. Most probably, the mixture enrichment strategy has to change in order that such vehicles comply with this test. This by turn will lead to a reduction of the e^{COLD}/e^{HOT} ratio. However the magnitude of the effect of such modification at higher temperatures is arguable. Because of this reason and in the absence of a more detailed analysis for the time being, it was decided to abandon any correction of e^{COLD}/e^{HOT} ratio.

Therefore, equation (6) in the case of post-Euro I vehicle classes yields:

$$E_{COLD;i,j} = bc_{i,j} \times \beta_{i,EURO\ I} \times N_j \times M_j \times e_{hot,\ i,\ EURO\ I} \times (e^{COLD} / e^{HOT} - 1)|_{i,EURO\ I} \qquad (17)$$

Respective modifications should also be brought in equation (7) in cases where $bc_{i,j} \times \beta_{i,EURO\ I} > S_U$. It is obvious that the corrected value should be used for the mileage fraction during the warming up phase.

8.2 Diesel passenger cars

8.2.1 Pre Euro I

Hot emissions

Based on a relatively large number of measured data on emissions of diesel passenger cars <2.5 tonnes (Hassel et al., 1987; Pattas et al., 1985; Rijkeboer et al., 1989; 1990) enabled to differentiate between cylinder capacities and to come up with speed dependent emission factors for conventional (pre Euro I) vehicles. Emission factors to be introduced in equation (4) for the calculation of hot emissions from conventional diesel passenger cars are given in Table 8-13.

Table 8-13: Speed dependency of emission and consumption factors for conventional diesel vehicles <2.5 t

Pollutant	Engine Capacity	Speed Range [km/h]	Emission Factor [g/km]	R^2
CO	All capacities	10-130	$5.41301V^{-0.574}$	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 capacities	10-130	$4.61\ V^{-0.937}$	0.794
PM	All capacities	10-130	$0.45 – 0.0086V + 0.000058V^2$	0.439
Fuel Consumption	All capacities	10-130	$118.489 – 2.084V + 0.014V^2$	0.583

Cold start emissions

Cold start over-emissions from diesel vehicles are not very significant compared to gasoline vehicles. Therefore, no distinction is made between conventional and Euro I vehicles. e^{COLD}/e^{HOT} ratios for calculating cold start over-emissions for those vehicles are quoted in Table 8-14.

Table 8-14: Over-emission ratios e^{COLD} / e^{HOT} for diesel passenger cars (temperature range -10°C to 30°C)

Pollutant	e^{COLD} / e^{HOT}
CO	$1.9 – 0.03\ t_a$
NO_x	$1.3 – 0.013\ t_a$
VOC	$3.1 – 0.09\ t_a$ [(1)]
PM	$3.1 – 0.1\ t_a$ [(2)]
Fuel Consumption	$– 0.008\ t_a$

[(1)] VOC: if ta > 29°C then $e^{COLD} / e^{HOT} > 0.5$
[(2)] PM: if ta > 26°C then $e^{COLD} / e^{HOT} > 0.5$

8.2.2 Euro I and post-Euro I

Hot emissions

Hot emissions estimates for Euro I and post-Euro I vehicles are calculated as a function of speed. They have been developed in the framework of the *Artemis* project. Table 8-15 provides the factors of the function used to calculate the emission factors. The generic function used in this case is:

$$EF = (a + c \times V + e \times V^2)/(1 + b \times V + d \times V^2) + f/V \qquad (18)$$

Table 8-15: Values for eq.(18) to calculate emissions from Euro 1 and later diesel passenger cars

Pollutant	Emission Standard	Engine capacity	Speed Range (km/h)	R^2	a	b	c	d	e	f
CO	Euro I	All capacities	10-130	0.94	9.96E-01		-1.88E-02		1.09E-04	
	Euro II	All capacities	10-130	0.91	9.00E-01		-1.74E-02		8.77E-05	
	Euro III	All capacities	10-130	0.95	1.69E-01		-2.92E-03		1.25E-05	1.10E+00
HC	Euro I	<2.0	10-130	0.93	1.42E-01	1.38E-02	-2.01E-03	-1.90E-05	1.15E-05	
		>2.0	10-130	0.98	1.59E-01		-2.46E-03		1.21E-05	
	Euro II	<2.0	10-130	0.99	1.61E-01	7.46E-02	-1.21E-03	-3.35E-04	3.63E-06	
		>2.0	10-130	0.98	5.01E+04	3.80E+04	8.03E+03	1.15E+03	-2.66E+01	
	Euro III	<2.0	10-130	0.99	9.65E-02	1.03E-01	-2.38E-04	-7.24E-05	1.93E-06	
		>2.0	10-130	0.54	9.12E-02		-1.68E-03		8.94E-06	
NO_x	Euro I	All capacities	10-130	0.96	3.10E+00	1.41E-01	-6.18E-03	-5.03E-04	4.22E-04	
	Euro II	All capacities	10-130	0.94	2.40E+00	7.67E-02	-1.16E-02	-5.00E-04	1.20E-04	
	Euro III	All capacities	10-130	0.92	2.82E+00	1.98E-01	6.69E-02	-1.43E-03	-4.63E-04	
PM	Euro I	All capacities	10-130	0.70	1.14E-01		-2.33E-03		2.26E-05	
	Euro II	All capacities	10-130	0.71	8.66E-02		-1.42E-03		1.06E-05	
	Euro III	All capacities	10-130	0.81	5.15E-02		-8.80E-04		8.12E-06	
FC	Euro I	<2.0	10-130	0.98	1.45E+02	6.73E-02	-1.88E-01	-3.17E-04	9.47E-03	
		>2.0	10-130	0.96	1.95E+02	7.19E-02	1.87E-01	-3.32E-04	9.99E-03	
	Euro II	<2.0	10-130	0.97	1.42E+02	4.98E-02	-6.51E-01	-1.69E-04	1.32E-02	
		>2.0	10-130	0.96	1.95E+02	7.19E-02	1.87E-01	-3.32E-04	9.99E-03	
	Euro III	<2.0	10-130	0.95	1.62E+02	1.23E-01	2.18E+00	-7.76E-04	-1.28E-02	
		>2.0	10-130	0.96	1.95E+02	7.19E-02	1.87E-01	-3.32E-04	9.99E-03	

Cold start emissions

In order to calculate cold-start emissions of Euro I and later diesel passenger cars, the β-parameter is calculated by the formula given in Table 8-8 for all classes, while e^{COLD}/e^{HOT} ratios are quoted in Table 8-14 and are the same as in the case of conventional vehicles. However, some additional reductions need to be applied for vehicle technologies post-Euro 1 (RFij), which are given in Table 8-16. Based, on these, application of equation (6) in this case yields:

$$E_{COLD;i,j} = \beta_{i,j} \times N_j \times M_j \times (100\text{-}RF_{i,j}) / 100 \times e_{HOT;\, i,\, EURO\, I} \times (e^{COLD} / e^{HOT}|_{i,EURO\, I} - 1) \quad (19)$$

A similar transformation needs to be made in the case of equation (7).

Table 8-16: Emission reduction percentage for post-Euro 1 diesel passenger cars applied to vehicles complying with directive 91/441/EEC.

Diesel Passenger Cars	**CO [%]**	**NOx [%]**	**VOC [%]**	**PM [%]**
Euro II - 94/12/EC	0	0	0	0
Euro III - 98/69/EC Stage 2000	0	23	15	28
Euro IV - 98/69/EC Stage 2005	0	47	31	55

8.3 LPG passenger cars

The methodology introduced in the case of gasoline passenger cars is valid also in the case of LPG vehicles. However, it has to be stressed that the amount of data in the case of LPG vehicles was very limited and therefore a large number of assumptions and extrapolations had to be made on the basis of existing information to provide a consistent set of emission factors to calculate hot and cold start emissions.

Hot emissions

Equation (4) is applied to calculate hot emissions for conventional and Euro I LPG vehicles. Table 8-17 provides hot emission factors for conventional passenger cars and Table 8-18 for those complying with 91/441/EEC (Euro I). The former emission factors have been developed in the framework of earlier COPERT exercises and the latter ones in the framework of MEET (Samaras and Ntziachristos, 1997). With respect to post-Euro I LPG vehicles and in the absence of more updated data, reduction factors over Euro I emission factors are proposed. These can be introduced by means of equation (20), while the reduction factors are given in Table 8-19:

$$e_{HOT;\, i,\, j,\, k} = (100\text{-}RF_{i,j}) / 100 \times e_{HOT;\, i,\, EURO\, I,\, k} \quad (20)$$

Cold start emissions

Very few data on cold start over-emission from LPG vehicles are available (AQA, 1990; Hauger et al.; 1991). For consistency however and since LPG emission limitation technology is similar to that of gasoline vehicles, the methodology applied to calculate emissions from gasoline vehicles is also applied here. Table 8-20 provides over-emission ratios which are valid for all emission classes of LPG vehicles. Equations (6) and (7) are applied up to Euro I vehicles while equation (19) is applied to post-Euro I ones. Reduction factors for the β-parameter equal those of gasoline vehicles (Table 8-12).

Table 8-17: Speed Dependency of Emission Factors for LPG Vehicles <2.5 t

Pollutant	**Engine Capacity**	**Speed Range**	**Emission Factor [g/km]**	**R^2**
CO	All categories	10-130	$12.523-0.418 \cdot V+0.0039 \cdot V^2$	0.893
NOx	All categories	10-130	$0.77 \cdot V^{0.285}$	0.598
VOC	All categories	10-130	$26.3 \cdot V^{-0.865}$	0.967
Fuel Consumption	All categories	Urban Rural Highway	59 45 54	- - -

Table 8-18: Speed dependency of emission and consumption factors for LPG vehicles <2.5t, complying with directive 91/441/EEC

Pollutant	**Cylinder Capacity**	**Speed Range [km/h]**	**Emission Factor [g/km]**
CO	All categories	10-130	$0.00110V^2 - 0.1165V + 4.2098$
NO_x	All categories	10-130	$0.00004V^2 - 0.0063V + 0.5278$
VOC	All categories	10-130	$0.00010V^2 - 0.0166V + 0.7431$
Fuel Consumption	All categories	10-130	$0.00720V^2 - 0.9250V + 74.625$

Table 8-19: Emission reduction percentage for post Euro I LPG passenger cars, applied to vehicles complying with directive 91/441/EEC (Euro I).

Engine Capacity	**LPG Passenger Cars**	**CO [%]**	**NOx [%]**	**VOC[%]**
CC < 1.4 l	Euro II - 94/12/EC	32	64	79
	Euro III - 98/69/EC Stage 2000	44	76	85
	Euro IV - 98/69/EC Stage 2005	66	87	97
1.4 l < CC < 2.0 l	Euro II - 94/12/EC	32	64	79
	Euro III - 98/69/EC Stage 2000	44	76	86
	Euro IV - 98/69/EC Stage 2005	66	87	97
CC > 2.0 l	Euro II - 94/12/EC	32	64	76
	Euro III - 98/69/EC Stage 2000	44	76	84
	Euro IV - 98/69/EC Stage 2005	65	87	95

Table 8-20: Over-emission ratios e^{COLD} / e^{HOT} for LPG passenger cars (temperature range of –10°C to 30°C)

Pollutant	**e^{COLD} / e^{HOT}**
CO	$3.66 - 0.09\ t_a$
NO_x	$0.98 - 0.006\ t_a$
VOC	$2.24 - 0.06\ t_a$ (1)
Fuel Consumption	$1.47 - 0.009\ t_a$

(1) VOC: if ta > 29°C then $e^{COLD} / e^{HOT} > 0.5$

8.4 Two-stroke passenger cars

Few measured data are available (Appel et al., 1989; Jileh, 1991; Pattas et al., 1983) which have been used to derive emission factors for urban, rural and highway driving for two-stroke gasoline powered cars in the framework of older COPERT exercises. Total emission factors (hot + cold) are given in Table 8-21. They are relevant mainly for some Eastern European countries (and to some extent for Germany). However, it should be noted that due to the limited knowledge of the authors about the actual driving behaviour in Eastern Europe (e.g. average speed on urban and rural roads and on highways) and the limited number of test data, the emission factors are less reliable than, for example, those given for other gasoline passenger cars.

Table 8-21: Emission Factors for Gasoline Two-Stroke Vehicles <2.5 t

Driving Mode	CO [g/km]	NO_x [g/km]	VOC [g/km]	Fuel Consumption [g/km]
Urban	20.7	0.30	15.4	111.5
Rural	7.50	1.0	7.20	66.0
Highway	8.70	0.75	5.90	56.9

8.5 Hybrid passenger cars <1.6l

Few measured data are available which have been used to derive emission factors hybrid gasoline powered cars in the framework of new *Artemis* exercises. Only Euro IV vehicles less than <1.6 thermal engine capacity were used in the measurements. The methodology is similar to gasoline passenger cars and the equation used to calculate the emission factors is:

$$EF = a + c \times V + e \times V^2 \quad (21)$$

The factors used in the equation can be found in Table 8-22.

Table 8-22: Values for eq.(21) to calculate emissions from hybrid gasoline passenger cars

Pollutant	Emission Standard	Engine capacity	Speed Range (km/h)	R^2	a	c	e
CO	Euro IV	All capacities	10-130	1	1.95E-04	3.80E-05	-2.64E-07
HC	Euro IV	All capacities	10-130	1	5.50E-04	-8.54E-06	4.94E-08
NO_x	Euro IV	All capacities	10-130	1	1.48E-02	-4.20E-04	4.29E-06
FC	Euro IV	All capacities	10-130	1	1.94E+01	6.06E-02	7.54E-04

8.6 Gasoline light duty vehicles

<u>Hot emissions</u>

The emissions of these vehicles within EU countries were covered by the different ECE steps. All those vehicle classes have been introduced in a common "Conventional" class and emission factors for pollutants of Group 1 are given in Table 8-23. Emission factors of Euro I vehicles can also be found in the same Table. Hot emission factors of post-Euro I vehicles are calculated by application of equation (20) by introducing the reduction factors given in Table 8-24.

Table 8-23: Speed dependency of emission and consumption factors for gasoline light duty vehicles <3.5 t

Pollutant	Vehicle Class	Speed Range [km/h]	Emission Factor [g/km]	R^2
CO	Conventional	10-110	$0.01104V^2 - 1.5132V + 57.789$	0.732
	EURO I	10-120	$0.0037V^2 - 0.5215V + 19.127$	0.394
NO_x	Conventional	10-110	$0.0179V + 1.9547$	0.142
	EURO I	10-120	$7.55E-05V^2 - 0.009V + 0.666$	0.0141
VOC	Conventional	10-110	$67.7E-05V^2 - 0.117V + 5.4734$	0.771
	EURO I	10-120	$5.77E-05V^2 - 0.01047V + 0.5462$	0.358
Fuel Consumption	Conventional	10-110	$0.0167V^2 – 2.649V + 161.51$	0.787
	EURO I	10-120	$0.0195V^2 – 3.09V + 188.85$	0.723

Table 8-24: Emission reduction percentage post-Euro 1 light duty vehicles applied to vehicles complying with directive 93/59/EEC (Euro I)

Gasoline Light Duty Vehicles	CO [%]	NOx [%]	VOC [%]
Euro II - 96/69/EC	39	66	76
Euro III - 98/69/EC Stage 2000	48	79	86
Euro IV - 98/69/EC Stage 2005	72	90	94

PM emissions from gasoline light duty vehicles can be considered similar to passenger cars (Table 8-10).

<u>Cold start emissions</u>

The same over-emission ratios applied in the case of gasoline passenger cars of engine capacity >2.0 l are also applied in the case of light duty vehicles in the absence of more detailed data. Although this assumption used to be a very rough estimate for past vehicle classes, due to the very different emission standards of light duty vehicles and passenger cars, it tends to be a reality today since the technology introduced nowadays in light duty vehicles does not significantly differ from respective passenger cars. Therefore the over-emission ratios proposed in Table 8-7 (pre-Euro I) and Table 8-11 (Euro I and on) are applied in the case of light duty vehicles. Furthermore, equations (6), (7) are valid for pre-Euro I vehicles and equation (19) for Euro I and later ones in conjunction with the β-parameter reduction factors given in Table 8-12.

8.7 Diesel light duty vehicles

Diesel light duty vehicles are treated as passenger cars. Hot emission factor speed dependencies have been developed in the framework of older COPERT exercises (Conventional vehicles) and in the MEET project (Euro I and later vehicles) and are quoted in Table 8-25 for pollutants of Group 1. Cold start over-emissions up to Euro I are calculated by equation (6), where e^{COLD}/e^{HOT} ratios are selected from Table 8-14. Emission factors of post-Euro I vehicle classes are calculated by the functions corresponding to Euro I vehicles by introducing the reduction factors given in Table 8-26 both for hot and cold start emissions (equations (20) and (19), respectively).

Table 8-25: Speed dependency of emission and consumption factors for diesel light duty vehicles <3.5 t

Pollutant	**Vehicle Class**	**Speed Range [km/h]**	**Emission Factor [g/km]**	**R^2**
CO	Conventional	10-110	$20E\text{-}05V^2 - 0.0256V + 1.8281$	0.136
	EURO I	10-110	$22.3E\text{-}05V^2 - 0.026V + 1.076$	0.301
NOx	Conventional	10-110	$81.6E\text{-}05V^2 - 0.1189V + 5.1234$	0.402
	EURO I	10-110	$24.1E\text{-}05V^2 - 0.03181V + 2.0247$	0.0723
VOC	Conventional	10-110	$1.75E\text{-}05V^2 - 0.00284V + 0.2162$	0.0373
	EURO I	10-110	$1.75E\text{-}05V^2 - 0.00284V + 0.2162$	0.0373
PM	Conventional	10-110	$1.25E\text{-}05V^2 - 0.000577V + 0.288$	0.0230
	EURO I	10-110	$4.5E\text{-}05V^2 – 0.004885V + 0.1932$	0.224
Fuel Consumption	Conventional	10-110	$0.02113V^2 - 2.65V + 148.91$	0.486
	EURO I	10-110	$0.0198V^2 - 2.506V + 137.42$	0.422

Table 8-26: Emission reduction percentage for future diesel light duty vehicles applied to vehicles complying with directive 93/59/EEC

Emission Standard	**CO [%]**	**NOx [%]**	**VOC [%]**	**PM [%]**
Euro II - 96/69/EC	0	0	0	0
Euro III - 98/69/EC Stage 2000	18	16	38	33
Euro IV - 98/69/EC Stage 2005	35	32	77	65

8.8 Gasoline heavy duty vehicles

Only hot emissions are calculated for gasoline heavy duty vehicles. Emission factors derived from an extrapolation of results from smaller vehicles are presented in Table 8-27 and are distinguished only to the three driving modes (urban, rural, highway). Total emission estimates are therefore calculated by application only of equation (4).

Table 8-27: Emission factors for heavy Duty gasoline vehicles >3.5 t

Driving Mode	**CO [g/km]**	**NOx [g/km]**	**VOC [g/km]**	**Fuel Consumption [g/km]**
Urban	70	4.5	7.0	225
Rural	55	7.5	5.5	150
Highway	55	7.5	3.5	165

8.9 Diesel heavy duty vehicles and busses

Speed dependencies of emission factors for diesel heavy duty vehicles have been built on the results provided by the *Artemis* Project. Similarly, the methodology provides hot emission factors for urban busses and coaches. The emission factors are provided for conventional, Euro I to Euro V standards. Due to the large number of data required to calculate emissions from those categories, all relevant information can be found as an Annex to this guidebook chapter The emissions covered by the methodology are CO, VOC, NOx, PM and Fuel Consumption (FC).

Equations (22) to (31) represent the main equations used to calculate the emission factors, while the Annex contains the necessary parameters in a specific structure. The name of the files in the Annex is “EFs_GXX%_LYYY%.xls”, where XX is the road gradient and YYY is the load factor of the vehicle. The sheet names correspond to the emission factors described in the file, namely CO, THC (VOC), NOx, and PM.

For each sheet, column G describes the function while columns I to M contain the factors used in the equation. As an example, file “EFs_G00%_L050%.xls” contains the emission factors for a road gradient 0% and a load factor of 50%. Sheet “FC” describes the fuel consumption emission functions. The equation for Euro 1, <15t midi Urban Buses is:

$EF = e + (a \times \exp(-b \times V)+c \times \exp(-d \times V))$
where *EF* is the emission factor, *V* is the vehicle speed and the different parameters are found in the columns I to M in the *Annex* file, namely: a=18.51 – b=0.074 – c=2779,01 – d=1.148 and e=5.25.

Equations (22) to (31), describe all the different equations that are potentially used in the *Annex* to calculate heavy duty vehicle and bus emission factors.

$$EF = (a + (b \times V))+(((c - b) \times (1-\exp(((-1) \times d) \times V))) / d) \quad (22)$$

$$EF = (e + (a \times \exp(((-1) \times b) \times V))) + (c \times \exp(((-1) \times d) \times V)) \quad (23)$$

$$EF = 1 / (((c \times (V^2)) + (b \times V)) + a) \quad (24)$$

$$EF = 1 / (a + (b \times (V^c))) \quad (25)$$

$$EF = 1 / (a + (b \times V)) \quad (26)$$

$$EF = a - (b \times \exp(((-1) \times c) \times (V^d))) \quad (27)$$

$$EF = a + (b / (1+\exp((((-1) \times c) + (d \times \ln(x))) + (e \times V)))) \quad (28)$$

$$EF = c + (a \times \exp(((-1) \times b) \times V)) \quad (29)$$

$$EF = c + (a \times \exp(b \times V)) \quad (30)$$

$$EF = \exp(a + (b / V)) + (c \times \ln(V)) \quad (31)$$

8.10 Two-stroke mopeds <50 cm³

Mopeds are mostly driven under "urban" driving conditions and therefore only an urban emission factor value is proposed in Table 8-28 and Table 8-29. Emissions factors should be considered as bulk values which include the cold start fraction, therefore no distinction is made to hot and cold start emissions.

Table 8-28: Emission and consumption factors for mopeds (corresponding to urban driving conditions)

Mopeds	Emission Standard	CO [g/km]	NOx [g/km]	VOC [g/km]	Fuel Consumption
< 50 cm³	Conventional	13.80	0.02	13.91	25.00
	Euro I	5.60	0.02	2.73	15.00
	Euro II	1.30	0.26	1.56	12.08
	Euro III	1.00	0.26	1.20	10.50

Table 8-29: PM emission factors for conventional and post Euro mopeds (corresponding to urban driving conditions)

Pollutant	Emission Standard	Speed Range [km/h]	Emission Factor [gr/km]
PM	Conventional	10 - 110	1.88E-01
	Euro I	10 - 110	7.55E-02
	Euro II	10 - 110	3.76E-02
	Euro III	10 - 110	1.14E-02

8.11 Motorcycles >50 cm³

The equation used to calculate the emission factor of Euro Conventional and Euro I motorcycles over 50 cm³ engine displacement is eq. (21). The coefficients to calculate these emission factors up to the Euro I emission standard are given in Table 8-30 for 2-stroke vehicles and

Table 8-32 for 4-stroke ones. For more recent vehicle technologies, reduction factors over the Euro 1 emission factor are proposed for2-stroke ones, which should be applied according to Table 8-31. Urban, rural and highway emission factors are proposed for 4-stroke motorcycles of improved technology in Table 8-33.

Table 8-30: Speed dependency of emission and consumption factors for conventional and Euro I 2 stroke motorcycles of engine displacement over 50 cm³

Pollutant	**Emission Standard**	**Speed Range [km/h]**	**Coefficients**		
			e	**c**	**a**
CO	Conventional	10 - 60	-1.000E-03	1.720E-01	1.810E+01
		60 - 110	1.000E-04	5.000E-02	2.150E+01
	Euro I	10 - 60	-6.300E-03	7.150E-01	-6.900E+00
		60 - 110	-7.000E-04	1.570E-01	6.000E+00
NOx	Conventional	10 - 60	3.000E-05	-2.000E-03	6.400E-02
		60 - 110	-2.000E-05	4.900E-03	-1.570E-01
	Euro I	10 - 60	2.000E-05	-1.000E-03	3.200E-02
		60 - 110	-2.000E-05	4.100E-03	-1.520E-01

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Table 8-30: Speed dependency of emission and consumption factors for conventional and Euro I 2 stroke motorcycles of engine displacement over 50 cm³

Pollutant	Emission Standard	Speed Range [km/h]	Coefficients		
			e	c	a
HC	Conventional	10 - 60	3.500E-03	-4.090E-01	2.010E+01
		60 - 110	3.000E-04	-5.240E-02	1.060E+01
	Euro I	10 - 60	-1.000E-03	9.700E-02	3.900E+00
		60 - 110	-3.000E-04	3.250E-02	5.200E+00
Fuel Consumption	Conventional	10 - 60	6.300E-03	-6.028E-01	4.440E+01
		60 - 110	-5.000E-04	2.375E-01	1.820E+01
	Euro I	10 - 60	-1.100E-03	2.008E-01	1.780E+01
		60 - 110	-1.000E-03	2.425E-01	1.460E+01

Table 8-31: Emission correction factors for Euro II and later 2 stroke motorcycles of engine displacement over 50 cm³ over Euro I

Pollutant	Emission Standard	Speed Range [km/h]	Equation	Correction Factor CF
CO	Euro II	10 - 110	$EF_{Euro\ I} \times CF$	6.88E-01
	Euro III	10 - 110		1.67E-01
NOx	Euro II	10 - 110		3.70E+00
	Euro III	10 - 110		1.00E+01
HC	Euro II	10 - 110		3.00E-01
	Euro III	10 - 110		1.20E-01
Fuel Consumption	Euro II	10 - 110		9.10E-01
	Euro III	10 - 110		7.00E-01

Table 8-32: Speed dependency of emission and consumption factors for 4 stroke conventional and Euro I motorcycles of engine displacement over 50cm³

Pollutant	Cylinder Capacity	Emission Standard	Speed Range [km/h]	Coefficients		
				e	c	a
CO	<250cm³	Conventional	10 - 60	1.93E-02	-1.92E+00	6.83E+01
			60 - 110	1.70E-03	1.21E-01	9.50E+00
		Euro I	10 - 60	-4.68E-04	1.08E-01	9.33E+00
			60 - 110	-4.68E-04	1.08E-01	9.33E+00
	250<cc<750cm³	Conventional	10 - 60	1.39E-02	-1.42E+00	5.50E+01
			60 - 110	9.00E-04	-9.90E-03	1.78E+01
		Euro I	10 - 60	1.51E-03	-4.02E-02	8.73E+00
			60 - 110	1.51E-03	-4.02E-02	8.73E+00
	>750cm³	Conventional	10 - 60	1.23E-02	-1.19E+00	4.28E+01
			60 - 110	5.00E-04	1.24E-01	6.90E+00
		Euro I	10 - 60	2.79E-03	-3.42E-01	1.71E+01
			60 - 110	2.79E-03	-3.42E-01	1.71E+01

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Table 8-32: Speed dependency of emission and consumption factors for 4 stroke conventional and Euro I motorcycles of engine displacement over 50cm^3

Pollutant	Cylinder Capacity	Emission Standard	Speed Range [km/h]	Coefficients		
				e	c	a
NOx	$<250cm^3$	Conventional	10 - 60	5.00E-05	-1.00E-03	9.00E-02
			60 - 110	2.00E-05	6.00E-04	1.02E-01
		Euro I	10 - 60	7.66E-05	-2.73E-03	2.32E-01
			60 - 110	7.66E-05	-2.73E-03	2.32E-01
	$250<cc<750cm^3$	Conventional	10 - 60	5.00E-05	-9.00E-04	9.20E-02
			60 - 110	2.00E-05	7.00E-04	1.04E-01
		Euro I	10 - 60	5.23E-05	4.30E-04	1.91E-01
			60 - 110	5.23E-05	4.30E-04	1.91E-01
	$>750cm^3$	Conventional	10 - 60	5.00E-05	-8.00E-04	1.00E-01
			60 - 110	2.00E-05	8.00E-04	1.12E-01
		Euro I	10 - 60	1.43E-04	-5.32E-03	1.94E-01
			60 - 110	1.43E-04	-5.32E-03	1.94E-01
HC	$<250cm^3$	Conventional	10 - 60	1.90E-03	-2.11E-01	6.95E+00
			60 - 110	9.00E-04	-1.41E-01	6.42E+00
		Euro I	10 - 60	-1.53E-04	3.44E-03	1.21E+00
			60 - 110	0.00E+00	0.00E+00	8.70E-01
	$250<cc<750cm^3$	Conventional	10 - 60	1.50E-03	-1.64E-01	5.51E+00
			60 - 110	1.00E-05	5.00E-04	8.60E-01
		Euro I	10 - 60	1.59E-04	-2.58E-02	1.78E+00
			60 - 110	1.59E-04	-2.58E-02	1.78E+00
	$>750cm^3$	Conventional	10 - 60	2.20E-03	-2.57E-01	9.28E+00
			60 - 110	1.00E-04	-3.10E-02	3.29E+00
		Euro I	10 - 60	3.36E-04	-5.12E-02	2.68E+00
			60 - 110	3.36E-04	-5.12E-02	2.68E+00
Fuel Consumption	$<250cm^3$	Conventional	10 - 60	1.89E-02	-1.87E+00	6.79E+01
			60 - 110	8.00E-04	1.61E-01	1.15E+01
		Euro I	10 - 60	8.40E-03	-6.77E-01	3.57E+01
			60 - 110	8.40E-03	-6.77E-01	3.57E+01
	$250<cc<750cm^3$	Conventional	10 - 60	2.73E-02	-2.85E+00	9.89E+01
			60 - 110	2.10E-03	-1.55E-01	2.92E+01
		Euro I	10 - 60	6.44E-03	-6.96E-01	4.65E+01
			60 - 110	6.44E-03	-6.96E-01	4.65E+01
	$>750cm^3$	Conventional	10 - 60	2.87E-02	-3.11E+00	1.16E+02
			60 - 110	1.80E-03	-1.64E-01	3.70E+01
		Euro I	10 - 60	7.22E-03	-1.08E+00	7.66E+01
			60 - 110	7.22E-03	-1.08E+00	7.66E+01

Table 8-33: Emission and consumption factors for 4 stroke Euro II and Euro III motorcycles of engine displacement over 50cm³

Pollutant	Cylinder Capacity	Emission Standard	Speed Range [km/h]	Emission Factor [gr/km]		
				Urban	Rural	Highway
CO	All Categories	Euro II	10 - 110	6.472	5.947	9.309
	All Categories	Euro III	10 - 110	4.705	1.581	2.241
NOx	All Categories	Euro II	10 - 110	0.195	0.265	0.531
	All Categories	Euro III	10 - 110	0.126	0.150	0.329
HC	All Categories	Euro II	10 - 110	1.053	0.557	0.612
	All Categories	Euro III	10 - 110	0.628	0.193	0.179
Fuel Consumption	All Categories	Euro II	10 - 110	Euro I	Euro I	Euro I
	All Categories	Euro III	10 - 110	Euro I	Euro I	Euro I

Table 8-34 also includes PM emission factors from power two wheelers, which are particularly important for 2-stroke vehicles. These emission factors correspond to a mix of mineral and synthetic lubricant used for 2-stroke engines.

Table 8-34: PM Emission factors for 2 and 4 stroke conventional and post Euro motorcycles of engine displacement over 50cm³

Pollutant	**Cylinder Capacity**	**Emission Standard**	**Speed Range [km/h]**	**Emission Factor [gr/km]**
PM	2-stroke	Conventional	10 - 110	2.0E-01
		Euro I	10 - 110	8.0E-02
		Euro II	10 - 110	4.0E-02
		Euro III	10 - 110	1.2E-02
	<250cm3	Conventional	10 - 110	2.0E-02
		Euro I	10 - 110	2.0E-02
		Euro II	10 - 110	5.0E-03
		Euro III	10 - 110	5.0E-03
	250<cc<750cm3	Conventional	10 - 110	2.0E-02
		Euro I	10 - 110	2.0E-02
		Euro II	10 - 110	5.0E-03
		Euro III	10 - 110	5.0E-03
	>750cm3	Conventional	10 - 110	2.0E-02
		Euro I	10 - 110	2.0E-02
		Euro II	10 - 110	5.0E-03
		Euro III	10 - 110	5.0E-03

8.12 Emissions of non-regulated pollutants

8.12.1 Distinction to methane / non methane VOC emissions

8.12.2 Legislation regulates total VOC emissions with no distinction to methane / non-methane split. Hence, previous tables have provided emission factors for VOC emissions. However, since CH_4 is a greenhouse gas, we need different emission factors to calculate its contribution. In order to calculate hot CH_4 emissions, equation (4) can be applied with the values given in PM characteristics

New emission factors for PM characteristics have been developed on the basis of the *Particulates* project and are presented in the following tables. These include the "Active Surface Area" in cm²/km, the "Total Particle Number" in #/km, and the "Solid Particle Number" in #/km , differentiated in three different classes (< 50 nm, 50-100 nm, 100-1000 nm). The total particle number emitted by vehicles is only indicative of the total emission flux, since vehicles emit both solid and volatile particles and the number concentration of the latter depends on the ambient conditions (temperature, humidity, traffic conditions, etc.). The values given in the following tables have been obtained in the laboratory under conditions expected to maximize the concentration of these particles, hence they should be considered to represent a close to maximum emission rate. More details on the sampling conditions and the relevance of these values is given by Samaras et al. (2005).

Table 8-36. Methane emission factors have been derived from the literature for all types of vehicles (Bailey et al. 1989, Volkswagen 1989, OECD 1991, Zajontz et al. 1991).

Table 8-35: Methane (CH_4) emission factors (mg/km) for stabilised (hot) thermal conditions (Conventional)

Vehicle Type	Fuel	Vehicle Technology/Class	Speed Range	CH_4 Emission Factors [mg/km]		
				Urban	Rural	Highway
Passenger Cars	Gasoline	pre-Euro	10 - 130	$0.0331V^2 - 5.73V + 268$		
Light Duty Vehicles	Gasoline	pre-Euro	10 - 130	150	40	25

NMVOC emission are deduced as the remainder of the subtraction of CH_4 total emissions from VOC total emissions, as calculated by equation (1). Hence, if VOC and CH_4 have been calculated by equation (1), NMVOC emissions can also be calculated by:

$$E_{NMVOC} = E_{VOC} - E_{CH4} \quad (32)$$

8.12.3 PM characteristics

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New emission factors for PM characteristics have been developed on the basis of the *Particulates* project and are presented in the following tables. These include the “Active Surface Area” in cm²/km, the “Total Particle Number” in #/km, and the “Solid Particle Number” in #/km , differentiated in three different classes (< 50 nm, 50-100 nm, 100-1000 nm). The total particle number emitted by vehicles is only indicative of the total emission flux, since vehicles emit both solid and volatile particles and the number concentration of the latter depends on the ambient conditions (temperature, humidity, traffic conditions, etc.). The values given in the following tables have been obtained in the laboratory under conditions expected to maximize the concentration of these particles, hence they should be considered to represent a close to maximum emission rate. More details on the sampling conditions and the relevance of these values is given by Samaras et al. (2005).

Table 8-36: Bulk methane (CH_4) emission factors for different vehicle categories and driving conditions

Vehicle Type	Fuel	Vehicle Technology/Class	CH_4 Emission Factors (mg/km)			
			Urban		Rural	Highway
			Cold	Hot		
Passenger Car	Gasoline	Euro 1	45	26	16	14
		Euro 2	94	17	13	11
		Euro 3	83	3	2	4
		Euro 4	57	2	2	0
	Diesel	pre-Euro	22	28	12	8
		Euro 1	18	11	9	3
		Euro 2	6	7	3	2
		Euro 3	7	3	0	0
		Euro 4	0	0	0	0
	LPG	pre-ECE	80		35	25
		Euro 1				
		Euro 2				
		Euro 3 and later				
Light Duty Vehicles	Gasoline	Euro 1	45	26	16	14
		Euro 2	94	17	13	11
		Euro 3	83	3	2	4
		Euro 4	57	2	2	0
	Diesel	pre-Euro	22	28	12	8
		Euro 1	18	11	9	3
		Euro 2	6	7	3	2
		Euro 3	7	3	0	0
		Euro 4	0	0	0	0
Heavy Duty Truck & Bus	Gasoline	All Technologies	140		110	70
	Diesel	GVW<16t	85		23	20
		GVW>16t	175		80	70

		Urban Busses&Coaches	175	80	70
	CNG	pre-Euro 4	5400		
		Euro 4 and later (+EEV)	900		
Power Two Wheeler	Gasoline	<50 cm^3	219	219	219
		>50 cm^3 2-stroke	150	150	150
		>50 cm^3 4-stroke	200	200	200

Table 8-37: PM characteristics of Diesel Passenger Cars

Pollutant	**Category**	**Fuel sulphur content**	**Emission Factor**		
			Urban	**Rural**	**Highway**
Active surface area [m²/km]	PC diesel Euro-1	later than 2000	2.10E+01	1.91E+01	2.94E+01
	PC diesel Euro-2	2005-2009	1.68E+01	1.71E+01	2.78E+01
		2000			3.62E+01
	PC diesel Euro-3	2005-2009	1.53E+01	1.34E+01	1.85E+01
		2000			3.93E+01
	PC diesel Euro-3 DPF	2005-2009	1.21E-02	1.32E-02	2.20E-01
		2000		4.03E+00	4.46E+01
	PC petrol Euro-1	later than 2000	6.82E-01	4.33E-01	4.98E-01
	PC petrol Euro-3	later than 2000	2.38E-02	3.32E-02	7.43E-02
	PC petrol Euro-3 DISI	later than 2000	2.04E+00	1.77E+00	2.48E+00
Total particle number [#/km]	PC diesel Euro-1	later than 2000	4.04E+14	3.00E+14	3.21E+14
	PC diesel Euro-2	2005-2009	2.12E+14	2.05E+14	4.35E+14
		2000			7.10E+14
	PC diesel Euro-3	2005-2009	1.64E+14	1.73E+14	2.82E+14
		2000			1.23E+15
	PC diesel Euro-3 DPF	2005-2009	6.71E+10	9.00E+12	1.79E+14
		2000		1.67E+14	1.34E+15
	PC petrol Euro-1	later than 2000	8.76E+12	7.35E+12	1.81E+13
	PC petrol Euro-3	later than 2000	6.99E+11	5.26E+12	5.59E+12
	PC petrol Euro-3 DISI	later than 2000	1.47E+13	1.13E+13	9.02E+13

Table 8-38: Solid particle number emission from Diesel Passenger Cars (not affected by fuel sulphur content)

Pollutant	**Category**	**Emission Factor (#/km)**		
		Urban	**Rural**	**Highway**
Number of solid particles <50 nm	PC diesel Euro-1	8.5E+13	8.6E+13	7.2E+13
	PC diesel Euro-2	7.6E+13	7.6E+13	6.1E+13
	PC diesel Euro-3	7.9E+13	7.1E+13	5.8E+13

	PC diesel Euro-3 DPF	5.5E+10	4.0E+10	2.3E+11
	PC gasoline Euro-1	3.2E+12	2.4E+12	8.6E+11
	PC gasoline Euro-3	9.6E+10	1.1E+11	5.5E+10
	PC gasoline Euro-3 DISI	8.1E+12	6.1E+12	2.8E+12
Number of solid particles 50-100 nm	PC diesel Euro-1	9.3E+13	7.8E+13	7.3E+13
	PC diesel Euro-2	8.8E+13	7.7E+13	7.2E+13
	PC diesel Euro-3	8.7E+13	6.8E+13	6.9E+13
	PC diesel Euro-3 DPF	2.3E+10	1.6E+10	9.4E+10
	PC gasoline Euro-1	1.4E+12	1.0E+12	3.4E+11
	PC gasolineEuro-3	4.4E+10	5.4E+10	2.8E+10
	PC gasoline Euro-3 DISI	6.5E+12	3.6E+12	1.9E+12
Number of solid particles 100-1000 nm	PC diesel Euro-1	5.4E+13	3.8E+13	4.0E+13
	PC diesel Euro-2	5.1E+13	3.6E+13	4.0E+13
	PC diesel Euro-3	4.5E+13	3.2E+13	3.5E+13
	PC diesel Euro-3 DPF	1.6E+10	1.2E+10	2.8E+10
	PC gasoline Euro-1	5.2E+11	3.7E+11	1.2E+11
	PC gasoline Euro-3	2.6E+10	3.4E+10	5.1E+10
	PC gasoline Euro-3 GDI	4.1E+12	2.1E+12	1.5E+12

Table 8-39 to Table 8-43 include particle properties information for busses and heavy duty vehicles, following the classification of Table 1-2. Further to the technology classification given in Table 3-6, some additional technologies are included in these tables, just because of their large influence on PM emissions. These tables include Euro II and Euro III vehicles retrofitted with continuously regenerated particle filters (CRDPF) and selective catalytic reduction aftertreatment (SCR). They also include new emission technologies (Euro IV and Euro V) equipped with original equipment aftertreatment devices.

Table 8-39: PM characteristics of Buses

Pollutant	Emission Standard	Speed Range [km/h]	Emission Factor		
			Urban	Rural	Highway
Active Surface Area [cm²/km]	Euro II & III	10 - 110	5.65E+05	1.99E+05	2.57E+05
	Euro II & III + CRDPF	10 - 110	8.07E+04	1.77E+04	2.18E+04
	Euro II & III+SCR	10 - 110	9.13E+05	3.37E+05	3.93E+05
	Euro IV +CRDPF	10 - 110			
	Euro V + SCR	10 - 110			
Total Particle Number [#/km]	Euro II & III	10 - 110	6.88E+14	4.55E+14	1.12E+15
	Euro II & III + CRDPF	10 - 110	2.72E+14	4.77E+13	8.78E+13
	Euro II & III+SCR	10 - 110	7.66E+14	5.68E+14	1.28E+15
	Euro IV +CRDPF	10 - 110	5.93E+12	3.57E+12	2.93E+12
	Euro V + SCR	10 - 110	1.73E+13	1.09E+13	1.22E+13
Solid Particle Number < 50 nm [#/km]	Euro II & III	10 - 110	1.25E+14	5.08E+13	7.43E+13
	Euro II & III + CRDPF	10 - 110	3.87E+12	1.89E+12	4.18E+12
	Euro II & III+SCR	10 - 110	1.19E+14	5.26E+13	7.67E+13
	Euro IV +CRDPF	10 - 110	1.25E+10	6.43E+09	8.20E+09
	Euro V + SCR	10 - 110	7.98E+12	2.87E+12	2.04E+12

Solid Particle Number 50-100 nm [#/km]	Euro II & III	10 - 110	1.44E+14	5.44E+13	6.82E+13
	Euro II & III + CRDPF	10 - 110	3.31E+12	1.43E+12	2.54E+12
	Euro II & III+SCR	10 - 110	1.57E+14	6.14E+13	7.25E+13
	Euro IV +CRDPF	10 - 110	1.04E+10	4.14E+09	3.88E+09
	Euro V + SCR	10 - 110	9.13E+12	3.06E+12	2.10E+12
Solid Particle Number 100-1000 nm [#/km]	Euro II & III	10 - 110	2.09E+14	7.25E+13	7.16E+13
	Euro II & III + CRDPF	10 - 110	2.29E+12	8.53E+11	1.12E+12
	Euro II & III+SCR	10 - 110	3.30E+14	1.21E+14	1.10E+14
	Euro IV +CRDPF	10 - 110	3.27E+10	9.48E+09	5.89E+09
	Euro V + SCR	10 - 110	1.57E+13	5.16E+12	3.36E+12

Table 8-40: PM characteristics of Coaches

Coaches					
Pollutant	**Emission Standard**	**Speed Range [km/h]**	**Emission Factor**		
			Urban	**Rural**	**Highway**
Active Surface Area [cm²/km]	Euro II & III	10 - 110	6.75E+05	2.23E+05	2.13E+05
	Euro II & III + CRDPF	10 - 110	9.65E+04	1.98E+04	1.81E+04
	Euro II & III+SCR	10 - 110	1.09E+06	3.77E+05	3.26E+05
	Euro IV +CRDPF	10 - 110			
	Euro V + SCR	10 - 110			
Total Particle Number [#/km]	Euro II & III	10 - 110	8.23E+14	5.09E+14	9.28E+14
	Euro II & III + CRDPF	10 - 110	3.25E+14	5.34E+13	7.28E+13
	Euro II & III+SCR	10 - 110	9.16E+14	6.35E+14	1.06E+15
	Euro IV +CRDPF	10 - 110	7.29E+12	4.03E+12	2.42E+12
	Euro V + SCR	10 - 110	2.15E+13	1.24E+13	1.01E+13
Solid Particle Number < 50 nm [#/km]	Euro II & III	10 - 110	1.49E+14	5.68E+13	6.16E+13
	Euro II & III + CRDPF	10 - 110	4.63E+12	2.11E+12	3.47E+12
	Euro II & III+SCR	10 - 110	1.43E+14	5.89E+13	6.36E+13
	Euro IV +CRDPF	10 - 110	1.53E+10	7.27E+09	6.76E+09
	Euro V + SCR	10 - 110	9.92E+12	3.27E+12	1.69E+12
Solid Particle Number 50-100 nm [#/km]	Euro II & III	10 - 110	1.72E+14	6.08E+13	5.65E+13
	Euro II & III + CRDPF	10 - 110	3.96E+12	1.60E+12	2.10E+12
	Euro II & III+SCR	10 - 110	1.88E+14	6.86E+13	6.01E+13
	Euro IV +CRDPF	10 - 110	1.28E+10	4.68E+09	3.19E+09

	Euro V + SCR	10 - 110	1.14E+13	3.49E+12	1.73E+12
Solid Particle Number 100-1000 nm [#/km]	Euro II & III	10 - 110	2.49E+14	8.11E+13	5.94E+13
	Euro II & III + CRDPF	10 - 110	2.74E+12	9.54E+11	9.30E+11
	Euro II & III+SCR	10 - 110	3.95E+14	1.36E+14	9.13E+13
	Euro IV +CRDPF	10 - 110	4.02E+10	1.07E+10	4.85E+09
	Euro V + SCR	10 - 110	1.95E+13	5.89E+12	2.77E+12

Table 8-41: PM characteristics of HDVs 3.5-7.5 tn

HDVs 3.5-7.5 tn					
Pollutant	**Emission Standard**	**Speed Range [km/h]**	**Emission Factor**		
			Urban	**Rural**	**Highway**
Active Surface Area [cm²/km]	Euro II & III	10 - 110	2.62E+05	1.19E+05	1.61E+05
	Euro II & III + CRDPF	10 - 110	3.74E+04	1.06E+04	1.36E+04
	Euro II & III+SCR	10 - 110	4.23E+05	2.02E+05	2.45E+05
	Euro IV +CRDPF	10 - 110			
	Euro V + SCR	10 - 110			
Total Particle Number [#/km]	Euro II & III	10 - 110	3.19E+14	2.72E+14	6.99E+14
	Euro II & III + CRDPF	10 - 110	1.26E+14	2.85E+13	5.48E+13
	Euro II & III+SCR	10 - 110	3.55E+14	3.40E+14	8.01E+14
	Euro IV +CRDPF	10 - 110	2.73E+12	2.12E+12	1.80E+12
	Euro V + SCR	10 - 110	7.96E+12	6.41E+12	7.44E+12
Solid Particle Number < 50 nm [#/km]	Euro II & III	10 - 110	5.79E+13	3.04E+13	4.64E+13
	Euro II & III + CRDPF	10 - 110	1.80E+12	1.13E+12	2.61E+12
	Euro II & III+SCR	10 - 110	5.52E+13	3.15E+13	4.79E+13
	Euro IV +CRDPF	10 - 110	5.75E+09	3.81E+09	5.04E+09
	Euro V + SCR	10 - 110	3.66E+12	1.69E+12	1.24E+12
Solid Particle Number 50-100 nm [#/km]	Euro II & III	10 - 110	6.68E+13	3.25E+13	4.26E+13
	Euro II & III + CRDPF	10 - 110	1.53E+12	8.56E+11	1.59E+12
	Euro II & III+SCR	10 - 110	7.27E+13	3.67E+13	4.53E+13
	Euro IV +CRDPF	10 - 110	4.78E+09	2.46E+09	2.38E+09
	Euro V + SCR	10 - 110	4.19E+12	1.81E+12	1.28E+12
Solid Particle Number 100-1000 nm [#/km]	Euro II & III	10 - 110	9.66E+13	4.34E+13	4.47E+13
	Euro II & III + CRDPF	10 - 110	1.06E+12	5.10E+11	7.01E+11
	Euro II & III+SCR	10 - 110	1.53E+14	7.26E+13	6.88E+13
	Euro IV +CRDPF	10 - 110	1.51E+10	5.62E+09	3.62E+09
	Euro V + SCR	10 - 110	7.21E+12	3.05E+12	2.04E+12

Table 8-42: PM characteristics of rigid HDVs 7.5-14 tn

HDVs 7.5-16 tn					
Pollutant	**Emission Standard**	**Speed Range [km/h]**	**Emission Factor**		
			Urban	**Rural**	**Highway**
Active Surface Area [cm2/km]	Euro II & III	10 - 110	5.56E+05	2.19E+05	2.37E+05
	Euro II & III + CRDPF	10 - 110	7.95E+04	1.95E+04	2.00E+04
	Euro II & III+SCR	10 - 110	8.99E+05	3.70E+05	3.61E+05
	Euro IV +CRDPF	10 - 110			
	Euro V + SCR	10 - 110			
Total Particle Number [#/km]	Euro II & III	10 - 110	6.78E+14	5.00E+14	1.03E+15
	Euro II & III + CRDPF	10 - 110	2.68E+14	5.24E+13	8.07E+13
	Euro II & III+SCR	10 - 110	7.54E+14	6.23E+14	1.18E+15
	Euro IV +CRDPF	10 - 110	5.81E+12	3.90E+12	2.66E+12
	Euro V + SCR	10 - 110	1.69E+13	1.18E+13	1.10E+13
Solid Particle Number < 50 nm [#/km]	Euro II & III	10 - 110	1.23E+14	5.58E+13	6.83E+13
	Euro II & III + CRDPF	10 - 110	3.82E+12	2.07E+12	3.84E+12
	Euro II & III+SCR	10 - 110	1.17E+14	5.78E+13	7.05E+13
	Euro IV +CRDPF	10 - 110	1.22E+10	7.02E+09	7.44E+09
	Euro V + SCR	10 - 110	7.77E+12	3.12E+12	1.84E+12
Solid Particle Number 50-100 nm [#/km]	Euro II & III	10 - 110	1.42E+14	5.97E+13	6.27E+13
	Euro II & III + CRDPF	10 - 110	3.26E+12	1.57E+12	2.33E+12
	Euro II & III+SCR	10 - 110	1.55E+14	6.73E+13	6.66E+13
	Euro IV +CRDPF	10 - 110	1.02E+10	4.52E+09	3.52E+09
	Euro V + SCR	10 - 110	8.90E+12	3.33E+12	1.89E+12
Solid Particle Number 100-1000 nm [#/km]	Euro II & III	10 - 110	2.05E+14	7.95E+13	6.58E+13
	Euro II & III + CRDPF	10 - 110	2.26E+12	9.36E+11	1.03E+12
	Euro II & III+SCR	10 - 110	3.25E+14	1.33E+14	1.01E+14
	Euro IV +CRDPF	10 - 110	3.20E+10	1.04E+10	5.35E+09
	Euro V + SCR	10 - 110	1.53E+13	5.62E+12	3.02E+12

Table 8-43: PM characteristics of rigid HDVs 14-32 t and truck trailer/articulated 14-34t

HDVs 16-32 tn					
Pollutant	**Emission Standard**	**Speed Range [km/h]**	**Emission Factor**		
			Urban	**Rural**	**Highway**
Active Surface Area [cm2/km]	Euro II & III	10 - 110	8.68E+05	3.38E+05	3.14E+05
	Euro II & III + CRDPF	10 - 110	1.24E+05	3.01E+04	2.65E+04
	Euro II & III+SCR	10 - 110	1.40E+06	5.71E+05	4.79E+05
	Euro IV +CRDPF	10 - 110			
	Euro V + SCR	10 - 110			
Total Particle Number [#/km]	Euro II & III	10 - 110	1.06E+15	7.71E+14	1.36E+15
	Euro II & III + CRDPF	10 - 110	4.19E+14	8.08E+13	1.07E+14
	Euro II & III+SCR	10 - 110	1.18E+15	9.62E+14	1.56E+15
	Euro IV +CRDPF	10 - 110	9.07E+12	6.02E+12	3.54E+12
	Euro V + SCR	10 - 110	2.64E+13	1.83E+13	1.46E+13
Solid Particle Number < 50 nm [#/km]	Euro II & III	10 - 110	1.92E+14	8.61E+13	9.05E+13
	Euro II & III + CRDPF	10 - 110	5.96E+12	3.20E+12	5.09E+12
	Euro II & III+SCR	10 - 110	1.83E+14	8.92E+13	9.35E+13
	Euro IV +CRDPF	10 - 110	1.91E+10	1.09E+10	9.89E+09
	Euro V + SCR	10 - 110	1.22E+13	4.83E+12	2.45E+12
Solid Particle Number 50-100 nm [#/km]	Euro II & III	10 - 110	2.22E+14	9.22E+13	8.31E+13
	Euro II & III + CRDPF	10 - 110	5.09E+12	2.42E+12	3.09E+12
	Euro II & III+SCR	10 - 110	2.41E+14	1.04E+14	8.84E+13
	Euro IV +CRDPF	10 - 110	1.59E+10	6.99E+09	4.67E+09
	Euro V + SCR	10 - 110	1.39E+13	5.15E+12	2.52E+12
Solid Particle Number 100-1000 nm [#/km]	Euro II & III	10 - 110	3.21E+14	1.23E+14	8.73E+13
	Euro II & III + CRDPF	10 - 110	3.52E+12	1.44E+12	1.37E+12
	Euro II & III+SCR	10 - 110	5.08E+14	2.06E+14	1.34E+14
	Euro IV +CRDPF	10 - 110	5.00E+10	1.60E+10	7.10E+09
	Euro V + SCR	10 - 110	2.39E+13	8.69E+12	4.02E+12

8.12.4 Nitrous oxide (N_2O) emissions

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Nitrous oxide emission factors have been developed on the basis of an LAT/AUTh study (Papathanasiou and Tzirgas, 2005), based on literature data collected in studies around the world. N_2O emission factors are particularly important for catalyst vehicles, and especially under conditions that the catalyst is under partial oxidizing behaviour. This may occur wither when the catalyst has not yet reached its light-off temperature or when the catalyst is aged. Just because the emission of N_2O received increased importance lately, due to its contribution to the greenhouse effect, a detailed calculation of N_2O needs to take vehicle age (mileage) into account. In parallel, the aftertreatment ageing depends on the fuel sulphur level. Hence different emission factors need to be derived depending on the fuel sulphur content. In order to take both these effects into account, N_2O emission factors are calculated according to eq. (33), with its parameters receiving values from Table 8-44 to Table 8-51 for different passenger cars and light duty vehicles. These values differ according to the fuel sulphur level and the driving conditions (urban, rural, highway). In particular, the urban emission factor is distinguished between a cold-start and a hot-start one.

$$EF_{N2O} = [a \times Mileage + b] \times EF_{BASE} \quad (33)$$

Passenger Cars

Table 8-44: Parameters for eq.(33) to calculate N_2O emission factors for gasoline passenger cars under cold urban conditions

Emission Standard	Sulphur content (ppm)	Base EF (mg/km)	a	b
Pre-Euro	<500	10.0	-	-
	>500	7.0	-	-
Euro I	<30	17.5	5.60E-07	0.936
	30-350	40.5	1.76E-06	0.839
	>350	57.6	7.24E-06	0.748
Euro II	<30	12	5.85E-07	0.978
	30-350	24	4.61E-07	0.972
	>350	37	2.41E-06	0.918
Euro III	<30	7.9	5.68E-07	0.950
	30-90	11.4	-2.54E-07	1.02
	90-150	11.7	-5.61E-07	1.04
Euro IV	<30	5.4	3.79E-07	0.960
	30-90	6.4	4.46E-07	0.951
	90-150	10.5	4.51E-07	0.950

Table 8-45: Parameters for eq. (33) to calculate N_2O emission factors for gasoline passenger cars under hot urban conditions

Emission Standard	Sulphur content (ppm)	Base EF [gr/km]	a	b
Pre Euro	<500	10	-	-
	>500	0.269	-	-
Euro I	90-350	23.2	8.81E-07	0.92
	>350	60.4	1.54E-05	0.255
Euro II	90-350	11.1	9.21E-07	0.962
	>350	17.9	3.14E-06	0.93
Euro III	<30	1.33	1.85E-06	0.829
	30-90	1.75	2.34E-06	0.801
	90-150	3.04	-3.34E-07	1.03
Euro IV	<30	1.94	6.61E-07	0.931
	30-90	2.42	2.39E-06	0.738
	90-150	4.16	8.65E-07	0.903

Table 8-46: Parameters for eq. (33) to calculate N_2O emission factors for gasoline passenger cars under hot rural conditions

Emission Standard	Sulphur content (ppm)	Base EF [gr/km]	a	b
Pre Euro	<500	-	-	-
	>500	6.46	-	-
Euro I	<30	9.2	1.31E-06	0.851
	30-350	18.5	2.90E-06	0.747
	>350	48.9	1.37E-05	0.227
Euro II	S<30	4.03	1.45E-06	0.945
	90<=S<=150	4.19	4.93E-06	0.799
	S=500	-	-	-
Euro III	<30	0.333	1.35E-06	0.875
	30-90	1.07	4.10E-06	0.539
	90-150	2.2	4.20E-06	0.68
Euro IV	<30	0.291	2.61E-06	0.726
	30-90	1.1	4.09E-06	0.549
	90-150	2.47	4.82E-07	0.946

Table 8-47: Parameters for eq. (33) to calculate N_2O emission factors for gasoline passenger cars under hot highway conditions

Emission Standard	Sulphur content (ppm)	Base EF [gr/km]	a	b
Pre Euro	<500	-	-	-
	>500	-	-	-
Euro I	<30	4.66	1.30E-06	0.846
	30-350	9.35	2.87E-06	0.739
	>350	24.7	1.33E-05	0.219
Euro II	<30	2.25	1.45E-06	0.944
	30-350	2.33	4.92E-06	0.797
	>350	-	-	-
Euro III	<30	0.191	1.49E-06	0.967
	30-90	0.61	6.32E-06	0.832
	90-150	1.25	5.56E-06	0.9
Euro IV	<30	0.167	3.30E-06	0.918
	30-90	0.629	6.23E-06	0.838
	90-150	1.41	5.03E-07	0.987

Light Duty vehicles

Table 8-48: Parameters for eq. (33) to calculate N_2O emission factors for gasoline LDVs under cold urban conditions

Emission Standard	Sulphur content (ppm)	Base EF [gr/km]	a	b
Pre Euro	>500	-	-	-
Euro I	<350	46.5	3.30E-07	0.933
	>350	83.6	1.55E-05	0.686
Euro II	All	68	2.13E-06	0.812
Euro III	<30	16.8	3.38E-07	0.957
	30-90	20.5	-1.81E-07	1.02
	90-150	35.9	-2.84E-07	1.02
Euro IV	<30	13.7	1.14E-06	0.87
	30-90	16.5	4.75E-07	0.946
	90-150	23.2	1.27E-07	0.986

Table 8-49: Parameters for eq. (33) to calculate N_2O emission factors for gasoline LDVs under hot urban conditions

Emission Standard	Sulphur content (ppm)	Base EF [gr/km]	a	b
Pre Euro	>500	-	-	-
Euro I	<350	41.5	2.33E-06	0.53
	>350	83.6	2.77E-05	0.458
Euro II	All	-	-	-
Euro III	<30	7.4	2.81E-06	0.64
	30-90	12.7	1.41E-06	0.83
	90-150	36.7	1.44E-06	0.86
Euro IV	<30	1.2	6.57E-07	0.925
	30-90	0.9	5.72E-07	0.935
	90-150	7.9	3.07E-07	0.965

Table 8-50: Parameters for eq. (33) to calculate N_2O emission factors for gasoline LDVs under hot rural conditions

Emission Standard	Sulphur Content (ppm)	Base EF [gr/km]	a	b
Pre Euro	>500	-	-	-
Euro I	<350	-	-	-
	>350	26.3	2.96E-05	0.49
Euro II	All	-	-	-
Euro III	<30	1.4	1.27E-06	0.837
	30-90	6	1.88E-06	0.77
	90-150	18.1	1.78E-06	0.83
Euro IV	<30	0.3	6.33E-06	0.278
	30-90	2.2	3.62E-06	0.587
	90-150	8.7	2.03E-06	0.768

Table 8-51 Parameters for eq. (33) to calculate N_2O emission factors for gasoline LDVs under hot highway conditions

Emission Standard	Sulphur Content (ppm)	Base EF [gr/km]	a	b
Pre Euro	>500	-	-	-
Euro I	<350	-	-	-
	>350	26.3	2.96E-05	0.49
Euro II	All	-	-	-
Euro III	<30	1.4	1.27E-06	0.837
	30-90	6	1.88E-06	0.77
	90-150	18.1	1.78E-06	0.83
Euro IV	<30	0.3	6.33E-06	0.278
	30-90	2.2	3.62E-06	0.587
	90-150	8.7	2.03E-06	0.768

Nitrous oxide emission factors for diesel vehicles and motorcycles are not that important compared to catalyst equipped passenger cars and are more roughly estimated on the basis of earlier literature review (Pringent et al., 1989; Perby, 1990; de Reydellet, 1990; Potter, 1990; OECD, 1991; Zajontz et al., 1991 and others) and the work of TNO (2002). These data are shown in Table 8-52. For heavy duty vehicles and motorcycles, there is no separate methodology for estimating cold start over-emissions but they are assumed to be already incorporated in the bulk emission factors.

Table 8-52: Bulk (hot + cold) nitrous oxide (N_2O) emission factors (mg/km)

Vehicle category	Urban Cold	Urban Hot	Rural	Highway
Diesel Passenger Cars				
Conventional	0	0	0	0
Euro I	0	2	4	4
Euro II	3	4	6	6
Euro III	15	9	4	4
Euro IV	15	9	4	4
LPG Passenger Cars				
Conventional	0	0	0	0
Euro I	38	21	13	8
Euro II	23	13	3	2
Euro III	9	5	2	1
Euro IV	9	5	2	1
Diesel Light Duty Vehicles				
Conventional	0	0	0	0
Euro I	0	2	4	4
Euro II	3	4	6	6
Euro III	15	9	4	
Euro IV	15	9	4	4
Heavy Duty Vehicles				
Gasoline > 3.5 t	6		6	6
Diesel < 7.5 t	30		30	30
Diesel 7.5 t < W < 16 t	30		30	30
Diesel 16 t < W < 32 t	30		30	30
Diesel W > 32 t	30		30	30
Urban Buses	30		-	-
Coaches	30		30	30
Motorcycles				
< 50 cm³	1		1	1
> 50 cm³ 2 stroke	2		2	2
> 50 cm³ 4 stroke	2		2	2

8.12.5 Ammonia (NH_3) emissions

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Ammonia emissions from passenger cars and light duty vehicles are estimated on a similar manner to N_2O emissions, presented in the previous section, according to eq.27. The relevant parameters are given in Table 8-53 to Table 8-60.

Passenger Cars

Table 8-53: Parameters for eq. (33) to calculate NH_3 emission factors for gasoline passenger cars under cold urban conditions

Emission Standard	Sulphur Content [ppm]	Base EF [gr/km]	a	b
Euro I	<150	50	1.52E-06	0.765
	150-350	11.7	2.92E-06	0.351
Euro II	<150	51	1.70E-06	0.853
	150-350	14.6	3.89E-06	0.468
	>350	173	8.09E-06	0.974
Euro III-4	<10	5.79	2.82E-06	0.73
	10-30	5.35	1.77E-06	0.819
	>30	4.82	4.33E-06	0.521

Table 8-54: Parameters for eq. (33) to calculate NH_3 emission factors for gasoline passenger cars under hot urban conditions

Emission Standard	Sulphur Content [ppm]	Base EF [gr/km]	a	b
Euro I	<150	-	-	-
	150-350	-	-	-
Euro II	<150	143	1.47E-06	0.964
	150-350	-	-	-
	>350	210	7.75E-06	0.975
Euro III-4	<10	1.72	3.84E-06	0.616
	10-30	1.85	1.31E-06	0.862
	>30	1.61	4.18E-06	0.526

Table 8-55: Parameters for eq. (33) to calculate NH_3 emission factors for gasoline passenger cars under hot rural conditions

Emission Standard	Sulphur Content [ppm]	Base EF [gr/km]	a	b
Euro I	<!50	131	5.94E-08	0.999
	150-350	100	8.95E-07	0.978
Euro II	<150	148	5.95E-08	0.999
	150-350	90.7	9.08E-07	0.992
	>350	-	-	-
Euro III-4	<10	23.8	2.19E-06	0.782
	10-30	29.5	5.90E-08	0.994
	>30	28.9	8.31E-07	0.908

Table 8-56: Parameters for eq. (33) to calculate NH_3 emission factors for gasoline passenger cars under hot highway conditions

Emission Standard	Sulphur Content [ppm]	Base EF [gr/km]	a	b
Euro I	<150	73.3	5.94E-08	0.998
	150-350	56.2	8.86E-07	0.968
Euro II	<150	83.3	5.94E-08	0.999
	150-350	51	9.05E-07	0.988
	>350			
Euro III and IV	<10	52.16	2.69E-06	0.96
	10-30	64.64	5.95E-08	0.999
	>30	63.36	9.02E-07	0.985

Light Duty vehicles

Table 8-57: Parameters for eq. (33) to calculate NH_3 emission factors for gasoline LDVs under cold urban conditions

Emission Standard	Sulphur Content [ppm]	Base EF [gr/km]	a	b
Euro I	<150	50	1.52E-06	0.765
	150-350	11.7	2.92E-06	0.351
Euro II	<150	51	1.70E-06	0.853
	150-350	14.6	3.89E-06	0.468
	>350	173	8.09E-06	0.974
Euro III and IV	<10	5.79	2.82E-06	0.73
	10-30	5.35	1.77E-06	0.819
	>30	4.82	4.33E-06	0.521

Table 8-58: Parameters for eq. (33) to calculate NH_3 emission factors for gasoline LDVs under hot urban conditions

Emission Standard	Sulphur Content [ppm]	Base EF [gr/km]	a	b
Euro I	<150	-	-	-
	150-350	-	-	-
Euro II	<150	143	1.47E-06	0.964
	150-350	-	-	-
	>350	210	7.75E-06	0.975
Euro III and IV	<10	1.72	3.84E-06	0.616
	10-30	1.85	1.31E-06	0.862
	>30	1.61	4.18E-06	0.526

Table 8-59: Parameters for eq. (33) to calculate NH_3 emission factors for gasoline LDVs under hot rural conditions

Emission Standard	Sulphur Content [ppm]	Base EF [gr/km]	a	b
Euro I	<150	131	5.94E-08	0.999
	150-350	100	8.95E-07	0.978
Euro II	<150	148	5.95E-08	0.999
	150-350	90.7	9.08E-07	0.992
	>350	-	-	-
Euro III and IV	<10	23.8	2.19E-06	0.782
	10-30	29.5	5.90E-08	0.994
	>30	28.9	8.31E-07	0.908

Table 8-60: Parameters for eq. (33) to calculate NH_3 emission factors for gasoline LDVs under hot highway conditions

Emission Standard	Sulphur Content [ppm]	Base EF [gr/km]	a	b
Euro I	<150	73.3	5.94E-08	0.998
	150-350	56.2	8.86E-07	0.968
Euro II	<150	83.3	5.94E-08	0.999
	150-350	51	9.05E-07	0.988
	>350			
Euro III and IV	<10	52.16	2.69E-06	0.96
	10-30	64.64	5.95E-08	0.999
	>30	63.36	9.02E-07	0.985

For all other vehicle classes, bulk ammonia emission factors are given in Table 8-61. No separate calculation is made for cold start over-emissions. These emission factors are based on literature review only and should be considered as broad estimates (de Reydellet, 1990; Volkswagen, 1989).

Table 8-61: Bulk (hot + cold) ammonia (NH_3) emission factors (mg/km)

Vehicle category	Urban	Rural	Highway
Passenger Cars			
Gasoline Conventional	2	2	2
Diesel CC < 2.0 l	1	1	1
Diesel CC > 2.0 l	1	1	1
LPG	nd	nd	nd
2 - stroke	2	2	2
Light Duty Vehicles			
Diesel	1	1	1
Heavy Duty Vehicles			
Gasoline Veh. > 3.5 t	2	2	2
Diesel < 7.5 t	3	3	3
Diesel 7.5 t < W < 16 t	3	3	3
Diesel 16 t < W < 32 t	3	3	3
Diesel W > 32 t	3	3	3
Urban Buses	3	-	-
Coaches	3	3	3
Motorcycles			
< 50 cm³	1	1	1
> 50 cm³ 2 stroke	2	2	2
> 50 cm³ 4 stroke	2	2	2

8.12.6 PAHs and POPs

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Emission factors (in [µg/km]) for polycyclic aromatic hydrocarbons (PAHs) and persistent organic pollutants (POPs) are given in Table 8-62 for different species and vehicle categories. A rough distinction is made to conventional (pre Euro I) and closed loop catalyst equipped vehicles (Euro I and on). For diesel passenger cars and light duty vehicles, different emission factors are quoted for direct injection and indirect injection vehicles. Since statistical information on the distribution of fleet vehicles according to their combustion concept is difficult to collect, it is proposed to use the average (DI, IDI) emission factor to estimate emissions from diesel non heavy duty vehicles.

Methodoloy is applicable for the six protocol pollutants (indeno(1,2,3-cd)pyrene, benzo(k)fluoranthene, benzo(b)fluoranthene, benzo(ghi)perylene, fluoranthene, benzo(a)pyrene) and several others. Those emission factors should be considered as bulk values and no distinction is made to hot and cold start emissions. They have been developed on the basis of literature review including the following sources: BUWAL, 1994; TNO, 1993b; Volkswagen, 1989. Application of equation (4) with those emission factors provides total emissions of PAHs and POPs per vehicle class.

Although this introduces just another simplification, PAHs and POPs emissions from 4 stroke motorcycles are estimated with the same emission factors used for conventional gasoline passenger cars. This approach is due to modification as soon any results on emissions of such species from motorcycles become available.

Table 8-62: PAHs and POPs bulk (hot + cold) emission factors

Species	Bulk emission factors (µg/km)					
	Gasoline PC & LDV		Diesel PC &LDV		HDV	LPG
	Convent.	Euro I & on	DI	IDI	DI	
indeno(1,2,3-cd)pyrene	1.03	0.39	0.70	2.54	1.40	0.01
benzo(k)fluoranthene	0.30	0.26	0.19	2.87	6.09	0.01
benzo(b)fluoranthene	0.88	0.36	0.60	3.30	5.45	
benzo(ghi)perylene	2.90	0.56	0.95	6.00	0.77	0.02
fluoranthene	18.22	2.80	18.00	38.32	21.39	1.36
benzo(a)pyrene	0.48	0.32	0.63	2.85	0.90	0.01
pyrene	5.78	1.80	12.30	38.96	31.59	1.06
perylene	0.11	0.11	0.47	0.41	0.20	
anthanthrene	0.07	0.01	0.07	0.17		
benzo(b)fluorene	4.08	0.42	24.00	5.21	10.58	0.71
benzo(e)pyrene	0.12	0.27	4.75	8.65	2.04	
triphenylene	7.18	0.36	11.80	5.25	0.96	0.48
benzo(j)fluoranthene	2.85	0.06	0.32	0.16	13.07	
dibenzo(a,j)anthacene	0.28	0.05	0.11	0.12		
dibenzo(a,l)pyrene	0.23	0.01		0.12		
3,6-dimethyl-phenanthrene	4.37	0.09	4.85	1.25		0.18
benzo(a)anthracene	0.84	0.43	3.30	2.71	2.39	0.05
acenaphthylene			25.92	25.92		
acenapthene			34.65	34.65		
fluorene					39.99	
chrysene	0.43	0.53	2.40	7.53	16.24	
phenanthrene	61.72	4.68	85.50	27.63	23.00	4.91
napthalene	11.20	610.19	2100	650.5	56.66	40.28
anthracene	7.66	0.80	3.40	1.37	8.65	0.38
coronene	0.90	0.05	0.06	0.05	0.15	
dibenzo(ah)anthracene	0.01	0.03	0.24	0.56	0.34	

8.12.7 Dioxins and furans

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Emission factors of Dioxins and Furans are given in Table 8-63 separately to other POPs because an aggregate toxicity equivalent emission factor is provided in this case. This emission factor takes into account the toxicity of different Dioxin and Furan species according to the NATO - Committee on the Challenges of the Modern Society (NATO-CCMS). Actual emission rates of different Dioxin and Furan species have been collected from the available literature sources (Umweltbundesamt, 1996). The final value is a bulk emission factor expressed in [pg/km]. Due to the limited available information, emission factors provided need to be reconsidered when updated data become available. In order to keep a consistent approach for all vehicle sources, Dioxin and Furan emissions from 4 stroke motorcycles are calculated with the same toxicity equivalent emission factors as of conventional gasoline vehicles.

Table 8-63: Dioxins and Furans toxicity equivalence emission factors

	Toxicity Equivalent Emission Factors [pg/km]		
Polychlorinated Dibenzo Dioxins	**PC Gasoline Conventional**	**PC Diesel IDI**	**Heavy Duty Diesel**
TeCDD.TOTAL	3.8	0.2	1.4
PeCDD.TOTAL	5.2	0.2	0.9
HxCDD. TOTAL	1.0	0.1	0.3
HpCDD.TOTAL	0.2	0.0	0.2
OCDD	0.1	0.0	0.2
Total Dioxins	10.3	0.5	3.0
Polychlorinated Dibenzo Furans			
TeCDF.TOTAL	3.6	0.1	0.6
PeCDF.TOTAL	8.2	0.5	2.8
HxCDF.TOTAL	8.1	0.4	3.9
HpCDF.TOTAL	1.3	0.0	0.5
OCDF	0.0	0.0	0.1
Total Furans	21.2	1.0	7.9

8.13 Fuel consumption dependant emission factors

Emissions of heavy metals are calculated by means of equation (12). Table 8-64 provides emission factors of heavy metals for different vehicle categories.

Table 8-64: Heavy metal emission factors for all vehicle categories in mg/kg fuel

Category	Cadmium	Copper	Chromium	Nickel	Selenium	Zinc
Passenger cars, gasoline	0.01	1.7	0.05	0.07	0.01	1
Passenger cars, gasoline catalyst	0.01	1.7	0.05	0.07	0.01	1
Passenger cars, diesel	0.01	1.7	0.05	0.07	0.01	1
Passenger cars, LPG	0.0	0.0	0.0	0.0	0.0	0.0
Light duty vehicles, gasoline	0.01	1.7	0.05	0.07	0.01	1
Light duty vehicles, gasoline catalyst	0.01	1.7	0.05	0.07	0.01	1
Light duty vehicles, diesel	0.01	1.7	0.05	0.07	0.01	1
Heavy duty vehicles, gasoline	0.01	1.7	0.05	0.07	0.01	1
Heavy duty vehicles, diesel	0.01	1.7	0.05	0.07	0.01	1
Motorcycles < $50cm^3$	0.01	1.7	0.05	0.07	0.01	1
Motorcycles > $50cm^3$	0.01	1.7	0.05	0.07	0.01	1

8.14 Emission degradation functions

Tables 8.38 and 8.39 provide the degradation functions to be used for simulating the deterioration of emission performance of gasoline passenger cars and light duty vehicles equipped with three way catalysts. Relevant methodology given in section 5.7.1

Table 8-65: Emission degradation due to vehicle age for Euro I and Euro II gasoline passenger cars and light duty vehicles

$MC = A^M \times M^{MEAN} + B^M$	Capacity Class [l]	Average Mileage [km]	A^M	B^M (Value at 0 km)	Value at ≥ 120000 km
Correction for V<19 km/h (MC_{URBAN})					
CO - MC_{URBAN}	≤1.4	29,057	1.523E-05	0.557	2.39
	1.4-2.0	39,837	1.148E-05	0.543	1.92
	>2.0	47,028	9.243E-06	0.565	1.67
NO_x - MC_{URBAN}	ALL	44,931	1.598E-05	0.282	2.20
HC - MC_{URBAN}	≤1.4	29,057	1.215E-05	0.647	2.10
	1.4-2.0	39,837	1.232E-05	0.509	1.99
	>2.0	47,028	1.208E-05	0.432	1.88
Correction for V>63 km/h (MC_{ROAD})					
CO - MC_{ROAD}	≤1.4	29,057	1.689E-05	0.509	2.54
	1.4-2.0	39,837	9.607E-06	0.617	1.77
	>2.0	47,028	2.704E-06	0.873	1.20
NO_x - MC_{ROAD}	ALL	47,186	1.220E-05	0.424	1.89
HC - MC_{ROAD}	≤1.4	29,057	6.570E-06	0.809	1.60
	1.4-2.0	39,837	9.815E-06	0.609	1.79
	>2.0	47,028	6.224E-06	0.707	1.45

Table 8-66: Emission degradation due to vehicle age for Euro III and Euro IV gasoline passenger cars and light duty vehicles (and Euro I & II vehicles in case of an enhanced I&M scheme)

$MC = A^M \times M^{MEAN} + B^M$	Capacity Class [l]	Average Mileage [km]	A^M	B^M (Value at 0 km)	Value at ≥ 160000 km
Correction for V<19 km/h (MC_{URBAN})					
CO - MC_{URBAN}	≤1.4	32,407	7.129E-06	0.769	1.91
	>1.4	16,993	2.670E-06	0.955	1.38
NO_x - MC_{URBAN}	≤1.4	31,313	0	1	1
	>1.4	16,993	3.986E-06	0.932	1.57
HC - MC_{URBAN}	≤1.4	31,972	3.419E-06	0.891	1.44
	>1.4	17,913	0	1	1
Correction for V>63 km/h (MC_{ROAD})					
CO - MC_{ROAD}	≤1.4	30,123	1.502E-06	0.955	1.20
	>1.4	26,150	0	1	1
NO_x - MC_{ROAD}	ALL	26,150	0	1	1
HC - MC_{ROAD}	ALL	28,042	0	1	1

Table 8-67: Emission degradation correction factor as a function of speed

Speed - V [km/h]	Mileage Correction - MCorr [-]
≤19	M_{URBAN}
≥63	M_{ROAD}
>19 and <63	$MC_{URBAN} + \frac{(V-19)\cdot(MC_{ROAD} - MC_{URBAN})}{44}$

8.15 Fuel effects functions

Table 8-68, Table 8-69 and Table 8-70 provide the correction functions required to estimate the effect of fuel properties on emissions according to section 5.7.2.

Table 8-68: Relations between emissions and fuel properties for passenger cars and light duty vehicles

Pollutant	Correction factor equation
CO	FCorr = [2.459 - 0.05513 × (E100) + 0.0005343 × $(E100)^2$ + 0.009226 × (ARO)-0.0003101 × (97-S)] × [1-0.037 × (O_2 - 1.75)] × [1-0.008 × (E150 - 90.2)]
VOC	FCorr = [0.1347 + 0.0005489 × (ARO) + 25.7 × (ARO) × $e^{(-0.2642\ (E100))}$ - 0.0000406 × (97-S)] × [1-0.004 × (OLEFIN - 4.97)] × [1-0.022 × (O_2 - 1.75)] × [1-0.01 × (E150 - 90.2)]
NOx	FCorr = [0.1884 - 0.001438 × (ARO) + 0.00001959 × (ARO) × (E100) - 0.00005302 × (97 - S)] × [1+0.004 × (OLEFIN - 4.97)] × [1+0.001 × (O_2 - 1.75)] × [1+0.008 × (E150 - 90.2)]

Legend: O_2 = Oxygenates in %
S = Sulphur content in ppm
ARO = Aromatics content in %
OLEFIN = Olefins content in %
E100 = Mid range volatility in %
E150 = Tail end volatility in %

Table 8-69: Relations between emissions and fuel properties for Diesel passenger cars and light duty vehicles

Pollutant	Correction factor equation
CO	FCorr=-1.3250726 + 0.003037 × DEN - 0.0025643 × PAH - 0.015856 × CN + 0.0001706 × T_{95}
VOC	FCorr=-0.293192 + 0.0006759 × DEN - 0.0007306 × PAH - 0.0032733 × CN - 0.000038 × T_{95}
NOx	FCorr=1.0039726 - 0.0003113 × DEN + 0.0027263 × PAH - 0.0000883 × CN - 0.0005805 × T_{95}
PM	FCorr=(-0.3879873 + 0.0004677 × DEN + 0.0004488 × PAH + 0.0004098 × CN + 0.0000788 × T_{95}) × [1 - 0.015 · × (450 - S)/100]

Legend: DEN = Density at 15°C [kg/m3]
S = Sulphur content in ppm
PAH = Polycyclic aromatics content in %
CN = Cetane number
T95 = Back end distillation in °C

Table 8-70: Relations between emissions and fuel properties for Diesel heavy duty vehicles

Pollutant	Correction factor equation
CO	FCorr = 2.24407 - 0.0011 × DEN + 0.00007 × PAH - 0.00768 × CN - 0.00087 × T_{95}
VOC	FCorr = 1.61466 - 0.00123 × DEN + 0.00133 × PAH - 0.00181 × CN - 0.00068 × T_{95}
NOx	FCorr = -1.75444 + 0.00906 × DEN - 0.0163 × PAH + 0.00493 × CN + 0.00266 × T_{95}
PM	FCorr = [0.06959 + 0.00006 × DEN + 0.00065 × PAH - 0.00001 × CN] × [1-0.0086 × (450 - S)/100]

Legend: DEN = Density at 15°C [kg/m³]
S = Sulphur content in ppm
PAH = Polycyclic aromatics content in %
CN = Cetane number
T_{95} = Back end distillation in °C

9 SPECIES PROFILES

The content of non methane VOCs in different species is given in Table 9-1a and Table 9-1b. Proposed fractions have been obtained by results published in the literature (BUWAL, 1994; TNO, 1993; Volkswagen, 1989; Umweltbundesamt, 1996). Fractions quoted in those Tables are applied to the total NMVOC emissions from vehicle classes classified as conventional (pre Euro I) or closed loop catalyst equipped (Euro I and on) gasoline passenger cars and light duty vehicles, diesel passenger cars and light duty vehicles, diesel heavy duty vehicles and LPG passenger cars. A common speciation is proposed for diesel passenger cars and light duty vehicles, regardless of the combustion concept (DI or IDI).

NMVOC speciation from four stroke motorcycles is estimated with fractions derived from conventional gasoline vehicles as in the case of PAHs and POPs. This approach needs to be reconsidered when more complete data become available.

The last row of Table 9-1b shows the total that these fractions sum to. It is assumed that the remaining fraction consists of PAHs and POPs.

Table 9-1a: Composition of NMVOC in exhaust emissions (alkanes, cycloalkanes, alkenes, alkines)

Group	Species	NMVOC Fraction (% wt.)				
		Gasoline 4 stroke		Diesel PC & LDV	HDV	LPG
		Convent.	Euro I & on	IDI & DI		
ALKANES	ethane	1.65	3.19	0.33	0.03	2.34
	propane	0.47	0.65	0.11	0.10	49.85
	butane	2.90	5.24	0.11	0.15	15.50
	isobutane	1.29	1.59	0.07	0.14	6.95
	pentane	1.78	2.15	0.04	0.06	0.35
	isopentane	4.86	6.81	0.52		1.26
	hexane	1.29	1.61			
	heptane	0.36	0.74	0.20	0.30	0.18
	octane	0.56	0.53	0.25		0.04
	2-methylhexane	0.80	1.48	0.45	0.63	0.25
	nonane	0.06	0.16	0.67		0.01
	2-methylheptane		0.57	0.12	0.21	0.09
	3-methylhexane	0.56	1.14	0.22	0.35	0.19
	decane	0.22	0.19	1.18	1.79	
	3-methylheptane	0.40	0.54	0.20	0.27	0.08
	Alkanes C10-C12	0.03	1.76	2.15		0.01
	Alkanes C>13	0.06	1.45	17.91	27.50	
CYCLOALKANES	All	0.88	1.14	0.65	1.16	0.10
ALKENES	ethylene	8.71	7.30	10.97	7.01	5.20
	propylene	4.87	3.82	3.60	1.32	5.19
	propadiene		0.05			
	1-butene	0.50	0.73			
	isobutene	4.21	2.22	1.11	1.70	0.63
	2-butene	1.27	1.42	0.52		0.53
	1,3-butadiene	1.42	0.91	0.97	3.30	0.15
	1-pentene	0.09	0.11			
	2-pentene	0.23	0.34			
	1-hexene		0.17			
	dimethylhexene		0.15			
ALKINES	1-butine	0.05	0.21			
	propine	0.76	0.08			
	acetylene	5.50	2.81	2.34	1.05	1.28

Table 9-1b: Composition of NMVOC in exhaust emissions (aldehydes, ketones, aromatics)

Group	Species	NMVOC Fraction (% wt.)				
		Gasoline 4 stroke		Diesel PC & LDV	HDV	LPG
		Convent.	Euro I & on	IDI & DI		
ALDEHYDES	formaldehyde	2.08	1.70	12.00	8.40	1.56
	acetaldahyde	0.59	0.75	6.47	4.57	1.81
	acrolein	0.16	0.19	3.58	1.77	0.59
	benzaldehyde	0.60	0.22	0.86	1.37	0.03
	crotonaldehyde	0.02	0.04	1.10	1.48	0.36
	methacrolein		0.05	0.77	0.86	0.10
	butyraldehyde		0.05	0.85	0.88	0.11
	isobutanaldehyde			2.09	0.59	
	propionaldehyde	0.11	0.05	1.77	1.25	0.70
	hexanal			0.16	1.42	
	i-valeraldehyde			0.11	0.09	0.01
	valeraldehyde		0.01	0.41	0.40	
	o-tolualdehyde	0.19	0.07	0.24	0.80	
	m-tolualdehyde	0.38	0.13	0.34	0.59	
	p-tolualdehyde	0.19	0.06	0.35		
KETONES	acetone	0.21	0.61	2.94		0.78
	methylethlketone	0.11	0.05	1.20		
AROMATICS	toluene	12.84	10.98	0.69	0.01	1.22
	ethylbenzene	4.78	1.89	0.29		0.24
	m,p-xylene	6.66	5.43	0.61	0.98	0.75
	o-xylene	4.52	2.26	0.27	0.40	0.26
	1,2,3 trimethylbenzen	0.59	0.86	0.25	0.30	0.05
	1,2,4 trimethylbenzen	2.53	4.21	0.57	0.86	0.25
	1,3,5 trimethylbenzen	1.11	1.42	0.31	0.45	0.08
	styrene	0.57	1.01	0.37	0.56	0.02
	benzene	6.83	5.61	1.98	0.07	0.63
	C9	3.12	4.21	0.78	1.17	0.25
	C10		3.07			
	C>13	6.01	3.46	13.37	20.37	
TOTALS (all NMVOC species)		**99.98**	**99.65**	**99.42**	**96.71**	**99.98**

10 UNCERTAINTY ESTIMATES

10.1 Fuel consumption balance

Several input data in applying the methodology can obviously be only estimates. Such data include total annual mileage, share of mileage to different driving modes (urban, rural, highway), mean travelling speeds, etc. There is a certain degree of uncertainty in estimating these data. A firm checkpoint in estimating the accuracy of calculations is that the total calculated fuel consumption per fuel type should equal the consumption statistics for the level of activity considered. If however the calculated value does not match the true one, the "soft" input variables should be modified. "Soft" in this case denotes those variables associated with large uncertainty. Since the availability of statistical data differs from one country to another, it is up to national experts to make the appropriate modifications. However, the authors have the impression that the distribution of mileage in driving conditions (urban, rural, highway) and the respective average travelling speeds are those variables for which most attention should be given in most of the cases.

10.2 Unleaded fuel allocation

This method is only relevant for calculations corresponding to pre-2000 runs when unleaded fuel was available. In such cases, even if fuel balance has provided close values for calculated and statistical fuel consumption for each vehicle type, a similar situation may be observed when actual consumption of unleaded fuel exceeds the calculated one. However, it was known that drivers of conventional (non-catalyst) vehicles sporadically refuelled their vehicles with unleaded gasoline to benefit from the lower prices due to lower taxation. Therefore, statistical values provided for unleaded fuel consumption cannot be solely used to check the quality of calculations via an unleaded fuel balance because of the failure to identify the exact use of this fuel type. In this case, an alternative approach is proposed.

It is assumed that passenger cars originally considered to use leaded gasoline, have also the potential to operate on unleaded fuel, in cases where the statistical value provided for unleaded fuel exceeds the respective calculated one. To account for this, it is proposed that one or more vehicle classes should be shifted to the use of unleaded fuel, until the calculated consumption of unleaded fuel equals or just exceeds the statistical one. This change should start from the most recent leaded gasoline class ("Improved Conventional" vehicles) and should reach up to "PRE ECE" ones in cases where a large positive deviation exists between the statistical and the calculated value. Preferably, consumption of vehicles of large engine capacity is corrected first. Table 10-1 provides the exact sorting of vehicle classes proposed for allocating unleaded fuel.

Table 10-1: Sorting order of vehicle classes originally operating on leaded gasoline and participating in the unleaded fuel allocation algorithm (classes appearing first in the table are the ones for which leaded to unleaded shift occurs first)

Sort Order	Legislation Class	Subsector
1	Improved Conventional	Gasoline 1.4 - 2.0 l
2	Improved Conventional	Gasoline <1.4 l
3	ECE 15/04	Gasoline >2.0 l
4	ECE 15/04	Gasoline 1.4 - 2.0 l
5	ECE 15/04	Gasoline <1.4 l
6	ECE 15/03	Gasoline >2.0 l
7	ECE 15/03	Gasoline 1.4 - 2.0 l
8	ECE 15/03	Gasoline <1.4 l
9	ECE 15/02	Gasoline >2.0 l
10	ECE 15/02	Gasoline 1.4 - 2.0 l
11	ECE 15/02	Gasoline <1.4 l
12	ECE 15/00-01	Gasoline >2.0 l
13	ECE 15/00-01	Gasoline 1.4 - 2.0 l
14	ECE 15/00-01	Gasoline <1.4 l
15	PRE ECE	Gasoline >2.0 l
16	PRE ECE	Gasoline 1.4 - 2.0 l
17	PRE ECE	Gasoline <1.4 l

However, in actual inventories corrections should not exceed a few vehicle classes. In cases where a large number of classes need to be shifted from leaded to unleaded fuel use, input data should be checked and probably corrected. Moreover, the ban of unleaded fuel that took place in 2000 in most Member States (and by 2002 to all MSs), renders this discussion obsolete for post 2000 runs.

10.3 Range of application of hot emission factors

Emission factors proposed by the methodology have been derived in the framework of different scientific programmes. Emission factors of former technology passenger cars and light duty vehicles have been developed in the frame of older COPERT/CORINAIR activities (Eggleston et al., 1989) while emissions from recent vehicles are calculated on the basis of the work conducted in the frame of MEET (Samaras and Ntziachristos, 1998). Emission factors for heavy-duty trucks, coaches and busses originate from the German/Swiss Handbook of emission factors (Keller et al., 1995). Also, emission factors for mopeds and motorcycles are derived from the same work with further processing by TNO (Rijkeboer R.C., 1997).

It follows that because of the large range of data utilised and processing involved, different limitations/restrictions are associated with the emission factors of different vehicle classes. However, general directions which should be followed when applying the methodology include:

Application of the emission factors should only be made within the speed ranges given in the respective tables providing the emission factors. Those ranges have been defined according to the availability of the input data. Extrapolation of the proposed formulas to lower/higher speeds is therefore not advised, because this is not justified on the basis of the available experimental data.

The proposed formulas should only be used with average travelling speed and by no means can be considered an accurate approach when only instant speed values are available. Emission factors can be considered representative of emission performance with constant speed only at high velocities (>100 km/h) when, in general, speed fluctuation is relatively low.

The emission factors should not be applied in cases in which the driving pattern differs too much from what is common, e.g. in traffic calming areas.

The three road types (highway, urban, rural) are obviously synonyms for certain driving patterns which are to some extent typical, but not the same in all countries and cities, e.g. there are indications that highway driving in Germany takes place at a higher average speed than in Belgium, or urban driving in Athens takes place at a lower average speed than in Berlin, and so on. Moreover, it is possible that driving patterns depend on additional parameters, such as age of the vehicle or cylinder capacity. Such dependencies should only be taken into account if sound statistical data are available.

As in all cases of the application of estimation methodologies, the results obtained are subject to uncertainties. Since the true emissions are unknown, it is impossible to calculate the accuracy of the estimates. However, one can obtain an estimate of their precision. This estimate also provides an impression of the accuracy, if the methodology used for estimating road traffic emissions represents a reliable image of reality. These uncertainties are the results of errors which can be divided into random and systematic ones.

Random errors are those caused by:

- the inaccuracy of the measurement devices and techniques,
- the lack of a sufficient number of representative measurements, e.g., for heavy duty vehicles, cold starts, and evaporative emissions,
- erroneous data with regard to vehicle usage.

In principle systematic errors may be distinguished into two categories:

- Errors concerning emission factors and measurements:
- Errors in the patterns used to simulate actual road traffic; this means that driving cycles may not be representative of real-life road traffic, e.g., typical speed and acceleration of real driving conditions may be considerably different from those used in off-road dynamometer tests, thus systematically underestimating vehicle emissions
- Errors in the emission factors used for the calculations. Sufficient emission measurements are not available in all countries; therefore, average values derived from measurements in other countries have to be used. This can lead to significant variations because in some countries vehicles are undergoing periodic emission tests, so measured emission factors may not be representative of the vehicle fleets of other

countries; this can bias the emission factor measurements and the evaluation of the effects of Inspection/Maintenance programmes and degradation of emission control equipment.

Errors concerning assessment of vehicle park and usage:

- Erroneous assumptions of vehicle usage. In many countries the actual vehicle usage is not known, in some others, data from only a few statistical investigations are available. Most important are errors in total kilometres travelled and in the average trip length. However, the fuel balance (i.e., the comparison of the calculated fuel consumption with the statistically known one), is a valuable means to check the validity of the various assumptions made and to avoid major errors.
- Erroneous estimates of the vehicle park. Not all sub-categories of the methodology presented here appear in the statistics and, therefore, have to be estimated. To take an example, assessing the number of gasoline and diesel vehicles >2.5 t which belong to the category "Light Duty Trucks" and those which belong to the category "Heavy Duty Vehicles" involves much uncertainty, since the exact numbers are not available. The same may hold true for splitting a certain category into different age and technology groups, as the real numbers are again not always known.

Table 10-2 provides qualitative indications of the "precision" which can be allocated to the calculation of the individual emissions. In general, no emission measurements were available for post Euro I passenger cars and light duty vehicles. Therefore, a “D” index should be assigned to these vehicle technologies. However, despite the “D” indication, a sound engineering approach has been used to derive their emissions (see Ntziachristos and Samaras, 2001). Hence, it is expected that those emission factors should not much deviate from actual levels.

In order to illustrate the above evaluation, Table 10-3 presents as an example the estimate of the band of errors expressed as the coefficient of variation (CV = standard deviation / mean value) of the measured VOC emission factors and fuel consumption factors. It is interesting to note that the mean CV for measured VOC emission factors is 48.7% while the mean CV for fuel consumption factors is 12.1%. Moreover, measured data from older ECE classes (conventional cars) show lower variation than measurements of catalyst-equipped vehicles. This is probably because the emission level of catalyst vehicles is much dependant on the condition of the aftertreatment system (maintenance condition, thermal condition, etc.). Hence, even if their emission level is much below conventional vehicles, their variability is larger. Moreover, a fraction vehicles in the Euro I technology class are a collection of vehicles following different national standards and consecutively emission control techniques of different efficiency. Thirdly, a large number of driving cycles with different dynamic conditions has been utilised for the production of the emission factors and this increases the variability of the results.

Table 10-2: Precision Indicators of the Emission Estimate for the Different Vehicle Categories and Pollutants

Legend: A: Statistically significant emission factors based on sufficiently large set of measured and evaluated data; B: Emission factors non statistically significant based on a small set of measured re-evaluated data; C:

Emission factors estimated on the basis of available literature; D: Emission factors estimated applying similarity considerations and/or extrapolation. See text for later than Euro I vehicles.

Vehicle Category	**Pollutants**										
	NOx	**CO**	**NMVOC**	**CH_4**	**PM**	**N_2O**	**NH_3**	**SO_2**	**CO_2**	**Pb**	**FC**
Gasoline Passenger Cars											
Up to Open Loop	A	A	A	A	-	C	C	A	A	B	A
Euro I	A	A	A	A	-	B	B	A	A	A	A
Diesel Passenger Cars											
Up to Euro I	A	A	A	A	A	B	B	A	A	-	A
LPG Passenger Cars	A	A	A	-	-	--	-	-	A	-	A
2 Stroke Passenger Cars	B	B	B	D	-	D	D	A	B	B	B
Light Duty Vehicles											
Gasoline up to Euro I	A	A	A	B	-	B	B	A	A	A	A
Diesel up to Euro I	A	A	A	B	A	B	B	A	A	-	A
Heavy Duty Vehicles											
Gasoline	D	D	D	D	-	D	D	D	D	D	D
Diesel	A	A	A	B	A	B	B	A	A	-	A
Two Wheelers											
<50 cm³	A	A	A	B	-	B	B	A	A	A	A
> 50 cm³ 2 stroke	A	A	A	B	-	B	B	A	A	A	A
> 50 cm³ 4 stroke	A	A	A	B	-	B	B	A	A	A	A
Cold Start Emissions											
Pass. Cars Conventional	B	B	B	-	-	-	-	-	B	B	B
Pass. Cars Euro I	A	A	A	A	-	-	-	A	A	A	A
Pass. Cars Diesel Conv.	C	C	C	-	C	-	-	-	B	-	C
Pass. Cars Diesel Euro I	A	A	A	A	A	-	-	A	A	A	A
Pass. Cars LPG	C	C	C	-	-	-	-	-	B	-	C
Gas Light Duty Vehicles	D	D	D	-	-	-	-	-	D	D	D
Diesel Light Duty Veh.	D	D	D	-	D	-	-	-	D	-	D

Table 10-3: Estimated error of emission factors, according to the variance of measured data for Passenger Cars < 3.5 t

Emission Factor	**Legislation / Technology**	**Cylinder Capacity**	**Mean CV [%]**
	Gasoline Cars		
VOC	PRE ECE	All categories	16.5
	ECE 15-00/01	All categories	32.6
	ECE 15-02	All categories	32.7
	ECE 15-03	All categories	25.5
	ECE 15-04	All categories	32.8
	Improved Conventional	CC < 1.4 l	32.8
		1.4 l < CC < 2.0 l	39.9
	Open Loop	CC < 1.4 l	47.5
		1.4 l < CC < 2.0 l	49.2
	Euro I	CC < 1.4 l	76.7
		1.4 l < CC < 2.0 l	87.5
		CC > 2.0 l	111.2
FC	PRE ECE	CC < 1.4 l	3.2
	ECE 15-00/01		11.4
	ECE 15-02		9.5
	ECE 15-03		10.3
	ECE 15-04		10.3
	Improved Conventional		15.9
	Open Loop		15.0
	Euro I		10.6
	PRE ECE	1.4 l < CC < 2.0 l	3.1
	ECE 15-00/01		9.6
	ECE 15-02		10.7
	ECE 15-03		10.9
	ECE 15-04		25.8
	Improved Conventional		22.4
	Open Loop		20.7
	Euro I		14.8
	PRE ECE	CC > 2.0 l	6.3
	ECE 15-00/01		12.2
	ECE 15-02		6.7
	ECE 15-03		8.6
	ECE 15-04		11.0
	Euro I		17.5
	Diesel Cars		
VOC		1.4 l < CC < 2.0 l	28.4
		CC > 2.0 l	54.5
FC		1.4 l < CC < 2.0 l	21.4
		CC > 2.0 l	21.6
	LPG Cars		
VOC		All categories	9.2
FC		All categories	20.0

CV: coefficient of variation (= standard deviation / mean value)

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

The work on emission factors for traffic is a continuously improving task. The points which are the main focus for revision are:

i) Cold start modelling including the improvement brought with the new emissions test at –7°C.
ii) Evaporation modelling, especially taking into account alcohol blends in gasoline
iii) Enhancement of the methodology related to CO_2 emission, considering bio-fuels, CO_2-neutral fuels, etc.
iv) Improvement of the expression of emission factors, including some metric of driving behaviour (except of speed) as an independent variable.
v) Independent estimations, e.g. nation-wide surveys, of total annual mileage driven on the three road classes by each of the vehicle categories.
vi) Methodology and statistical input for estimating the spatial allocation of vehicle emissions;

Moreover, it should be mentioned that the estimation of emissions from road traffic might be, more than in the case of other source categories, a task which requires permanent updating. This is due to the relatively large and rapid changes in this sector over short time periods, e.g. the turnover of fleets is rather short, legislation changes quickly, the number of vehicles increases steadily and so on. These changes not only require the continuation of the work on emission factors, but also the adaptation of the methodology.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

In order to meet the CORINAIR requirements, and in particular the one that data should be suitable for advanced long-range dispersion models, this information in principle should be available for the smallest territorial unit (NUTS 3 level).

For countries for which the required input data are not available at this low level, it seems to be more appropriate to start at NUTS level 0 (national level) and to allocate emissions to other NUTS levels with the help of available surrogate data. National particularities can be taken into account by this top-down approach via the composition of the vehicle parc, the driving conditions and the temperature dependency of some emission factors, and the influence of road gradient on heavy vehicle emissions. In such cases the following guidelines apply:

i) Urban emissions should be allocated to urban areas only, e.g. by localising geographically all cities with more than 20,000 inhabitants and allocating the emissions via the population living in each of the cities. A list of these cities including their geographical co-ordinates can be provided by EUROSTAT.

ii) Rural emissions should be spread all over the country, but only outside urban areas, e.g. by taking the non-urban population density of a country.

iii) Highway emissions should be allocated to highways only, that means: all roads on which vehicles are driven in accordance with the "highway driving pattern", not necessarily what is called "Autobahnen" in Germany, "autoroutes" in France, "autostrade" in Italy and so on. As a simple distribution key, the length of such roads in the territorial unit can be taken.

Some of the statistical data needed for carrying out the allocation of emissions can be found in EUROSTAT publications but in general national statistics are more detailed.

For countries which have the required input available at smaller NUTS level (including for example traffic counting) it is proposed to make use of this information and to apply a bottom-up approach, building the national total by summing up emissions from the smaller units. However, in such cases it is recommended to cross-check the total obtained in this way with the total calculated by using the top-down approach in order to balance possible deviations in the statistics. As already mentioned, it has been shown (Zachariadis and Samaras, 1997; Moussiopoulos et al., 1996) that the proposed methodology can be used with a sufficient degree of certainty at a higher resolution too, i.e. for the compilation of urban emission inventories with a spatial resolution of 1x1 km^2 and a temporal resolution of 1 hour.

However, the amount of information given in this report (statistical data and calculated values) is suitable for the compilation of national emission inventories. Application of the methodology at higher spatial resolution has to be done only when more detailed data are available from the user. As a general guideline, it can be proposed that the smaller area of application should be the one for which it can be considered that the fuel sold in this region (statistical consumption), equals the actual consumption of the vehicles operating in this region.

13 TEMPORAL DISAGGREGATION CRITERIA

The temporal resolution of road transport emissions is particularly important as input in mesoscale air quality models or for local air pollution assessment. In this case, the patterns of the traffic load, in conjunction with the variation over time of the average vehicle speed. should be used for the calculation of temporal variation of the emissions. This means that traffic counts and speed recordings (or estimates) should be available for the modelled area.

In principle, the two approaches (top down and bottom up) mentioned above for the spatial disaggregation apply here as well: In the top down approach total road traffic emissions are first spatially and then temporally disaggregated over the area, using traffic load and speed variation in a dimensionless form as the basic disaggregation pattern. In the bottom-up approach emissions are calculated on the basis of the available patterns and then summed up. Again, in such cases it is recommended to cross-check the total obtained in this way with the total calculated by using the top-down approach in order to balance possible deviations in the statistics.

According to the proposed methodology cold-start emissions are calculated on a monthly basis providing already a temporal resolution. However, special attention should be paid on the allocation of the cold-start extra emissions in urban areas. If solid data are lacking, then the following suggestion could be helpful: The urban area can be divided into three districts, a central business district, a residential district and an intermediate district. By coupling the districts with the trip patterns of the city, it is in principle possible to come up with a first approximation of temporal (and spatial) allocation of cold start emissions.

At this point it has to be recalled that spatial and temporal disaggregation of the emissions is coupled with a deterioration of the accuracy of the emission estimates. This is particularly true in the case of road transport emissions, because:

i) at high resolution the random character of transport activities dominates the emission estimates and
ii) the emission factors proposed are aggregated emission factors, averaged over a large number of driving cycles, therefore not necessarily representative of the instantaneous emissions of vehicles driven under actual conditions.

Emission Estimates for Urban areas

Spatially and temporally disaggregated emission inventories are necessary in order to make reliable air quality simulations and predict ambient concentration levels with reasonable accuracy. Several attempts to create a refined motor vehicle emission inventory have been made up to now, in particular for urban areas. These attempts can be distinguished in top-down (or macroscale) and bottom-up (or microscale) approaches. Evidently the bottom-up method attempts to simulate reality more accurately and requires more effort than the top-down method, although it is not yet clear whether such a degree of sophistication could bring more reliable emission estimates and consequently support better air quality simulations.

Figure 13.1 illustrates a methodological approach that can be followed in order to make maximum usage of both approaches in the creation of such an emission inventory. In the bottom-up approach motor vehicle emissions are calculated for each street or road of the area under simulation at an hourly basis; according to the top-down approach, the whole area is simulated on an annual basis. In principle, the top-down and bottom-up estimates of motor vehicle emissions are carried out independently. In each case the "hard facts", i.e. the most reliable information (such as traffic counts, statistics of vehicle registrations and measured emission factors) are the starting point; uncertain parameters are then assessed according to relevant knowledge and reasonable assumptions. In the top-down approach the fuel balance constitutes already an internal calibration point: calculated and statistical fuel consumption should not vary greatly.

After the independent estimates have been carried out, the estimated activity and emission data of the two approaches (in terms of calculated total annual vehicle kilometres, cold start annual vehicle kilometres and emission factors) are compared, and it is attempted to resolve the discrepancies that may be identified. This reconciliation procedure leads to a re-estimation of the most uncertain parameters of each approach. At this point, emission factors are evidently a crucial parameter; more analytical microscale estimates apply modal emission factors which are expressed as a function of instantaneous vehicle speed and acceleration and therefore differ from average speed dependent emission factors that are regularly used in macroscale models. In that case the harmonisation of the two different sets of emission factors is required as well. The activity and emission data having been reconciled, the next step is to calculate total fuel consumption and emissions with both approaches and compare their aggregate results.

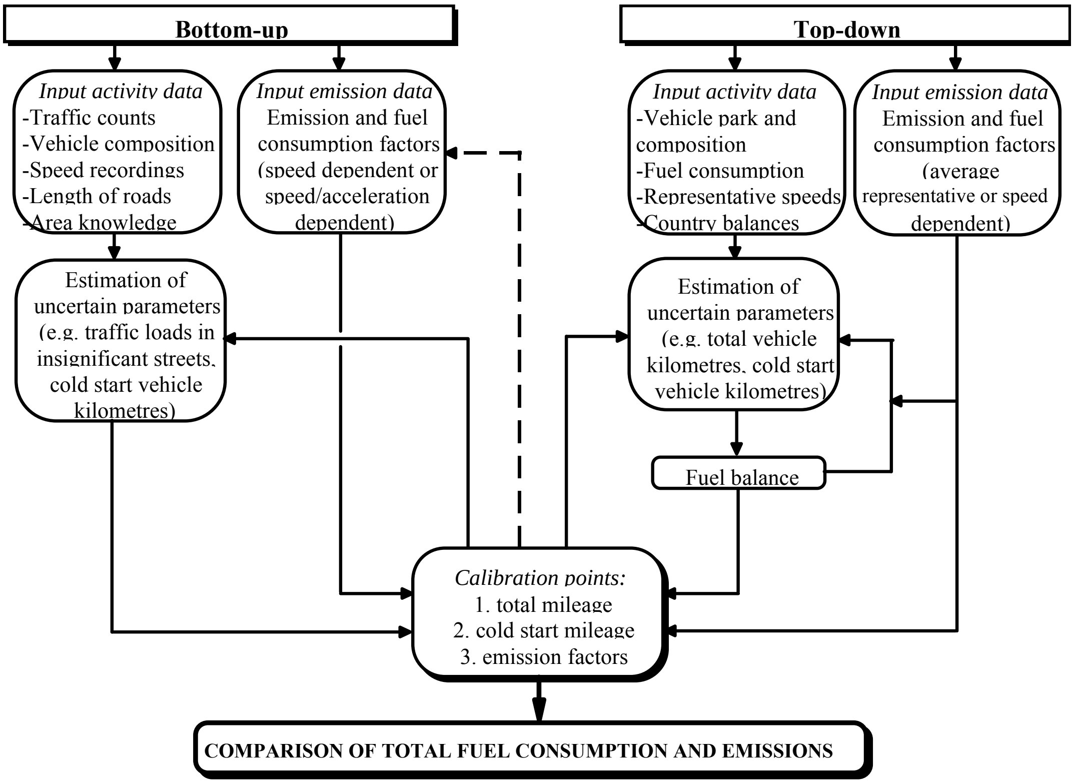

Figure 13.1: Proposed reconciliation method in applying bottom-up and top-down approaches when building an urban emission inventory

The scheme shown in Fig. 13.1 gives an overview of the required information for such an approach. Evidently most of these data are sufficiently available in most European cities. An aspect that should not be overlooked, however, is the knowledge of the area and its traffic patterns, so that appropriate assumptions can be conducted. It is therefore necessary to create inventories with the close co-operation of local experts.

14 ADDITIONAL COMMENTS

As mentioned above the results of this work will be included into the fourth version of the COPERT (**Co**mputer **P**rogramme to Calculate **E**missions from **R**oad **T**raffic) computer programme. This program is officially used by several countries for reporting emissions of road transport.

15 SUPPLEMENTARY DOCUMENTS

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16 VERIFICATION PROCEDURES

In the following only some concepts for emissions inventory verification are outlined, that are applicable in the case of road transport emission inventories. For a more detailed discussion on these issues, refer to Mobley et al. 1994 (see Chapter on "Procedures for Verification of Emission Inventories" in this Guidebook). In general these approaches can be categorised into soft and ground truth verification approaches. Specifically:

i) The first category comprises:

Comparison of alternate estimates: These estimates can be compared to each other to infer the validity of the data based on the degree of agreement among these estimates. Such a process can help to homogenise data developed through different approaches.

Quality Attribute Ratings: This approach involves the development of a semi-quantitative procedure that could assign a value for a component of an emissions inventory or to the collective emissions inventory. An example of such a technique (called the Data Attribute Rating System) is in development in US EPA. A numerical scale is used to rank a list of attributes in a relative priority against the set of criteria selected to represent the reliability of each attribute estimate.

ii) The second category comprises:
Survey Analyses: Some common methodologies for estimating emissions from area sources rely on a per capita or per area emission factor. The results of a statistical sampling based on these principles could be applied to develop regionally specific emission or allocation factors that depend on population density, economic demographics etc.

Indirect Source Sampling: These approaches can use remote measurement techniques (FTIR, Ultra Violet Spectrometry, Gas Radiometer). Specifically the Gas Filter Radiometer Emission Test System has been used to measure in use motor vehicle emissions.

Ambient Ratio Studies: Typically these measurement programmes include a rural measurement side, two or more sides in the downtown area and two or more sides in the downwind sector. Grid based and trajectory modelling approaches are used to simulate the urban area and model predictions are compared to the observed concentrations.

Tunnel Studies: Concentrations can be measured at both the upwind and downwind portals of the tunnel and the emissions rate can be calculated by the air difference. The measured concentrations data may be used to estimate the mass emissions rate for the sampling period.

Air Quality Modelling: This is a complex activity in which atmospheric processes are simulated through the solution of a series of mathematical expressions. All models involve simplifying assumptions to represent the process active in the atmosphere. The lack of understanding of all the atmospheric processes and the simplifying assumptions contribute to a significant uncertainty in model outputs.

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18.1 List of abbreviations

CC	Cylinder Capacity of the Engine
CH_4	Methane
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
FC	Fuel Consumption
GVW	Gross Vehicle Weight
HDV	Heavy Duty Vehicle
I&M	Inspection and Maintenance
LDV	Light Duty Vehicle
LPG	Liquid Petroleum Gas
NH_3	Ammonia
NMVOC	Non-Methane Volatile Organic Compounds
N_2O	Nitrous Oxide
NO_x	Nitrogen Oxides (sum of NO and NO_2)
NUTS	Nomenclature of Territorial Units for Statistics (0 to III). According to the EU definition, NUTS 0 is the territory of individual Member States
OBD	On-Board Diagnostics
Pb	Lead
PC	Passenger Car
SNAP	Selective Nomenclature for Air Pollution
SOx	Sulphur Oxides
VOC	Volatile Organic Compounds

18.2 List of symbols

$\mathbf{A_0 \ldots A_6}$	constants for the emission correction due to road gradient
$\mathbf{A^M}$	emission performance degradation per kilometre
$\mathbf{B^M}$	relative emission level of brand new vehicles
bc	correction coefficient for the β-parameter to be applied for improved catalyst vehicles
$\mathbf{E_{HOT}}$	total emissions during thermally stabilised (hot) engine and exhaust aftertreatment conditions
$\mathbf{E^{CALC}}$	emission of a fuel dependent pollutant (CO_2, SO_2, Pb, HM) estimated on the basis of the calculated fuel consumption
$\mathbf{E^{CORR}}$	corrected emission of a fuel dependent pollutant (CO_2, SO_2, Pb, HM) on the basis of the statistical fuel consumption
$\mathbf{e^{COLD}/e^{HOT}}$	ratio of emissions of cold to hot engines

$\mathbf{e_{HOT}}$	average fleet representative baseline emission factor in [g/km] for thermally stabilised (hot) engine and exhaust aftertreatment conditions
EF	fuel consumption specific emission factor
ES	emission standard according to the legislation
e(V)	mathematical expression of the speed dependency of e_{HOT}
f(V)	equation (e.g. formula of "best fit" curve) of the frequency distribution of the mean speeds which corresponds to the driving patterns of vehicles on road classes "rural", "urban" and "highway"
$\mathbf{FC^{CALC}}$	calculated fuel consumption)
$\mathbf{FCe_{HOT}}$	hot emission factor corrected for the use of improved fuel
FCorr	emission correction for the use of conventional or improved fuel
$\mathbf{FC^{STAT}}$	statistical (true) total consumption
GCorr	emission correction factor for the effect of road gradient
$\mathbf{GCe_{HOT}}$	corrected hot emission factor for road gradient
k	weight related content of any component in the fuel [kg/kg fuel]
$\mathbf{LCe_{HOT}}$	corrected hot emission factor for vehicle load
LCorr	vehicle load correction factor
LP	the actual vehicle load factor (expressed as a percentage of the maximum load. That is, **LP** = 0 denotes an unloaded vehicle and **LP** = 100 represents a totally laden one)
$\mathbf{l_{trip}}$	average trip length [km]
M	average mileage in [km]
$\mathbf{MCe_{HOT}}$	hot emission factor corrected for degraded vehicle performance due to mileage
MCorr	**c**orrection coefficient for emission performance degradation due to mileage
$\mathbf{M^{MEAN}}$	mean fleet mileage [km]
N	number of vehicles [veh.]
$\mathbf{r_{H:C}}$	ratio of hydrogen to carbon atoms in fuel
RF	reduction factor for emissions of pollutant of a class over a reference class
S	share of mileage driven in different road types
t	ambient temperature [°C]
V	vehicle mean travelling speed in [km/h]
β	fraction of mileage driven with cold engines

18.3 List of indices

a	monthly mean
Base	referred to the base fuel quality
c	cycle (c= UDC, EUDC)
COLD	referring to cold start over-emissions
Fuel	referred to improved fuel quality
HIGHWAY	referring to highway driving conditions
HOT	referring to thermally stabilised engine conditions
i	pollutant index (i = 1-36)
j	vehicle class (j = 1-105)
jm	vehicle class operating on fuel type m
k	road classes (k= urban, rural, highway)
m	fuel type (m= gasoline, diesel , LPG)
Pb	Lead content in fuel
RURAL	referring to rural driving conditions
S	Sulphur content in fuel
TOT	referring to total calculations
URBAN	referring to urban driving conditions

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20 POINT OF ENQUIRY

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