Category		Title
NFR	1.A.3.b.i 1.A.3.b.ii 1.A.3.b.iii 1.A.3.b.iv	Passenger cars Light commercial trucks Heavy-duty vehicles including buses Mopeds & motorcycles
SNAP	0701 0702 0703 0704 0705	Passenger cars Light commercial vehicles < 3.5 t Heavy-duty vehicles > a3.5 t and buses Mopeds and motorcycles < 50 cm^3 Motorcycles > 50 cm^3
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Contents

1 Overview ... 3
1.1 General description ... 3
1.2 Structure and origins of this chapter ... 4
2 Description of sources ... 4
2.1 Process description ... 4
2.2 Techniques ... 7
2.3 Controls ... 8
3 Calculation methods ... 16
3.1 Choice of method ... 18
3.2 Tier 1 method ... 19
3.3 Tier 2 method ... 25
3.4 Tier 3 method ... 48
4 Data quality ... 110
4.1 Completeness ... 110
4.2 Avoiding double counting with other sectors ... 110
4.3 Verification ... 110
4.4 Bottom-up vs. top-down inventories ... 112
4.5 Uncertainty assessment ... 114
4.6 Gridding ... 121
4.7 Weakest aspects/priority area for improvement in current methodology ... 121
5 Glossary ... 122
5.1 List of abbreviations ... 122
5.2 List of symbols ... 123
5.3 List of indices ... 124
6 Supplementary documents, references and bibliography ... 125
6.1 Supplementary documents ... 125
6.2 References ... 125
6.3 Bibliography ... 131
7 Point of enquiry ... 131
Appendix 1 Bulk Tier 1 emission factors for selected European countries 132
Appendix 2 History of the development of the road transport chapter 144
Appendix 3 Controls ... 145
Appendix 4 Accompanying files ... 150
Appendix 5 HDV correspondence ... 150

1 Overview

1.1 General description

This chapter provides the methodology, emission factors and relevant activity data to enable exhaust emissions to be calculated for the following categories of road vehicles:

- passenger cars (NFR code 1.A.3.b.i)
- light commercial vehicles (1) (< 3.5 t) (NFR code 1.A.3.b.ii)
- heavy-duty vehicles (2) (> 3.5 t) and buses (NFR code 1.A.3.b.iii)
- mopeds & motorcycles (3) (NFR code 1.A.3.b.iv)

It does not cover non-exhaust emissions such as fuel evaporation from vehicles (NFR code 1.A.3.b.v), tyre wear and brake wear (NFR code 1.A.3.b.vi), or road wear (NFR code 1.A.3.b.vii).

The most important pollutants emitted by road vehicles include:

- ozone precursors (CO, NO_x, NMVOCs (4));
- greenhouse gases (CO_2, CH_4, N_2O);
- acidifying substances (NH_3, SO_2);
- particulate matter mass (PM) including black carbon (BC) and organic carbon (OC);
- carcinogenic species (PAHs (5) and POPs (6));
- toxic substances (dioxins and furans);
- heavy metals.

The Definition of PM, and NMVOC EFs

All PM mass emission factors reported in this chapter refer to $PM_{2.5}$, as the coarse fraction ($PM_{2.5-10}$) is negligible in vehicle exhausts. Emission factors for particulate matter are presented in terms of particle number and surface area for different size ranges. PM mass emission factors correspond to primary emissions from road traffic and not the formation of secondary aerosol from chemical reactions in the atmosphere minutes or hours after release. It should be further clarified that the measurement procedure regulated for vehicle exhaust PM mass characterisation requires that samples are taken at a temperature lower than 52ºC. At this temperature, PM contains a large fraction of condensable species. Hence, PM mass emission factors in this chapter are considered to include both filterable and condensable material.

Also, fuel/energy consumption figures can be calculated. For NMVOCs, emission factors for 68 separate substances are provided.

(1) LCVs
(2) HDVs
(3) This sector includes mini cars and ATVs, and will be labeled L-category in specific sections in this report
(4) NMVOCs = non-methane volatile organic compounds
(5) PAHs = polycyclic aromatic hydrocarbons
(6) POPs = persistent organic pollutants

1.2 Structure and origins of this chapter

The original Corinair 1985 emissions inventory (Eggleston et al, 1989) has been updated a number of times. The Tier 1 and Tier 2 emission factors included in this chapter were calculated on the basis of the Tier 3 methodology, by applying some default values, by the team at Aristotle University, Thessaloniki and later by EMISIA SA. Annex 2 provides a brief history of the previous versions of this chapter.

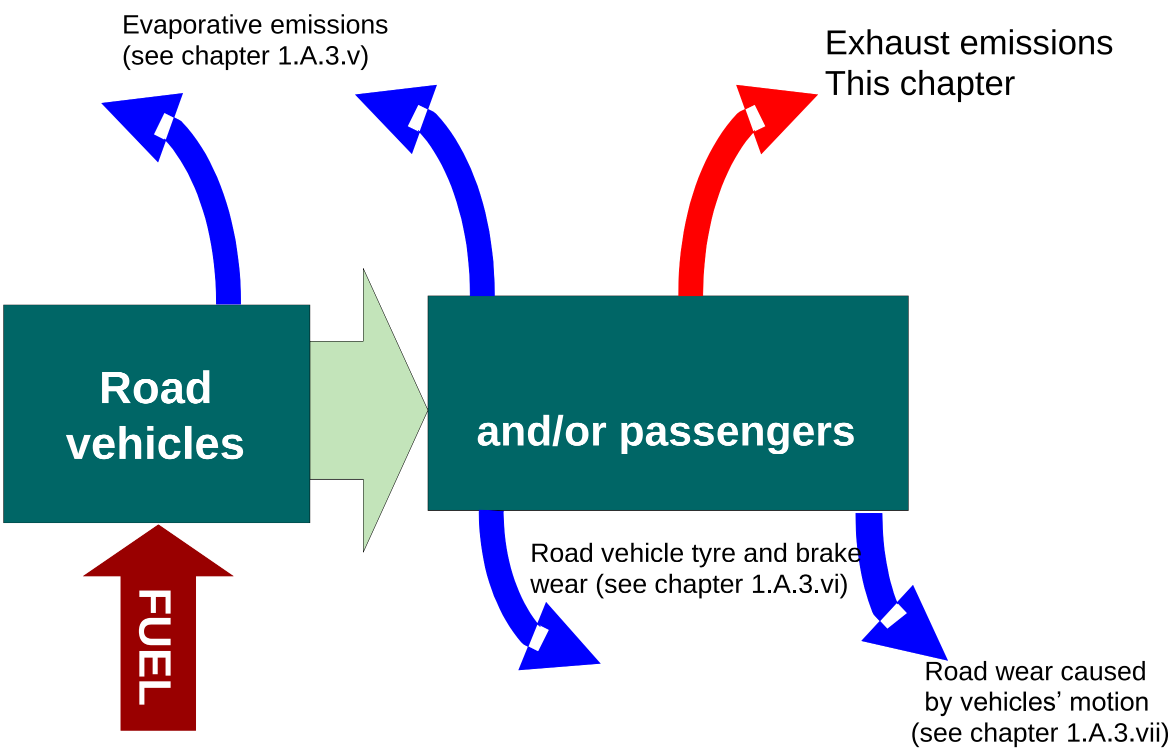
2 Description of sources

2.1 Process description

2.1.1 Overview

Exhaust emissions from road transport arise from the combustion of fuels such as petrol, diesel, liquefied petroleum gas (LPG), and natural gas in internal combustion engines. The air/fuel charge may be ignited by a spark ('spark-ignition' or 'positive-ignition' engines), or it may ignite spontaneously when compressed ('compression-ignition' engines). The emissions from road vehicles are illustrated schematically in Figure 2-1, with red, the exhaust emissions being those covered in this chapter, whilst the other emission processes are covered in other chapters.

Figure 2-1: Flow diagram emissions from road transport.



2.1.2 Summary of activities covered

Exhaust emissions from road transport are reported according to the four different NFR codes listed in subsection 1.1. The correspondence between these NFR codes and the vehicle categories specified by the United Nations Economic Commission for Europe (UNECE) is explained in Table 2-1. For more detailed emission estimation methods these four categories are often sub-divided according to the fuel used, and by engine size, weight or technology level of the vehicle. For certain pollutants, the emission factors can be further sub-divided according to three types of driving: 'highway', 'rural' and 'urban'.

Table 2-1: Definition of road vehicle categories

NFR Code	Vehicle category		Official Classification
1.A.3.b.i	**Passenger Cars**		**M1**: vehicles used for the carriage of passengers and comprising not more than eight seats in addition to the driver's seat.
	Petrol	Mini	
	Petrol	Small	
	Petrol	Medium	
	Petrol	Large-SUV-Executive	
	Diesel	Mini	
	Diesel	Small	
	Diesel	Medium	
	Diesel	Large-SUV-Executive	
	Petrol Hybrid	Mini	
	Petrol Hybrid	Small	
	Petrol Hybrid	Medium	
	Petrol Hybrid	Large-SUV-Executive	
	Petrol PHEV	Small	
	Petrol PHEV	Medium	
	Petrol PHEV	Large-SUV-Executive	
	Diesel PHEV	Large-SUV-Executive	
	LPG Bi-fuel	Mini	
	LPG Bi-fuel	Small	
	LPG Bi-fuel	Medium	
	LPG Bi-fuel	Large-SUV-Executive	
	CNG Bi-fuel	Mini	
	CNG Bi-fuel	Small	
	CNG Bi-fuel	Medium	
	CNG Bi-fuel	Large-SUV-Executive	
	Battery electric	Mini	
	Battery electric	Small	
	Battery electric	Medium	
	Battery electric	Large-SUV-Executive	
1.A.3.b.ii	**Light Commercial Vehicles < 3.5 t**		**N1**: vehicles used for the carriage of goods and having a maximum weight not exceeding 3.5 tonnes.
	Petrol	N1-I	
	Petrol	N1-II	
	Petrol	N1-III	
	Diesel	N1-I	
	Diesel	N1-II	

	Diesel	N1-III	
	Battery electric	N1-I	
	Battery electric	N1-II	
	Battery electric	N1-III	
1.A.3.b.iii	**Heavy-Duty Vehicles**		**N2**: vehicles used for the carriage of goods and having a maximum weight exceeding 3.5 tonnes but not exceeding 12 tonnes. **N3**: vehicles used for the carriage of goods and having a maximum weight exceeding 12 tonnes.
	Petrol	>3,5 t	
	Diesel	Rigid <=7,5 t	
	Diesel	Rigid 7,5 - 12 t	
	Diesel	Rigid 12 - 14 t	
	Diesel	Rigid 14 - 20 t	
	Diesel	Rigid 20 - 26 t	
	Diesel	Rigid 26 - 28 t	
	Diesel	Rigid 28 - 32 t	
	Diesel	Rigid >32 t	
	Diesel	Articulated 14 - 20 t	
	Diesel	Articulated 20 - 28 t	
	Diesel	Articulated 28 - 34 t	
	Diesel	Articulated 34 - 40 t	
	Diesel	Articulated 40 - 50 t	
	Diesel	Articulated 50 - 60 t	
	CNG	Rigid <=7,5 t	
	CNG	Rigid 7,5 - 12 t	
	CNG	Rigid >12 t	
	CNG	Articulated <40 t	
	LNG	Articulated <40 t	
	Diesel	Urban Buses Midi <=15 t	**M2**: vehicles used for the carriage of passengers and comprising more than eight seats in addition to the driver's seat, and having a maximum weight not exceeding 5 tonnes. **M3**: vehicles used for the carriage of passengers and comprising more than eight seats in addition to the driver's seat, and having a maximum weight exceeding 5 tonnes.
	Diesel	Urban Buses Standard 15 - 18 t	
	Diesel	Urban Buses Articulated >18 t	
	Diesel	Coaches Standard <=18 t	
	Diesel	Coaches Articulated >18 t	
	Diesel Hybrid	Urban Diesel Buses Hybrid	
	CNG	Urban CNG Buses	
	Biodiesel	Urban Biodiesel Buses	
	Battery electric	-	
1.A.3.b.iv	**L-Category**		**L1e**: Light two-wheel powered vehicles with an engine cylinder capacity not exceeding 50 cm^3, a maximum design speed not exceeding 45 km/h and a maximum continuous or net power ≤ 4000 W **L2e**: Three-wheel mopeds with a maximum design speed not exceeding 45 km/h, a maximum continuous rated or net power ≤ 4000 W and mass in running order ≤ 270 kg.
	Petrol	Mopeds 2-stroke <50 cm^3	
	Petrol	Mopeds 4-stroke <50 cm^3	

	Petrol	Motorcycles 2-stroke >50 cm³	**L3e**: Two-wheel motorcycle with an engine cylinder capacity exceeding 50 cm³ or a design speed exceeding 45 km/h, or a maximum continuous or net power exceeding 4000 W. **L4e**: Two-wheel motorcycle with side-car, with a maximum of four seating positions including the driver on the motorcycle, with side car and a maximum of two seating positions for passengers in the side car. **L5e**: Powered tricycle with mass in running order ≤ 1000 kg and three-wheel vehicle that cannot be classified as a L2e vehicle.
	Petrol	Motorcycles 4-stroke <250 cm³	
	Petrol	Motorcycles 4-stroke 250 - 750 cm³	
	Petrol	Motorcycles 4-stroke >750 cm³	
	Diesel	Micro-cars	**L6e**: Light quadricycle with maximum design vehicle speed ≤ 45 km/h and mass in running order ≤ 425 kg and engine capacity ≤ 50 cm³ if a PI engine, or engine capacity ≤ 500 cm³ if a CI engine. **L7e**: Heavy quadricycle with mass in running order ≤ 450 kg for the transport of passengers, or ≤ 600 kg for the transport of goods.
	Petrol	All-Terrain Vehicles (Quad & ATVs)	

Emission factors for L-category vehicles in this methodology do not cover all types and sub-types of vehicles in this category. This is a very diverse category of vehicles ranging from small electric bicycles to diesel tractors. Their numbers are still quite small compared to other vehicle types in Europe. Significant growth dynamics seem to exist for some of these types, such as L6e and L7e vehicle types. Hence, new emission factors have been developed and presented in this chapter. For the vehicle sub-types not included in the methodology, it is recommended to allocate them to the moped or motorcycle categories available or even to the newly generated small petrol car category (especially the petrol tricycle and quadricycle vehicles). Similarly, diesel quadricycles should be allocated to the smaller category of diesel passenger cars (mini), in the absence of better information. The error is considered small due to the small size of the stock.

2.2 Techniques

The combustion process produces CO_2 and H_2O as the main products. Unfortunately, combustion also produces several by-products which either originate from incomplete fuel oxidation (CO, hydrocarbons (THC), particulate matter (PM)) or 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 installed various aftertreatment devices — such as catalytic converters and diesel particle filters (DPFs) — to reduce pollutant emissions. However, such devices may, as a result of their action, also produce small quantities of pollutants such as NH_3 and N_2O.

Gasoline (and other spark-ignition) engines are used in small vehicles of up to 3.5 t gross vehicle weight (GVW), primarily because of their superior power-weight ratio and their wider operational range compared with diesel engines, but also for reasons such as lower noise and more refined operation. For very small vehicles (mopeds and motorcycles), two-stroke engines have been favoured, especially in the past, because they provide the highest power-weight ratio of all concepts. However, such engines have become less and less popular in recent years due to strict emission regulations. On the other hand, diesel (and other compression-ignition) engines dominate in heavy-duty applications because of their greater fuel efficiency and torque compared with petrol engines. However, in recent years there has been a significant shift to diesel engines in the passenger car market, and in several European countries, diesel cars have the largest share of new registrations. Member States' data on passenger car registrations, collected by the European Environment Agency in accordance with Regulation (EC) No 443/2009, show that more than 40% of passenger cars in Europe in 2014 were diesel, with shares exceeding 55% for countries like Belgium, France, Ireland, Luxembourg and Spain. This is a result of the higher fuel efficiency of diesel engines and technological improvements which have led to increased power output for a given engine size.

A number of new technologies are designed to reduce both energy consumption and pollutant emissions. These technologies include the following:

- new types of internal combustion engines, such as gasoline direct injection (GDI), controlled auto-ignition (CAI), homogeneous charge compression ignition (HCCI);
- new fuels, such as CNG, reformulated grades, and hydrogen;
- alternative powertrains, such as hybrids (i.e. a combination of an internal combustion engine and an electric motor), plug-in hybrids that can be recharged from the grid power, fuel cell vehicles, electric, etc.

Some of these technologies (e.g. GDI, hybrids) have already become quite popular, whereas others (such as electric and fuel cells) 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 good-quality activity data and emission factors. This chapter of the Guidebook aims to cover the emissions from all the technologies which are currently in widespread use, in a systematic manner that will allow the production of high-quality emission inventories.

2.3 Controls

Emissions from road vehicles have been controlled by European legislation since the 1970s. In order to meet the increasingly stringent requirements of the legislation, vehicle manufacturers have continually improved engine technologies and have introduced various emission-control systems. As a result, modern vehicles have emission levels for regulated pollutants (CO, NO_x, THC) which are more than an order of magnitude lower than those of vehicles entering service two decades ago.

Road vehicles are usually classified according to their level of emission control technology, which is actually defined in terms of the emission legislation with which they are compliant. Using the vehicle classes described in Table 2-2 different groups can be identified, each with its own relevant legislation. These groups are described in more detail in the following subsections.

It should also be noted that, in accordance with the legislation, a slightly different notation is used in this chapter to refer to the emission standards for Light Commercial Vehicles (LCVs), Heavy Duty Vehicles (HDVs) and two-wheel vehicles. For LCVs and L-category vehicles, Arabic numerals are used (e.g. Euro 1, Euro 2, etc.), whereas for HDVs roman numerals are used (e.g. Euro I, Euro II, etc.).

The table below lists the different vehicle technologies addressed by the methodology as well as the introduction year (year of first registration) in the vehicle fleet based on European legislation. Minor differences concerning the date of introduction across countries are expected, however, they are not included in the table. A more detailed description of the emission standards may be found in Appendix 3.

Table 2-2: Implementation years of the European emission standards

Vehicle category	Type	Euro Standard	Start Date	End Date
Passenger Cars	All Petrol	PRE ECE		up to 1971
		ECE 15/00-01	1972	1977
		ECE 15/02	1978	1980
		ECE 15/03	1981	1985
		ECE 15/04	1985	1992
		Improved Conventional	1985	1990
		Open Loop	1985	1990
		Euro 1	1992	1996
		Euro 2	1996	1999
		Euro 3	2000	2004
		Euro 4	2005	2009
		Euro 5	2010	2014
		Euro 6 a/b/c	2014	2019
		Euro 6 d-temp	2019	2020
		Euro 6 d/e	2021	2026
		Euro 7	2026 and later	
	All Diesel	Conventional		up to 1992
		Euro 1	1992	1996
		Euro 2	1996	2000
		Euro 3	2000	2005
		Euro 4	2005	2010
		Euro 5	2010	2014
		Euro 6 a/b/c	2014	2019
		Euro 6 d-temp	2019	2020
		Euro 6 d/e	2021	2026
		Euro 7	2026 and later	
	All LPG	Conventional		up to 1991
		Euro 1	1992	1996
		Euro 2	1996	1999
		Euro 3	2000	2004
		Euro 4	2005	2009
		Euro 5	2010	2014
		Euro 6 a/b/c	2015	2016
		Euro 6 d-temp	2017	2019
		Euro 6 d/e	2020	2026
		Euro 7	2026 and later	
	All CNG	Euro 4	2005	2009
		Euro 5	2010	2014
		Euro 6 a/b/c	2015	2016
		Euro 6 d-temp	2017	2019
		Euro 6 d/e	2020	2026
		Euro 7	2026 and later	
	All Petrol Hybrid	Euro 4		Up to 2009
		Euro 5	2010	2014
		Euro 6 a/b/c	2014	2019
		Euro 6 d-temp	2019	2020

Vehicle category	Type	Euro Standard	Start Date	End Date
		Euro 6 d/e	2021	2026
		Euro 7	2026 and later	
	All Petrol PHEV	Euro 6 a/b/c		Up to 2019
		Euro 6 d-temp	2019	2020
		Euro 6 d/e	2021	2026
		Euro 7	2026 and later	
	All Diesel PHEV	Euro 6 a/b/c		Up to 2019
		Euro 6 d-temp	2019	2020
		Euro 6 d/e	2021	2026
		Euro 7	2026 and later	
	All Battery electric	Euro 6 a/b/c		Up to 2019
		Euro 6 d-temp	2019	2020
		Euro 6 d/e	2021	2026
		Euro 7	2026 and later	
Light Commercial Vehicles	All Petrol	Conventional		up to 1993
		Euro 1	1993	1997
		Euro 2	1997	2001
		Euro 3	2001	2006
		Euro 4	2006	2010
		Euro 5	2011	2015
		Euro 6 a/b/c	2016	2017
		Euro 6 d-temp	2018	2020
		Euro 6 d/e	2021	2026
		Euro 7	2026 and later	
	All Diesel	Conventional		up to 1993
		Euro 1	1993	1997
		Euro 2	1997	2001
		Euro 3	2001	2006
		Euro 4	2006	2011
		Euro 5	2011	2015
		Euro 6 a/b/c	2015	2017
		Euro 6 d-temp	2018	2020
		Euro 6 d/e	2021	2026
		Euro 7	2026 and later	
	All Battery electric	Euro 6 a/b/c		Up to 2019
		Euro 6 d-temp	2019	2020
		Euro 6 d/e	2021	2026
		Euro 7	2026 and later	
Heavy Duty Trucks	All Petrol	Conventional		
	All Diesel	Conventional		Up to 1992
		Euro I	1992	1995
		Euro II	1996	2000

Vehicle category	Type	Euro Standard	Start Date	End Date
		Euro III	2000	2005
		Euro IV	2005	2008
		Euro V	2008	2013
		Euro VI A/B/C	2013	2019
		Euro VI D/E	2019	2028
		Euro VII	2028 and later	
	All CNG	Euro VI D/E		Up to 2028
		Euro VII	2028 and later	
	All LNG	Euro VI D/E		Up to 2028
		Euro VII	2028 and later	
Buses	All Diesel	Conventional		Up to 1992
		Euro I	1992	1995
		Euro II	1996	2000
		Euro III	2000	2005
		Euro IV	2005	2008
		Euro V	2008	2013
		Euro VI A/B/C	2013	2019
		Euro VI D/E	2019	2028
		Euro VII	2028 and later	
	All CNG	Euro I		Up to 1995
		Euro II	1996	2000
		Euro III	2000	2005
		EEV	2005	2013
		Euro VI D/E	2013	2028
		Euro VII	2028 and later	
	All Battery electric	Euro VI A/B/C		Up to 2019
		Euro VI D/E	2019	2028
		Euro VII	2028 and later	
L-Category	All Mopeds and Micro-cars	Conventional		up to 1999
		Euro 1	1999	2002
		Euro 2	2002	2006
		Euro 3	2006	2016
		Euro 4	2016	2020
		Euro 5	2020 and later	
	All Motorcycles	Conventional		up to 1999
		Euro 1	1999	2003
		Euro 2	2003	2006
		Euro 3	2006	2013
		Euro 4	2016	2020
		Euro 5	2020 and later	

2.3.1 Summary of vehicle technologies/control measures

Table 2-3 provides a summary of all vehicle categories and technologies (emission standards) covered by the present methodology.

Table 2-3: Summary of all vehicle classes covered by the methodology

Vehicle category	Type	Euro Standard
Passenger Cars	Petrol Mini	Euro 4
		Euro 5
		Euro 6 a/b/c
		Euro 6 d-temp
		Euro 6 d/e
		Euro 7
	Petrol Small Petrol Medium Petrol Large-SUV-Executive	PRE ECE
		ECE 15/00-01
		ECE 15/02
		ECE 15/03
		ECE 15/04
		Improved Conventional
		Open Loop
		Euro 1
		Euro 2
		Euro 3
		Euro 4
		Euro 5
		Euro 6 a/b/c
		Euro 6 d-temp
		Euro 6 d/e
		Euro 7
	Diesel Mini	Euro 4
		Euro 5
		Euro 6 a/b/c
		Euro 6 d-temp
		Euro 6 d/e
		Euro 7
	Diesel Small Diesel Medium Diesel Large-SUV-Executive	Conventional
		Euro 1
		Euro 2
		Euro 3
		Euro 4
		Euro 5
		Euro 6 a/b/c
		Euro 6 d-temp
		Euro 6 d/e
		Euro 7
	Petrol Hybrid all categories	Euro 4
		Euro 5
		Euro 6 a/b/c
		Euro 6 d-temp
		Euro 6 d/e
		Euro 7
	Petrol PHEV all categories	Euro 6 a/b/c
		Euro 6 d-temp
		Euro 6 d/e
		Euro 7
	Diesel PHEV Large-SUV-Executive	Euro 6 a/b/c
		Euro 6 d-temp

Vehicle category	Type	Euro Standard
		Euro 6 d/e
		Euro 7
	LPG Bi-fuel Mini	Euro 4
		Euro 5
		Euro 6 a/b/c
		Euro 6 d-temp
		Euro 6 d/e
		Euro 7
	LPG Bi-fuel Small LPG Bi-fuel Medium LPG Bi-fuel Large-SUV-Executive	Conventional
		Euro 1
		Euro 2
		Euro 3
		Euro 4
		Euro 5
		Euro 6 a/b/c
		Euro 6 d-temp
		Euro 6 d/e
		Euro 7
	CNG Bi-fuel all categories	Euro 4
		Euro 5
		Euro 6 a/b/c
		Euro 6 d-temp
		Euro 6 d/e
		Euro 7
	Battery electric Mini Battery electric Small Battery electric Medium Battery electric Large-SUV-Executive	Euro 6 a/b/c
		Euro 6 d-temp
		Euro 6 d/e
		Euro 7
Light Commercial Vehicles	Petrol N1-I Petrol N1-II Petrol N1-III	Conventional
		Euro 1
		Euro 2
		Euro 3
		Euro 4
		Euro 5
		Euro 6 a/b/c
		Euro 6 d-temp
		Euro 6 d/e
		Euro 7
	Diesel N1-I Diesel N1-II Diesel N1-III	Conventional
		Euro 1
		Euro 2
		Euro 3
		Euro 4
		Euro 5
		Euro 6 a/b/c
		Euro 6 d-temp
		Euro 6 d/e
		Euro 7
	Battery electric N1-I Battery electric N1-II Battery electric N1-III	Euro 6 a/b/c
		Euro 6 d-temp
		Euro 6 d/e
		Euro 7
Heavy Duty Trucks	Petrol >3,5 t	Conventional
	All Diesel Rigid/Articulated categories	Conventional
		Euro I
		Euro II

Vehicle category	Type	Euro Standard
		Euro III
		Euro IV
		Euro V
		Euro VI A/B/C
		Euro VI D/E
		Euro VII
	All CNG categories	Euro VI D/E
		Euro VII
	All LNG categories	Euro VI D/E
		Euro VII
Buses	Urban Buses all categories	Conventional
		Euro I
		Euro II
		Euro III
		Euro IV
		Euro V
		Euro VI A/B/C
		Euro VI D/E
		Euro VII
	Coaches all categories	Conventional
		Euro I
		Euro II
		Euro III
		Euro IV
		Euro V
		Euro VI A/B/C
		Euro VI D/E
		Euro VII
	Urban CNG Buses	Euro I
		Euro II
		Euro III
		EEV
		Euro VI D/E
		Euro VII
	Urban Diesel Hybrid	Euro VI A/B/C
		Euro VI D/E
		Euro VII
	Urban Biodiesel Buses	Conventional
		Euro I
		Euro II
		Euro III
		Euro IV
		Euro V
		Euro VI A/B/C
		Euro VI D/E
		Euro VII
	Battery electric	Euro VI A/B/C
		Euro VI D/E
		Euro VII
L-Category	Mopeds all categories	Conventional
		Euro 1
		Euro 2
		Euro 3
		Euro 4
		Euro 5
	Motorcycles all categories	Conventional
		Euro 1

Vehicle category	Type	Euro Standard
		Euro 2
		Euro 3
		Euro 4
		Euro 5
	Micro-cars	Euro 1
		Euro 2
		Euro 3
		Euro 4
		Euro 5
	All-Terrain Vehicles (Quad & ATVs)	Euro 1
		Euro 2
		Euro 3
		Euro 4
		Euro 5

Note:

The methodology and emission factors presented in the subsequent chapters can be also applied in countries not following the Euro standards, provided that a correspondence between the national technological classification and European legislation classes can be approximated. This, most probably, will require some assumptions regarding the emission control technology in the vehicle, the year of manufacturing/registration of the vehicle and the general maintenance level of the operating stock. In some cases, a limited number of emission measurements may be available at the national level. These can be used to classify vehicles in one of the technology classes of this methodology by comparing the emission factors proposed with the emission level of the measured vehicles.

3 Calculation methods

The emission estimation methodology covers exhaust emissions of CO, NO_x, NMVOC, CH_4, CO_2, N_2O, NH_3, SO_x, exhaust PM, PAHs and POPs, dioxins and furans, PCBs, HCB, and heavy metals contained in the fuel and lubricant (lead, arsenic, cadmium, copper, chromium, mercury, nickel, selenium and zinc). NO_x emissions are further split into NO and NO_2. PM is also divided into elemental carbon and organic carbon as a function of vehicle technology. A detailed speciation of NMVOCs is also provided, and this covers homologous series such as alkanes, alkenes, alkynes, aldehydes, ketones and aromatics compounds. PM mass emissions in vehicle exhaust mainly fall in the $PM_{2.5}$ size range. Therefore, all PM mass emission factors are assumed to correspond to $PM_{2.5}$. Emission factors for particle number and surface are also provided for different particle size ranges.

According to the level of detail available, and the approach adopted for the calculation of emissions, the aforementioned pollutants can be divided into the following four groups:

Group 1: pollutants for which a detailed methodology exists, based on specific emission factors and covering different traffic situations (i.e. urban, rural, highway) and engine conditions. The pollutants included in this group are listed in Table 3-1.

Group 2: emissions of Group 2 pollutants are estimated based on fuel consumption, and the results are of the same quality as those for the pollutants in Group 1. These pollutants are listed in Table 3-2.

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

Group 4: pollutants which are derived as a fraction of total NMVOC emissions. A small fraction of ‘residual’ NMVOCs is considered to be PAHs. The speciation of NMVOCs covers the homologous series listed in Table 3-4.

Table 3-1: Pollutants included in Group 1 and equivalent terms in methodology

Pollutant	Equivalent
Carbon monoxide (CO)	Given as CO
Nitrogen oxides (NO_x: NO and NO_2)	Given as NO_2 equivalent
Volatile organic compounds (VOCs)	Given as $CH_{1,85}$ equivalent (also given as HC in emission standards)
Methane (CH_4)	Given as CH_4
Non-methane VOCs (NMVOCs)	Given as VOCs (or HC) minus CH_4
Nitrous oxide (N_2O)	Given as N_2O
Ammonia (NH_3)	Given as NH_3
Particulate matter (PM)	The mass of particles collected on a filter was kept below 52 °C during diluted exhaust sampling. This corresponds to total (filterable and condensable) $PM_{2.5}$. Coarse exhaust PM (i.e. > 2.5 µm diameter) is considered to be negligible, hence PM=$PM_{2.5}$.
Particle number and surface area	Given as particle number and particle active surface per kilometre, respectively

Table 3-2: Pollutants included in Group 2 and equivalent terms in methodology

Pollutant	Equivalent
Carbon dioxide (CO_2)	Given as CO_2
Sulphur dioxide (SO_2)	Given as SO_2
Lead (Pb)	Given as Pb
Arsenic (As)	Given as As
Cadmium (Cd)	Given as Cd
Chromium (Cr)	Given as Cr
Copper (Cu)	Given as Cu
Mercury (Hg)	Given as Hg
Nickel (Ni)	Given as Ni
Selenium (Se)	Given as Se
Zinc (Zn)	Given as Zn

Table 3-3: Pollutants included in Group 3 and equivalent terms in methodology

Pollutant	Equivalent
Polycyclic aromatic hydrocarbons (PAHs) and persistent organic pollutants (POPs)	Detailed speciation, including indeno(1,2,3-cd) pyrene, benzo(k)fluoranthene, benzo(b)fluoranthene, benzo(g,h,i)perylene, fluoranthene, benzo(a)pyrene
Polychlorinated dibenzo dioxins (PCDDs) and polychlorinated dibenzo furans (PCDFs)	Given as dioxins and furans respectively
Polychlorinated biphenyls (PCBs) and hexachlorobenzene (HCB)	Given as PCB and HCB respectively

Table 3-4: Pollutants included in Group 4 and equivalent terms in methodology

Pollutant	Equivalent
Alkanes (C_nH_{2n+2}):	Given in alkanes speciation
Alkenes (C_nH_{2n}):	Given in alkenes speciation
Alkynes (C_nH_{2n-2}):	Given in alkynes 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
Aromatic compounds	Given in aromatics speciation

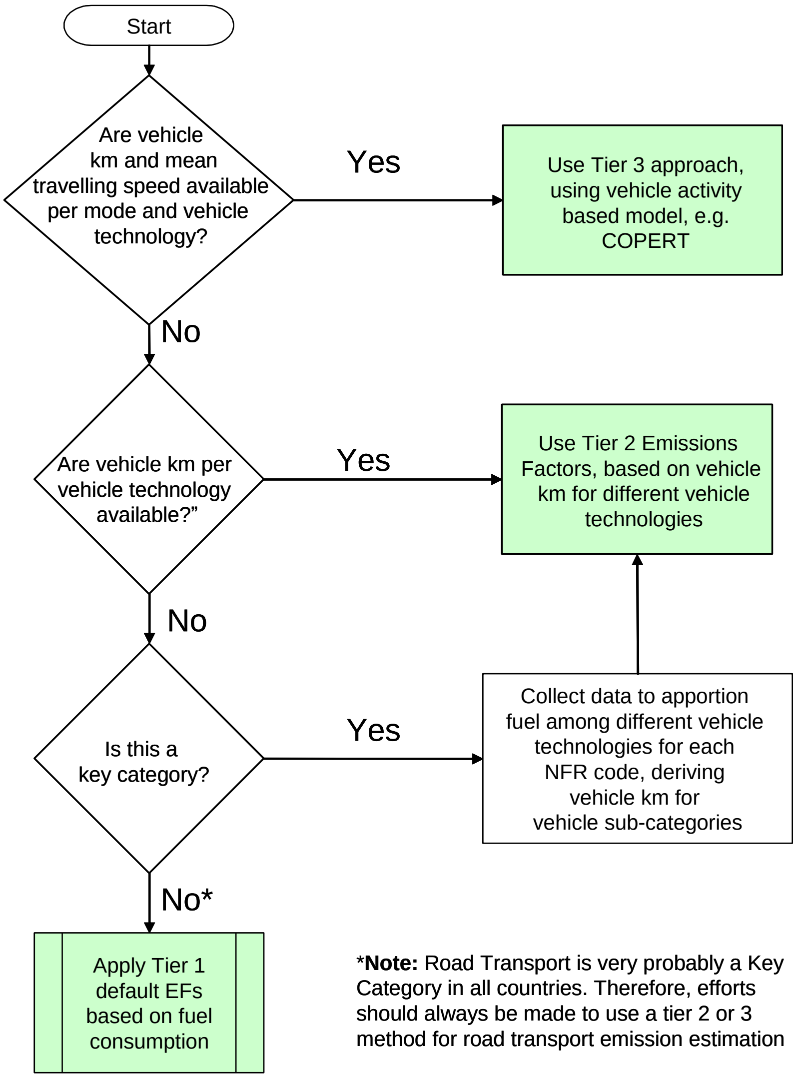
3.1 Choice of method

In Figure 3-1 a procedure is presented to enable a method for estimating exhaust emissions from road transport to be selected. This decision tree applies to all nations.

The Tier 1 methodology uses fuel as the activity indicator, in combination with average fuel-specific emission factors. It is similar to the Tier 1 methodology described in the IPCC 2006 guidelines and provides an inventory that is disaggregated according to the four NFR codes for exhaust emissions. It is also similar to the 'simpler methodology' described in previous versions of this Guidebook (Ntziachristos and Kouridis, 2007), except that default emission factors are provided for all nations, with appropriately wide upper and lower values. Country-specific values are provided in Table A1-0-1 to Table A1-0-31of Appendix 1.

In practice, road transport is very probably a key category in all countries. Therefore, the Tier 1 method should only be used in the absence of any more detailed information than fuel statistics. Furthermore, in such a situation the country needs to make every effort to collect the detailed statistics required for use with the higher Tier methods, preferably Tier 3.

Figure 3-1: Decision tree for exhaust emissions from road transport



3.2 Tier 1 method

3.2.1 Algorithm

The Tier 1 approach for exhaust emissions uses the following general equation:

$$E_i = \sum_j \left(\sum_m (FC_{j,m} \times EF_{i,j,m})\right) \qquad (1)$$

Where:

E_i	=	emission of pollutant i [g],
$FC_{j,m}$	=	fuel consumption of vehicle category j using fuel m [kg],

$EF_{i,j,m}$ = fuel consumption-specific emission factor of pollutant i for vehicle category j and fuel m [g/kg].

The vehicle categories to be considered are passenger cars, light commercial vehicles, heavy-duty vehicles and L-category vehicles. The fuels to be considered include petrol, diesel, LPG and natural gas.

This equation requires the fuel consumption/sales statistics to be split by vehicle category, as national statistics do not provide vehicle category details. Guidance on splitting fuel consumption/sales for Tier 1 is provided in subsection 3.2.3.

3.2.2 Tier 1 emission factors

The Tier 1 emission factors ($EF_{i,j,m}$) have been calculated based on the Tier 3 method, assuming a typical EU-27 fleet and activity data for 2010, taken from New Mobility Patterns Study (Papadimitriou et al. (2022)), to apply to countries with older vehicle fleets. The emission factors are given in Table 3-5 to Table 3-12.

However, a consequence of this approach, in the context of the legislative emission requirements for more modern vehicles, is that the Tier 1 emission factors will give somewhat higher emission values than a Tier 2 or 3 methodology for countries whose fleet comprises vehicles which comply with more recent (i.e. later than Euro 5 / Euro V) emission standards.

In Table 3-5 to Table 3-10, the maximum values correspond to uncontrolled vehicle technology, and the minimum values correspond to the latest vehicle technology in 2010. Table 3-11 proposes black carbon (BC) fractions of PM.

Table 3-5: Tier 1 emission factors for CO and NMVOCs

Category	Fuel	CO (g/kg fuel)			NMVOC (g/kg fuel)		
		Mean	Min	Max	Mean	Min	Max
PC	Petrol	48.36	8.60	338.69	7.75	1.15	176.89
	Diesel	2.41	0.52	11.23	0.51	0.02	3.26
	LPG	58.22	14.56	139.93	9.43	1.48	20.85
LCV	Petrol	118.70	11.75	356.95	7.42	0.67	53.99
	Diesel	6.81	4.82	21.77	1.23	0.48	2.86
HDV	Diesel	6.10	2.79	13.80	0.90	0.13	7.01
	CNG (Buses)	3.98	2.20	15.12	0.14	0.06	0.39
L-category	Petrol	244.88	8.46	588.11	92.74	6.47	323.68

Table 3-6: Tier 1 emission factors for NO_X and PM

Category	Fuel	NO_x (g/kg fuel)			PM (g/kg fuel)		
		Mean	Min	Max	Mean	Min	Max
PC	Petrol	3.98	0.44	30.49	0.02	0.004	0.042
	Diesel	11.77	7.79	14.84	0.78	0.002	4.772
	LPG	5.48	0.90	41.45	0.03	0.012	0.042
LCV	Petrol	5.93	0.33	37.31	0.02	0.005	0.034
	Diesel	13.48	10.43	27.86	1.22	0.002	4.772
HDV	Diesel	25.95	10.48	47.22	0.55	0.015	2.448
	CNG (Buses)	17.10	9.67	29.73	0.02	0.019	0.036
L-category	Petrol	7.23	0.89	22.06	0.51	0.058	6.599

Table 3-7: Tier 1 emission factors for N_2O and NH_3

Category	Fuel	N_2O (g/kg fuel)			NH_3 (g/kg fuel)		
		Mean	Min	Max	Mean	Min	Max
PC	Petrol	0.07	0.01	0.21	0.84	0.02	1.93
	Diesel	0.11	0.03	0.19	0.02	0.01	0.04
	LPG	0.16	0.02	0.35	1.02	0.03	1.85
LCV	Petrol	0.10	0.01	0.35	0.77	0.02	2.04
	Diesel	0.07	0.03	0.14	0.01	0.01	0.03
HDV	Diesel	0.07	0.02	0.23	0.02	0.01	0.11
	CNG (Buses)	0.27	0.18	0.33	N/A	N/A	N/A
L-category	Petrol	0.05	0.04	0.09	0.05	0.04	0.11

Table 3-8: Tier 1 emission factors for ID(1,2,3-cd)P and B(k)F

Category	Fuel	ID(1,2,3-cd)P (g/kg fuel)			B(k)F (g/kg fuel)		
		Mean	Min	Max	Mean	Min	Max
PC	Petrol	7.88E-06	4.42E-06	2.04E-05	4.56E-06	2.86E-06	5.98E-06
	Diesel	2.98E-05	2.02E-05	4.49E-05	2.82E-05	5.87E-06	4.24E-05
	LPG	1.98E-07	1.91E-07	1.98E-07	1.98E-07	1.91E-07	1.98E-07
LCV	Petrol	7.15E-06	4.21E-06	1.77E-05	3.88E-06	2.81E-06	5.15E-06
	Diesel	2.25E-05	1.99E-05	3.17E-05	2.12E-05	5.87E-06	2.99E-05
HDV	Diesel	5.45E-06	2.85E-06	1.36E-05	2.37E-05	1.24E-05	5.93E-05
	CNG (Buses)	3.80E-06	2.52E-06	4.53E-06	1.65E-05	1.10E-05	1.97E-05
L-category	Petrol	1.22E-05	6.51E-06	3.18E-05	6.13E-06	4.34E-06	1.49E-05

Table 3-9: Tier 1 emission factors for B(b)F and B(a)P

Category	Fuel	B(b)F (g/kg fuel)			B(a)P (g/kg fuel)		
		Mean	Min	Max	Mean	Min	Max
PC	Petrol	7.15E-06	4.08E-06	1.74E-05	5.81E-06	3.63E-06	9.51E-06
	Diesel	3.59E-05	1.72E-05	5.41E-05	3.20E-05	9.39E-06	4.82E-05
	LPG	N/A	N/A	N/A	1.98E-07	1.91E-07	1.98E-07
LCV	Petrol	6.44E-06	3.89E-06	1.51E-05	5.03E-06	3.46E-06	8.25E-06
	Diesel	2.70E-05	1.72E-05	3.82E-05	2.41E-05	9.39E-06	3.41E-05
HDV	Diesel	2.12E-05	1.11E-05	5.30E-05	3.50E-06	1.83E-06	8.76E-06
	CNG (Buses)	1.48E-05	9.82E-06	1.76E-05	2.44E-06	1.62E-06	2.91E-06
L-category	Petrol	1.09E-05	6.01E-06	2.72E-05	8.12E-06	5.34E-06	1.84E-05

Table 3-10: Tier 1 emission factors for lead (Pb)

Category	Fuel	Pb (g/kg fuel)		
		Mean	Min	Max
PC	Petrol	1.21E-03	8.27E-04	1.31E-03
	Diesel	1.52E-03	1.19E-03	1.66E-03
	LPG	1.45E-03	1.06E-03	1.84E-03
LCV	Petrol	1.23E-03	1.17E-03	1.71E-03
	Diesel	1.56E-03	1.42E-03	1.58E-03
HDV	Diesel	9.66E-04	5.17E-04	2.38E-03
	CNG (Buses)	6.63E-04	4.40E-04	7.90E-04
L-category	Petrol	8.33E-04	7.86E-04	1.62E-03

Table 3-11: Tier 1 BC fractions of PM

Vehicle category	f-BC
Petrol passenger cars	0.12
Petrol light-duty vehicles	0.05
Diesel passenger cars	0.57
Diesel light-duty vehicles	0.55
Diesel heavy-duty vehicles	0.53
Petrol L-category	0.11

Table 3-12: Tier 1 CO_2 emission factors for different road transport fossil fuels

Subsector units	Fuel	kg CO_2 per kg of fuel[1]
All vehicle types	Petrol	3.168
All vehicle types	Diesel	3.180
All vehicle types	LPG[2]	3.031
All vehicle types	CNG[3](or LNG)	2.749
All vehicle types	E5[4]	3.063
All vehicle types	E10[4]	2.964
All vehicle types	E85[4]	2.026
All vehicle types	ETBE11[5]	3.094
All vehicle types	ETBE22[5]	3.021

Notes:
[1] CO_2 emission factors are based on an assumed 100% oxidation of the fuel carbon (ultimate CO_2).
[2] LPG assumed to be 50% propane + 50% butane.
[3] CNG and LNG are assumed to be 100% methane.
[4] E5, E10 and E85 blends are assumed to consist of 5, 10 and 85% vol. respectively ethanol (bio-ethanol or synthetic ethanol) and 95, 90 and 15% respectively petrol.
[5] ETBE11 and ETBE22 blend assumed to consist of 11 and 22% vol. respectively ETBE and 89 and 78% respectively petrol.

Table 3-13: Tier 1 CO_2 emission factors from the combustion of lubricant oil[1]

Category	Fuel	CO_2 from lubricant (g/kg fuel)		
		Mean	Min	Max
PC	Petrol	6.45	3.56	8.01
	Diesel	7.31	5.16	10.57
	LPG	7.73	6.96	7.88
LCV	Petrol	5.48	3.85	6.33
	Diesel	5.62	4.86	8.17
HDV	Diesel	1.89	0.99	4.74
	CNG (Buses)	3.09	0.86	5.83
L-category	Petrol	33.28	2.30	173.15

Note: [1] These emission factors assume typical consumption values for lubricant oil used in automotive applications.

The emissions of SO_2 per fuel-type *m* are estimated by assuming that all sulphur in the fuel is transformed completely into SO_2, using the formula:

$$E_{SO_2,m} = 2 \times k_{S,m} \times FC_m \qquad (2)$$

where:

$E_{SO2,m}$ = emissions of SO_2 per fuel m [g],

$k_{S,m}$ = weight-related sulphur content in the fuel of type m [g/g fuel],

FC_m = fuel consumption of fuel m [g].

Typical values for fuel sulphur content are given below for the periods before mandatory improved fuel specifications, following the first improvement in fuel specification (January 2000 = Fuel 2000), the second (January 2005 = Fuel 2005) and the regulation of fuel sulphur to maximum 10 ppm by January

2009 (Fuel 2009). Again, typical emission factors for Tier 1 for a number of countries can be found in Appendix 1.

Table 3-14: Tier 1 — Typical sulphur content of the fuel (1 ppm = 10^{-6} g/g fuel)

Fuel	1996 Base fuel (Market average)	Fuel 2000	Fuel 2005	Fuel 2009 and later
Petrol	165 ppm	130 ppm	40 ppm	5 ppm
Diesel	400 ppm	300 ppm	40 ppm	3 ppm

3.2.3 Activity data

The Tier 1 approach requires relevant fuel statistics, i.e. the volumes (or weights) of fuel sold for road transport use, and for each type of fuel used.

For the majority of fuels (petrol, diesel, LPG) these statistics are usually available at a national level. However, for slow-fill CNG vehicles (often filled from the natural gas grid), data could be more challenging to obtain, and estimations may need to be made. However, for most countries, this is probably a negligible contribution to road transport consumption and emissions at present.

The Tier 1 methodology also requires that the fuel sales are disaggregated according to the four vehicle categories. Hence, the inventory compiler should also make sure when using the Tier 1 algorithm that the total amount of each type of fuel sold is equal to the sum of the fuel consumed by the different vehicle categories, i.e.:

$$FC_m = \sum_j (FC_{j,m}) \qquad (3)$$

Table 3-15 shows which fuel types are used in which vehicle categories.

The basis for this disaggregation may be the nation’s vehicle statistics combined with estimates of annual usage, such as km driven, and fuel consumption (g/km) for the different vehicle categories.

Table 3-15: Tier 1 — Typical fuel consumption figures, per km, by category of vehicle

Vehicle category (j)	Fuel	Typical fuel consumption (g/km)
Passenger cars	Petrol	61.9
	Diesel	56.8
	LPG	58.1
	E85	79.1
	CNG	61.6
LCV	Petrol	72.5
	Diesel	79.0
HDV	Diesel	216.8
	CNG (buses)	405.5
L-category	Petrol	27.7

A more detailed approach for estimating the fuel consumption split by vehicle category is provided in the Tier 3 methodology.

3.3 Tier 2 method

3.3.1 Algorithm

The Tier 2 approach considers the fuel used by different vehicle categories and their emission standards. Hence, the four broad vehicle categories used in the Tier 1 approach to describe the four NFR codes are sub-divided into different technologies *k* according to emission-control legislation (see Table 3-16).

Table 3-16: Summary of all vehicle classes covered by the Tier 2 methodology

Vehicle category (j)	Type	Legislation/technology (k)
Passenger cars	Petrol Mini	Euro 4, Euro 5, Euro 6
	Petrol Small, Medium, Large-SUV-Executive	PRE ECE, ECE 15/00-01, ECE 15/02, ECE 15/03, ECE 15/04, Improved Conventional, Open-Loop, Euro 1 – Euro 6
	Diesel Mini	Euro 4 - Euro 6
	Diesel Small, Medium, Large-SUV-Executive	Conventional, Euro 1 – Euro 6
	LPG Mini	Euro 4 - Euro 6
	LPG Small, Medium, Large-SUV-Executive	Conventional, Euro 1 – Euro 6
	Petrol Hybrid	Euro 4 - Euro 6
	Petrol PHEV	Euro 6 up to 2016 – Euro 6
	Diesel PHEV Large	Euro 6
	CNG	Euro 4, Euro 5, Euro 6
Light commercial vehicles	Petrol (N1-I, N1-II, N1-III)	Conventional, Euro 1 – Euro 6
	Diesel (N1-I, N1-II, N1-III)	
Heavy-duty vehicles	Petrol >3.5 t	Conventional
	Diesel Rigid, Articulated	Conventional, Euro I - Euro VI
Buses	Urban CNG buses	Euro I – Euro VI
	Urban Diesel Buses, Coaches	Conventional, Euro I - Euro VI
	Urban Diesel Hybrid	Euro VI
Mopeds	Petrol 2-stroke < 50 cm³	Conventional, Euro 1 - Euro 5
	Petrol 4-stroke < 50 cm	
Motorcycles	Petrol 2-stroke > 50 cm³	Conventional, Euro 1 - Euro 5
	Petrol 4-stroke 50–250 cm³	
	Petrol 4-stroke 250–750 cm³	
	Petrol 4-stroke > 750 cm³	
Micro-cars	Diesel	Conventional, Euro 1 - Euro 5
Quad & ATVs	Petrol	Conventional, Euro 1 - Euro 5

Therefore, the user needs to provide the number of vehicles and the annual mileage per technology (or the number of vehicle-km per technology). These vehicle-km data are multiplied by the Tier 2 emission factors.

Hence, the algorithm used is:

$$E_{i,j} = \sum_k (<M_{j,k}> \times EF_{i,j,k}) \qquad (4)$$

or

$E_{i,j} = \sum_k (N_{j,k} \times M_{j,k} \times EF_{i,j,k})$ (5)

where,

$<M_{j,k}>$ = total annual distance driven by all vehicles of category *j* and technology *k* [veh-km],

$EF_{i,j,k}$ = technology-specific emission factor of pollutant *i* for vehicle category *j* and technology k [g/veh-km],

$M_{j,k}$ = average annual distance driven per vehicle of category *j* and technology *k* [km/veh],

$N_{j,k}$ = number of vehicles in the nation's fleet of category *j* and technology *k.*

It is repeated that the vehicle categories *j* are passenger cars, light commercial vehicles, heavy-duty vehicles and L-category vehicles. The vehicle technologies *k* were given in Table 3-16.

3.3.2 Emission factors

The Tier 2 emission factors are stated in units of grammes per vehicle-kilometre, and for each vehicle, technology is given in Table 3-16. These average European emission factors were determined using the Tier 3 methodology which follows by using typical values for driving speeds, ambient temperatures, highway-rural-urban mode mix, trip length, etc.

The following Tables contain technology- and fuel-specific emission factors for CO, NMVOC, NO_X, N_2O, NH_3, Pb, PM (considered to be PM_{10}), four PAHs, and CO_2. For information on BC fractions of PM, the values of Table 3-92 can be used. A figure for fuel consumption (g/km) is provided, derived from carbon balance so that fuel-based pollutants (SO_2, As, Cr, Cu, Ni, Se, Zn, Cd, and Hg) can be calculated using the Tier 1 emission factors (mass of pollutant per mass of fuel used).

It is worth noting here that the Tier 3 methodology allows the calculation of emissions with a more detailed analysis, as it takes into account more characteristics, such as load, gradient, speed, etc. Therefore, it is highly recommended that one should follow Tier 3 methodology for emissions calculations.

Table 3-17: Tier 2 exhaust emission factors for passenger cars, NFR 1.A.3.b.i

Type	Technology	CO	NMVOC	NO_x	N_2O	NH_3	Pb	CO_2
Units		g/km	g/km	g/km	g/km	g/km	g/km	g/km
Notes			Given as $THC-CH_4$	Given as NO_2 equivalent				
Petrol Mini	Euro 4	1.050	0.633	0.065	0.002	0.031	5.01E-05	154.700
	Euro 5	1.042	0.625	0.047	0.001	0.013	5.01E-05	154.690
	Euro 6 a/b/c	0.397	0.549	0.032	0.001	0.013	5.01E-05	154.663
	Euro 6 d-temp	0.397	0.549	0.032	0.001	0.013	5.01E-05	154.652
	Euro 6 d	0.397	0.342	0.032	0.001	0.013	5.01E-05	154.647
Petrol Small	PRE ECE	40.792	5.386	1.795	0.008	0.002	6.21E-05	243.259
	ECE 15/00-01	32.242	4.756	1.795	0.008	0.002	6.21E-05	206.112
	ECE 15/02	24.210	4.586	2.033	0.008	0.002	6.21E-05	199.419
	ECE 15/03	24.779	4.274	2.213	0.008	0.002	6.21E-05	199.419
	ECE 15/04	14.286	3.313	1.971	0.008	0.002	6.21E-05	179.891

	Improved Conventional	12.130	2.903	1.853	0.008	0.002	6.21E-05	196.526
	Open Loop	12.597	2.143	1.467	0.008	0.002	6.21E-05	198.323
	Euro 1	5.463	1.473	0.456	0.012	0.087	6.21E-05	173.288
	Euro 2	3.359	0.817	0.248	0.007	0.105	6.21E-05	170.121
	Euro 3	3.148	0.436	0.106	0.003	0.031	6.21E-05	174.866
	Euro 4	1.050	0.277	0.065	0.002	0.031	6.21E-05	182.346
	Euro 5	1.042	0.210	0.047	0.001	0.014	6.21E-05	182.336
	Euro 6 a/b/c	0.397	0.091	0.032	0.001	0.014	6.21E-05	182.309
	Euro 6 d-temp	0.397	0.078	0.032	0.001	0.013	6.21E-05	182.299
	Euro 6 d	0.397	0.044	0.032	0.001	0.013	6.21E-05	182.293
Petrol Medium	PRE ECE	40.792	6.055	2.402	0.008	0.002	7.42E-05	290.839
	ECE 15/00-01	32.242	4.574	2.402	0.008	0.002	7.41E-05	246.016
	ECE 15/02	24.210	4.339	2.296	0.008	0.002	7.41E-05	233.343
	ECE 15/03	24.779	4.393	2.406	0.008	0.002	7.41E-05	233.343
	ECE 15/04	14.286	3.449	2.539	0.008	0.002	7.41E-05	211.789
	Improved Conventional	5.712	2.859	2.406	0.008	0.002	7.41E-05	236.835
	Open Loop	7.178	1.936	1.235	0.008	0.002	7.41E-05	239.514
	Euro 1	4.962	0.992	0.454	0.012	0.088	7.41E-05	205.034
	Euro 2	2.998	0.528	0.247	0.007	0.107	7.41E-05	199.754
	Euro 3	2.827	0.300	0.105	0.003	0.032	7.41E-05	208.623
	Euro 4	0.954	0.187	0.064	0.002	0.031	7.41E-05	214.942
	Euro 5	0.946	0.163	0.047	0.001	0.014	7.41E-05	214.931
	Euro 6 a/b/c	0.397	0.055	0.032	0.001	0.014	7.41E-05	214.905
	Euro 6 d-temp	0.397	0.052	0.032	0.001	0.013	7.41E-05	214.894
	Euro 6 d	0.397	0.036	0.032	0.001	0.013	7.41E-05	214.889
Petrol Large-SUV-Executive	PRE ECE	40.792	5.574	3.708	0.008	0.002	8.68E-05	350.658
	ECE 15/00-01	32.242	4.565	3.708	0.008	0.002	8.67E-05	273.083
	ECE 15/02	24.210	4.417	2.581	0.008	0.002	8.67E-05	285.759
	ECE 15/03	24.779	4.416	3.355	0.008	0.002	8.67E-05	285.759
	ECE 15/04	14.286	3.793	2.715	0.008	0.002	8.67E-05	266.593
	Euro 1	3.974	0.815	0.423	0.013	0.089	8.67E-05	262.608
	Euro 2	2.287	0.403	0.225	0.007	0.108	8.67E-05	271.743
	Euro 3	2.195	0.227	0.095	0.003	0.032	8.67E-05	245.230
	Euro 4	0.765	0.146	0.058	0.002	0.032	8.67E-05	286.352
	Euro 5	0.757	0.122	0.041	0.001	0.015	8.67E-05	286.342
	Euro 6 a/b/c	0.397	0.045	0.032	0.001	0.014	8.67E-05	286.315
	Euro 6 d-temp	0.397	0.041	0.032	0.001	0.013	8.67E-05	286.305
	Euro 6 d	0.397	0.289	0.032	0.001	0.013	8.67E-05	286.299
Diesel Mini	Euro 4	0.092	0.017	0.599	0.008	0.001	5.00E-05	118.891
	Euro 5	0.035	0.001	0.562	0.008	0.002	5.00E-05	118.878
	Euro 6 a/b/c	0.052	0.001	0.507	0.006	0.007	5.00E-05	118.845
	Euro 6 d-temp	0.041	0.001	0.086	0.006	0.007	5.00E-05	118.832

	Euro 6 d	0.040	0.001	0.074	0.006	0.007	5.00E-05	118.826
Diesel Small	Conventional	0.667	0.180	0.567	0.000	0.001	6.20E-05	194.469
	Euro 1	0.415	0.057	0.697	0.003	0.001	6.20E-05	171.494
	Euro 2	0.295	0.040	0.729	0.005	0.001	6.20E-05	178.119
	Euro 3	0.093	0.024	0.786	0.008	0.001	6.20E-05	168.739
	Euro 4	0.092	0.017	0.599	0.008	0.001	6.20E-05	168.739
	Euro 5	0.035	0.001	0.562	0.008	0.002	6.20E-05	168.726
	Euro 6 a/b/c	0.052	0.001	0.507	0.006	0.007	6.20E-05	168.693
	Euro 6 d-temp	0.041	0.001	0.086	0.006	0.007	6.20E-05	168.680
	Euro 6 d	0.040	0.001	0.074	0.006	0.007	6.20E-05	168.673
Diesel Medium	Conventional	0.667	0.180	0.567	0.000	0.001	7.40E-05	194.469
	Euro 1	0.415	0.057	0.697	0.003	0.001	7.40E-05	171.494
	Euro 2	0.295	0.040	0.729	0.005	0.001	7.40E-05	178.119
	Euro 3	0.093	0.024	0.786	0.008	0.001	7.40E-05	168.739
	Euro 4	0.092	0.017	0.599	0.008	0.001	7.40E-05	168.739
	Euro 5	0.035	0.001	0.562	0.008	0.002	7.40E-05	168.726
	Euro 6 a/b/c	0.052	0.001	0.507	0.006	0.007	7.40E-05	168.693
	Euro 6 d-temp	0.041	0.001	0.086	0.006	0.007	7.40E-05	168.680
	Euro 6 d	0.040	0.001	0.074	0.006	0.007	7.40E-05	168.673
Diesel Large-SUV-Executive	Conventional	0.667	0.180	0.905	0.000	0.001	8.66E-05	194.469
	Euro 1	0.415	0.085	0.697	0.003	0.001	8.66E-05	231.178
	Euro 2	0.295	0.119	0.729	0.005	0.001	8.66E-05	231.178
	Euro 3	0.093	0.047	0.786	0.008	0.001	8.66E-05	231.178
	Euro 4	0.092	0.017	0.599	0.008	0.001	8.66E-05	231.178
	Euro 5	0.035	0.001	0.562	0.008	0.002	8.66E-05	231.165
	Euro 6 a/b/c	0.052	0.001	0.507	0.006	0.007	8.66E-05	231.132
	Euro 6 d-temp	0.041	0.001	0.086	0.006	0.007	8.66E-05	231.119
	Euro 6 d	0.040	0.001	0.074	0.006	0.007	8.66E-05	231.113
LPG Bifuel	Conventional	7.998	1.151	2.466	0.000	0.002	7.40E-05	179.081
	Euro 1	5.658	0.741	0.458	0.019	0.089	7.40E-05	175.449
	Euro 2	3.981	0.355	0.213	0.009	0.109	7.40E-05	175.449
	Euro 3	2.859	0.190	0.109	0.004	0.032	7.40E-05	175.449
	Euro 4	0.940	0.100	0.064	0.004	0.032	7.40E-05	175.449
	Euro 5	0.940	0.100	0.054	0.001	0.015	7.40E-05	175.438
	Euro 6 a/b/c	0.191	0.002	0.020	0.001	0.014	7.40E-05	175.412
	Euro 6 d-temp	0.191	0.002	0.020	0.001	0.013	7.40E-05	175.401
	Euro 6 d	0.191	0.002	0.020	0.001	0.013	7.40E-05	175.396
Hybrid Petrol Small	Euro 4	0.745	0.239	0.037	0.002	0.031	4.98E-05	129.433
	Euro 5	0.745	0.192	0.037	0.001	0.031	4.98E-05	129.422
	Euro 6 a/b/c	0.075	0.087	0.014	0.001	0.031	4.98E-05	129.396
	Euro 6 d-temp	0.075	0.073	0.014	0.001	0.031	4.98E-05	129.385
	Euro 6 d	0.075	0.388	0.014	0.001	0.031	4.98E-05	129.380

Hybrid Petrol Medium	Euro 4	0.649	0.164	0.037	0.002	0.031	5.94E-05	134.313
	Euro 5	0.649	0.156	0.037	0.001	0.031	5.94E-05	134.302
	Euro 6 a/b/c	0.075	0.051	0.014	0.001	0.031	5.94E-05	134.275
	Euro 6 d-temp	0.075	0.049	0.014	0.001	0.031	5.94E-05	134.265
	Euro 6 d	0.075	0.034	0.014	0.001	0.031	5.94E-05	134.260
Hybrid Petrol Large	Euro 4	0.460	0.122	0.031	0.002	0.031	6.97E-05	141.809
	Euro 5	0.460	0.115	0.031	0.001	0.031	6.97E-05	141.799
	Euro 6 a/b/c	0.075	0.040	0.014	0.001	0.031	6.97E-05	141.772
	Euro 6 d-temp	0.075	0.037	0.014	0.001	0.031	6.97E-05	141.762
	Euro 6 d	0.075	0.303	0.014	0.001	0.031	6.97E-05	141.756
PHEV Petrol Small	Euro 6 a/b/c	0.056	0.146	0.010	0.001	0.023	3.83E-05	112.616
	Euro 6 d-temp	0.056	0.120	0.010	0.001	0.023	3.83E-05	112.605
	Euro 6 d	0.056	0.660	0.010	0.001	0.023	3.83E-05	112.600
PHEV Petrol Medium	Euro 6 a/b/c	0.056	0.080	0.010	0.001	0.023	4.58E-05	126.631
	Euro 6 d-temp	0.056	0.072	0.010	0.001	0.023	4.58E-05	126.620
	Euro 6 d	0.056	0.832	0.010	0.001	0.023	4.58E-05	126.615
PHEV Petrol Large	Euro 6 a/b/c	0.056	0.065	0.010	0.001	0.023	5.34E-05	149.717
	Euro 6 d-temp	0.056	0.059	0.010	0.001	0.023	5.34E-05	149.707
	Euro 6 d	0.056	0.491	0.010	0.001	0.023	5.34E-05	149.701
PHEV Diesel Large	Euro 6 a/b/c	0.039	0.001	0.381	0.004	0.005	5.76E-05	140.152
	Euro 6 d-temp	0.031	0.001	0.064	0.004	0.005	5.76E-05	140.139
	Euro 6 d	0.030	0.001	0.056	0.004	0.005	5.76E-05	140.132
CNG Bifuel	Euro 4	0.940	0.036	0.064	0.002	0.031	5.00E-05	170.311
	Euro 5	0.940	0.036	0.054	0.001	0.013	5.00E-05	170.300
	Euro 6 a/b/c	0.379	0.036	0.034	0.001	0.013	5.00E-05	170.274
	Euro 6 d-temp	0.059	0.004	0.007	0.001	0.013	5.00E-05	137.664
	Euro 6 d	0.059	0.004	0.007	0.001	0.013	5.00E-05	137.659

Table 3-18: Tier 2 exhaust emission factors for passenger cars, NFR 1.A.3.b.i

Type	Technology	PM2.5	ID(1,2,3,cd)P	B(k)F	B(b)F	B(a)P
Units		g/km	g/km	g/km	g/km	g/km
Notes		PM2.5=PM10=TSP				
Petrol Mini	Euro 4	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 5	9.59E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 a/b/c	4.74E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d-temp	4.09E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d	4.09E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
Petrol Small	PRE ECE	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	ECE 15/00-01	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	ECE 15/02	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	ECE 15/03	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07

	ECE 15/04	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	Improved Conventional	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	Open Loop	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	Euro 1	2.35E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 2	2.35E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 3	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 4	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 5	9.59E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 a/b/c	4.74E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d-temp	4.09E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d	4.09E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
Petrol Medium	PRE ECE	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	ECE 15/00-01	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	ECE 15/02	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	ECE 15/03	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	ECE 15/04	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	Improved Conventional	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	Open Loop	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	Euro 1	2.35E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 2	2.35E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 3	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 4	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 5	9.59E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 a/b/c	4.74E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d-temp	4.09E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d	4.09E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
Petrol Large-SUV-Executive	PRE ECE	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	ECE 15/00-01	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	ECE 15/02	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	ECE 15/03	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	ECE 15/04	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	Euro 1	2.35E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 2	2.35E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 3	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 4	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 5	9.59E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 a/b/c	4.74E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d-temp	4.09E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d	4.09E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
Diesel Mini	Euro 4	3.83E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 5	2.01E-04	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 6 a/b/c	1.93E-04	1.62E-06	1.53E-06	1.95E-06	1.74E-06

	Euro 6 d-temp	1.93E-04	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 6 d	1.93E-04	1.62E-06	1.53E-06	1.95E-06	1.74E-06
Diesel Small	Conventional	2.44E-01	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 1	8.95E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 2	5.94E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 3	4.56E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 4	3.83E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 5	2.01E-04	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 6 a/b/c	1.93E-04	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 6 d-temp	1.93E-04	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	Euro 6 d	1.93E-04	1.03E-06	3.00E-07	8.80E-07	4.80E-07
Diesel Medium	Conventional	2.44E-01	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 1	8.95E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 2	5.94E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 3	4.56E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 4	3.83E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 5	2.01E-04	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 6 a/b/c	1.93E-04	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 6 d-temp	1.93E-04	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	Euro 6 d	1.93E-04	1.03E-06	3.00E-07	8.80E-07	4.80E-07
Diesel Large-SUV-Executive	Conventional	2.44E-01	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 1	8.95E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 2	5.94E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 3	4.56E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 4	3.83E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 5	2.01E-04	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 6 a/b/c	1.93E-04	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 6 d-temp	1.93E-04	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 6 d	1.93E-04	1.62E-06	1.53E-06	1.95E-06	1.74E-06
LPG Bifuel Mini	Euro 4	1.10E-03	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 5	1.10E-03	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 6 a/b/c	6.18E-04	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 6 d-temp	6.18E-04	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 6 d	6.18E-04	1.00E-08	1.00E-08	0.00E+00	1.00E-08
LPG Bifuel Small	Conventional	2.35E-03	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 1	2.35E-03	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 2	2.35E-03	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 3	1.10E-03	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 4	1.10E-03	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 5	1.10E-03	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 6 a/b/c	6.18E-04	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 6 d-temp	6.18E-04	1.00E-08	1.00E-08	0.00E+00	1.00E-08

	Euro 6 d	6.18E-04	1.00E-08	1.00E-08	0.00E+00	1.00E-08
LPG Bifuel Medium	Conventional	2.35E-03	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 1	2.35E-03	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 2	2.35E-03	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 3	1.10E-03	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 4	1.10E-03	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 5	6.18E-04	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 6 a/b/c	6.18E-04	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 6 d-temp	6.18E-04	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 6 d	6.18E-04	1.00E-08	1.00E-08	0.00E+00	1.00E-08
LPG Bifuel Large	Conventional	2.35E-03	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 1	2.35E-03	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 2	2.35E-03	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 3	1.10E-03	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 4	1.10E-03	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 5	6.18E-04	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 6 a/b/c	6.18E-04	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 6 d-temp	6.18E-04	1.00E-08	1.00E-08	0.00E+00	1.00E-08
	Euro 6 d	6.18E-04	1.00E-08	1.00E-08	0.00E+00	1.00E-08
Hybrid Petrol Mini	Euro 4	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 5	9.59E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 a/b/c	4.74E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d-temp	4.09E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d	4.09E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
Hybrid Petrol Small	Euro 4	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 5	9.59E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 a/b/c	4.74E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d-temp	4.09E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d	4.09E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
Hybrid Petrol Medium	Euro 4	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 5	9.59E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 a/b/c	4.74E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d-temp	4.09E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d	4.09E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
Hybrid Petrol Large	Euro 4	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 5	9.59E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 a/b/c	4.74E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d-temp	4.09E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d	4.09E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
PHEV Petrol Small	Euro 6 a/b/c	3.56E-04	2.93E-07	1.95E-07	2.70E-07	2.40E-07
	Euro 6 d-temp	3.07E-04	2.92E-07	1.95E-07	2.70E-07	2.40E-07
	Euro 6 d	3.07E-04	2.93E-07	1.95E-07	2.70E-07	2.40E-07

PHEV Petrol Medium	Euro 6 a/b/c	3.56E-04	2.93E-07	1.95E-07	2.70E-07	2.40E-07
	Euro 6 d-temp	3.07E-04	2.93E-07	1.95E-07	2.70E-07	2.40E-07
	Euro 6 d	3.07E-04	2.93E-07	1.95E-07	2.70E-07	2.40E-07
PHEV Petrol Large	Euro 6 a/b/c	3.56E-04	2.93E-07	1.95E-07	2.70E-07	2.40E-07
	Euro 6 d-temp	3.07E-04	2.93E-07	1.95E-07	2.70E-07	2.40E-07
	Euro 6 d	3.07E-04	2.93E-07	1.95E-07	2.70E-07	2.40E-07
PHEV Diesel Large	Euro 6 a/b/c	1.45E-04	1.22E-06	1.15E-06	1.46E-06	1.31E-06
	Euro 6 d-temp	1.45E-04	1.22E-06	1.15E-06	1.46E-06	1.31E-06
	Euro 6 d	1.45E-04	1.22E-06	1.15E-06	1.46E-06	1.31E-06
CNG Bifuel Mini	Euro 4	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 5	6.18E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 a/b/c	6.18E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d-temp	6.18E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d	6.18E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
CNG Bifuel Small	Euro 4	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 5	6.18E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 a/b/c	6.18E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d-temp	6.18E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d	7.97E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
CNG Bifuel Medium	Euro 4	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 5	6.18E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 a/b/c	6.18E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d-temp	6.18E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d	6.18E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
CNG Bifuel Large	Euro 4	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 5	6.18E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 a/b/c	7.97E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d-temp	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07

Table 3-19: Tier 2 exhaust emission factors for light commercial vehicles, NFR 1.A.3.b.ii

Type	Technology	CO	NMVOC	NO_x	N_2O	NH_3	Pb	CO_2
Units		g/km	g/km	g/km	g/km	g/km	g/km	g/km
Notes			Given as THC-CH_4	Given as NO_2 equivalent				
Petrol N1-I	Conventional	6.814	1.227	1.225	0.008	0.002	7.41E-05	229.905
	Euro 1	5.392	0.763	0.438	0.013	0.089	7.41E-05	202.966
	Euro 2	3.331	0.388	0.247	0.007	0.109	7.41E-05	198.712
	Euro 3	3.089	0.214	0.105	0.003	0.032	7.41E-05	207.372
	Euro 4	1.016	0.137	0.065	0.002	0.032	7.41E-05	214.025
	Euro 5	1.011	0.123	0.047	0.001	0.016	7.41E-05	214.014
	Euro 6 a/b/c	0.371	0.040	0.032	0.001	0.014	7.41E-05	213.988

	Euro 6 d-temp	0.371	0.036	0.032	0.001	0.013	7.41E-05	213.977
	Euro 6 d	0.371	0.032	0.032	0.001	0.013	7.41E-05	213.972
Petrol N1-II	Conventional	27.801	3.077	2.889	0.008	0.002	1.05E-04	271.549
	Euro 1	11.260	0.760	0.556	0.030	0.089	1.05E-04	318.563
	Euro 2	7.706	0.386	0.240	0.037	0.109	1.05E-04	318.563
	Euro 3	6.830	0.230	0.137	0.007	0.032	1.05E-04	318.563
	Euro 4	2.538	0.142	0.072	0.005	0.032	1.05E-04	318.563
	Euro 5	2.007	0.131	0.043	0.001	0.015	1.05E-04	210.985
	Euro 6 a/b/c	0.770	0.040	0.023	0.001	0.014	1.05E-04	210.959
	Euro 6 d-temp	0.770	0.045	0.023	0.001	0.013	1.05E-04	210.948
	Euro 6 d	0.770	0.312	0.023	0.001	0.013	1.05E-04	210.943
Petrol N1-III	Conventional	27.801	3.360	2.889	0.008	0.002	1.05E-04	271.549
	Euro 1	11.260	0.777	0.556	0.030	0.089	1.05E-04	318.563
	Euro 2	7.706	0.410	0.240	0.037	0.109	1.05E-04	318.563
	Euro 3	6.830	0.250	0.137	0.007	0.032	1.05E-04	318.563
	Euro 4	2.538	0.151	0.072	0.005	0.032	1.05E-04	318.563
	Euro 5	2.007	0.129	0.043	0.001	0.015	1.05E-04	210.985
	Euro 6 a/b/c	0.770	0.034	0.023	0.001	0.014	1.05E-04	210.959
	Euro 6 d-temp	0.770	0.041	0.023	0.001	0.013	1.05E-04	210.948
	Euro 6 d	0.770	0.291	0.023	0.001	0.013	1.05E-04	210.943
Diesel N1-I	Conventional	0.671	0.181	0.553	0.000	0.001	7.40E-05	189.356
	Euro 1	0.408	0.057	0.685	0.003	0.001	7.40E-05	169.141
	Euro 2	0.294	0.040	0.711	0.005	0.001	7.40E-05	176.138
	Euro 3	0.094	0.024	0.772	0.008	0.001	7.40E-05	167.297
	Euro 4	0.092	0.017	0.578	0.008	0.001	7.40E-05	167.297
	Euro 5	0.036	0.001	0.551	0.008	0.002	7.40E-05	167.284
	Euro 6 a/b/c	0.052	0.001	0.497	0.006	0.007	7.40E-05	167.251
	Euro 6 d-temp	0.041	0.001	0.084	0.006	0.007	7.40E-05	167.238
	Euro 6 d	0.039	0.001	0.073	0.006	0.007	7.40E-05	167.231
Diesel N1-II & N1-III	Conventional	1.310	0.154	1.665	0.000	0.001	1.05E-04	285.369
	Euro 1	0.564	0.159	1.248	0.003	0.001	1.05E-04	255.543
	Euro 2	0.564	0.165	1.248	0.005	0.001	1.05E-04	255.543
	Euro 3	0.495	0.109	1.037	0.008	0.001	1.05E-04	255.543
	Euro 4	0.389	0.039	0.839	0.008	0.001	1.05E-04	255.543
	Euro 5	0.000	0.000	1.374	0.008	0.002	1.05E-04	242.218
	Euro 6 a/b/c	0.000	0.000	1.108	0.006	0.007	1.05E-04	242.185
	Euro 6 d-temp	0.001	0.000	0.512	0.006	0.007	1.05E-04	242.172
	Euro 6 d	0.001	0.000	0.142	0.006	0.007	1.05E-04	242.165

Table 3-20: Tier 2 exhaust emission factors for light commercial vehicles, NFR 1.A.3.b.ii

Type	Technology	PM2.5	ID(1,2,3,cd)P	B(k)F	B(b)F	B(a)P

Units		g/km	g/km	g/km	g/km	g/km
Notes		PM2.5=PM10=TSP				
Petrol N1-I	Conventional	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	Euro 1	2.35E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 2	2.35E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 3	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 4	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 5	7.92E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 a/b/c	4.75E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d-temp	4.10E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d	4.10E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
Petrol N1-II	Conventional	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	Euro 1	2.35E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 2	2.35E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 3	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 4	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 5	7.94E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 a/b/c	4.74E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d-temp	4.10E-04	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	Euro 6 d	4.10E-04	1.03E-06	3.00E-07	8.80E-07	4.80E-07
Petrol N1-III	Conventional	2.35E-03	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	Euro 1	2.35E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 2	2.35E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 3	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 4	1.10E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 5	7.94E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 a/b/c	4.74E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 6 d-temp	4.10E-04	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	Euro 6 d	4.10E-04	1.03E-06	3.00E-07	8.80E-07	4.80E-07
Diesel N1-I	Conventional	2.38E-01	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 1	8.52E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 2	5.80E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 3	4.40E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 4	3.79E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 5	2.01E-04	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 6 a/b/c	1.93E-04	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 6 d-temp	1.93E-04	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	Euro 6 d	1.93E-04	1.03E-06	3.00E-07	8.80E-07	4.80E-07
Diesel N1-II & N1-III	Conventional	3.50E-01	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 1	1.16E-01	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 2	1.16E-01	1.62E-06	1.53E-06	1.95E-06	1.74E-06

	Euro 3	8.52E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 4	4.59E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 5	2.01E-04	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 6 a/b/c	1.93E-04	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 6 d-temp	1.93E-04	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 6 d	1.93E-04	1.62E-06	1.53E-06	1.95E-06	1.74E-06

Table 3-21: Tier 2 exhaust emission factors for heavy-duty vehicles, NFR 1.A.3.b.iii

Type	Technology	CO	NMVOC	NO_x	N_2O	NH_3	Pb	CO_2
Units		g/km	g/km	g/km	g/km	g/km	g/km	g/km
Notes			Given as $THC-CH_4$	Given as NO_2 equivalent				
Petrol >3.5 t	Conventional	3.153	5.141	4.280	0.006	0.002	1.71E-04	489.531
Diesel Rigid <=7.5 t	Conventional	1.644	0.836	4.460	0.030	0.003	1.71E-04	378.489
	Euro I	0.610	0.149	3.252	0.004	0.003	1.71E-04	332.738
	Euro II	0.509	0.095	3.411	0.004	0.003	1.71E-04	320.091
	Euro III	0.544	0.083	2.563	0.003	0.003	1.71E-04	337.385
	Euro IV	0.294	0.017	1.804	0.006	0.003	1.71E-04	334.610
	Euro V	0.548	0.016	1.190	0.018	0.011	1.71E-04	323.846
	Euro VI A/B/C	0.053	0.010	0.167	0.017	0.009	1.71E-04	326.146
	Euro VI D/E	0.053	0.009	0.119	0.017	0.009	1.71E-04	326.146
Diesel Rigid 7.5 - 12 t	Conventional	1.886	0.632	7.766	0.030	0.003	1.71E-04	522.567
	Euro I	0.913	0.255	4.629	0.004	0.003	1.71E-04	463.497
	Euro II	0.806	0.166	4.919	0.004	0.003	1.71E-04	448.532
	Euro III	0.893	0.146	3.761	0.003	0.003	1.71E-04	469.932
	Euro IV	0.442	0.025	2.622	0.006	0.003	1.71E-04	461.059
	Euro V	0.792	0.024	1.847	0.018	0.011	1.71E-04	455.847
	Euro VI A/B/C	0.086	0.016	0.249	0.017	0.009	1.71E-04	460.900
	Euro VI D/E	0.086	0.015	0.192	0.017	0.009	1.71E-04	460.900
Diesel Rigid 12 - 14 t	Conventional	2.069	0.697	8.238	0.030	0.003	1.71E-04	559.900
	Euro I	1.024	0.281	4.946	0.009	0.003	1.71E-04	493.948
	Euro II	0.906	0.182	5.281	0.008	0.003	1.71E-04	477.687
	Euro III	1.000	0.160	4.128	0.005	0.003	1.71E-04	498.410
	Euro IV	0.487	0.026	2.855	0.012	0.003	1.71E-04	484.271
	Euro V	0.874	0.026	2.041	0.036	0.011	1.71E-04	458.335
	Euro VI A/B/C	0.099	0.018	0.264	0.035	0.009	1.71E-04	462.848
	Euro VI D/E	0.099	0.017	0.198	0.035	0.009	1.71E-04	462.848
Diesel Rigid 14 - 20 t	Conventional	2.779	0.999	9.997	0.030	0.003	1.71E-04	702.120
	Euro I	1.344	0.356	5.942	0.009	0.003	1.71E-04	585.827
	Euro II	1.146	0.223	6.464	0.008	0.003	1.71E-04	566.799
	Euro III	1.336	0.196	5.101	0.005	0.003	1.71E-04	588.931
	Euro IV	0.644	0.030	3.525	0.012	0.003	1.71E-04	565.270

	Euro V	1.116	0.034	3.035	0.036	0.011	1.71E-04	542.019
	Euro VI A/B/C	0.143	0.023	0.409	0.035	0.009	1.71E-04	546.063
	Euro VI D/E	0.144	0.022	0.315	0.035	0.009	1.71E-04	546.063
Diesel Rigid 20 - 26 t	Conventional	2.090	0.496	10.295	0.030	0.003	1.73E-04	822.313
	Euro I	1.721	0.441	7.297	0.009	0.003	1.73E-04	713.905
	Euro II	1.535	0.277	7.897	0.008	0.003	1.73E-04	694.547
	Euro III	1.693	0.242	6.363	0.005	0.003	1.73E-04	715.702
	Euro IV	0.773	0.039	4.422	0.012	0.003	1.73E-04	690.826
	Euro V	1.366	0.042	3.424	0.036	0.011	1.73E-04	672.094
	Euro VI A/B/C	0.146	0.028	0.437	0.035	0.009	1.73E-04	676.189
	Euro VI D/E	0.146	0.026	0.324	0.035	0.009	1.73E-04	676.189
Diesel Rigid 26 – 28 t	Conventional	2.205	0.520	10.759	0.030	0.003	1.73E-04	863.235
	Euro I	1.819	0.453	7.635	0.009	0.003	1.73E-04	751.795
	Euro II	1.596	0.291	8.173	0.008	0.003	1.73E-04	731.332
	Euro III	1.774	0.259	6.470	0.005	0.003	1.73E-04	755.474
	Euro IV	0.794	0.042	4.503	0.012	0.003	1.73E-04	734.012
	Euro V	1.367	0.043	3.397	0.036	0.011	1.73E-04	714.666
	Euro VI A/B/C	0.166	0.028	0.452	0.035	0.009	1.73E-04	723.332
	Euro VI D/E	0.167	0.027	0.339	0.035	0.009	1.73E-04	723.332
Diesel Rigid 28 – 32 t	Conventional	2.466	0.540	12.280	0.030	0.003	1.73E-04	967.643
	Euro I	2.087	0.485	8.804	0.013	0.003	1.73E-04	859.308
	Euro II	1.780	0.309	9.365	0.013	0.003	1.73E-04	853.455
	Euro III	1.998	0.272	7.383	0.007	0.003	1.73E-04	864.615
	Euro IV	0.877	0.048	5.183	0.019	0.003	1.73E-04	845.351
	Euro V	1.548	0.046	3.457	0.055	0.011	1.73E-04	821.800
	Euro VI A/B/C	0.189	0.031	0.470	0.053	0.009	1.73E-04	831.839
	Euro VI D/E	0.189	0.029	0.351	0.053	0.009	1.73E-04	831.839
Diesel Rigid >32 t	Conventional	2.476	0.544	12.256	0.030	0.003	1.73E-04	966.835
	Euro I	2.117	0.498	8.746	0.013	0.003	1.73E-04	853.471
	Euro II	1.897	0.315	9.380	0.013	0.003	1.73E-04	834.827
	Euro III	2.053	0.274	7.560	0.007	0.003	1.73E-04	855.343
	Euro IV	0.888	0.047	5.289	0.019	0.003	1.73E-04	830.637
	Euro V	1.617	0.048	3.615	0.055	0.011	1.73E-04	812.198
	Euro VI A/B/C	0.159	0.032	0.445	0.053	0.009	1.73E-04	817.309
	Euro VI D/E	0.159	0.030	0.320	0.053	0.009	1.73E-04	817.309
Diesel Articulated 14 - 20 t	Conventional	2.615	0.881	9.457	0.030	0.003	1.73E-04	658.606
	Euro I	1.296	0.313	5.649	0.009	0.003	1.73E-04	561.361
	Euro II	1.114	0.196	6.102	0.008	0.003	1.73E-04	544.321
	Euro III	1.279	0.168	4.858	0.005	0.003	1.73E-04	566.084
	Euro IV	0.591	0.028	3.363	0.012	0.003	1.73E-04	544.794
	Euro V	1.006	0.028	2.574	0.036	0.011	1.73E-04	526.359
	Euro VI A/B/C	0.108	0.019	0.287	0.035	0.009	1.73E-04	531.595

	Euro VI D/E	0.108	0.018	0.241	0.035	0.009	1.73E-04	531.595
Diesel Articulated 20 - 28 t	Conventional	2.071	0.450	10.156	0.030	0.003	1.76E-04	808.618
	Euro I	1.758	0.409	7.284	0.009	0.003	1.76E-04	723.058
	Euro II	1.541	0.257	7.688	0.008	0.003	1.76E-04	692.928
	Euro III	1.710	0.246	6.117	0.005	0.003	1.76E-04	716.110
	Euro IV	0.743	0.038	4.260	0.012	0.003	1.76E-04	694.118
	Euro V	1.282	0.036	3.078	0.036	0.011	1.76E-04	676.854
	Euro VI A/B/C	0.151	0.024	0.322	0.035	0.009	1.76E-04	682.300
	Euro VI D/E	0.151	0.023	0.265	0.035	0.009	1.76E-04	682.300
Diesel Articulated 28 - 34 t	Conventional	2.167	0.446	10.711	0.030	0.003	1.78E-04	846.559
	Euro I	1.877	0.409	7.622	0.013	0.003	1.78E-04	760.398
	Euro II	1.642	0.257	8.008	0.013	0.003	1.78E-04	742.089
	Euro III	1.795	0.221	6.393	0.007	0.003	1.78E-04	753.216
	Euro IV	0.762	0.040	4.442	0.019	0.003	1.78E-04	731.523
	Euro V	1.285	0.037	3.001	0.055	0.011	1.78E-04	716.358
	Euro VI A/B/C	0.148	0.024	0.313	0.053	0.009	1.78E-04	722.230
	Euro VI D/E	0.149	0.023	0.256	0.053	0.009	1.78E-04	722.230
Diesel Articulated 34 - 40 t	Conventional	2.523	0.541	12.163	0.030	0.003	1.78E-04	964.040
	Euro I	2.193	0.497	8.634	0.014	0.003	1.78E-04	852.736
	Euro II	1.935	0.311	9.250	0.014	0.003	1.78E-04	833.390
	Euro III	2.111	0.269	7.480	0.008	0.003	1.78E-04	853.673
	Euro IV	0.875	0.047	5.195	0.021	0.003	1.78E-04	829.132
	Euro V	1.542	0.044	3.503	0.059	0.011	1.78E-04	819.353
	Euro VI A/B/C	0.150	0.029	0.338	0.057	0.009	1.78E-04	824.921
	Euro VI D/E	0.151	0.028	0.272	0.057	0.009	1.78E-04	824.921
Diesel Articulated 40 - 50 t	Conventional	2.740	0.558	13.593	0.030	0.003	1.80E-04	1067.212
	Euro I	2.442	0.519	9.578	0.014	0.003	1.80E-04	944.437
	Euro II	2.114	0.327	10.200	0.014	0.003	1.80E-04	942.005
	Euro III	2.323	0.281	8.245	0.008	0.003	1.80E-04	947.725
	Euro IV	0.939	0.052	5.775	0.021	0.003	1.80E-04	925.235
	Euro V	1.685	0.048	3.518	0.059	0.011	1.80E-04	916.659
	Euro VI A/B/C	0.156	0.031	0.357	0.057	0.009	1.80E-04	922.164
	Euro VI D/E	0.156	0.030	0.281	0.057	0.009	1.80E-04	922.164
Diesel Articulated 50 - 60 t	Conventional	3.234	0.629	16.435	0.030	0.003	1.80E-04	1276.893
	Euro I	2.964	0.603	11.463	0.014	0.003	1.80E-04	1143.635
	Euro II	2.557	0.381	12.098	0.014	0.003	1.80E-04	1120.955
	Euro III	2.777	0.326	9.772	0.008	0.003	1.80E-04	1143.762
	Euro IV	1.090	0.062	6.618	0.021	0.003	1.80E-04	1119.076
	Euro V	1.944	0.056	3.869	0.059	0.011	1.80E-04	1106.398
	Euro VI A/B/C	0.181	0.037	0.408	0.057	0.009	1.80E-04	1116.041
	Euro VI D/E	0.181	0.035	0.317	0.057	0.009	1.80E-04	1116.041

Table 3-22: Tier 2 exhaust emission factors for heavy-duty vehicles, NFR 1.A.3.b.iii

Type	Technology	PM2.5	ID(1,2,3,cd)P	B(k)F	B(b)F	B(a)P
Units		g/km	g/km	g/km	g/km	g/km
Notes		PM2.5=PM10=TSP				
Petrol >3.5 t	Conventional	0.00E+00	1.40E-06	6.09E-06	5.45E-06	9.00E-07
Diesel Rigid <=7.5 t	Conventional	2.43E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro I	9.85E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro II	5.77E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro III	4.99E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro IV	1.44E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro V	1.37E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI A/B/C	1.37E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI D/E	1.37E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
Diesel Rigid 7.5 - 12 t	Conventional	2.41E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro I	1.50E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro II	8.96E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro III	7.80E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro IV	2.07E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro V	1.97E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI A/B/C	1.97E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI D/E	1.97E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
Diesel Rigid 12 - 14 t	Conventional	2.66E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro I	1.66E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro II	9.91E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro III	8.57E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro IV	2.17E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro V	2.01E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI A/B/C	2.00E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI D/E	2.00E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
Diesel Rigid 14 - 20 t	Conventional	3.51E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro I	2.14E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro II	1.20E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro III	1.13E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro IV	2.64E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro V	2.41E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI A/B/C	2.38E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI D/E	2.38E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
Diesel Rigid 20 - 26 t	Conventional	3.64E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro I	2.76E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro II	1.56E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro III	1.42E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07

	Euro IV	3.29E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro V	3.01E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI A/B/C	2.97E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI D/E	2.97E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
Diesel Rigid 26 – 28 t	Conventional	3.83E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro I	2.88E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro II	1.66E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro III	1.48E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro IV	3.43E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro V	3.19E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI A/B/C	3.17E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI D/E	3.17E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
Diesel Rigid 28 – 32 t	Conventional	4.25E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro I	3.23E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro II	1.92E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro III	1.64E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro IV	3.95E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro V	3.64E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI A/B/C	3.63E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI D/E	3.63E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
Diesel Rigid >32 t	Conventional	4.32E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro I	3.34E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro II	1.97E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro III	1.66E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro IV	3.92E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro V	3.63E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI A/B/C	3.59E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI D/E	3.59E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
Diesel Articulated 14 - 20 t	Conventional	3.30E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro I	2.07E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro II	1.18E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro III	1.08E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro IV	2.51E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro V	2.62E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI A/B/C	2.60E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI D/E	2.60E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
Diesel Articulated 20 - 28 t	Conventional	3.59E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro I	2.75E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro II	1.60E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro III	1.41E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro IV	3.22E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro V	3.38E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07

	Euro VI A/B/C	3.35E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI D/E	3.35E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
Diesel Articulated 28 - 34 t	Conventional	3.80E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro I	2.96E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro II	1.72E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro III	1.45E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro IV	3.33E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro V	3.58E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI A/B/C	3.55E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI D/E	3.55E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
Diesel Articulated 34 - 40 t	Conventional	4.37E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro I	3.42E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro II	2.02E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro III	1.68E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro IV	3.86E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro V	4.12E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI A/B/C	4.07E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI D/E	4.07E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
Diesel Articulated 40 - 50 t	Conventional	4.82E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro I	3.83E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro II	2.28E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro III	1.80E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro IV	4.21E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro V	4.61E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI A/B/C	4.55E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI D/E	4.55E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
Diesel Articulated 50 - 60 t	Conventional	5.69E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro I	4.58E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro II	2.77E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro III	2.21E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro IV	4.91E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro V	5.57E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI A/B/C	5.51E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI D/E	5.51E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07

Table 3-23: Tier 2 exhaust emission factors for buses, NFR 1.A.3.b.iii

Type	Technology	CO	NMVOC	NO_x	N_2O	NH_3	Pb	CO_2
Units		g/km	g/km	g/km	g/km	g/km	g/km	g/km
Notes			Given as $THC-CH_4$	Given as NO_2 equivalent				
Urban CNG Buses	Euro I	8.400	0.200	16.500	0.101	N/A	3.23E-04	1525.191
	Euro II	2.700	0.200	15.000	0.101	N/A	3.23E-04	1415.459

	Euro III	1.000	0.020	10.000	0.101	N/A	3.23E-04	1250.860
	EEV	0.793	0.029	3.451	0.101	N/A	3.23E-04	980.325
Urban Diesel Buses Midi <=15 t	Conventional	5.115	2.957	9.926	0.025	0.003	3.23E-04	915.399
	Euro I	1.770	0.425	7.354	0.010	0.003	3.23E-04	731.702
	Euro II	1.585	0.302	8.016	0.010	0.003	3.23E-04	703.036
	Euro III	1.731	0.272	7.037	0.005	0.003	3.23E-04	745.204
	Euro IV	0.876	0.042	4.305	0.011	0.003	3.23E-04	686.883
	Euro V	1.550	0.039	4.926	0.028	0.011	3.23E-04	662.879
	Euro VI A/B/C	0.290	0.027	1.180	0.035	0.009	3.23E-04	736.665
	Euro VI D/E	0.290	0.026	1.135	0.035	0.009	3.23E-04	736.665
Urban Diesel Buses Standard 15 - 18 t	Conventional	5.280	1.743	15.898	0.025	0.003	3.23E-04	1150.301
	Euro I	2.422	0.607	9.777	0.010	0.003	3.23E-04	974.495
	Euro II	2.161	0.424	10.592	0.010	0.003	3.23E-04	941.809
	Euro III	2.379	0.382	9.175	0.005	0.003	3.23E-04	987.669
	Euro IV	1.143	0.061	5.748	0.011	0.003	3.23E-04	923.564
	Euro V	2.055	0.054	6.170	0.028	0.011	3.23E-04	886.878
	Euro VI A/B/C	0.421	0.037	1.343	0.035	0.009	3.23E-04	967.451
	Euro VI D/E	0.421	0.036	1.263	0.035	0.009	3.23E-04	967.451
Urban Diesel Buses Articulated >18 t	Conventional	6.762	1.825	20.106	0.025	0.003	3.26E-04	1425.543
	Euro I	3.243	0.672	12.380	0.010	0.003	3.26E-04	1232.082
	Euro II	2.931	0.461	13.105	0.010	0.003	3.26E-04	1202.000
	Euro III	3.089	0.411	11.414	0.005	0.003	3.26E-04	1244.559
	Euro IV	1.394	0.075	7.511	0.011	0.003	3.26E-04	1184.991
	Euro V	2.577	0.063	6.260	0.028	0.011	3.26E-04	1136.553
	Euro VI A/B/C	0.496	0.042	2.050	0.035	0.009	3.26E-04	1254.854
	Euro VI D/E	0.496	0.041	1.949	0.035	0.009	3.26E-04	1254.854
Urban Diesel Hybrid Buses	Euro VI A/B/C	0.173	0.028	1.007	0.026	0.007	3.23E-04	627.463
	Euro VI D/E	0.173	0.028	1.007	0.026	0.007	3.23E-04	627.463
Diesel Coaches Standard <=18 t	Conventional	1.886	0.509	9.410	0.030	0.003	1.70E-04	760.916
	Euro I	1.577	0.482	7.190	0.009	0.003	1.70E-04	700.826
	Euro II	1.402	0.340	8.087	0.008	0.003	1.70E-04	699.459
	Euro III	1.706	0.332	6.692	0.005	0.003	1.70E-04	753.461
	Euro IV	0.907	0.048	4.570	0.012	0.003	1.70E-04	735.485
	Euro V	1.572	0.054	4.378	0.036	0.011	1.70E-04	726.220
	Euro VI A/B/C	0.222	0.037	0.609	0.035	0.009	1.70E-04	734.737
	Euro VI D/E	0.222	0.034	0.440	0.035	0.009	1.70E-04	734.737
Diesel Coaches Articulated >18 t	Conventional	2.297	0.613	11.373	0.030	0.003	1.72E-04	920.898
	Euro I	1.884	0.557	8.539	0.009	0.003	1.72E-04	818.926
	Euro II	1.633	0.380	9.358	0.008	0.003	1.72E-04	807.756
	Euro III	1.900	0.356	7.365	0.005	0.003	1.72E-04	820.208
	Euro IV	0.973	0.052	5.069	0.012	0.003	1.72E-04	799.431
	Euro V	1.765	0.059	4.624	0.036	0.011	1.72E-04	827.881
	Euro VI A/B/C	0.237	0.041	0.616	0.035	0.009	1.72E-04	841.503

	Euro VI D/E	0.237	0.038	0.429	0.035	0.009	1.72E-04	841.503

Table 3-24: Tier 2 exhaust emission factors for buses, NFR 1.A.3.b.iii

Type	Technology	PM_{10}2.5	ID(1.2.3.cd)P	B(k)F	B(b)F	B(a)F
Units		g/km	g/km	g/km	g/km	g/km
Notes		PM2.5=PM10=TSP				
Urban CNG Buses	Euro I	2.00E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro II	1.00E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro III	1.00E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	EEV	9.58E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
Urban Diesel Buses Midi <=15 t	Conventional	7.77E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro I	2.69E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro II	1.32E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro III	1.40E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro IV	3.39E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro V	5.90E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI A/B/C	5.68E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI D/E	5.68E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
Urban Diesel Buses Standard 15 - 18 t	Conventional	6.93E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro I	3.72E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro II	1.82E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro III	1.86E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro IV	4.64E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro V	7.92E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI A/B/C	7.61E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI D/E	7.61E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
Urban Diesel Buses Articulated >18 t	Conventional	8.64E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro I	4.66E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro II	2.43E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro III	2.25E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro IV	5.73E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro V	1.01E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI A/B/C	9.72E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI D/E	9.72E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
Urban Diesel Hybrid Buses	Euro VI A/B/C	6.80E-03	1.05E-06	4.57E-06	4.09E-06	6.75E-07
	Euro VI D/E	6.80E-03	1.05E-06	4.57E-06	4.09E-06	6.75E-07
Diesel Coaches Standard <=18 t	Conventional	3.30E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro I	2.60E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro II	1.37E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro III	1.51E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro IV	3.64E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07

	Euro V	4.66E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI A/B/C	4.62E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI D/E	4.62E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
Diesel Coaches Articulated >18 t	Conventional	3.99E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro I	3.03E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro II	1.60E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro III	1.67E-01	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro IV	3.95E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro V	5.31E-02	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI A/B/C	5.30E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07
	Euro VI D/E	5.30E-03	1.40E-06	6.09E-06	5.45E-06	9.00E-07

Table 3-25: Tier 2 exhaust emission factors for L-category vehicles, NFR 1.A.3.b.iv

Type	Technology	CO	NMVOC	NO_x	N_2O	NH_3	Pb	CO_2
Units		g/km	g/km	g/km	g/km	g/km	g/km	g/km
Notes			Given as $THC\text{-}CH_4$	Given as NO_2 equivalent				
Mopeds 2-stroke <50 cm³	Conventional	13.850	8.430	0.052	0.001	0.001	3.84E-05	82.161
	Euro 1	4.334	3.562	0.166	0.001	0.001	3.84E-05	66.365
	Euro 2	2.638	2.702	0.157	0.001	0.001	3.84E-05	66.365
	Euro 3	3.495	1.899	0.375	0.001	0.001	3.84E-05	56.193
	Euro 4	2.213	0.645	0.044	0.001	0.001	3.84E-05	54.677
	Euro 5	2.213	0.988	0.044	0.001	0.001	3.84E-05	54.465
Mopeds 4-stroke <50 cm³	Conventional	13.850	8.473	0.052	0.001	0.001	3.84E-05	82.161
	Euro 1	6.313	1.064	0.203	0.001	0.001	3.84E-05	66.365
	Euro 2	3.957	1.014	0.157	0.001	0.001	3.84E-05	66.365
	Euro 3	3.495	1.897	0.375	0.001	0.001	3.84E-05	56.193
	Euro 4	2.213	0.644	0.044	0.001	0.001	3.84E-05	54.677
	Euro 5	2.213	0.988	0.044	0.001	0.001	3.84E-05	54.465
Motorcycles 2-stroke >50 cm³	Conventional	18.200	8.636	0.029	0.002	0.002	2.55E-05	99.828
	Euro 1	12.007	3.018	0.043	0.002	0.002	2.55E-05	92.372
	Euro 2	9.499	1.662	0.050	0.002	0.002	2.55E-05	92.372
	Euro 3	4.921	1.098	0.050	0.002	0.002	2.55E-05	56.510
	Euro 4	4.808	1.035	0.058	0.002	0.002	2.55E-05	55.763
	Euro 5	4.349	1.027	0.038	0.002	0.002	2.55E-05	55.551
Motorcycles 4-stroke <250 cm³	Conventional	16.962	1.375	0.351	0.002	0.002	2.55E-05	98.789
	Euro 1	13.541	1.041	0.371	0.002	0.002	2.55E-05	81.230
	Euro 2	5.118	0.490	0.325	0.002	0.002	2.55E-05	67.238
	Euro 3	1.148	0.179	0.068	0.002	0.002	2.55E-05	53.467
	Euro 4	0.990	0.177	0.033	0.002	0.002	2.55E-05	53.161
	Euro 5	0.869	0.522	0.022	0.002	0.002	2.55E-05	53.161

Motorcycles 4-stroke 250 - 750 cm³	Conventional	20.210	2.260	0.332	0.002	0.002	2.55E-05	122.658
	Euro 1	9.627	1.219	0.323	0.002	0.002	2.55E-05	114.944
	Euro 2	2.920	0.613	0.118	0.002	0.002	2.55E-05	104.947
	Euro 3	0.420	0.348	0.063	0.002	0.002	2.55E-05	156.212
	Euro 4	0.221	0.221	0.023	0.002	0.002	2.55E-05	125.479
	Euro 5	0.194	0.243	0.015	0.002	0.002	2.55E-05	125.479
Motorcycles 4-stroke >750 cm³	Conventional	20.210	2.583	0.172	0.002	0.002	2.55E-05	141.673
	Euro 1	9.627	1.179	0.213	0.002	0.002	2.55E-05	134.388
	Euro 2	2.920	0.567	0.186	0.002	0.002	2.55E-05	131.977
	Euro 3	0.420	0.418	0.065	0.002	0.002	2.55E-05	156.222
	Euro 4	0.221	0.271	0.023	0.002	0.002	2.55E-05	125.522
	Euro 5	0.194	0.270	0.015	0.002	0.002	2.55E-05	125.522
Petrol Quad & ATVs	Euro 1	11.130	2.438	0.365	0.002	0.002	3.03E-05	180.621
	Euro 2	6.492	1.428	0.365	0.002	0.002	3.03E-05	180.621
	Euro 3	6.702	1.398	0.382	0.002	0.002	3.03E-05	180.621
	Euro 4	1.591	1.384	0.247	0.002	0.002	3.03E-05	175.207
	Euro 5	0.887	1.015	0.079	0.002	0.002	3.03E-05	175.207
Diesel Micro-car	Euro 1	0.618	1.127	0.628	0.000	0.0003	3.84E-05	105.687
	Euro 2	0.618	1.135	0.628	0.001	0.0003	3.84E-05	105.687
	Euro 3	0.618	1.140	0.628	0.004	0.0003	3.84E-05	105.687
	Euro 4	0.618	0.132	0.532	0.004	0.0003	3.84E-05	95.158

Table 3-26: Tier 2 emission factors for L-category vehicles, NFR 1.A.3.b.iv

Type	Technology	PM2.5	ID(1,2,3,cd)P	B(k)F	B(b)F	B(a)P
Units		g/km	g/km	g/km	g/km	g/km
Notes		PM2.5=PM10=TSP				
Mopeds 2-stroke <50 cm³	Conventional	1.76E-01	2.06E-07	6.00E-08	1.76E-07	9.60E-08
	Euro 1	4.50E-02	7.80E-08	5.20E-08	7.20E-08	6.40E-08
	Euro 2	2.60E-02	7.80E-08	5.20E-08	7.20E-08	6.40E-08
	Euro 3	8.11E-03	7.80E-08	5.20E-08	7.20E-08	6.40E-08
	Euro 4	1.71E-03	7.80E-08	5.20E-08	7.20E-08	6.40E-08
	Euro 5	1.71E-03	7.80E-08	5.20E-08	7.20E-08	6.40E-08
Mopeds 4-stroke <50 cm³	Conventional	1.76E-01	2.06E-07	6.00E-08	1.76E-07	9.60E-08
	Euro 1	4.00E-02	7.80E-08	5.20E-08	7.20E-08	6.40E-08
	Euro 2	7.00E-03	7.80E-08	5.20E-08	7.20E-08	6.40E-08
	Euro 3	8.11E-03	7.80E-08	5.20E-08	7.20E-08	6.40E-08
	Euro 4	1.71E-03	7.80E-08	5.20E-08	7.20E-08	6.40E-08
	Euro 5	1.71E-03	7.80E-08	5.20E-08	7.20E-08	6.40E-08
Motorcycles 2-stroke >50 cm³	Conventional	2.00E-01	5.15E-07	1.50E-07	4.40E-07	2.40E-07
	Euro 1	8.00E-02	1.95E-07	1.30E-07	1.80E-07	1.60E-07
	Euro 2	4.00E-02	1.95E-07	1.30E-07	1.80E-07	1.60E-07

	Euro 3	1.20E-02	1.95E-07	1.30E-07	1.80E-07	1.60E-07
	Euro 4	1.20E-02	1.95E-07	1.30E-07	1.80E-07	1.60E-07
	Euro 5	1.20E-02	1.95E-07	1.30E-07	1.80E-07	1.60E-07
Motorcycles 4-stroke <250 cm³	Conventional	2.00E-02	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	Euro 1	2.00E-02	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 2	5.00E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 3	5.00E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 4	8.75E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 5	8.75E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
Motorcycles 4-stroke 250 - 750 cm³	Conventional	2.00E-02	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	Euro 1	2.00E-02	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 2	5.00E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 3	5.00E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 4	8.75E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 5	8.75E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
Motorcycles 4-stroke >750 cm³	Conventional	2.00E-02	1.03E-06	3.00E-07	8.80E-07	4.80E-07
	Euro 1	2.00E-02	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 2	5.00E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 3	5.00E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 4	8.75E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 5	8.75E-04	3.90E-07	2.60E-07	3.60E-07	3.20E-07
Petrol Quad & ATVs	Euro 1	7.33E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 2	3.66E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 3	3.66E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 4	3.66E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
	Euro 5	3.66E-03	3.90E-07	2.60E-07	3.60E-07	3.20E-07
Diesel Micro-car	Euro 1	4.81E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 2	4.81E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 3	4.81E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06
	Euro 4	2.56E-02	1.62E-06	1.53E-06	1.95E-06	1.74E-06

The preceding tables provided emission factors for different vehicle categories, fuels and vehicle technologies, and for the principal pollutants which are affected by vehicle technology. Other pollutants (e.g. SO_2 and heavy metals) originate directly from the fuel and lubricant combustion. Therefore, Table 3-27 provides the fuel/energy consumption for each different combination of vehicle type, fuel and vehicle technology. These data, when multiplied by the Tier 1 emission factors for pollutants originating directly from fuel consumption (Table 3-12 to Table 3-14) give the Tier 2 emission factors.

Table 3-27: Tier 2 average fuel/energy consumption values

Vehicle category	Sub-category	Technology	FC (g/km)	EC (MJ/km)*
Passenger cars	Petrol Mini	Euro 4 and later	49	2.14
	Petrol Small	PRE-ECE to open loop	65	2.85
		Euro 1 and later	56	2.45

	Petrol Medium	PRE-ECE to open loop	77	3.37
		Euro 1 and later	66	2.89
	Petrol Large-SUV-Executive	PRE-ECE to open loop	95	4.16
		Euro 1 and later	86	3.76
	Diesel Small	Euro 4 and later	38	1.62
	Diesel Medium	Conventional	63	2.69
		Euro 1 and later	55	2.35
	Diesel Large-SUV-Executive	Conventional	75	3.2
		Euro 1 and later	73	3.12
	LPG	Conventional	59	2.75
		Euro 1 and later	57	2.65
	2-stroke	Conventional	82	3.59
	Hybrid Petrol Small	Euro 4 and later	34	1.49
	Hybrid Petrol Medium	Euro 4 and later	34	1.49
	Hybrid Petrol Large-SUV-Executive	Euro 4 and later	34	1.49
	PHEV Petrol Small	Euro 6 and later	34	1.49
	PHEV Petrol Medium	Euro 6 and later	34	1.49
	PHEV Petrol Large-SUV-Executive	Euro 6 and later	34	1.49
	PHEV Diesel Large-SUV-Executive	Euro 5 and later	73	3.12
	E85	Euro 4 and later	87	3.33
	CNG	Euro 4 and later	63	3.02
Light commercial vehicles	Petrol	Conventional	85	3.72
		Euro 1 and later	70	3.06
	Diesel	Conventional	89	3.8
		Euro 1 and later	80	3.42
Heavy-duty trucks	Petrol > 3.5 t	Conventional	177	7.75
	<=7.5 t	Conventional	125	5.34
		Euro I and later	101	4.31
	7.5-16 t	Conventional	182	7.77
		Euro I and later	155	6.62
	16-32 t	Conventional	251	10.72
		Euro I and later	210	8.97
	> 32 t	Conventional	297	12.68
		Euro I and later	251	10.72
Buses	Urban CNG buses	HD Euro I	555	26.64
		HD Euro II	515	24.72
		HD Euro III	455	21.84
		EEV	455	21.84
	Urban buses, standard	Conventional	366	15.63
		Euro I and later	301	12.85
	Coaches, standard	Conventional	263	11.23
		Euro I and later	247	10.55
	Urban Diesel Hybrid	Euro VI	225	9.85
L-category	Mopeds 2-stroke < 50 cm³	Conventional	25	1.09
		Euro 1	20	0.88
	Mopeds 2-stroke < 50 cm³	Euro 2	20	0.88
		Euro 3 and later	20	0.88
	Mopeds 4-stroke < 50 cm³	Conventional	25	1.09
		Euro 1	20	0.88
		Euro 2	20	0.88
		Euro 3 and later	20	0.88
	Motorcycles 2-stroke > 50 cm³	Conventional	33	1.44
		Euro 1	25	1.09
		Euro 2	23	1.01
		Euro 3 and later	17	0.74
	Motorcycles 4-stroke < 250 cm³	Conventional	32	1.4
		Euro 1 and later	36	1.58
	Motorcycles 4-stroke 250–750 cm³	Conventional	37	1.62
		Euro 1 and later	36	1.58
	Motorcycles 4-stroke > 750 cm³	Conventional	45	1.97
		Euro 1 and later	46	2.01
	Mini cars Diesel	Conventional	34	1.44
		Euro 1	30	1.26
		Euro 2	30	1.26
		Euro 3	30	1.26
		Euro 4	27	1.13

		Euro 5	27	1.13
	ATVs	Conventional	47	2.07
		Euro 1	41	1.79
		Euro 2	41	1.79
		Euro 3	41	1.79
		Euro 4	40	1.74
		Euro 5	40	1.74

*based on the default calorific values included in Table 3-28

3.3.3 Activity data

In principal, traffic activity data are available from the national statistics offices of all countries, and international statistical organisations and institutes (e.g. Eurostat, International Road Federation (IRF)). These statistics tend to be vehicle-orientated, providing details on fleet composition. Detailed data on vehicle stocks for all EU-27 countries and CH, NO, and TR can be also found on the COPERT website (https://www.emisia.com/utilities/copert/). These data have no official status but are a result of a research project (TRACCS, Ntziachristos et al., 2013). However, they can be used as a good guide in the absence of more detailed information.

For the annual distance driven per vehicle technology (typical values can be found also on the COPERT website, as above), the energy consumption calculated on the basis of appropriate assumptions for an annual mileage of the different vehicle categories can be balanced with available energy statistics. Then by applying a trial-and-error approach, it is possible to reach a good match between the calculated and the statistical energy consumption per fuel. This is a good indication that the activity data that have been used to estimate emissions are consistent with the total energy consumed in the country for road transportation.

3.4 Tier 3 method

In the Tier 3 method described here, exhaust emissions are calculated using a combination of firm technical data (e.g. emission factors) and activity data (e.g. total vehicle km). This approach was entitled 'Detailed Methodology' in the previous version of the Guidebook and is implemented in COPERT. Alternative Tier 3 methods can be found in tools such as Artemis, the DACH-NL Handbook of Emission Factors, and other national models (for example EMV in Sweden, Liipasto in Finland, and Versit+ in the Netherlands).

3.4.1 Algorithm

In the following Tier 3 approach, total exhaust emissions from road transport are calculated as the sum of hot emissions (when the engine is at its normal operating temperature) and emissions during transient thermal engine operation (termed 'cold-start' emissions). It should be noted that, in this context, the word 'engine' is used as shorthand for 'engine and any exhaust aftertreatment devices'. The distinction between emissions during the 'hot' stabilised phase and the transient 'warming-up' phase is necessary because of the substantial difference in vehicle emission performance during these two conditions. Concentrations of some pollutants during the warming-up period are many times higher than during hot operation, and a different methodological approach is required to estimate the additional emissions during this period. To summarise, total emissions can be calculated by means of the following equation:

$$E_{TOTAL} = E_{HOT} + E_{COLD} \qquad (6)$$

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).

Vehicle emissions are heavily dependent on engine operation conditions. Different driving situations impose different engine operation conditions, and therefore a distinct emission performance. In this respect, a distinction is made between urban, rural and highway driving.

As will be demonstrated later, different activity data and emission factors are attributed to each driving situation. Cold-start emissions are attributed mainly to urban driving (and secondarily to rural driving), as it is expected that a limited number of trips start at highway conditions. Therefore, as far as driving conditions are concerned, total emissions can be calculated by means of the equation:

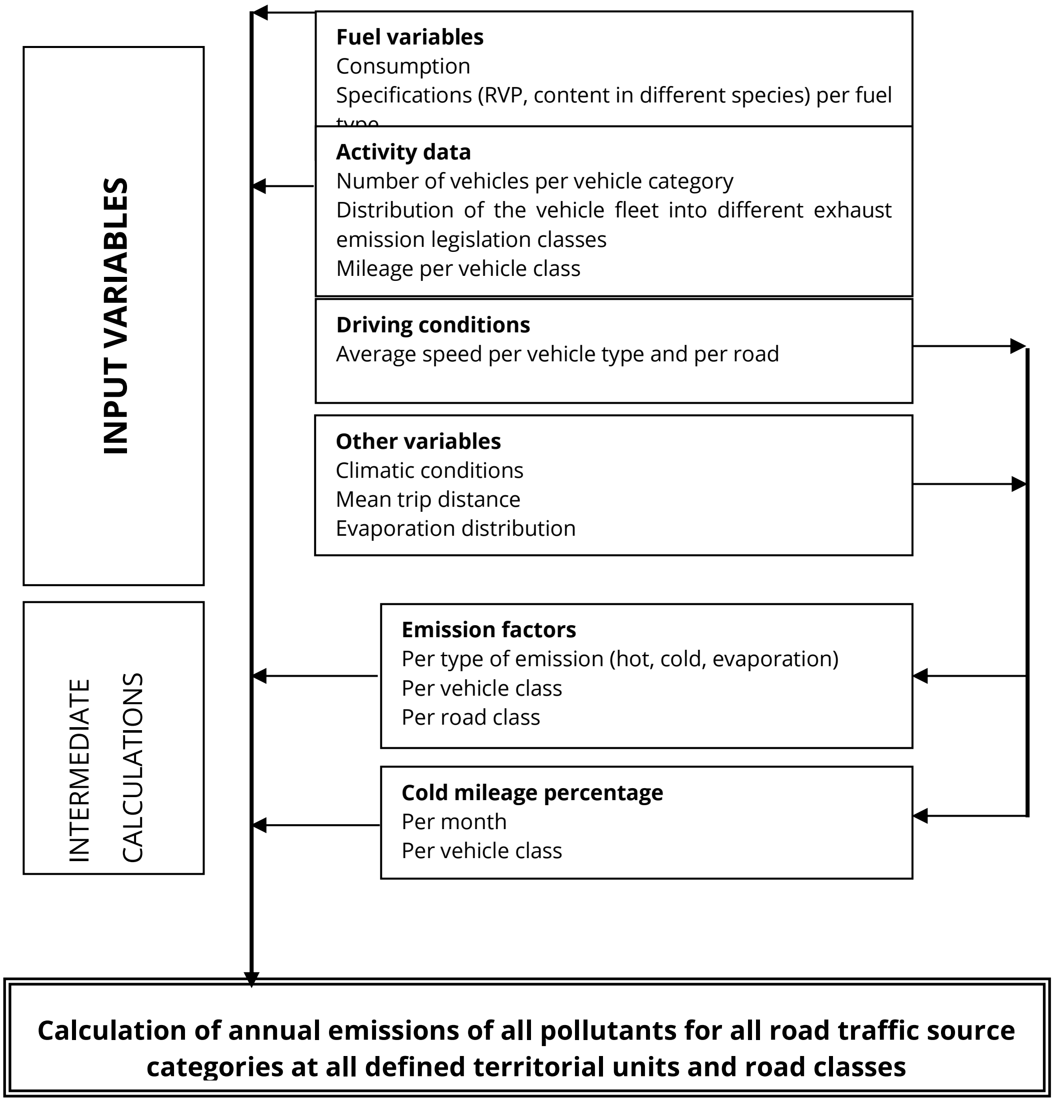
$$E_{TOTAL} = E_{URBAN} + E_{RURAL} + E_{HIGHWAY} \quad (7)$$

where:

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

Total emissions are calculated by combining activity data for each vehicle category with appropriate emission factors. The emission factors vary according to the input data (driving situations, climatic conditions).

Figure 3-2: Flow chart of the application of the baseline methodology



Hot emissions

Hot exhaust emissions depend upon a variety of factors, including the distance that each vehicle travels, its speed (or road type), its age, its engine size and its weight. As will be explained later, many countries do not have robust data for these parameters. Therefore, a method to estimate emissions from the available data has been proposed. However, it is important that each country uses the best data available; this is an issue to be resolved by each individual country.

The basic formula for estimating hot emissions for a given time period, and using experimentally obtained emission factors, is:

$$\text{emission [g]} = \text{emission factor [g/km]} \times \text{number of vehicles [veh]} \times \text{mileage per vehicle [km/veh]}$$

Different emission factors, numbers of vehicles and mileages per vehicle need to be used for each vehicle category and class. The time period (month, year, etc.) depends upon the application.

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:

$$E_{HOT;\,i,\,k,\,r} = N_k \times M_{k,r} \times e_{HOT;\,i,\,k,\,r} \tag{8}$$

where,

$E_{HOT;\,i,\,k,\,r}$ = hot exhaust emissions of the pollutant i [g], produced in the period concerned by vehicles of technology k driven on roads of type r,

N_k = number of vehicles [veh] of technology k in operation in the period concerned,

$M_{k,r}$ = mileage per vehicle [km/veh] driven on roads of type r by vehicles of technology k,

$e_{HOT;\,i,\,k,\,r}$ = emission factor in [g/km] for pollutant i, relevant for the vehicle technology k, operated on roads of type r.

The pollutants, vehicle classes and road classes are as follows:

i pollutants in Group 1 and Group 3,

k vehicle technologies in Table 2-3,

r road class (‘urban’, ‘rural’, and ‘highway’).

Note: the same formula is also applied for the calculation of the total energy consumed by vehicles of the specific class. However, in the case of energy consumption, an additional distinction needs to be made for different fuel types.

Vehicle speed, which is introduced into the calculation via the different driving modes, has a major influence on exhaust emissions, and different approaches have been developed to take this into account. For the emission factors presented in this chapter, two alternative methods can be used:

- to select a single average speed which 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 apply the emission factor values presented in subsection 3.4.3;
- to define mean speed distribution curves $f_{j,\,k}(V)$ and to integrate over the emission curves, i.e.:

$$e_{HOT;\,i,\,k,\,r} = \int [e(V) \times f_{k,\,r}(V)]\, dV \tag{9}$$

where,

V = speed of vehicles on the different road classes,

e(V) = expression of the speed-dependency of eHOT; i, k, r,

$f_{k,\,r}(V)$ = equation (e.g. formula of ‘best fit’ curve) describing the frequency distribution of the mean speeds which corresponds to the driving patterns of vehicles on road classes ‘rural’, ‘urban’ and ‘highway’. The term fk,r(V) is a function of vehicle technology k and road type r.

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

Cold-start emissions

Cold starts result in additional exhaust emissions. They take place under all driving conditions. However, they seem to be most likely for urban and rural driving, as the number of starts in highway conditions is relatively limited (in principle start from parking lots next to highways). They occur for all vehicle categories, but emission factors are only available or can be reasonably estimated, for petrol, diesel and LPG cars and — assuming that these vehicles behave like passenger cars — light commercial vehicles, as well as most recent diesel heavy-duty vehicles technologies, so that only these categories are covered by the methodology. Moreover, they are not considered to be a function of vehicle age.

Cold-start 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 applied to the fraction of kilometres driven with a cold engine. This factor varies from country to country. Driving behaviour (varying trip lengths) and climatic conditions affect the time required to warm up the engine and/or the catalyst, and hence the fraction of a trip driven with a cold engine.

Cold-start emissions are introduced into the calculation as additional emissions per km using the following formula:

$$E_{COLD;\,i,\,j} = \beta_{i,\,k} \times N_k \times M_k \times e_{HOT;\,i,\,k} \times (e^{COLD} / e^{HOT}|_{i,k} - 1) \tag{10}$$

where,

$E_{COLD;\,i,\,k}$	=	cold-start emissions of pollutant *i* (for the reference year), produced by vehicle technology *k*,
$\beta_{i,\,k}$	=	fraction of mileage driven with a cold engine, or the catalyst operated below the light-off temperature for pollutant *i* and vehicle technology *k*,
N_k	=	number of vehicles [veh] of technology *k* in circulation,
M_k	=	total mileage per vehicle [km/veh] in vehicle technology *k*,
$e_{HOT;\,i,\,k}$	=	hot emission factor for pollutant *i* and vehicles of *k* technology,
$e^{COLD} / e^{HOT}|_{i,k}$	=	cold/hot emission quotient for pollutant *i* and vehicles of *k* technology.

The β-parameter depends upon ambient temperature t_a (for practical reasons the average monthly temperature can be used), and the 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 the available statistical data (André et al., 1998), a European value of 12.4 km has been established for the l_{trip} value. Moreover, the value of l_{trip} should be between 8 km and 15 km. Therefore, it is proposed that a value of 12.4 km can be used unless a firm national estimate is available. Table 3-35 presents the l_{trip} values used in the COPERT 1990 inventories by different Member States.

Note

l_{trip} is the mean trip distance in km. The definition of a "trip" and a "journey" are not always unequivocal. A trip is sometimes referred to as a small journey, with a journey having the meaning of a complete sequence of events with different destinations, different segments, etc. However, in calculating emissions, a "trip" should be seen as the travel segment defined between a key-on and a key-off event. For example, travelling between office and home with an intermediate stop to buy grocery. The first trip is this between office (key-on) and the grocery store (key-off). The second trip is between the store (second key-on) and home (second key-off). However, a travel between home and office with an intermediate stop to drop-off kids at school is a single trip, as only on engine-on/engine-off sequence is taking place. Trips for passenger cars can occur at any distance between a few meters (local commuting) to several hundred kilometres (interurban trips). The probability distribution of trips is a skewed one with a long tail of low frequency for long trips. According to research and national statistics, the average trip for a passenger car is in the order of ~12 km. National statistics of citizens' mobility can provide more robust values. The cold-start methodology included in this Guidebook is applicable only on passenger cars and light commercial vehicles. Care should be therefore given to take into account the mean distance of trips travelled with such vehicles only and not other means of transport.

Detailed numbers of vehicles and mileage per technology can be found on the following website: http://www.emisia.com/copert.

The introduction of more stringent emission standards for catalyst petrol vehicles has imposed shorter periods for the catalyst to reach the light-off temperature. This is reflected in the lower mileage driven under cold-start conditions. Therefore, the β-parameter is also a function of the level of emission-control legislation for petrol catalyst vehicles. Table 3-41 presents factors to be used for calculating the reduction in the β-parameter for current and future catalyst vehicles per pollutant.

The cold/hot emission quotient e^{COLD}/e^{HOT} also depends on the ambient temperature and the pollutant being 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 quotients were introduced for catalyst-equipped petrol vehicles in previous updates of this chapter. These quotients were based on the Methodologies to Estimate Emissions from Transport (MEET) project (MEET, 1999).

As has already been discussed, cold start emissions are normally only attributed to urban driving. However, a portion of cold start emissions may also be attributed to rural driving in cases where the mileage fraction driven under non-thermally stabilised engine conditions (β-parameter) exceeds the mileage share attributed to urban conditions (S_{URBAN}). This requires a transformation of equation (10), which yields the following:

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

$$E_{COLD\ URBAN;\ i,k} = S_{URBAN;\ k} \times N_k \times M_k \times e_{HOT\ URBAN;\ i,k} \times (e^{COLD} / e^{HOT}|_{i,k} - 1)$$
$$E_{COLD\ RURAL;\ i,k} = (\beta_{i,k} - S_{URBAN;\ k}) \times N_k \times M_k \times e_{HOT\ URBAN;\ i,k} \times (e^{COLD} / e^{HOT}|_{i,k} - 1) \quad (11)$$

In this case, it is considered that the total mileage driven under urban conditions corresponds to warm-up conditions, while the remaining excess emissions are attributed to rural driving. The case demonstrated by equation (11) 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 (11). This is because total cold-start emissions should not be differentiated according to the place of emission.

The calculation of N_2O, NH_3 and CH_4 emissions is based on 'cold urban', 'hot urban', 'rural' and 'highway' driving conditions. The following paragraphs present the calculation algorithm that is used in order to calculate the emissions of these pollutants. In particular, for methane (CH_4) the estimation is of importance because NMVOC emissions are calculated as the difference between VOCs and CH_4.

Firstly, one needs to check whether the mileage fraction driven under thermally non-stabilised engine conditions (β - parameter) exceeds the mileage share attributed to urban conditions (S_{URBAN}). For each vehicle category *j* and pollutant (*i* = CH_4, N_2O, NH_3) the calculation takes the form:

if $\beta_{i,\,k} > S_{URBAN;\,k}$ (12)

$E_{COLD\ URBAN;\,i,\,k} = \beta_{i,k} \times N_k \times M_k \times e_{COLD\ URBAN;\,i,\,k}$ (a)

$E_{COLD\ RURAL;\,i,\,k} = 0$ (b)

$E_{HOT\ URBAN;\,i,\,k} = 0$ (c)

$E_{HOT\ RURAL;\,i,\,k} = [S_{RURAL;\,k} - (\beta_{i,k} - S_{URBAN;\,k})] \times N_k \times M_k \times e_{HOT\ RURAL;\,i,\,k}$ (d)

$E_{HOT\ HIGHWAY;\,i,\,k} = S_{HIGHWAY;\,k} \times N_k \times M_k \times e_{HOT\ HIGHWAY;\,i,\,k}$ (e)

else if $\beta_{i,\,k} <= S_{URBAN;\,k}$ (13)

$E_{COLD\ URBAN;\,i,\,k} = \beta_{i,k} \times N_k \times M_k \times e_{COLD\ URBAN;\,i,\,k}$ (a)

$E_{COLD\ RURAL;\,i,\,k} = 0$ (b)

$E_{HOT\ URBAN;\,i,\,k} = (S_{URBAN;\,k} - \beta_{i,k}) \times N_k \times M_k \times e_{HOT\ URBAN;\,i,\,k}$ (c)

$E_{HOT\ RURAL;\,i,\,k} = S_{RURAL;\,k} \times N_k \times M_k \times e_{HOT\ RURAL;\,i,k}$ (d)

$E_{HOT\ HIGHWAY;\,i,\,k} = S_{HIGHWAY;\,k} \times N_k \times M_k \times e_{HOT\ HIGHWAY;\,i,\,k}$ (e)

where,

$S_{URBAN;\,k}$ = mileage share attributed to urban conditions for vehicle technology *k,*

$S_{RURAL;\,k}$ = mileage share attributed to rural conditions for vehicle technology *k,*

$S_{HIGHWAY;\,k}$ = mileage share attributed to highway conditions for vehicle technology *k,*

$e_{COLD\ URBAN;\,i,\,k}$ = urban cold-start emission factor for pollutant *i*, by vehicle technology *k*,

$e_{HOT\ URBAN;\,i,\,k}$ = urban hot emission factor for pollutant *i*, by vehicle technology *k*,

$e_{HOT\ RURAL;\,i,\,k}$ = rural hot emission factor for pollutant *i,* by vehicle technology *k,*

$e_{HOT\ HIGHWAY;\,i,\,k}$ = highway hot emission factor for pollutant *i*, by vehicle technology *k*.

Note

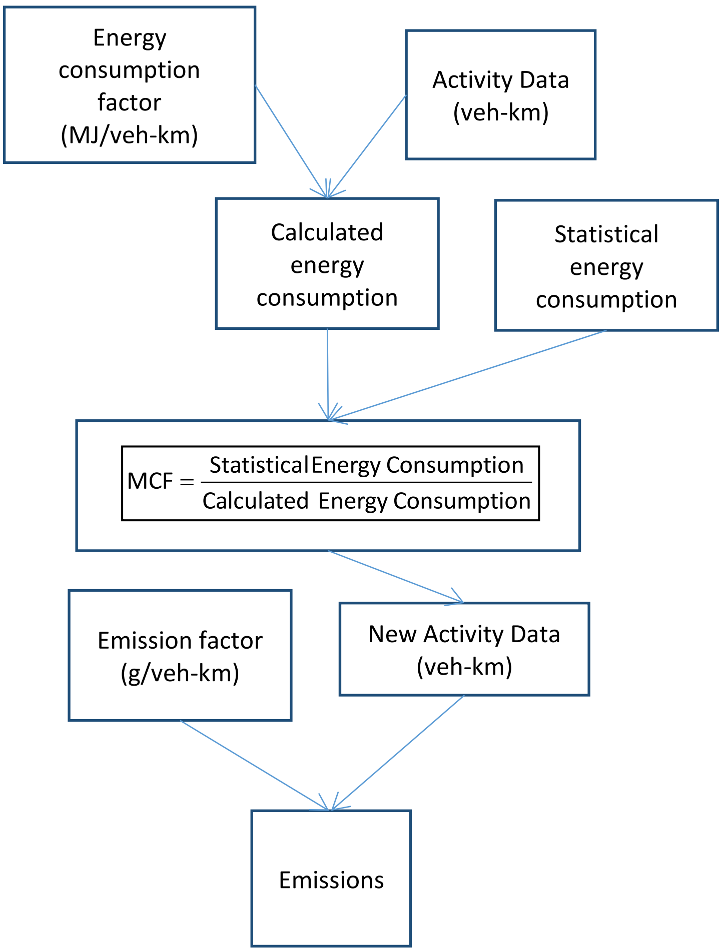
When compiling an urban inventory, the urban share (S_{URBAN}) should be set equal to 100%, whereas both rural (S_{RURAL}) and highway ($S_{HIGHWAY}$) shares should be set equal to zero. In any case, the sum of the three shares should always equal 100%, otherwise an error is introduced in the calculations.

Energy Balance

In previous versions of this chapter, it was suggested to carry out a fuel balance in order to ensure that all statistical fuel sold was accounted for in the calculations. However, since vehicles are using blends of fuels with different energy content (e.g. E5, B7, etc.), an energy balance is more appropriate, as the calorific value of the fuel available to the user may significantly differ per country. When performing the energy balance, the activity data is most frequently modified so that calculated energy consumption meets the statistical one reported by the country. Most often, this can be achieved by adjusting the annual kilometres travelled.

When calculating the vehicle fleet energy consumption a mileage correction factor (MCF) is applied to the mean activity to balance the statistical and calculated energy consumption. For the calculation of air pollutant emissions, the adjusted mean activity values are used. The following figure presents the adjustment algorithm.

Figure 3-3: Flow chart of the fuel energy balance algorithm



A summary of the variables required — and the intermediate calculated values — is given in the flow chart of Figure 3-2.

To facilitate the energy balance, energy consumption factors are introduced to replace the previously used fuel (mass) consumption factors. The conversion has been realised by using default calorific values for the fuel types presented in Table 3-28. These values refer to primary fuels, i.e. fuels produced at the refinery, and which can subsequently be blended with other fuels to produce the end fuel (e.g. E5, E85, B7, etc.).

Table 3-28: Default calorific and density values of primary fuels

Fuel	Density [kg/m^3]	CV [MJ/kg]
Petrol	750	43.774
Diesel	840	42.695
LPG	520	46.564
CNG	175	48
Biodiesel	890	37.3
Bioethanol	794	28.8
MTBE	740	35.1
ETBE	736	36.2

Fuel consumption-dependent emissions (excluding CO_2)

In principle, total emissions for pollutants which are dependent upon fuel consumption should be derived on the basis of the statistical (true) energy consumption, which is generally known from statistical sources. However, the necessity to allocate emissions to different vehicle categories (and technologies) cannot be covered solely by means of statistical consumption, as this is not provided separately for each vehicle class. In order to achieve both aims, fuel-dependent emissions should be calculated after the energy balance has been carried out as described above.

In this respect, the total emission estimate for any fuel-dependent pollutant is derived by the statistical energy consumption (except CO_2 due to the use of biofuels) while there is still information provided for the allocation of emissions to different vehicle classes.

Carbon dioxide emissions (CO_2)

Emissions of **ultimate CO_2** originate from three sources:

- Combustion of fuel
- Combustion of lubricant oil
- Addition of carbon-containing additives in the exhaust

Ultimate in this case means that the carbon contained in either of the three sources is fully oxidized into CO_2. The following paragraphs describe the methodology to calculate CO_2 in each case.

<u>CO_2 due to fuel combustion</u>

In the case of an oxygenated fuel described by the generic chemical formula $C_xH_yO_z$ the ratio of hydrogen to carbon atoms, and the ratio of oxygen to carbon atoms, are, respectively:

$$r_{H:C} = \frac{y}{x} \qquad r_{O:C} = \frac{z}{x} \tag{14}$$

If the fuel composition is known from ultimate chemical analysis, then the mass fractions of carbon, hydrogen and oxygen atoms in the fuel are *c*, *h*, and *o*, where *c* + *h* + *o* = 1. In this case, the ratios of hydrogen to carbon and oxygen to carbon in the fuel are respectively calculated as:

$$r_{H:C} = 11.916\frac{h}{c} \qquad r_{O:C} = 0.7507\frac{o}{c} \tag{15}$$

With these ratios, the mass of CO_2 emitted by vehicles in technology *k*, combusting fuel *m* can be calculated as:

$$E^{CALC}_{CO_2,k,m} = 44.011 \times \frac{FC^{CALC}_{k,m}}{12.011 + 1.008 r_{H:C,m} + 16.000 r_{O:C,m}} \tag{16}$$

Where FC^{CALC} is the fuel consumption of those vehicles for the time period considered.

Table 3-29 gives hydrogen:carbon and oxygen:carbon ratios for different fuel types. These originate from relevant regulations, which reflect ratios of the corresponding reference fuels used for vehicle testing (UN, 2015). Corresponding values for actual market fuels may substantially differ from the values quoted in Table 3-29. Also, calculated ratios for non-reference fuel blends are included in the table for guidance.

Oxygen in the fuel may be increased due to blending with oxygenated components and/or biofuels. In diesel fuel, the most widespread source of oxygen is biodiesel. Biodiesel is produced by the transesterification of organic oils derived from biomass (plant seeds, waste). It comprises a mix of fatty acid methylesters with speciation and proportions that depend on the feedstock. For example, rapeseed oil mostly consists of C18 acids, while coconut oil is lighter and comprises C12 oils (Karavalakis et al., 2010). The neat biodiesel ratios quoted in Table 3-30 try to cover this range.

In petrol, oxygen is found by blending fossil-derived petrol with oxygenated biofuels or synthetic fuels. Methanol, ethanol and their derivative ethers MTBE (Methyl Tertiary Butyl Ether) and ETBE (Ethyl Tertiary Butyl Ether) are the most widespread oxygen-carrying components for petrol fuel. Bioethanol is produced by fermenting sugars into alcohol. These sugars can come from a variety of agricultural sources such as cereals, sugar cane, potatoes, other crops, and increasingly even organic waste materials. However, ethanol may also be produced synthetically from ethylene, in which case it does not count as a biofuel. ETBE and MTBE are obtained by reacting ethanol and methanol respectively with isobutylene. Again, the ethanol used as a feedstock for their production may be of bio- or synthetic origin. However, as isobutylene is always of synthetic origin, ETBE and MTBE cannot be counted as neat biofuels.

When reporting CO_2 emissions, only the fossil fuel statistical consumption should be taken into account in the calculation. This is consistent with the IPCC 1996 and IPCC 2006 guidelines, according to which emissions associated with the use of biofuels are attributed to the Land Use, Land-Use

Change and Forestry sectors under IPCC. Hence, for reporting, the CO_2 calculated per vehicle category should be corrected according to the equation:

$$E^{CORR}_{CO_2,k,m} = E^{CALC}_{CO_2,k,m} \times \frac{FC^{STAT,\ FOSSIL}_{m}}{\sum_k FC^{CALC}_{k,m}} \tag{17}$$

In equation (17), the calculated CO_2 emission should be derived from equation (16), without considering the oxygen content of the biofuel part.

It should be noted that, depending on the production process, biodiesel might have a non-zero fossil fuel fraction, resulting in a not entirely carbon neutral fuel. One study (Ofgem, 2015) has, for example, shown that different production pathways may result in a fossil fuel carbon content of about 5.5%.

Table 3.30 contains the kg of fossil CO_2 per kg of FAME for the different production pathways.

Table 3-29: Ratios of hydrogen to carbon and oxygen to carbon atoms for different reference blend fuels (REF) used in vehicle testing and estimated values for non-reference fuels and blends

Fuel (*m*)	Typical Molecule	The ratio of hydrogen to carbon ($r_{H:C}$)	The ratio of oxygen to carbon ($r_{O:C}$)	kg CO_2 per kg of fuel[1]
Petrol	$[CH_{1.86}]_x$	1.86	0.0	3.169
Diesel	$[CH_{1.86}]_x$	1.86	0.0	3.169
Ethanol	C_2H_5OH	3.00	0.5	1.911
Methanol	CH3OH	4.00	1.00	1.373
Biodiesel	[CH]x-COOH	1.95-2.03	0.11-0.13	2.797-2.727
ETBE	C6H14O	2.33	0.167	2.584
MTBE	C5H12O	2.40	0.20	2.496
Natural Gas / Biogas (REF)	CH4, market fuels also contain heavier HC	4.00	0.00	2.473
LPG (REF)	C3H8 (15%)-C4H10 (85 %), market fuels may contain different proportions	2.525	0.00	3.024
E5		1.92	0.026	3.063
E10 (REF)		1.98	0.053	2.964
E75		2.73	0.38	2.111
E85 (REF)		2.84	0.429	2.026
ETBE11		1.91	0.018	3.094
ETBE22		1.96	0.036	3.021
B7 (REF)		1.86	0.007	3.144
B10		1.86	0.010	3.133
B20		1.87	0.020	3.096
B30		1.88	0.030	3.059

Notes:

[1] CO_2 emission factors are based on an assumed 100% oxidation of the fuel carbon (ultimate CO_2).

E5 and E10 are widely available in Europe and can be used directly in petrol vehicles without any modifications to the engine. E85 is used in engines modified to accept higher content of ethanol. Such flexi-fuel vehicles (FFV) are designed to run on any mixture of petrol or ethanol with up to 85% ethanol by volume. E85 is widely used in Sweden and also available in other European countries, e.g. Finland.

Table 3-30: Overview of biodiesel production pathways and the respective fossil CO_2 ratio in FAME CO_2

Production pathway	kg fossil CO_2 / kg FAME
Sunflower	0.150
Rapeseed	0.147
Palm oil	0.145
Cottonseed	0.152
Tallow	0.148
Lard	0.147

CO_2 due to lubricant oil

New and properly maintained vehicles normally consume small amounts of lubrication oil, due to the oil film developed on the inner cylinder walls. This oil film is exposed to combustion and is burned along with the fuel. Wear due to prolonged engine operation usually increases lube oil consumption, so this should be expected to increase, on average, with vehicle age. A different vehicle category, operating with 2-stroke engine, consumes much more lubricant oil as this is fed in the intake of the vehicle in blend form with the fuel or through a separate injector. A much higher lube oil quantity is needed in this case, which is practically completely combusted in the cylinder. Oil combustion, although a less important factor than fuel combustion, also leads to CO_2 production and should be taken into account in the national totals for completeness.

Table 3-31 contains typical oil consumption factors for different vehicle types, fuel used and vehicle age. All values are in a mass of oil consumed (kg) per 10 000 km of vehicle operation. This dataset was compiled using input from various sources, such as internet references, and interviews with vehicle maintenance experts and fleet operators in Greece. The definition of an ‘old’ vehicle is ambiguous; in general, a vehicle is considered old at or beyond its typical useful life (normally ~150 000 for a passenger car).

Table 3-31 : Lubricant oil consumption rate for different vehicle types, fuel and age in kg/10 000km

Category	Fuel/engine category	Age	kg/10 000 km		
			Mean	Min	Max
PC	Petrol	Old	1.45	0.85	2.13
	Petrol	New	1.28	0.85	1.70
	Diesel	Old	1.49	0.85	2.13
	Diesel	New	1.28	0.43	2.13
LCV	Petrol	Old	1.45	0.85	2.13
	Petrol	New	1.28	0.85	1.70
	Diesel	Old	1.49	0.85	2.13
	Diesel	New	1.28	0.43	2.13
Urban Buses	Diesel	Old	8.50		
	Diesel	New	0.85		

Coaches	Diesel	Old	1.91	1.70	2.13
	Diesel	New	1.70	1.28	2.13
HDV	Diesel	Any	1.56		
Mopeds	2-stroke	Old	10.20	6.80	13.60
	2-stroke	New	6.80	5.10	8.50
Motorcycles	4-stroke	Any	0.43		
Micro-cars	Diesel	Any	1.28	0.85	2.13
Quad & ATVs	Petrol	Any	0.43		

CO_2 emissions due to lube oil consumption can be calculated by means of equation (16), where fuel consumption should be replaced by the values of Table 3-31. This will lead to CO_2 emitted in kg per 10 000 km which has to be converted to t/km by multiplying with 10^{-7}. Typical values for lube oil hydrogen to carbon ratio ($r_{H:C}$) is 2.08, while oxygen to carbon ratio ($r_{O:C}$) is 0.

<u>CO_2 due to exhaust additives</u>

Aftertreatment systems used to reduce NO_x emissions utilize an aqueous solution of urea as a reducing agent. These are common in Euro V and Euro VI heavy-duty vehicles and are expected to become widespread in Euro 6 diesel light commercial vehicles as well. Urea has a chemical type of $(NH_2)_2CO$ and when it is injected upstream of a hydrolysis catalyst in the exhaust line, then the following reaction takes place:

$$(NH_2)_2CO + H_2O \rightarrow 2NH_3 + CO_2$$

The ammonia formed by this reaction is the primary agent that reacts with nitrogen oxides to reduce them to nitrogen. However, this hydrolysis equation also leads to the formation of a carbon dioxide molecule that is released into the atmosphere. This contributes to the total CO_2 emitted from these vehicles.

The specifications of commercially available urea solution as an SCR agent for mobile use are regulated by DIN 70070, which specifies that urea should be in aqueous solution at a content of 32.5% wt (±0.7%) and a density of 1.09 g/cm^3. If total commercial urea solution sales are known (UC in litres), then total ultimate CO_2 emissions (in kg) by the use of the additive can be calculated by means of the following equation:

$$E_{CO2,urea} = 0.26 \times UC \tag{18}$$

The coefficient 0.26 (kg CO_2/lt urea solution) takes into account the density of urea solution, the molecular masses of CO_2 and urea and the content of urea in the solution. If total urea consumption is known in kg, then the coefficient needs to change to 0.238 (kg CO_2/kg urea solution).

If total urea solution consumption is not known, then one may assume that the consumption of urea solution is ~5-7% of fuel consumption at a Euro V level and ~3-4% of fuel consumption at a Euro VI level. Therefore, one first needs to calculate the share of SCR-equipped vehicles in each technology class and calculate their fuel consumption, then apply a coefficient in the range proposed above and sum up to calculate UC. After doing so, CO_2 emission can be calculated by applying equation (18).

Sulphur dioxide (SO_2) emissions

Emissions of SO_2 are estimated by assuming that all the sulphur in the fuel as well as the sulphur contained in the consumed lubricant is completely transformed into SO_2. To calculate the emitted SO_2 the following formula is used:

$$E=2\times k_{S,m}\times FC_{k,m}^{Calc}+2\times k_{S,l}\times LC_{k,l}^{Calc} \quad (19)$$

where,

$\boldsymbol{k_{S,m}}$ = weight-related sulphur content in the fuel of type m [kg/kg fuel]
$\boldsymbol{k_{S,l}}$ = weight-related sulphur content in the lubricant of type l [kg/kg lubricant]

Lead (Pb) and other heavy metals emissions

Emissions of lead have been significantly dropped in Europe, as a result of unleaded petrol introduction already from the early 1990s. In the case of the few instances where leaded fuel is still available, Hassel et al. (1987) identified that only approximately 75% of the total lead is emitted to the atmosphere. Therefore, for inventories referring to the early 1990s it is advised to provide a reduced fuel lead content in the fuel specifications according to the abovementioned observation. This is mathematically expressed in the following equation.

$$E_{Pb,k}^{CALC} = 0.75\times k_{Pb,m}\times FC_{k,m}^{CALC} \quad (20)$$

where,
$k_{Pb,m}$ = weight-related lead content of petrol (type m) in [kg/kg fuel].

With regard to the emission of all other heavy metal species, as well as trace lead content of unleaded petrol, the fuel metal content factors provided (μg/kg) are assumed to include fuel and engine wear. Therefore, these are apparent fuel metal content which should provide equivalent heavy metal emissions to fuel and engine-wear. In this case, it is considered that the total quantity is emitted to the atmosphere (i.e. there are no losses in the engine). Therefore, emissions of heavy metals included in Group 2 are calculated by means of the equation:

$$E_{i,k}^{CALC} = k_{i,m}\times FC_{k,m}^{CALC} \quad (21)$$

where,

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

Lubricant oil also contains a number of heavy metals which are assumed to be emitted to the atmosphere when oil burning occurs in the combustion chamber (especially in the case of 2-stroke engines). A similar approach is followed in order to calculate emissions of heavy metals from lubricant oil by using the following equation:

$$E_{i,k}^{CALC} = k_{i,m}\times LC_{k,m}^{CALC} \quad (22)$$

where,

$k_{i,m}$ = weight-related content of heavy metal *i* in lubricant type *m* [mg/kg lubricant].

Similarly to CO_2 emissions, SO_2 and HM emissions must also be reported separately, especially in the case of 2-stroke engines. Lubricant consumption in 2-stroke engines is considered intentional, therefore emissions must be reported under 1A3b. On the other hand, 4-stroke engine lubricant consumption is undesirable and should not take place. However small amounts are consumed in the combustion chamber and their emissions should be reported in 2G.

The apparent fuel metal content factors considered originate from the work of Winther and Slentø (2010) and have been reviewed by the TFEIP expert panel in transport. Despite the efforts to obtain reliable values, available information has been very limited and the uncertainty in the estimate of these values is still considered quite high.

Emission corrections

Equations (8) – (9) are used to calculate **baseline** emissions. Corrections are applied to the results in order to accommodate the variation in emissions resulting from the following:

- *vehicle age (mileage)*. The baseline emission factors to be used in equation (8) correspond to a fleet of average mileage (30 000–60 000 km) and a degradation factor is therefore inherent. For petrol and diesel passenger cars and light commercial vehicles only, further emission degradation — due to increased mileage — should be modelled using additional degradation factors. However, for the sake of consistency among 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 low fleet age. However, when inventories and forecasts for future years need to be made, it is advisable to correct emission factors according to mileage to introduce the effect of vehicle age in the calculations.
- *improved fuels*. Improved fuels have become mandatory in the EU since 2000. The effects of improved fuels on emissions from current and older vehicles can again be accommodated using appropriate correction factors. These corrections should only be applied in inventories compiled for years after the introduction of the improved fuels.
- road gradient and vehicle load. Corrections need to be made to heavy-duty vehicle emissions for uphill and downhill driving. 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 a 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 applied.

Emission degradation due to vehicle age

Correction factors need to be applied to the hot baseline emission factors for petrol and diesel passenger cars and light commercial vehicles to account for different vehicle ages. These correction factors are given by the equation:

$$MC_{C,i} = A_M \times M_{MEAN} + B_M \qquad (23)$$

where,

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

Degradation of the emissions is assumed that starts after 50 000 km and do not further increase after 200 000 km. Therefore, MC is equal to 1 below 50 000 km and remains stable above 200 000 km.

Fuel effects

Fuels of improved specification became mandatory in Europe in two steps: January 2000 (Fuel 2000) and January 2005 (Fuel 2005) respectively. The specifications of these fuels are displayed in Table 3-32 (petrol) and Table 3-33 (diesel). Because of their improved properties, the fuels result in lower emissions from vehicles. Therefore, the stringent emission standards of Euro 3 technology (introduced ~2000) are achieved with Fuel 2000, and the more stringent emission standards of Euro 4 and 5 with Fuel 2005. Table 3-34 shows the base emission factors for fuel considered for each vehicle class.

However, the use of such fuels also results in reduced emissions from pre-Euro 3 vehicle technologies, for which the 1996 market average fuel is considered as a basis (Table 3-34). These reductions are applicable to both hot and cold-start emissions. To correct the hot emission factors, equations derived in the framework of The European Programme on Emissions, Fuels and Engine Technologies (EPEFE) programme (ACEA and Europia, 1996) are applied. Table 3-86, Table 3-87 and Table 3-88 display the equations for different vehicle categories and classes.

Table 3-32: Petrol 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	0.002	0.00002

Table 3-33: Diesel fuel specifications

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

Table 3-34: Base fuels for each vehicle class

Vehicle Class	Base Fuel	Available Improved Fuel Qualities
Pre- Euro 3	1996 base fuel	Fuel 2000, Fuel 2005
Euro 3	Fuel 2000	Fuel 2005
Euro 4	Fuel 2005	Fuel 2009
Euro 5 and later	Fuel 2009	-

The hot emission factors are corrected according to the equation:

$$FCe_{HOT;\, i,\, k,\, r} = FCorr_{i,\, k,\, Fuel} \,/\, FCorr_{i,\, k,\, Base} \times e_{HOT;\, i,\, k,\, r} \qquad (24)$$

where,

$FCe_{HOT;\, i,\, k,\, r}$: = the hot emission factor, corrected for the use of improved fuel for pollutant *i* of vehicle technology *k* driven on road class *r*,

$FCorr_{i,\, k,\, Fuel}$: = the fuel correction for pollutant *i*, vehicle technology *k*, calculated with equations given in Table 3-86, Table 3-87 and Table 3-88 for the available improved fuel qualities (Table 3-34),

$FCorr_{i,\, k,\, Base}$: = the fuel correction for pollutant *i*, calculated with equations given in Table 3-86, Table 3-87 and Table 3-88 for the base fuel quality of vehicle technology *k* (Table 3-34).

Equation (24) should not be used to provide the deterioration of emissions where an older fuel is used in a newer technology (e.g. use of Fuel 2000 in Euro 4 vehicles) by inversion of FC coefficients. The emission factor calculated via equation (24) should be introduced in equations (8) and (10) or (11) respectively to estimate hot and cold-start emissions.

3.4.2 Relevant activity statistics

In principle, vehicle statistics are readily available from the national statistical offices of all countries, and from international statistical organisations and institutes (e.g. Eurostat, IRF). However, it must be stressed that these statistics are almost exclusively vehicle-oriented (i.e. comprising fleet data), with information about aggregated categories only (e.g. passenger cars, trucks, buses, motorcycles). In addition, little information referring to the age and technology distribution can be found in a consistent form, and very little information is available as regards activity (except for 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. Detailed data on vehicle stocks for all EU-27 countries and CH, HR, NO, TR can be also found on the COPERT website (http://www.emisia.com/copert). These data have no official status but are a result of a research project (Ntziachristos et al., 2008). However, they can be used as a good guide in the absence of more detailed information. Data for several other countries can be produced in an indirect way. The following may be helpful in this respect:

- *age and technology distribution*: the (generally available) time series on fleet evolution and annual new registrations can be used to derive estimates of appropriate scrappage rates. By combining the above with the implementation dates of certain technologies, a relatively good picture of the fleet composition in specific years can be obtained;
- *mileage driven and mileage split*: energy/fuel consumption calculated on the basis of appropriate assumptions for an annual mileage of the different vehicle categories can be balanced with available fuel statistics. By applying the abovementioned energy balance methodology, it is possible to reach acceptable estimates of mileage.

For the calculation of cold-start related emissions, the mean trip length is necessary. Table 3-35 provides the figures submitted by national experts in a previous COPERT exercise. Although these data refer to traffic conditions a decade ago, they can still be used with confidence because mean trip length is a highly aggregate value which little varies from year-to-year.

3.4.3 Emissions factors

The Tier 3 emission factors for non-catalyst petrol cars were developed by 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 petrol catalyst-equipped cars, improved diesel cars (91/441/EEC and later) and diesel heavy-duty vehicles, the emission factors are derived from the results of the Artemis project. The emission factors for light commercial vehicles originate from the MEET project, and those for L-category vehicles are taken from various DG GROW studies.

Table 3-35: 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		

Table 3-36: Coding 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 A1: the average speed of the vehicles under the driving modes A2: driving mode dependent emission factors	The average trip length per vehicle trip the average monthly 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 B1: the average speed of the vehicles under the driving modes 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 driving mode dependent emission factors	No Cold Start Overemission Calculations	No Evaporation Calculations
D	the total annual fuel consumption of the vehicle	No Cold Start Overemission Calculations	No Evaporation Calculations

	category fuel consumption related emission factors		

*Attributed only to NMVOC emissions from gasoline powered vehicles

The emission factors can be broadly separated into two classes according to the pollutant: those for which a detailed evaluation is necessary and possible, and those for which simpler 'bulk' emission factors or equations can be provided. The pollutants CO, VOCs and NO_x and PM (as well as energy consumption) are in the first category, whereas SO_2, NH_3, Pb, CO_2, N_2O and (partly) CH_4 are in the second one.

The presentation of the emission factors firstly covers CO, VOCs, NO_x and PM (the pollutants which have been regulated in legislation), and energy consumption, for the individual SNAP activities. The 'bulk' emission factors for unregulated pollutants — SO_2, NH_3, Pb, CO_2, N_2O and CH_4 — are then addressed. Table 3-36 and Table 3-37 show the level of detail which is necessary for the calculation of emissions from each vehicle technology.

Table 3-37: 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	EC
Petrol 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 1 to Euro 7	A1	A1	A1	A1	B2	A2	A2	D	D	D	D	A1
Diesel passenger cars												
Conventional	A1	A1	A1	A1	A1	C	C	D	D	D	D	A1
Euro 1 to Euro 7	A1	A1	A1	A1	A1	C	C	D	D	D	D	A1
LPG passenger cars	A1	A1	A1	A2	-	C	-	-	D	-	-	A1
E85 passenger cars	A1	A1	A1	A1	-	A2	A2	D	D	D	D	A1
CNG passenger cars	A1	A1	A1	A1	-	A2	A2	D	D	D	D	A1
Petrol Hybrid passenger cars	A1	A1	A1	A1	B2	A2	A2	D	D	D	D	A1
Petrol PHEV passenger cars	A1	A1	A1	A1	B2	A2	A2	D	D	D	D	A1
Diesel PHEV passenger cars	A1	A1	A1	A1	A1	C	C	D	D	D	D	A1
Battery electric passenger cars	-	-	-	-	-	-	-	-	-	-	-	A1
Light commercial vehicles												
Petrol < 3.5 t conventional	A1	A1	A1	A2	-	A2	A2	D	D	D	D	A1
Petrol < 3.5 t Euro 1 to Euro 7	A1	A1	A1	A1	B2	A2	A2	D	D	D	D	A1
Diesel < 3.5 t conventional	A1	A1	A1	A2	A1	A2	A2	D	D	D	D	A1
Diesel < 3.5 t Euro 1 to Euro 7	A1	A1	A1	A2	A1	A2	A2	D	D	D	D	A1
Battery electric light commercial vehicles	-	-	-	-	-	-	-	-	-	-	-	A1
Heavy-duty vehicles > 3.5 t												
Petrol 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 VII	B1	B1	B1	C	B1	C	C	D	D	D	D	B1
Buses and coaches conventional	B1	B1	B1	C	B1	C	C	D	D	D	D	B1
Buses and coaches Euro I to VII	B1	B1	B1	C	B1	C	C	D	D	D	D	B1
CNG heavy-duty vehicles	B1	B1	B1	C	B1	C	C	D	D	D	D	B1
LNG heavy-duty vehicles	B1	B1	B1	C	B1	C	C	D	D	D	D	B1
Battery electric buses	-	-	-	-	-	-	-	-	-	-	-	B1
L-category vehicles												
Mopeds < 50 cm³	B2	B2	B2	C	B2	C	C	D	D	D	D	B2
Motorcycles 2-stroke > 50 cm³	B1	B1	B1	C	B2	C	C	D	D	D	D	B1
Motorcycles 4-stroke 50–250 cm³	B1	B1	B1	C	B2	C	C	D	D	D	D	B1
Motorcycles 4-stroke 250–750 cm³	B1	B1	B1	C	B2	C	C	D	D	D	D	B1
Motorcycles 4-stroke > 750 cm³	B1	B1	B1	C	B2	C	C	D	D	D	D	B1
Micro-cars	B1	B1	B1	C	B2	C	C	D	D	D	D	B1
Quad & ATVs	B1	B1	B1	C	B2	C	C	D	D	D	D	B1

Petrol passenger cars

Hot Emissions

Hot emission factors are speed dependent and are expressed in g/km. They differ by fuel, vehicle class and engine technology. In previous versions of this chapter a number of functions were provided to calculate hot emission factors for the different vehicle categories. All these functions are now consolidated into a single equation. Due to the large number of the equation coefficients required to calculate emissions for all the different vehicle categories, all relevant figures can be found in Appendix 4. The emissions covered by the methodology are CO, VOC, NO_x, PM and energy consumption.

The following generic equation can be used to calculate the speed (V) dependent emission factors (EF) for all vehicle classes and pollutants. Where necessary a reduction factor (RF) is applied.

$$EF = (Alpha \times V^2 + Beta \times V + Gamma + Delta / V) / (Epsilon \times V^2 + Zeta \times V + Eta) \times (1 - RF) \quad (25)$$

Cold start emissions

Pre Euro 1 vehicles

Table 3-38 provides e^{COLD}/e^{HOT} emission quotients for the pollutants in Group 1. The β-parameter is calculated by means of the equation provided in Table 3-39. The introduction of the values in equation (10), together with the hot emission factors quoted previously, provides estimates of cold-start emissions.

Table 3-38: Cold-start emission quotient (e^{COLD}/e^{HOT}) for conventional petrol vehicles (temperature range of –10 °C to 30 °C)

Pollutant or EC	e^{COLD} / e^{HOT}
CO	$3.7 - 0.09\ t_a$
NO_x	$1.14 - 0.006\ t_a$
VOC	$2.8 - 0.06\ t_a$
Energy consumption	$1.47 - 0.009\ t_a$

Table 3-39: Cold mileage percentage β

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

Euro 1 to Euro 5 vehicles

Table 3-40: Over-emission ratios e^{COLD} / e^{HOT} for Euro 1 to Euro 5 petrol 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	Mini, Small	5– 33	-20 : 15	0.156	-0.155	3.519
		34–45	-20 : 15	0.538	-0.373	-6.24
		5–45	> 15	8.032E-02	-0.444	9.826
	Medium	5–33	-20 : 15	0.121	-0.146	3.766
		34–45	-20 : 15	0.299	-0.286	-0.58
		5–45	> 15	5.03E-02	-0.363	8.604
	Large-SUV-Executive	5–33	-20 : 15	7.82E-02	-0.105	3.116
		34–45	-20 : 15	0.193	-0.194	0.305
		5–45	> 15	3.21E-02	-0.252	6.332
NOx	Mini, Small	5–25	> -20	4.61E-02	7.38E-03	0.755
		26–45	> -20	5.13E-02	2.34E-02	0.616
	Medium	5–25	> -20	4.58E-02	7.47E-03	0.764
		26–45	> -20	4.84E-02	2.28E-02	0.685
	Large-SUV-Executive	5–25	> -20	3.43E-02	5.66E-03	0.827
		26–45	> -20	3.75E-02	1.72E-02	0.728
VOC	Mini, Small	5–35	-20 : 15	0.154	-0.134	4.937
		36–45	-20 : 15	0.323	-0.240	0.301
		5–45	> 15	9.92E-02	-0.355	8.967
	Medium	5–35	-20 : 15	0.157	-0.207	7.009
		36–45	-20 : 15	0.282	-0.338	4.098
		5–45	> 15	4.76E-02	-0.477	13.44
	Large-SUV-Executive	5–35	-20 : 15	8.14E-02	-0.165	6.464
		36–45	-20 : 15	0.116	-0.229	5.739
		5–45	> 15	1.75E-02	-0.346	10.462
EC	All classes	-	-10 : 30	0	-0.009	1.47

Note: If the calculated value of e^{COLD} /e^{HOT} is less than 1, a value of 1 should be used.

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 for Euro 1 and later vehicles.

Table 3-40 provides e^{COLD}/e^{HOT} emission quotients for three main pollutants and energy consumption. The values are a result of fitting the existing COPERT methodology to the results published by MEET, and are a function of ambient temperature and average trip speed. Two speed regions have been introduced (5–25 km/h and 25–45 km/h). As in the case of the hot emission factors, the value introduced for speed should correspond to the mean trip speed, and not to the instantaneous speed. The speed range proposed is sufficient to cover most applications because excess cold-start emissions are allocated to urban driving only.

For CO and VOCs, the excess cold-start 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, the excess emission of these 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 defined for CO and VOCs.

Generally, the cold-start effect becomes negligible above 25 °C in the case of CO, and above 30 °C in the case of VOCs. This is not only because excess emission under such ambient conditions is small, but also because engines cool down more slowly and the actual engine start-up temperature can still be high after several hours of parking.

The mileage fraction driven during the warm-up phase is calculated by means of the formula provided in Table 3-39. After calculating the β-parameter and e^{COLD}/e^{HOT}, the application of equations (10) or (11) is straightforward.

Compared with Euro 1 vehicles, the emission reduction during the warm-up phase of post-Euro 1 vehicles is mainly due to the reduced time which is required for new catalytic systems to reach the light-off temperature. This time reduction is further reflected in a decrease in the distance travelled with a partially warm engine and/or exhaust aftertreatment devices. Therefore, reduced cold start emissions are modelled by decreasing the value of the *β*-parameter (i.e. the mileage fraction driven with a cold or partially warm engine). Table 3-41 provides the reduction factors ($bc_{i,k}$) to be applied to the *β*-parameter according to the pollutant and vehicle class.

Table 3-41: β-reduction factors ($bc_{i,k}$) for Euro 1 to Euro 5 petrol vehicles (relative to Euro 1)

Emission legislation	CO	NOx	VOC
Euro 2 — 94/12/EC	0.72	0.72	0.56
Euro 3 — 98/69/EC Stage 2000	0.62	0.32	0.32
Euro 4 and Euro 5	0.18	0.18	0.18

On the other hand, there is no evidence to support the use of different values of e^{COLD}/e^{HOT} for different vehicle classes ([7]). This means that the e^{COLD}/e^{HOT} values calculated for Euro 1 vehicles can be also applied to later vehicle classes without further reductions. Similarly, the hot emission factor used in the estimation of cold-start emissions should also be the Euro 1 value.

Therefore, in the case of post-Euro 1 vehicles, equation (10) becomes:

$$E_{COLD;i,k} = bc_{i,k} \times \beta_{i,Euro\ 1} \times N_k \times M_k \times e_{hot,\ i,\ Euro\ 1} \times (e^{COLD} / e^{HOT} - 1)|_{i,\ Euro\ 1} \qquad (26)$$

Similar modifications should also be brought into equation (11) in cases where $bc_{i,k} \times \beta_{i,EURO\ 1} > S_U$. Obviously, the corrected value should be applied to the mileage fraction during the warm-up phase.

([7]) 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.

Euro 6 vehicles

Table 3-42: Over-emission ratios e^{COLD} / e^{HOT} for Euro 6 petrol vehicles (*V*: speed in km/h, t_a: temperature in °C)

Case	Speed [km/h]	Temp [°C]	$e^{COLD}/e^{HOT} = A \times V + B \times t_a + C$		
			A	B	C
CO	5–45	< 0	-0.235	-1.306	19.882
	5–45	> 0	-0.110	0.000	17.461
NOx	5–45	< 0	0.097	-0.181	5.651
	5–45	> 0	0.089	0.000	7.257
VOC	5–45	< 0	0.317	-3.612	38.115
	5–45	> 0	0.166	0.000	43.859

Note: If the calculated value of e^{COLD} /e^{HOT} is less than 1, a value of 1 should be used. Table 3-42 provides e^{COLD}/e^{HOT} emission quotients for three main pollutants. The EC quotients for Euro 6 are the same from Euro 1 to Euro 5. The values are a result of fitting the existing COPERT methodology to the measurement data from Euro 6 passenger cars and are a function of ambient temperature and average trip speed. Two temperature regions have been introduced below and above zero degrees. The cold overemission from the most recent Euro Standards is not affected by the temperature above 0°C, and as a result, the temperature coefficient is considered 0.

The part of the l_{trip} driven in cold conditions is described by the parameter Beta. The most recent technologies reduce the distance in cold conditions and as a result, a β-reduction factor is implemented.

Table 3-43 β-reduction factors (bci,k) for Euro 6 petrol vehicles

Pollutant	bc (β-reduction factor)
CO	$0.1902 - 0.006 * l_{trip}$
NOx	$0.1573 - 0.005 * l_{trip}$
VOC	$0.2072 - 0.0066 * l_{trip}$

In the case of Euro 6 vehicles, equation 10 becomes:

$E_{COLD}; i, j = \beta i, k \times bc_{i,k}\ Nk \times Mk \times e^{HOT}; i, k \ \times (e^{COLD} / e^{HOT}|i,k - 1)$

Diesel passenger cars

Hot emissions

Experimental data from measurements on diesel passenger cars < 2.5 tonnes (Hassel et al., 1987; Pattas et al., 1985; Rijkeboer et al., 1989; 1990) enabled a differentiation to be made between cylinder capacities for NO_x, and speed-dependent emission factors to be developed for conventional (pre-Euro 1) vehicles. For later technologies, it is worth noting that some manufacturers produced diesel cars equipped with DPFs even at the Euro 3 stage. These vehicles were not significantly different from 'conventional' Euro 3 vehicles in terms of emissions of NOx, CO or HC, but did have lower PM emissions.

The emission factors to be introduced in equation (8) for the calculation of hot emissions from diesel passenger cars (all technologies from conventional to Euro 6) can be calculated by applying equation (25) and using the coefficients included in the accompanying Excel file.

Cold-start emissions

Pre Euro 1 to Euro 5 vehicles

Excess cold-start emissions from diesel vehicles are not very significant compared with those from petrol vehicles. Therefore, no distinction is made between the different diesel vehicle types. The β-parameter is calculated for all vehicle classes using the formula given in Table 3-39 and the values of e^{COLD}/e^{HOT} are given in Table 3-44. Based on these, equation (10) can be applied to calculate cold start emissions from diesel passenger cars Equation (10) is valid for all Euro standards.

Table 3-44: Values of e^{COLD} / e^{HOT} for diesel passenger cars (temperature range -10 °C to 30 °C)

Pollutant or EC	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)
Energy consumption	$1.34 – 0.008\ t_a$

Note: (1) VOC: if t_a > 29 °C then e^{COLD} / e^{HOT} = 0.5; (2) PM: if t_a > 26 °C then e^{COLD} / e^{HOT} = 0.5

Euro 6 vehicles

Table 3-45 Over-emission ratios e^{COLD} / e^{HOT} for Euro 6 diesel vehicles (V: speed in km/h, ta: temperature in °C)

Case	Euro Standard	Speed [km/h]	Temp [°C]	$e^{COLD}/e^{HOT} = A \times V + B \times t_a + C$		
				A	B	C
CO	Euro 6 a/b/c	5–45	< 0	0.504	-4.197	7.588
		5–45	> 0	0.091	0.000	11.477
	Euro 6d-temp	5–45	< 0	0.820	-9.184	21.879
		5–45	> 0	0.147	0.000	25.089
	Euro 6d/e	5–45	< 0	0.897	-10.045	23.836
		5–45	> 0	0.161	0.000	27.347
NOx	Euro 6 a/b/c	5–45	< 0	0.015	-0.236	2.264
		5–45	> 0	0.005	0.000	2.327
	Euro 6d-temp	5–45	< 0	0.121	-1.948	11.415
		5–45	> 0	0.038	0.000	11.929
	Euro 6d/e	5–45	< 0	0.151	-2.435	14.019
		5–45	> 0	0.048	0.000	14.661
VOC	All Euro Standards	5–45	< 0	-0.545	-0.970	22.280
		5–45	> 0	-0.286	0.000	18.445

Note: If the calculated value of e^{COLD} /e^{HOT} is less than 1, a value of 1 should be used. Table 3-45 provides e^{COLD}/e^{HOT} emission quotients for three main pollutants. The EC and PM quotients for Euro 6 are the same from Euro 1 to Euro 6. The values are a result of fitting the existing COPERT methodology to the measurement data from Euro 6 passenger cars and are a function of ambient temperature and average trip speed. Two temperature regions have been introduced below and above zero degrees. The cold overemission from the most recent Euro Standards is not affected by the temperature above 0°C, and as a result, the temperature coefficient is considered 0.

The part of the l_{trip} driven in cold conditions is described by the parameter Beta. The most recent technologies reduce the distance in cold conditions and as a result a β-reduction factor is implemented (Table 3-46).

Table 3-46 β-reduction factors (bci,k) for Euro 6 diesel vehicles

Pollutant	bc (β-reduction factor)
CO	$0.2022 - 0.0064 * l_{trip}$
NOx	$0.1719 - 0.0055 * l_{trip}$
VOC	$0.2398 - 0.0076 * l_{trip}$

In the case of Euro 6 vehicles the equation (10) becomes:

$E_{COLD}; i, j = \beta i, k \times bc_{i,k}\ Nk \times Mk \times e^{HOT}; i, k \times (e^{COLD} / e^{HOT}|i,k - 1)$

LPG and CNG bi-fuel passenger cars

The methodology for petrol cars is also valid for LPG and CNG vehicles. However, it has to be stressed that the amount of data for LPG vehicles were 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 for hot and cold-start emissions.

LPG (and CNG) cars have become quite widespread in an effort to benefit from the lower fuel price of gas fuels compared to petrol and diesel. There are two main types of such vehicles: The ones which are produced by OEMs to operate as bi-fuel vehicles, and conventional petrol vehicles later retrofitted by their owners to operate with LPG (and/or CNG). Bi-fuel vehicles may operate under LPG/CNG or petrol fuel. Total emissions are calculated by adding the emissions of both operating conditions and taking into account the vehicle activity driven with either fuel.

With respect to conventional pollutant emissions, there is a general feeling that such vehicles are cleaner than their petrol counterparts, as a result of the lighter fuel used compared to petrol. Technically this is not true. Spark-ignition vehicles have been optimized to operate on petrol and shifting to a different fuel should not a priori be expected to decrease emissions. Moreover, the main emission control in spark-ignition vehicles occurs in the catalytic converter and it has to be guaranteed that the new fuel continues to retain optimal conditions for the catalyst to operate efficiently.

Vonk et al. (2010) compared the emission levels of LPG (and CNG) cars of Euro 4 technology with conventional petrol Euro 4. The OEM bi-fuelled cars emitted NO_x and PM at the same level as their petrol counterparts. On the other hand, retrofitted LPG vehicles emitted, on average, more than twice as much NOx and 2.5 times as much PM as petrol vehicles. Retrofitted vehicles exceeded the petrol-based NOx emission limit by 40%.

Retrofitted vehicles use simplified components to control emissions. The closed-loop controlled of the catalyst is either bypassed or is not as efficient as the OEM control. This results in higher emissions. Additionally, retrofitted vehicles need not be type-approved for their emission levels. A certificate for good installation is only issued by local authorities after the conversion and a simplified emission check (low and high idle) is performed. This is known to be able to detect large exceedances of CO and HC emission limits only.

Emissions from retrofitted cars may therefore become an air quality issue in areas where retrofits are frequent. Unfortunately, there are not much data available yet to develop detailed emission factors and activity data on retrofitted cars are sparse. It is recommended that LPG (and CNG) retrofit programmes are reviewed and number of retrofitted cars be monitored in order to track the extent of the problem.

Hot emissions

Equation (25) is used to calculate hot emissions for conventional, Euro 1 and Euro 2 LPG vehicles. Appendix 4 provides the values of the coefficients used to calculate the emission factors for those engine technologies. The former emission factors were developed in earlier COPERT exercises, and the latter in the MEET project. Post Euro 2 emission technologies use the same modelling and parameters as the equivalent technology step of medium petrol passenger cars.

CNG vehicles use the same modelling and parameters as the equivalent technology step of medium petrol passenger cars by applying a reduction factor for the energy consumption (difference in enthalpy of combustion). As a result, tailpipe CO_2 estimation is then computed using the calculated fuel consumption. VOC emissions also use the same concept.

LPG and CNG vehicles have been updated using recent PEMS measurements, for Euro 6d-temp and Euro 6d/e. The resulting emission factors can be seen in the Appendix 4.

Cold-start emissions

Very few data on cold-start emissions from conventional LPG vehicles are available (AQA, 1990; Hauger et al.; 1991). For consistency, however, and since LPG emission-control technology is similar to that of petrol vehicles, the methodology for calculating emissions from petrol vehicles is also applied here. Table 3-47 provides values of eCOLD/eHOT which are valid for conventional LPG vehicles to be used in equations (10) and (11). For Euro 1 and later LPG vehicles, the identical methodology of petrol passenger cars is used (Table 3-40). This is made on purpose. Both OEM and retrofitted LPG cars operate on petrol before the engine and the catalyst heat up. LPG is only used under fully warmed conditions. As a result, LPG and petrol car cold-start emissions are not expected to differ.

Table 3-47: Values of e^{COLD} / e^{HOT} for conventional LPG passenger cars (temperature range of –10°C to 30°C)

Pollutant or EC	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)
Energy consumption	$1.47 - 0.009\ t_a$

Note: VOC: if ta > 29 °C then eCOLD / eHOT > 0.5.

CNG vehicles are categorised as Euro 4 or higher, so their cold emissions are calculated using the methodology for Euro 1 and later petrol vehicles. For all emissions other than hydrocarbons, the same approach used for Euro 1 and later LPG vehicles are utilised; CNG vehicles use the same values (Table 3-40) as the equivalent petrol size vehicles.

For the calculation of hydrocarbons, Table 3-48 provides the values of e^{COLD}/e^{HOT} for Euro 4/5/6 CNG vehicles to be used in equations (10) and (11).

Table 3-48 Over-emission ratios e^{COLD} / e^{HOT} for Euro 4/5/6 CNG passenger cars compared to Euro 1 petrol vehicles (temperature range of –10°C to 30°C)

Case	Speed [km/h]	Temperature [°C]	$e^{COLD}/e^{HOT} = A \times V + B \times t_a + C$		
			A	B	C
VOC	5– 25	-20 : 15	0.11856	-0.15633	5.53804
	26–45	-20 : 15	0.21296	-0.25526	3.33963
	5–45	> 15	0.03594	-0.36023	10.3947

Hybrid passenger cars

The database of emission measurements to derive emission factors for hybrid petrol cars has been updated since COPERT v5.8 and currently exists six Euro 6 hybrid vehicles (both PHEV and pure hybrid) from measurements conducted by the Laboratory of Applied Thermodynamics (LAT) of the Mechanical Engineering Department of Aristotle University of Thessaloniki between 2020 and 2024. The methodology is similar to that for petrol cars, and equation (25) is used to calculate emission and consumption factors, expressed in g/km and MJ/km. Parameter values for equation (25) are given in Appendix 4.

Rechargeable vehicles

Plug-in hybrid electric vehicles (PHEVs) (or OVC-HEV: Off-Vehicle Charging Hybrid Electric Vehicle) use two energy sources for vehicle propulsion, an internal combustion engine (ICE) and a battery. The battery can be charged by plugging it into an external power source or on-board through the ICE and a generator. The operation of these vehicles can be divided into two main modes: charge-depleting (CD) mode and charge-sustaining (CS) mode. In CD mode the vehicle's operation is similar to a pure electric vehicle, as the energy for propulsion comes mainly from the electric motor, with the ICE switched off. In CS mode the state of charge (SOC) of the battery remains approximately the same and the main source of energy for propulsion is the ICE. The vehicle operates like a hybrid electric vehicle (HEV), as both the battery and the ICE are used. PHEVs can deliver a significant reduction in the overall emissions of GHG and air pollutants. The exact reduction amounts largely depend on the utility factor, which is the ratio of the distance driven in CD mode (i.e. the electric driving) between two charge cycles (Hooftman et al., 2020).

Equation (25) can be applied and all relevant parameters can be found in Appendix 4.

For pure electric (or battery electric) vehicles, exhaust emissions will be zero therefore these do not contribute to the road transport air pollutants inventory. All CO_2 emissions they implicitly produce will be due to electricity production, which is part of the power generation. Therefore, the methodology applied only for calculation of energy consumption. The energy consumption factors of battery electric vehicles (passenger cars, light-commercial vehicles and buses) can be seen in Appendix 4. The values are without considering auxiliaries.

Petrol light commercial vehicles

Hot emissions

The emissions of these vehicles within EU countries were initially regulated in the different ECE steps. All such vehicles have been combined in a common 'conventional' class. However, classes for Euro 1 and later light commercial vehicles have been introduced. A similar equation consolidation method as for the passenger cars has been used for the calculation of the speed dependant hot emission factors for petrol light commercial vehicles. Equation (25) can be applied and all relevant parameters can be found in Appendix 4. The emissions covered by the methodology are CO, VOC, NO_x, PM and energy consumption.

Cold start emissions

In the absence of more detailed data, the values of e^{COLD}/e^{HOT} for Large-SUV petrol cars (> 2.0 l) are also applied to light commercial vehicles. Although this assumption used to be a very rough estimate for past vehicle classes, due to the very different emission standards of light commercial vehicles and passenger cars, it is now likely to be more robust since the technology used in current light commercial vehicles does not differ significantly from that used in cars. Therefore, the values of e^{COLD}/e^{HOT} in Table 3-38 (pre-Euro 1) and Table 3-40 (Euro 1 to Euro 5) are applied to light commercial vehicles. The values of Table 3-42 are also applied to Euro 6 light commercial vehicles. Furthermore, equations (10), (11) are also valid for pre-Euro 1 vehicle and equation (26) for Euro 1 and later vehicles, in conjunction with the β-parameter reduction factors given in Table 3-41.

Diesel light commercial vehicles

Hot Emissions

Diesel light commercial vehicles are treated as passenger cars. Speed-dependent hot emission factors were developed in earlier COPERT exercises (conventional vehicles) and the MEET project (Euro 1 and later vehicles). To calculate hot emission factors Equation (25) can be applied and all relevant parameters can be found in Appendix 4. The emissions covered by the methodology are CO, VOC, NO_x, PM and energy consumption.

Cold-start emissions

Excess cold-start emissions for diesel light commercial vehicles are calculated using equation (10), with the e^{COLD}/e^{HOT} values calculated for all vehicle technologies as shown in Table 3-44 (from Euro 1 up to Euro 5 vehicles) and Table 3-45 (for Euro 6 vehicles). The β-parameter is calculated for all vehicle classes using the formula given in Table 3-39 and Table 3-46 depending on the euro standard.

Petrol heavy-duty vehicles

Only hot emissions are calculated for petrol heavy-duty vehicles. Emission factors — derived from an extrapolation of the data for smaller vehicles — can be found in Appendix 4.

Diesel heavy-duty vehicles

Hot emissions

Speed dependent emission factors for diesel heavy-duty vehicles (including urban buses and coaches) have been taken from HBEFA. The emission factors are provided for conventional vehicles and the Euro I to Euro VI emission standards. Recent measurements of Euro VI urban buses have been provided for the update of hot emission factors. Due to the large number of data required to calculate emissions from these categories, all relevant information can be found in Appendix 4. The emissions covered by the methodology are CO, VOC, NO_x, PM and energy consumption. For information on BC fractions of PM, please refer to Annex 4.

Distinct emission function parameters are provided for Euro V vehicles, depending on their emission control concept (EGR or SCR). In order to correctly estimate emissions, one needs to estimate the shares of the two technologies in the vehicle stock. For European Member States, it is estimated that approximately 75% of Euro V heavy-duty vehicles are equipped with SCR, the rest being equipped with EGR.

Cold emissions

Measurement data from Euro V and Euro VI Diesel heavy duty and buses were fitted in the existing COPERT methodology for cold emissions from passenger cars in a simpler approach with the use of the following equation.

$$E_{COLD;I,k} = \beta \times Nk \times Mk \times e^{COLD}|i,k$$

where,

ECOLD; i, k = cold-start emissions of pollutant i (for the reference year), produced by vehicle technology k,

β = fraction of mileage driven with a cold engine,

Nk = number of vehicles [veh] of technology k in circulation,

Mk = total mileage per vehicle [km/veh] in vehicle technology k,

e^{COLD}; i, k = cold emission factor for pollutant i and vehicles of k technology,

The beta parameter is calculated as a function of the l_{trip} with the assumption that the operating distance in cold conditions of a heavy-duty vehicle is 8.25 km using the following equation.

$\beta = 8.25 / l_{trip}$

if $\beta > 1$ then $\beta = 1$

The cold emission factor is dependent on the temperature and vehicle speed and calculated with the use of following equation:

$$e^{COLD} = A \times V + B \times ta + C$$

Hybrid heavy-duty vehicles

Speed dependent fuel and energy consumption factors for hybrid electric urban buses as well as their respective CO, NOX and SPN23 emission factors have been derived through recent measurements. For the rest pollutants, emission factors had been taken from a plug-in series Hybrid Electric bus which was simulated under various driving cycles representing realistic traffic conditions (Hooftman et al., 2020). All relevant information on the emissions and energy consumption factors can be found in Appendix 4.

Natural gas heavy-duty vehicles

Natural gas vehicles (NGVs) are now present in several urban captive fleets around Europe. France already has around 700 natural gas buses in operation, out of a total of 12 000, while 416 natural gas buses are in operation in Athens, in a fleet of 1 800 vehicles. Natural gas cannot be used as a fuel in a diesel engine or a petrol engine without modifications, because it has a high-octane number (120–130) and a cetane number below 50, which makes it unsuitable for diesel combustion. Most commercial systems, therefore, utilise a spark plug to initiate natural gas combustion, and a higher compression ratio than conventional petrol engines to take advantage of the high-octane rate and to increase efficiency. NGVs may also operate either in ‘stoichiometric’ mode for low emissions or in ‘lean’ mode for higher efficiency. In addition, high-pressure storage bottles are required to store compressed natural gas (CNG), while liquid natural gas (LNG) stored at low temperatures is not that common, mainly due to the higher complexity of storage on the bus. CNG powertrains are hence associated with more cost elements and higher maintenance costs than diesel engines.

Different CNG buses may have completely different combustion and after-treatment technologies, despite using the same fuel. Hence, their emission performance may significantly vary. Therefore, CNG buses also need to comply with specific emission standards (Euro II, Euro III, etc.). Due to the low NO_x and PM emissions compared with diesel, an additional emission standard has been set for CNG vehicles, known as the standard for Enhanced Environmental Vehicles (EEV). The emission limits imposed for EEV are even below Euro V, and usually, EEVs benefit from tax waivers and free entrance to low-emission zones.

New stoichiometric buses can meet the Euro VI and VII requirements, while older buses were usually registered as Euro II, Euro III or EEV. Also, CNG/LNG trucks have been imported meeting the Euro VI and VII requirements.

Typical emission and fuel consumption factors for CNG buses (based on Airparif[8] data) and CNG/LNG trucks (based on HBEFA[9] data), depending on their emission level, can be found in Appendix 4. More information on the derivation of these emission values is given in Ntziachristos et al. (2007).

Two-stroke and four-stroke mopeds < 50 cm³

Mopeds are mostly driven in urban areas, and therefore only urban emission factors are proposed. These emissions factors should be considered as bulk values which include the cold-start fraction. No distinction is made between hot and cold-start emissions. Even if single values are proposed the generic equation (25) can be used by applying the function parameters in Appendix 4 to calculate the emission factor.

Motorcycles > 50 cm³

The equation used to calculate the emission factor for motorcycles over 50 cm³ engine displacement is equation (25). The coefficients needed to calculate the emission factors are given in Appendix 4, for the different motorcycle categories. The emission factors of Euro 5 motorcycles have been recently revised based on measurements by the Laboratory of Applied Thermodynamics (LAT) of the Mechanical Engineering Department of Aristotle University of Thessaloniki and Graz University of Technology (TUG) conducted in 2023.

PM emissions from two-stroke vehicles are particularly important. The emission factors proposed to correspond to a typical mix of mineral and synthetic lubricants used for two-stroke engines. Full synthetic oil use would lead to lower PM emission factors.

Micro-cars and All-Terrain Vehicles (Quad & ATVs)

The source of the data used to develop the emission factors was the “Effect study of the environmental step Euro 5 for L-category vehicles” (Ntziachristos et al., 2017) and the tests performed therein. The tests were conducted at the chassis dynamometer of the Vehicle Emissions Laboratory VELA 1, which is part of the Sustainable Transport Unit (STU), Directorate for Energy Transport and Climate

[8] https://ermes-group.eu/sites/default/files/ERMES_Plenary_2021/Day_2/2.8_CAVELLIN.pdf
[9] https://www.hbefa.net/

(previously “Institute for Energy and Transport (IET)), Joint Research Centre (JRC), Ispra, Italy. The laboratory is able to perform emission tests in accordance with Regulation (EU) No 168/2013 and Regulation (EU) No 134/2014.

The calculation of the cold/hot start emissions produced by micro-cars and ATVs is based on the calculation algorithm reported by Ntziachristos et al. (2007). For each vehicle category k, and pollutant i (i = CO, HC, NOx, FC and PM), the emission level is calculated from equations (12) and (13). This form is a reduced version of the form given by Ntziachristos et al. (2007), where only urban environment emissions are calculated for micro-cars, while urban and rural environment emissions are calculated for ATVs, based on the average speeds of the regulatory driving cycles that were examined in the input data. Micro-cars and ATVs are generally not driven on highways.

The cold/hot start emission factors ($e_{COLD\ URBAN}$ / $e_{HOT\ URBAN}$) of the examined pollutants (CO, HC, NOx, FC and PM) for both micro-cars and ATVs, after being averaged on all the examined driving cycles and cycles’ parts/laps, are given in Table 3-49.

Table 3-49. Cold/hot start emission factors for micro-cars and ATVs

Category	Emission standard	EC [MJ/km]	NOx [g/km]	HC [g/km]	PM2.5 [g/km]	CO [g/km]
Micro-cars diesel	Conventional	1.449	0.589	0.308	0.250	1.152
	Euro 1	1.262	0.814	0.161	0.150	0.935
	Euro 2	1.262	0.814	0.161	0.150	0.935
	Euro 3	1.262	0.814	0.161	0.150	0.935
	Euro 4	1.136	0.689	0.120	0.080	0.935
	Euro 5	1.136	0.060	0.078	0.001	0.935
ATVs	Conventional	2.072	0.047	16.670	0.200	33.540
	Euro 1	1.795	0.300	9.000	0.080	13.320
	Euro 2	1.795	0.300	2.320	0.040	7.770
	Euro 3	1.795	0.300	2.320	0.040	7.770
	Euro 4	1.742	0.187	0.603	0.010	1.794
	Euro 5	1.742	0.060	0.088	0.002	1.000

Emissions factors of rest pollutants

Methane and NMVOCs

The emission legislation regulates total VOC emissions, with no distinction between methane and NMVOCs. The previous tables in this chapter have provided emission factors for VOCs. However, as CH_4 is a greenhouse gas, separate emission factors are required to calculate its contribution. In order to calculate hot CH_4 emissions, equation (8) can be applied with the values given in Table 3-50. Reduction factors for more recent technologies are given in Table 3-51. In reference to those tables, it should be noted that cold-start emission factors apply only to passenger cars and light commercial vehicles. In Table 3-51 the reductions are relative to Euro 1 for passenger cars and Euro I for heavy-duty vehicles. For two-wheel vehicles, the reductions are relative to conventional technology. The methane emission factors were derived from the literature for all types of vehicles (Bailey et al., 1989; Volkswagen, 1989; OECD, 1991, Zajontz et al., 1991), and the data from the Artemis project. Additional research (Bach et al, 2010; Zervas and Panousi, 2010; Timmons. 2010, Vonk et al, 2010) led to updated CH_4 factors for Euro Petrol/E85 passenger cars and CNG methane emissions.

Table 3-50: Methane (CH4) emission factors (mg/km)

Vehicle type	Fuel	Vehicle technology/class	Urban		Rural	Highway
			Cold	Hot		
Passenger cars	Petrol- Hybrid Petrol- PHEV	Conventional	201	131	86	41
		Euro 1	45	26	16	14
		Euro 2	94	17	13	11
		Euro 3	83	3	2	4
		Euro 4 and later	57	2.87	2.69	5.08
	Diesel- PHEV	Conventional	22	28	12	8
		Euro 1	18	11	9	3
		Euro 2	6	7	3	2
		Euro 3	3	3	3	3
		Euro 4	1.1	1.1		
		Euro 5 and later	0.075	0.075		
	LPG	Conventional and Euro 1	80	80	35	25
		Euro 2		19.2	8.4	6
		Euro 3		3	2	4
		Euro 4 and 5		2	2	1.25
		Euro 6 and later		0.48	0.4	0.56
	E85	All Technologies	57	2.87	2.69	5.08
	CNG	Euro 4, 5 and 6 a/b/c	*	57.3	27.73	43.39
		Euro 6d-temp and later	*	6	4.5	5
Light commercial vehicles	Petrol	Conventional	201	131	86	41
		Euro 1	45	26	16	14
		Euro 2	94	17	13	11
		Euro 3	83	3	2	4
		Euro 4 and later	57	2		
	Diesel	Conventional	22	28	12	8
		Euro 1	18	11	9	3
		Euro 2	6	7	3	2
		Euro 3	3	3		
		Euro 4	1.1	1.1		
		Euro 5 and later	0.0075	0.0075		
Heavy- duty vehicles	Petrol	All Technologies	-	140	110	70
	Diesel GVW <16t	Conventional and Euro I	-	85	23	20
		Euro II	-	54.4	20.01	18.6
		Euro III	-	47.6	21.39	18.2
		Euro IV, V and VI	-	2.55	1.61	1.2
		Euro VII	-	2.04	1.29	0.96
	Diesel GVW >16 t	Conventional and Euro I	-	175	80	70
		Euro II	-	112	69.6	65.1
		Euro III	-	98	74.4	63.7
		Euro IV, V and VI	-	5.25	5.6	4.2
		Euro VII	-	4.2	4.48	3.36
Buses	Diesel-Biodiesel Urban Buses and Coaches Hybrid Urban Buses	Conventional and Euro I	-	175	80	70
		Euro II	-	113.75	52	45.5
		Euro II	-	103.25	47.2	41.3
		Euro IV, V, VI	-	5.25	2.4	2.1
		Euro VII	-	4.2	1.92	1.68

	CNG	Euro I	-	6800		
		Euro II	-	4500		
		Euro III	-	1280		
		EEV	-	980		
L-category	Petrol <50 cm³ 2-stroke and 4-stroke	Conventional	-	219		
		Euro 1	-	43.8		
		Euro 2	-	24.09		
		Euro 3 and later	-	19.71		
	Petrol >50 cm³ 2-stroke	Conventional	-	150		
		Euro 1	-	99	106.5	97.5
		Euro 2	-	30	31.5	30
		Euro 3 and later	-	12	13.5	12
	Petrol <250 cm³ 4-stroke	Conventional	-	200		
		Euro 1	-	142	144	132
		Euro 2	-	136	92	92
		Euro 3 and later	-	82	32	28
	Petrol 250-750 cm³ 4-stroke	Conventional	-	200		
		Euro 1	-	148	174	156
		Euro 2	-	156	120	122
		Euro 3 and later	-	94	42	36
	Petrol >750 cm³ 4-stroke	Conventional	-	200		
		Euro 1	-	92	92	154
		Euro 2	-	84	62	102
		Euro 3 and later	-	50	22	30
	Micro-cars Diesel	Conventional	22	28	12	8
		Euro 1	18	11	9	3
		Euro 2	6	7	3	2
		Euro 3	3	3		
		Euro 4	1.1	1.1		
		Euro 5	0.075	0.075		
	Quad & ATVs	Conventional	-	200		
		Euro 1	-	92	92	154
		Euro 2	-	84	62	102
		Euro 3 and later	-	50	22	30

* Methane cold emissions from CNG passenger cars are calculated as a ratio of VOC cold emissions:

The NMVOC emission factors were calculated as the remainder of the subtraction of CH_4 emissions from total VOC emissions. Hence, after VOC and CH_4 have been calculated by equation (6), NMVOC emissions can also be calculated by:

$$E_{NMVOC} = E_{VOC} - E_{CH4} \quad (27)$$

$CH_{4\ cold} = 0.620\ VOC_{cold}$

Table 3-51: Methane (CH_4) emission reduction factors (%). Reductions are over Euro 1 for passenger cars, Euro I for heavy-duty vehicles and the conventional technology for two-wheel vehicles

Vehicle type	Fuel	Vehicle technology/class	CH_4 Emission Reduction Factors (%)		
			Urban	Rural	Highway
Passenger cars	LPG	Euro 2	76	76	76
		Euro 3	96.25	94.28	84
		Euro 4 and 5	97.5	94.28	95
		Euro 6 and later	99.4	99.5	99.3
Heavy-duty Trucks	Diesel	Euro II	36	13	7
		Euro III	44	7	9
		Euro IV, V and VI	97	93	94
		Euro VII	97.6	94.4	95.2
Buses	Diesel Biodiesel	Euro II	35	35	35
		Euro III	41	41	41
		Euro IV, V and VI	97	97	97
		Euro VI	97.6	97.6	97.6
L-category	Petrol	2-stroke < 50 cm^3 — Euro 1	80	80	80
		2-stroke < 50 cm^3 — Euro 2	89	89	89
		2-stroke < 50 cm^3 — Euro 3 and later	91	91	91
		4-stroke < 50 cm^3 — Euro 1	80	80	80
		4-stroke < 50 cm^3 — Euro 2	89	89	89
		4-stroke < 50 cm^3 — Euro 3 and later	91	91	91
		2-stroke > 50 cm^3 — Euro 1	34	29	35
		2-stroke > 50 cm^3 — Euro 2	80	79	80
		2-stroke > 50 cm^3 — Euro 3 and later	92	91	92
		4-stroke < 250 cm^3 — Euro 1	29	28	34
		4-stroke < 250 cm^3 — Euro 2	32	54	54
		4-stroke < 250 cm^3 — Euro 3 and later	59	84	86
		4-stroke 250–750 cm^3 — Euro 1	26	13	22
		4-stroke 250–750 cm^3 — Euro 2	22	40	39
		4-stroke 250-750 cm^3 — Euro 3 and later	53	79	82
		4-stroke > 750 cm^3 — Euro 1	54	54	23
		4-stroke > 750 cm^3 — Euro 2	58	69	49
		4-stroke > 750 cm^3 — Euro 3 and later	75	89	85
	Quad & ATVs	Euro 1	54	54	23
		Euro 2	58	69	49
		Euro 3 and later	75	89	85

PM characteristics

Hot emissions

Recent data for particle mass and number has been collected from laboratory measurements which has been verified by the literature of Giechaskiel (2020), Andersson et al. (2014), Valverde et al. (2018), Valverde et al. (2019), Kontses et al (2020) and Giechaskiel (2018). The data regard multiple powertrains of both light and heavy-duty vehicles and concern newer Euro standards (Euro 5 and later). For the calculation of hot PM emission factors, the overemissions due to cold start have been excluded from the analysis. The revised hot emission factors can be seen in Appendix 4 under the sheet “Hot emission parameters”.

Cold-start emissions

The same measurements and literature for (Euro 5 and later) light-duty vehicles was used for assessing the PM overemissions due to cold-start Giechaskiel (2020), Andersson et al. (2014), Valverde et al. (2018), Valverde et al. (2019), Kontses et al (2020) and Giechaskiel (2018).

In the case of PM (and SPN23), equation 10 for the calculation of cold start emissions is slightly modified:

$E_{COLD;\,i,\,j} = \beta_k \times N_k \times M_k \times e_{HOT;\,k} \times (e^{COLD} - e^{HOT}|_k)$

where,

$E_{COLD;\,k}$	=	cold-start emissions produced by vehicle technology *k*,
β_k	=	fraction of mileage driven with a cold engine, or the catalyst operated below the light-off temperature for vehicle technology *k*,
N_k	=	number of vehicles [veh] of technology *k* in circulation,
M_k	=	total mileage per vehicle [km/veh] in vehicle technology *k*,
$e_{HOT;\,k}$	=	hot emission factor for vehicles of *k* technology,
$e^{COLD}\|_k$	=	cold emission factor for vehicles of *k* technology.
$e^{HOT}\|_k$	=	hot emission factor for vehicles of *k* technology.

This formula stands only for Euro 5 and later vehicles. The cold factor is calculated according to the formula presented in equation (25) for the calculation of hot emission factor. Since the formula used for the calculation of cold-start emissions of PM (and SPN23) (for Euro 5 and later) vehicles is different than the one used for other pollutants, the coefficients are placed in different sheet in Appendix 4 which is entitled “cold parameters only for SPN23 and PM for Euro 5 and later”.

The cold start PM emissions of light-duty vehicles are revised since COPERT v5.8 based on data received from VTT Technical Research Centre of Finland Ltd (Aakko-Saksa, et al. 2020). VTT had recently conducted a study on PM emission factors for passenger cars in very cold temperatures. The focus is on the resulting exhaust emissions among the different fuels and Euro standards at -7°C. European chassis dynamometer driving cycle (NEDC) was used for the test. The study concluded that PM emissions at -7°C are order of magnitude(s) higher than 23°C. The resulting cold parameters for PM can be seen in Appendix 4.

Solid Particle Number > 23 nm (SPN23)

Emission regulation from the European Union focuses on Solid Particle Number > 23 nm (SPN23) for all types of vehicles. In 2011 (Euro 5b) a solid particle number (SPN) limit with a size cut-off at 23 nm (SPN23) was brought into force for light-duty diesel vehicles and two years later for heavy-duty ones. High SPN23 emissions were also observed from gasoline light-duty vehicles equipped with a direct injection (GDI) engine thus PM and SPN23 limits were implemented in 2009 and 2014, respectively. Detailed information on hot and cold SPN23 emission factors for all vehicles can be found in Appendix 4.

Light-Duty Vehicles

The engine size was not considered to have an impact on the particle emissions; thus, the categories of the same Euro cars were based on the aftertreatment technologies.

SPN23 emission factors [#/km] for older Euro standard categories (Euro 1 – 4) were based on a study (Vouitsis et al. 2017) that categorized these factors based on the driving condition (Urban, Rural, Highway).

For the most recent Euro standards (Euro 5 and 6) the impact of engine cold start in comparison to hot engine operation for the SPN23 was calculated. Like PM, the SPN23 emission factors had been derived from data from lab measurements and literature review (Andersson et al. 2014, Giechaskiel 2018, Giechaskiel 2020, Valverde et al., Joint Research Centre 2018, Valverde et al. 2019, Vouitsis et al. 2017). The mean emission factors for each type of petrol and diesel car were calculated for both cold and hot start in [#/km]. The cold-start SPN23 emissions are calculated in a similar way with PM and the coefficients for vehicles of Euro 5 and later technologies can be seen in "cold parameters only for SPN23 and PM for Euro 5 and later".

Table 3-52: Passenger car SPN23 emission factors for cold and hot start and Overemission

Passenger cars			Cold [#/km] Average	Confidence	Hot [#/km] Average	Confidence	[#] Overemission
Diesel	Euro 5	DPF	2.09E+11	1.53E+11	8.73E+10	7.53E+10	3.67E+12
Diesel	Euro 6	DPF	1.72E+11	9.05E+10	4.82E+10	2.86E+10	3.98E+12
Petrol	Euro 5	GDI	1.85E+12		7.65E+11		3.81E+13
Petrol	Euro 5	PFI	1.39E+12		6.10E+11		2.72E+13
Petrol	Euro 6	GDI	1.97E+12	4.27E+11	8.12E+11	3.08E+11	3.96E+13
Petrol	Euro 6	GDI+GPF	5.55E+11	1.77E+11	1.30E+11	7.28E+10	1.78E+13
Petrol	Euro 6	PFI	1.47E+12	5.37E+11	6.48E+11	4.19E+11	3.69E+13
CNG	Euro 6		5.04E+11	1.70E+11	2.63E+11	1.24E+11	6.01E+12

Table 3-53: SPN23 Urban, Rural and Highway emission factors for diesel passenger cars

Passenger cars		Urban [#/km]	Rural [#/km]	Highway [#/km]
Diesel	Euro 1	3.97E+14	2.52E+14	4.70E+14
Diesel	Euro 2	2.12E+14	2.05E+14	4.35E+14
Diesel	Euro 3	1.64E+14	1.73E+14	2.82E+14
Diesel	Euro 4	7.48E+13	5.52E+13	9.00E+13

Table 3-54: SPN23 Urban, Rural and Highway emission factors for petrol passenger cars

Passenger cars			Urban [#/km]	Rural [#/km]	Highway [#/km]
Petrol	Euro 1	PFI	8.76E+12	3.11E+12	1.81E+13
Petrol	Euro 2	PFI	6.16E+12	2.67E+12	1.18E+13

Petrol	Euro 3	PFI	3.07E+12	2.23E+12	5.60E+12
Petrol	Euro 4	PFI	9.00E+11	7.90E+11	8.40E+11
Petrol	Euro 4	GDI	9.50E+12	7.60E+12	6.06E+13

Table 3-55: SPN23 petrol passenger cars ratios over Euro 6 GDI

Passenger cars		SPN23 Cold [#/km]	Ratio /Euro 6 GDI
Euro 5	PFI	1.39E+12	0.70
Euro 6	GDI	1.97E+12	1
Euro 6	GDI+GPF	5.55E+11	0.28
Euro 6	PFI	1.47E+12	0.75

The diesel passenger cars equipped with Diesel Particulate Filter (DPF) appear to have significantly increased particle emissions during the Regeneration periods. It is important to estimate the duration and the frequency of the Regeneration in order to calculate the increased emissions.

Table 3-56: DPF Regeneration frequency and duration in diesel passenger cars

Passenger cars	Euro 5	Euro 6
Frequency [km]	500	400
Duration [km]	20	20
Out of Reg	0.96	0.95
In Reg	0.04	0.05

According to literature in both chassis dyno and PEMS tests, active regenerations appeared to increase PN by a factor of ~10. In the following table, the regeneration values for Euro 6 Diesel are presented as well as a comparison to hot emission factors.

Table 3-57: DPF Regeneration Euro 6 Diesel passenger cars

SPN23 [#/km]		
Regeneration	Average	6.47E+11
Regeneration	Confidence	1.97E+11
Hot	Average	4.82E+10
Regeneration/Hot		13.44

Heavy-Duty Vehicles

As with the passenger cars, the SPN23 emission factors for Euro Standards from I to V were split into Urban, Rural and Highway driving conditions as presented in the study by Vouitsis et al. 2017.

Table 3-58: SPN23 Urban, Rural and Highway emission factors for Euro I – V heavy-duty vehicles

Heavy-Duty Vehicle	Urban [#/kWh]	Rural [#/kWh]	Highway [#/kWh]
Euro I	7.34E+14	3.18E+14	3.28E+14
Euro II	5.13E+14	2.21E+14	2.30E+14
Euro III	5.13E+14	2.21E+14	2.30E+14
Euro IV	1.08E+14	5.54E+13	6.18E+13
Euro V	1.08E+14	5.54E+13	6.18E+13

Table 3-59: Heavy Duty vehicles Urban, Rural and Highway SPN23 emission factors Euro VI)

Heavy-Duty Vehicles		Average [#/kWh]	Confidence
Euro VI	Urban	1.79E+11	1.12E+11
Euro VI	Rural	6.09E+10	1.64E+10
Euro VI	Highway	4.75E+10	1.07E+10

L-Category

The average SPN23 emission factor from 14 Euro 4 Petrol 4s Motor measurements was 8,45E+11 [#/km] (confidence interval 2,78E+11). For Euro 5, the emission factors have been extracted from Kontses et al. (2020).

Nitrous oxide (N_2O) emissions

Nitrous oxide emission factors were developed in a LAT/AUTh study (Papathanasiou and Tzirgas, 2005), based on data collected in studies around the world. The same methodology was used in a more recent study (Pastramas et al., 2014) in order to develop the emission factors for Euro 5 and 6 vehicles. N_2O emissions are particularly important for catalyst vehicles, especially when the catalyst is under partially oxidising conditions. This may occur when the catalyst has not yet reached its light-off temperature or when the catalyst is aged. Because N_2O has increased in importance on account of its contribution to the greenhouse effect, a detailed calculation of N_2O needs to take vehicle age (cumulative mileage) into account. Moreover, aftertreatment ageing depends upon the fuel sulphur level. Hence, different emission factors need to be derived to allow for variation in fuel sulphur content. In order to take both these effects into account, N_2O emission factors are calculated according to equation (28), and the coefficients in Table 3-60 to Table 3-67 for different passenger cars and light commercial vehicles. These values differ according to the fuel sulphur level and the driving conditions (urban, rural, highway). With regard to Euro 5, Euro 6 and Euro 6 RDE emission standards, only one category of low sulphur level is given, since these technologies are not compatible with higher sulphur contents. In particular, cold-start and a hot-start emission factors are given for urban driving.

$$EF_{N2O} = [a \times CMileage + b] \times EF_{BASE} \quad (28)$$

Note

The **CMileage** value in this calculation corresponds to the mean cumulative mileage of a particular vehicle type. This corresponds to the mean odometer reading of vehicles of a particular type. The cumulative mileage is a good indication of the vehicle operation history. This should not be confused with the annual mileage driven by a vehicle, which corresponds to the distance travelled in a period of a year and typically ranges between 8 000 and 20 000 km. The cumulative mileage could be expressed as annual mileage times the years of life of a vehicle.

Table 3-60: Parameters for equation(28) to calculate N_2O emission factors for petrol, CNG and E85 passenger cars under cold urban conditions

Emission standard	Sulphur content (ppm)	Base EF (mg/km)	a	b
pre-Euro	All	10	0	1
Euro 1	0–30	17.5	5.60E-07	0.936
Euro 1	30-350	40.5	1.76E-06	0.839
Euro 1	> 350	57.6	7.24E-06	0.748
Euro 2	0-30	11.5	5.85E-07	0.978
Euro 2	30–350	24.4	4.61E-07	0.972
Euro 2	> 350	37.4	2.41E-06	0.918
Euro 3	0–30	7.9	5.68E-07	0.95
Euro 3	30–90	11.4	-2.54E-07	1.02
Euro 3	> 90	11.7	-5.61E-07	1.04
Euro 4	0–30	5.4	3.79E-07	0.96
Euro 4	30–90	6.4	4.46E-07	0.951
Euro 4	> 90	10.5	4.51E-07	0.95
Euro 5 and later	0-30	2.8	2.49E-06	0.559

Table 3-61: Parameters for equation (28) to calculate N_2O emission factors for petrol, CNG and E85 passenger cars under hot urban conditions

Emission standard	Sulphur content (ppm)	Base EF (mg/km)	a	b
pre-Euro	All	10	0	1
Euro 1	0–350	23.2	8.81E-07	0.92
Euro 1	> 350	60.4	1.54E-05	0.255
Euro 2	0–350	11.1	9.21E-07	0.962
Euro 2	> 350	17.9	3.14E-06	0.93
Euro 3	0–30	1.3	1.85E-06	0.829
Euro 3	30–90	1.8	2.34E-06	0.801
Euro 3	> 90	3	-3.34E-07	1.03
Euro 4	0–30	1.9	6.61E-07	0.931
Euro 4	30–90	2.4	2.39E-06	0.738
Euro 4	> 90	4.2	8.65E-07	0.903
Euro 5 and later	0-30	2.4	7.83E-07	0.861

Table 3-62: Parameters for equation (28) to calculate N_2O emission factors for petrol, CNG and E85 passenger cars under hot rural conditions

Emission standard	Sulphur content (ppm)	Base EF (mg/km)	a	b
pre-Euro	All	6.5	0	1
Euro 1	0–30	9.2	1.31E-06	0.851
Euro 1	30–350	18.5	2.90E-06	0.747
Euro 1	> 350	48.9	1.37E-05	0.227
Euro 2	0–30	4	1.45E-06	0.945
Euro 2	> 30	4.2	4.93E-06	0.799
Euro 3	0–30	0.3	1.35E-06	0.875
Euro 3	30–90	1.1	4.10E-06	0.539
Euro 3	> 90	2.2	4.20E-06	0.68
Euro 4	0–30	0.3	2.61E-06	0.726
Euro 4	30–90	1.1	4.09E-06	0.549
Euro 4	> 90	2.5	4.82E-07	0.946
Euro 5 and later	0-30	0.2	2.61E-06	0.726

Table 3-63: Parameters for equation (28) to calculate N_2O emission factors for petrol, CNG and E85 passenger cars under hot highway conditions

Emission standard	Sulphur content (ppm)	Base EF (mg/km)	a	b
pre-Euro	All	6.5	0	1
Euro 1	0–30	4.7	1.30E-06	0.846
Euro 1	30–350	9.4	2.87E-06	0.739
Euro 1	> 350	24.7	1.33E-05	0.219
Euro 2	0–30	2.2	1.45E-06	0.944
Euro 2	> 30	2.3	4.92E-06	0.797
Euro 3	0–30	0.19	1.49E-06	0.967
Euro 3	30–90	0.61	6.32E-06	0.832
Euro 3	> 90	1.3	5.56E-06	0.9
Euro 4	0–30	0.17	3.30E-06	0.918
Euro 4	30–90	0.63	6.23E-06	0.838
Euro 4	> 90	1.4	5.03E-07	0.987
Euro 5 and later	0-30	1	3.30E-06	0.918

Table 3-64: Parameters for equation (28) to calculate N_2O emission factors for petrol LCVs under cold urban conditions

Emission standard	Sulphur content (ppm)	Base EF (mg/km)	a	b
pre-Euro	All	10	0	1
Euro 1	0–350	46.5	3.30E-07	0.933
Euro 1	> 350	83.6	1.55E-05	0.686
Euro 2	All	67.7	2.13E-06	0.812
Euro 3	0–30	16.8	3.38E-07	0.957
Euro 3	30–90	20.5	-1.81E-07	1.02
Euro 3	> 90	32.9	-2.84E-07	1.02
Euro 4	0–30	13.7	1.14E-06	0.87
Euro 4	30–90	16.5	4.75E-07	0.946
Euro 4	> 90	23.2	1.27E-07	0.986
Euro 5 and later	0-30	2.8	2.49E-06	0.559

Table 3-65: Parameters for equation (28) to calculate N_2O emission factors for petrol LCVs under hot urban conditions

Emission standard	Sulphur content (ppm)	Base EF (mg/km)	a	b
pre-Euro	All	10	0	1
Euro 1	0–350	41.5	2.33E-06	0.53
Euro 1	> 350	60.4	1.54E-05	0.255
Euro 2	0–350	23.9	2.40E-06	0.68
Euro 2	> 350	42.1	1.17E-05	0.56
Euro 3	0–30	7.4	2.81E-06	0.64
Euro 3	30–90	12.7	1.41E-06	0.83
Euro 3	> 90	36.7	1.44E-06	0.86
Euro 4	0–30	1.2	6.57E-07	0.925
Euro 4	30–90	0.85	5.72E-07	0.935
Euro 4	> 90	7.9	3.07E-07	0.965
Euro 5 and later	0-30	2.4	7.83E-07	0.861

Table 3-66: Parameters for equation (28) to calculate N_2O emission factors for petrol LCVs under hot rural conditions

Emission standard	Sulphur content (ppm)	Base EF (mg/km)	a	b
pre-Euro	All	6.5	0	1
Euro 1	0–350	18.5	2.90E-06	0.747
Euro 1	> 350	26.3	2.96E-05	0.49
Euro 2	0–350	12.2	2.67E-06	0.76
Euro 2	> 350	21.1	1.92E-05	0.66
Euro 3	0–30	1.4	1.27E-06	0.837
Euro 3	30–90	6	1.88E-06	0.77
Euro 3	> 90	18.1	1.78E-06	0.83
Euro 4	0–30	0.3	6.33E-06	0.278
Euro 4	30–90	2.2	3.62E-06	0.587
Euro 4	> 90	8.7	2.03E-06	0.768
Euro 5 and later	0-30	0.2	2.61E-06	0.726

Table 3-67 Parameters for equation (28) to calculate N_2O emission factors for petrol LCVs under hot highway conditions

Emission standard	Sulphur content (ppm)	Base EF (mg/km)	a	b
pre-Euro	> 0	6.5	0	1
Euro 1	0–350	9.4	2.87E-06	0.739
Euro 1	> 350	26.3	2.96E-05	0.49
Euro 2	0–350	7.7	2.50E-06	0.75
Euro 2	> 350	21.1	1.92E-05	0.66
Euro 3	0–30	1.4	1.27E-06	0.837
Euro 3	30–90	6	1.88E-06	0.77
Euro 3	> 90	18.1	1.78E-06	0.83
Euro 4	0–30	0.3	6.33E-06	0.278
Euro 4	30–90	2.2	3.62E-06	0.587
Euro 4	> 90	8.7	2.03E-06	0.768
Euro 5 and later	0-30	1	3.30E-06	0.918

Nitrous oxide emissions from diesel vehicles without deNOx aftertreatment and motorcycles are substantially lower than those from catalyst-equipped passenger cars and are roughly estimated on the basis of the literature (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), Riemersma et al. (2003) and Pastramas et al., (2014). These data are shown in Table 3-68 and Table 3-69. For motorcycles and heavy-duty vehicles, there is no separate methodology for estimating excess cold-start emissions, but they are assumed to be already incorporated in the bulk emission factors.

Table 3-68: N_2O emission factors (mg/km) for diesel and LPG cars, diesel light commercial vehicles, and two-wheel vehicles.

Vehicle category	Urban cold	Urban hot	Rural	Highway
Diesel passenger cars and LCVs				
Conventional	0	0	0	0
Euro 1	0	2	4	4
Euro 2	3	4	6	6
Euro 3/4/5	15	9	4	4
Euro 6 up to 2016 / 2017-2019 / 2020+	9	11	4	4
Euro 7	9	11	4	4
LPG passenger cars				
Conventional	0	0	0	0
Euro 1	38	21	13	8
Euro 2	23	13	3	2
Euro 3	9	5	2	1
Euro 4	9	5	2	1
Euro 5	1.8	2.1	0.2	1
Euro 6	1.8	2.1	0.2	1
Euro 7	1.8	2.1	0.2	1
L-category				
< 50 cm^3	1		1	1
> 50 cm^3 2-stroke	2		2	2
> 50 cm^3 4-stroke	2		2	2

Table 3-69: N_2O emission factors (mg/km) for heavy-duty vehicles

HDV Category	Technology	Urban	Rural	Highway
Petrol > 3.5 t	Conventional	6	6	6
Rigid 7.5–12 t	Conventional	30	30	30
	HD Euro I	6	5	3
	HD Euro II	5	5	3
	HD Euro III	3	3	2
	HD Euro IV	6	7.2	5.8
	HD Euro V	15	19.8	17.2
	HD Euro VI	18.5	19	15
	HD Euro VII	8.6	8.8	6.9
Diesel Rigid and articulated 12–28 t and coaches (all types)	Conventional	30	30	30
	HD Euro I	11	9	7
	HD Euro II	11	9	6
	HD Euro III	5	5	4
	HD Euro IV	11.2	13.8	11.4
	HD Euro V	29.8	40.2	33.6
	HD Euro VI	37	39	29
	HD Euro VII	17.1	18	13.4
Diesel Rigid and articulated 28–34 t	Conventional	30	30	30
	HD Euro I	17	14	10
	HD Euro II	17	14	10
	HD Euro III	8	8	6
	HD Euro IV	17.4	21.4	17.4
	HD Euro V	45.6	61.6	51.6
	HD Euro VI	56.5	59.5	44.5
	HD Euro VII	26.1	27.5	20.6
Diesel Articulated > 34 t	Conventional	30	30	30
	HD Euro I	18	15	11
	HD Euro II	18	15	10
	HD Euro III	9	9	7
	HD Euro IV	19	23.4	19.2
	HD Euro V	49	66.6	55.8
	HD Euro VI	61	64	48
	HD Euro VII	28.2	29.6	22.2
Diesel urban buses (all types)	Conventional	30		
	HD Euro I	12		
	HD Euro II	12		
	HD Euro III	6		
	HD Euro IV	12.8		
	HD Euro V	33.2		
	HD Euro VI	41.5		
	HD Euro VII	19.2		

Values in Table 3-69 already designate that N_2O emissions from diesel vehicles equipped with de-NOx aftertreatment, such Euro V and Euro VI ones, may be substantially higher than vehicles without aftertreatment. Most of the Euro V/VI trucks achieve low NO_x emissions with the use of selective catalytic reduction (SCR) systems. In these, NO_x is reduced to N_2 by means of an ammonia carrier (urea) which acts as the reducing agent over an appropriate catalyst. In normal operation, SCR should lead to minimal N_2O production, as NO_x is effectively converted to N_2. However, there are at least two cases which can lead to excess N_2O emission. The SCR chemical mechanism forms N_2O as a by-product of the N_2 conversion. This can be stored under low-to-medium temperature conditions and can be later released when the temperature increases. The second, most important mechanism of N_2O formation in SCR systems is by oxidation of the ammonia introduced into the system. Several SCR configurations include a secondary oxidation catalyst, downstream of the primary SCR one, which aims at oxidizing ammonia that has “slipped” the main catalyst. This ammonia slip may occur when more ammonia is injected than what is at a minimum required to reduce NO_x. This is often the result of a miscalculation in the injected quantity or overshooting in urea injection, in an effort to make sure that no NO_x is emitted downstream of the SCR system. This slipped ammonia cannot be fully oxidized into N_2 in the oxidation catalyst and often is emitted as N_2O.

The values in Table 3-69 should be representative of well-operating SCR systems, i.e. without (excessive) ammonia slip. In case this occurs, N_2O emissions may increase disproportionally. High values of ammonia slip may occur for an aged system or due to malfunctions. One such study in Japan identified N_2O emissions to amount to up to 20% of CO_2 equivalent in the exhaust of an SCR equipped vehicle (Suzuki et al., 2008). N_2O emissions from SCR vehicles need to me monitored to reveal how much this is a problem in real-world conditions.

SCR systems will expand to diesel passenger cars as well, starting with Euro 6. It cannot currently be predicted how these systems will behave. First, passenger cars are expected to utilize SCR at a lower relative rate than diesel trucks do. Second, it is not determined yet whether SCR will precede DPFs in the exhaust line or vice versa. N_2O emissions may be drastically different in the two cases. Because of these unknowns, predicting the level and the trend of N_2O emission from SCR equipped passenger cars is currently not possible.

Ammonia (NH_3) emissions

Ammonia emissions from passenger cars and light commercial vehicles are estimated in a similar manner to N_2O emissions. The NH_3 emission factors are calculated according to equation (28) and the coefficients in Table 3-70 to Table 3-77. As already mentioned, these values differ according to the fuel sulphur level and the driving conditions (urban, rural, highway). With regard to Euro 5 and later emission standards, only one category of sulphur level is given, as for N_2O.

Table 3-70: Parameters for equation (28) to calculate NH_3 emission factors for petrol, LPG, CNG and E85 passenger cars under cold urban conditions

Emission standard	Sulphur content (ppm)	Base EF (mg/km)	A	b
pre-Euro	> 0	2	0	1
Euro 1	0–150	50	1.52E-06	0.765
Euro 1	> 150	11.7	2.92E-06	0.351
Euro 2	0-150	51	1.70E-06	0.853
Euro 2	> 150	14.6	3.89E-06	0.468
Euro 3	0–30	5.4	1.77E-06	0.819
Euro 3	> 30	4.8	4.33E-06	0.521
Euro 4	0–30	5.4	1.77E-06	0.819
Euro 4	> 30	4.8	4.33E-06	0.521
Euro 5 and later	> 0	13.8	3.23E-06	0.917

Table 3-71: Parameters for equation (28) to calculate NH_3 emission factors for petrol, LPG, CNG and E85 passenger cars under hot urban conditions

Emission standard	Sulphur content (ppm)	Base EF (mg/km)	A	b
pre-Euro	> 0	2	0	1
Euro 1	> 0	70	0	1
Euro 2	> 0	143	1.47E-06	0.964
Euro 3	0–30	1.9	1.31E-06	0.862
Euro 3	> 30	1.6	4.18E-06	0.526
Euro 4	0–30	1.9	1.31E-06	0.862
Euro 4	> 30	1.6	4.18E-06	0.526
Euro 5 and later	> 0	4.1	1.73E-06	0.955

Table 3-72: Parameters for equation (28) to calculate NH_3 emission factors for petrol, LPG, CNG and E85 passenger cars under hot rural conditions

Emission standard	Sulphur content (ppm)	Base EF (mg/km)	A	b
pre-Euro	> 0	2	0	1
Euro 1	0–150	131	5.94E-08	0.999
Euro 1	> 150	100	8.95E-07	0.978
Euro 2	0–150	148	5.95E-08	0.999
Euro 2	> 150	90.7	9.08E-07	0.992
Euro 3	0–30	29.5	5.90E-08	0.994
Euro 3	> 30	28.9	8.31E-07	0.908
Euro 4	0–30	29.5	5.90E-08	0.994
Euro 4	> 30	28.9	8.31E-07	0.908
Euro 5 and later	> 0	8	9.04E-07	0.977

Table 3-73: Parameters for equation (28) to calculate NH_3 emission factors for petrol, LPG, CNG and E85 passenger cars under hot highway conditions

Emission standard	Sulphur content (ppm)	Base EF (mg/km)	A	b
pre-Euro	> 0	2	0	1
Euro 1	0–150	73.3	5.94E-08	0.998
Euro 1	> 150	56.2	8.86E-07	0.968
Euro 2	0–150	83.3	5.94E-08	0.999
Euro 2	> 150	51	9.05E-07	0.988
Euro 3	0–30	64.6	5.95E-08	0.999
Euro 3	> 30	63.4	9.02E-07	0.985
Euro 4	0–30	64.6	5.95E-08	0.999
Euro 4	> 30	63.4	9.02E-07	0.985
Euro 5 and later	> 0	21.8	5.95E-08	0.999

Table 3-74: Parameters for equation (28) to calculate NH3 emission factors for petrol LCVs under cold urban conditions

Emission standard	Sulphur content (ppm)	Base EF (mg/km)	A	b
pre-Euro	> 0	2	0	1
Euro 1	0–150	50	1.52E-06	0.765
Euro 1	> 150	11.7	2.92E-06	0.351

Euro 2	0–150	51	1.70E-06	0.853
Euro 2	> 150	14.6	3.89E-06	0.468
Euro 3	0–30	5.4	1.77E-06	0.819
Euro 3	> 30	4.8	4.33E-06	0.521
Euro 4	0–30	5.4	1.77E-06	0.819
Euro 4	> 30	4.8	4.33E-06	0.521
Euro 5 and later	> 0	13.8	3.23E-06	0.917

Table 3-75: Parameters for equation (28) to calculate NH_3 emission factors for petrol LCVs under hot urban conditions

Emission standard	Sulphur content (ppm)	Base EF (mg/km)	A	b
pre-Euro	> 0	2	0	1
Euro 1	> 0	70	0	1
Euro 2	> 0	143	1.47E-06	0.964
Euro 3	0–30	1.9	1.31E-06	0.862
Euro 3	> 30	1.6	4.18E-06	0.526
Euro 4	0–30	1.9	1.31E-06	0.862
Euro 4	> 30	1.6	4.18E-06	0.526
Euro 5 and later	> 0	4.1	1.73E-06	0.955

Table 3-76: Parameters for equation (28) to calculate NH_3 emission factors for petrol LCVs under hot rural conditions

Emission standard	Sulphur content (ppm)	Base EF (mg/km)	A	b
pre-Euro	> 0	2	0	1
Euro 1	0–150	131	5.94E-08	0.999
Euro 1	> 150	100	8.95E-07	0.978
Euro 2	0–150	148	5.95E-08	0.999
Euro 2	> 150	90.7	9.08E-07	0.992
Euro 3	0–30	29.5	5.90E-08	0.994
Euro 3	> 30	28.9	8.31E-07	0.908
Euro 4	0–30	29.5	5.90E-08	0.994
Euro 4	> 30	28.9	8.31E-07	0.908
Euro 5 and later	> 0	8	9.04E-07	0.977

Table 3-77: Parameters for equation (28) to calculate NH_3 emission factors for petrol LCVs under hot highway conditions

Emission standard	Sulphur content (ppm)	Base EF (mg/km)	A	b
pre-Euro	> 0	2	0	1
Euro 1	0–150	73.3	5.94E-08	0.998
Euro 1	> 150	56.2	8.86E-07	0.968
Euro 2	0–150	83.3	5.94E-08	0.999
Euro 2	> 150	51	9.05E-07	0.988
Euro 3	0–30	64.6	5.95E-08	0.999
Euro 3	> 30	63.4	9.02E-07	0.985
Euro 4	0–30	64.6	5.95E-08	0.999
Euro 4	> 30	63.4	9.02E-07	0.985

Euro 5 and later	> 0	21.8	5.95E-08	0.999

For all other vehicle classes, bulk ammonia emission factors are given in Table 3-78. No separate calculation is required for excess cold-start emissions. These emission factors are based solely on a literature review and should be considered as broad estimates (de Reydellet, 1990; Volkswagen, 1989).

Table 3-78: Bulk (hot + cold) ammonia (NH_3) emission factors (mg/km)

Vehicle category	Urban	Rural	Highway
Passenger cars			
Diesel Euro 4 or earlier	1	1	1
Diesel Euro 5	1.9	1.9	1.9
Diesel Euro 6 and later	7	7	7
2-stroke	2	2	2
Light commercial vehicles			
Diesel Euro 4 or earlier	1	1	1
Diesel Euro 5 and later	Equal to Diesel PC		
Heavy-duty vehicles			
Petrol vehicle > 3.5 t	2	2	2
Diesel Euro IV or earlier	2,9	2,9	2,9
Diesel Euro V	11	11	11
Diesel Euro VI	9	9	9
Diesel Euro VII	2.6	2.6	2.6
Motorcycles			
< 50 cm³	1	1	1
> 50 cm³ 2-stroke	2	2	2
> 50 cm³ 4-stroke	2	2	2

PAHs and POPs

Emission factors (in µg/km) for specific polycyclic aromatic hydrocarbons (PAHs) and persistent organic pollutants (POPs) are given in Table 3-79. Different vehicle categories are covered. A rough distinction is made between conventional (pre-Euro I) and closed-loop catalyst vehicles (Euro I and later). For diesel passenger cars and light commercial vehicles, different emission factors are given for direct injection (DI) and indirect injection (IDI) vehicles. Since statistical information on the distribution of vehicles according to their combustion concept is difficult to collect, it is proposed that the average (DI, IDI) emission factor is used to estimate emissions from diesel non-heavy-duty vehicles.

The methodology is applicable to the four PAHs relevant for the UNECE POPs protocol: indeno(1,2,3-cd)pyrene, benzo(k)fluoranthene, benzo(b)fluoranthene, benzo(a)pyrene, and several others. These emission factors should be considered as bulk values, and no distinction is made between hot and cold-start emissions. They have been developed on the basis of a literature review, including the following sources: BUWAL (1994), TNO (1993b), Volkswagen (1989). The application of equation (8) to these emission factors provides total emissions of PAHs and POPs per vehicle class.

PAH and POP emissions from four-stroke motorcycles are estimated using the emission factors for conventional petrol cars. This approach will be modified as soon any data on emissions of these pollutants from motorcycles become available.

Table 3-79: PAHs and POPs bulk (hot + cold) emission factors

Species	Bulk emission factors (µg/km)					
	Petrol, E85, CNG PC & LCV		Diesel PC &LCV		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	

Emission factors for dioxins and furans are given in Table 3-80. These are provided separately to other POPs because an aggregate toxicity equivalent emission factor is provided. This emission factor takes into account the toxicity of different dioxin and furan compounds according to the NATO Committee on the Challenges of the Modern Society (NATO-CCMS). Actual emission factors for different dioxins and furans have been collected from the available literature (Umweltbundesamt, 1996) and from a relevant literature study (Pastramas et al. 2014). The final value is a bulk emission factor expressed in pg/km. Due to the limited available information, these emission factors need to be reconsidered when updated data become available, especially with regard to HCB and PCB, for which data from road vehicles are scarce or virtually non-existent. In order to ensure a consistent approach for all vehicle sources, dioxin and furan emissions from four-stroke motorcycles are calculated using the same toxicity equivalent emission factors as conventional petrol vehicles.

Table 3-80: PCDD, PCDF and PCB emission factors for passenger cars and light duty vehicles

Vehicle Category	Emission Standard	PCDD [pg I-Teq/km]	PCDF [pg I-Teq/km]	PCB [pg/km]
Petrol PCs	pre-Euro	10.3	21.2	6.4
	Euro 1	13	19	6.4
	Euro 2	13	19	6.4
	Euro 3	2.7	4.1	1.36
	Euro 4	2.7	4.1	1.36
	Euro 5, 6, 6 RDE and later	2.7	4.1	1.36
Diesel PCs	pre-Euro	0.5	1.00	1.5
	Euro 1	24.5	36.5	12.2
	Euro 2	24.5	36.5	12.2
	Euro 3	24.5	36.5	12.2
	Euro 4	24.5	36.5	12.2
	Euro 5, 6, 6 RDE and later	0.3	0.44	0.15
Petrol LDVs	pre-Euro	10.3	21.2	31.5
	Euro 1	13	19	6.4
	Euro 2	13	19	6.4
	Euro 3	2.7	4.1	1.36
	Euro 4	2.7	4.1	1.36
	Euro 5, 6, 6 RDE and later	2.7	4.1	1.36
Diesel LDVs	pre-Euro	0.5	1.00	1.5
	Euro 1	24.5	36.5	12.2
	Euro 2	24.5	36.5	12.2
	Euro 3	24.5	36.5	12.2
	Euro 4	24.5	36.5	12.2
	Euro 5, 6, 6 RDE and later	0.3	0.44	0.15

Table 3-81: PCDD, PCDF and PCB emission factors for heavy duty diesel vehicles, motorcycles and mopeds

Vehicle Category	Emission Standard	PCDD [pg I-Teq/km]	PCDF [pg I-Teq/km]	PCB [pg/km]
Diesel Heavy Duty	pre-Euro	25	38	10.9
	Euro 1	25	38	12.6
	Euro 2	25	38	12.6
	Euro 3	25	38	12.6
	Euro 4	25	38	12.6
	Euro 5	0.31	0.45	0.15
	Euro 6 and later	0.16	0.24	0.08
Motorcycles	pre-Euro	10.3	21.2	31.5
	Euro 1	13	19	6.4
	Euro 2	13	19	6.4
	Euro 3	2.7	4.1	1.36
	Euro 4	2.7	4.1	1.36
	Euro 5	2.7	4.1	1.36
	Euro 6	2.7	4.1	1.36
Mopeds	pre-Euro	10.3	21.2	31.5
	Euro 1	13	19	6.4
	Euro 2	13	19	6.4
	Euro 3	2.7	4.1	1.36
	Euro 4	2.7	4.1	1.36
	Euro 5	2.7	4.1	1.36
	Euro 6	2.7	4.1	1.36

With regard to HCB, emission factors are not given due to a complete lack of relevant data from road transport. An initial approach was to gather the emission factors from other sources (industrial, waste combustion, ship engines, etc.). However, due to the high variance of the emission factors from these sources, it was decided that more relevant testing is needed to develop emission factors that better represent road vehicles. When compared to the most similar source found, a ship's engine, it cannot be considered that a typical road vehicle's combustion is similar. In addition, the ambient air that a ship uses has a much higher concentration of chlorine than that of an average road vehicle, a factor that is connected to the formation of polychlorinated substances. It was therefore decided to suspend the development of emission factors for HCB from road vehicles until more relevant data have become available.

Heavy metals

Emissions of heavy metals are calculated by means of equation (21). Table 3-82 presents the apparent heavy metal emission factors. These values have been calculated by encompassing the impact of engine wear to the heavy metal emissions. Therefore, by multiplying these apparent factors with fuel consumption, it is expected that the combined emissions of fuel and engine wear are estimated.

Table 3-82: Heavy metal emission factors for all vehicle categories in ppm/wt fuel

Category	Pb	Cd	Cu	Cr	Ni	Se	Zn	Hg	As
Passenger cars, petrol	0.0016	0.0002	0.0045	0.0063	0.0023	0.0002	0.033	0.0087	0.0003
Passenger cars, diesel	0.0005	5 E-05	0.0057	0.0085	0.0002	0.0001	0.018	0.0053	0.0001
LCVs, petrol	0.0016	0.0002	0.0045	0.0063	0.0023	0.0002	0.033	0.0087	0.0003
LCVs, diesel	0.0005	5 E-05	0.0057	0.0085	0.0002	0.0001	0.018	0.0053	0.0001
HDVs, petrol	0.0016	0.0002	0.0045	0.0063	0.0023	0.0002	0.033	0.0087	0.0003
HDVs, diesel	0.0005	5 E-05	0.0057	0.0085	0.0002	0.0001	0.018	0.0053	0.0001
L-category	0.0016	0.0002	0.0045	0.0063	0.0023	0.0002	0.033	0.0087	0.0003

Emissions of heavy metals from lubricant consumption are calculated by means of equation (22). Table 3-83 presents the apparent heavy metal emission factors.

Table 3-83: Heavy metal emission factors for all vehicle categories in ppm/wt lubricant

Category	Pb	Cd	Cu	Cr	Ni	Se	Zn	Hg	As
Passenger cars, petrol	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0
Passenger cars, diesel	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0
LCVs, petrol	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0
LCVs, diesel	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0
HDVs, petrol	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0
HDVs, diesel	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0
L-category	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0

Emission degradation functions

Table 3-84 and Table 3-85 provide the Ad and Bd coefficients of the equation to determine the deterioration of emission performance of petrol and diesel passenger cars and light commercial vehicles.

Table 3-84 Deterioration coefficients for petrol passenger cars and light commercial vehicles

Euro Standard	Pollutant	A_M	B_M
Euro 1	CO	8.50E-06	0.575
	NOx	1.55E-05	0.225
	VOC	4.93E-06	0.753
Euro 2	CO	5.00E-06	0.750
	NOx	1.35E-05	0.325
	VOC	4.93E-06	0.753
Euro 3	CO	1.00E-05	0.500
	NOx	1.27E-05	0.365
	VOC	8.10E-07	0.960

Euro 4	CO	5.00E-06	0.750
	NOx	5.00E-06	0.750
	VOC	8.10E-07	0.960
Euro 5	CO	7.00E-06	0.650
	NOx	1.50E-05	0.250
	VOC	3.86E-06	0.807
Euro 6	CO	1.28E-06	0.936
	NOx	2.08E-06	0.896
	VOC	3.86E-06	0.807

Table 3-85 Deterioration coefficients for diesel passenger cars and light commercial vehicles

Euro Standard	Pollutant	A_M	B_M
Euro 1	CO	0.00E+00	1.0000
	NOx	0.00E+00	1.0000
	VOC	7.12E-06	0.6440
Euro 2	CO	2.50E-06	0.8750
	NOx	2.50E-06	0.8750
	VOC	7.12E-06	0.6440
Euro 3	CO	1.50E-06	0.9250
	NOx	1.50E-06	0.9250
	VOC	7.12E-06	0.6440
Euro 4	CO	3.00E-07	0.9850
	NOx	3.00E-07	0.9850
	VOC	7.12E-06	0.6440
Euro 5	CO	3.00E-07	0.9850
	NOx	3.00E-07	0.9850
	VOC	7.12E-06	0.6440
Euro 6	CO	2.32E-05	-0.1596
	NOx	1.82E-06	0.9090
	VOC	7.12E-06	0.6440

Fuel effects

Table 3-86, Table 3-87 and Table 3-88 provide the correction functions required to estimate the effect of fuel properties on emissions, according to subsection 4.6.

The use of biodiesel as a blend with diesel may also lead to some changes in emissions. The values proposed in Table 3-89 are differences in emissions caused by different blends with fossil diesel and correspond to a Euro 3 vehicle/engine technology. The effect of biodiesel on other technologies may vary, but the extent of the variation is difficult to estimate in the absence of detailed data. With regard to NO_x, CO_2 and CO, any effect of technology should be negligible, given the marginal effect of biodiesel on these pollutants in general. The effect of biodiesel on PM for different technologies is more difficult to assess. For older diesel technologies with no advanced combustion concepts and aftertreatment systems, biodiesel may lead to a higher reduction than the one shown in Table 3-89, because the presence of a carbon-oxygen chemical bond reduces the PM formation by intervening on its chemical mechanism. For more recent technologies, with ultra-high-pressure combustion and aftertreatment, the biodiesel effect is difficult to predict. On one hand, the chemical mechanism demotes PM formation. On the other hand, the different physical properties of the fuel (viscosity, surface tension, gum content, etc.) may change the flow characteristics and affect the in-cylinder spray development. This may lead to poor combustion and increase soot formation. Hence, the values proposed in Table 3-89 should be used with care for post-Euro 3 diesel technologies.

Table 3-86: Relations between emissions and fuel properties for passenger cars and light commercial 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)]
NO_x	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)]

Note: 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 3-87: Relations between emissions and fuel properties for diesel passenger cars and light commercial vehicles

Pollutant	Correction factor equation
CO	Fcorr=-1.3250726 + 0.003037 × DEN – 0.0025643 × PAH – 0.015856 × CN + 0.0001706 × T95
VOC	Fcorr=-0.293192 + 0.0006759 × DEN – 0.0007306 × PAH – 0.0032733 × CN – 0.000038 × T95
NOx	Fcorr=1.0039726 – 0.0003113 × DEN + 0.0027263 × PAH – 0.0000883 × CN – 0.0005805 × T95
PM	Fcorr=(-0.3879873 + 0.0004677 × DEN + 0.0004488 × PAH + 0.0004098 × CN + 0.0000788 × T95) × [1 – 0.015 . × (450 – S)/100]

Note: DEN = Density at 15 °C [kg/m^3], S = Sulphur content in ppm, PAH = Polycyclic aromatics content in %, CN = Cetane number, T95 = Back-end distillation in °C.

Table 3-88: 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 × T95
VOC	Fcorr = 1.61466 – 0.00123 × DEN + 0.00133 × PAH – 0.00181 × CN – 0.00068 × T95
NOx	Fcorr = -1.75444 + 0.00906 × DEN – 0.0163 × PAH + 0.00493 × CN + 0.00266 × T95
PM	Fcorr = [0.06959 + 0.00006 × DEN + 0.00065 × PAH – 0.00001 × CN] × [1-0.0086 × (450 – S)/100]

Note: 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

Table 3-89: Effect of biodiesel blends on diesel vehicle emissions

Pollutant	Vehicle type	B10	B20	B100
CO_2	Passenger cars	-1.5 %	-2.0 %	
	Light commercial vehicles	-0.7 %	-1.5 %	
	Heavy-duty vehicles	0.2 %	0.0 %	0.1 %
NO_x	Passenger cars	0.4 %	1.0 %	
	Light commercial vehicles	1.7 %	2.0 %	
	Heavy-duty vehicles	3.0 %	3.5 %	9.0 %
PM	Passenger cars	-13.0 %	-20.0 %	
	Light commercial vehicles	-15.0 %	-20.0 %	
	Heavy-duty vehicles	-10.0 %	-15.0 %	-47.0 %
CO	Passenger cars	0.0 %	-5.0 %	
	Light commercial vehicles	0.0 %	-6.0 %	
	Heavy-duty vehicles	-5.0 %	-9.0 %	-20.0 %
HC	Passenger cars	0.0 %	-10.0 %	
	Light commercial vehicles	-10.0 %	-15.0 %	
	Heavy-duty vehicles	-10.0 %	-15.0 %	-17.0 %

Species profiles

VOC Speciation

The separation of NMVOCs into different compounds is given in Table 3-90a and Table 3-90b. The recent study of Baptiste Marques et al. (2022)) has been used to allocate NMVOC emissions to groups (alkanes, cycloalkanes, alkenes, alkynes) while values from older studies have been utilized for fractions of the different species in each group (BUWAL, 1994; TNO, 1993; Volkswagen, 1989; Umweltbundesamt, 1996). The fractions in the Tables are applied to the total NMVOC emissions from conventional (pre-Euro 1) or closed-loop-catalyst (Euro 1 and later) petrol passenger cars and light commercial vehicles, diesel passenger cars and light commercial vehicles, diesel heavy-duty vehicles and LPG passenger cars. Common speciation is proposed for diesel passenger cars and light commercial vehicles, regardless of the combustion concept (DI or IDI).

The NMVOC speciation for four-stroke motorcycles is estimated using fractions derived from conventional petrol 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 3-90b shows the total sum of these fractions. It is assumed that the remaining fraction consists of PAHs and POPs.

Table 3-90a: Composition of NMVOC in exhaust emissions (alkanes, cycloalkanes, alkenes, alkynes)

Group	Species	NMVOC Fraction (% wt.)						
		Petrol 4 stroke			Diesel PC & LCV (IDI & DI)		HDV	LPG
		Convent.	Euro 1 - 4	Euro 5 & on	Convent. – Euro 4	Euro 5 & on		
ALKANES	ethane	1.65	3.19	3.08	0.33	0.27	0.03	2.34
	propane	0.47	0.65	0.63	0.11	0.09	0.10	49.85
	butane	2.90	5.24	5.06	0.11	0.09	0.15	15.50
	isobutane	1.29	1.59	1.53	0.07	0.06	0.14	6.95
	pentane	1.78	2.15	2.07	0.04	0.03	0.06	0.35
	isopentane	4.86	6.81	6.57	0.52	0.42		1.26
	hexane	1.29	1.61	1.55				
	heptane	0.36	0.74	0.71	0.20	0.16	0.30	0.18
	octane	0.56	0.53	0.51	0.25	0.20		0.04
	2-methylhexane	0.80	1.48	1.43	0.45	0.36	0.63	0.25
	nonane	0.06	0.16	0.15	0.67	0.54		0.01
	2-methylheptane		0.57	0.55	0.12	0.10	0.21	0.09
	3-methylhexane	0.56	1.14	1.10	0.22	0.18	0.35	0.19
	decane	0.22	0.19	0.18	1.18	0.95	1.79	
	3-methylheptane	0.40	0.54	0.52	0.20	0.16	0.27	0.08
	Alkanes C10-C12	0.03	1.76	1.70	2.15	1.73		0.01
	Alkanes C>13	0.06	1.45	1.40	17.91	14.38	27.50	
CYCLOALKANES	All	0.88	1.14	0.50	0.65	1.80	1.16	0.10
ALKENES	ethylene	8.71	7.30	0.198	10.97	2.70	7.01	5.20
	propylene	4.87	3.82	0.103	3.60	0.89	1.32	5.19
	propadiene		0.05	0.001				
	1-butene	0.50	0.73	0.020				
	isobutene	4.21	2.22	0.060	1.11	0.27	1.70	0.63
	2-butene	1.27	1.42	0.038	0.52	0.13		0.53
	1,3-butadiene	1.42	0.91	0.025	0.97	0.24	3.30	0.15
	1-pentene	0.09	0.11	0.003				
	2-pentene	0.23	0.34	0.009				
	1-hexene		0.17	0.005				
	dimethylhexene		0.15	0.004				
ALKYNES	1-butine	0.05	0.21	0.006				
	propine	0.76	0.08	0.002				
	acetylene	5.50	2.81	0.076	2.34	0.58	1.05	1.28

Table 3-90b: Composition of NMVOC in exhaust emissions (aldehydes, ketones, aromatics)

Group	Species	NMVOC Fraction (% wt.)						
		Petrol 4 stroke			Diesel PC & LCV (IDI & DI)		HDV	LPG
		Convent.	Euro 1 - 4	Euro 5 & on	Convent. – Euro 4	Euro 5 & on		
ALDEHYDES	formaldehyde	2.08	1.70	1.175	12.00	13.28	8.40	1.56
	acetaldahyde	0.59	0.75	0.518	6.47	7.16	4.57	1.81
	acrolein	0.16	0.19	0.131	3.58	3.96	1.77	0.59
	benzaldehyde	0.60	0.22	0.152	0.86	0.95	1.37	0.03
	crotonaldehyde	0.02	0.04	0.028	1.10	1.22	1.48	0.36
	methacrolein		0.05	0.035	0.77	0.85	0.86	0.10
	butyraldehyde		0.05	0.035	0.85	0.94	0.88	0.11
	isobutanaldehyde				2.09	2.31	0.59	
	propionaldehyde	0.11	0.05	0.035	1.77	1.96	1.25	0.70
	hexanal				0.16	0.18	1.42	
	i-valeraldehyde				0.11	0.12	0.09	0.01
	valeraldehyde		0.01	0.007	0.41	0.45	0.40	
	o-tolualdehyde	0.19	0.07	0.048	0.24	0.27	0.80	
	m-tolualdehyde	0.38	0.13	0.090	0.34	0.38	0.59	
	p-tolualdehyde	0.19	0.06	0.041	0.35	0.39		
KETONES	acetone	0.21	0.61	0.421	2.94	3.25		0.78
	methylethlketone	0.11	0.05	0.035	1.20	1.33		
AROMATICS	toluene	12.84	10.98	16.01	0.69	0.13	0.01	1.22
	ethylbenzene	4.78	1.89	2.76	0.29	0.05		0.24
	m,p-xylene	6.66	5.43	7.92	0.61	0.11	0.98	0.75
	o-xylene	4.52	2.26	3.30	0.27	0.05	0.40	0.26
	1,2,3 trimethylbenzene	0.59	0.86	1.25	0.25	0.05	0.30	0.05
	1,2,4 trimethylbenzene	2.53	4.21	6.14	0.57	0.11	0.86	0.25
	1,3,5 trimethylbenzene	1.11	1.42	2.07	0.31	0.06	0.45	0.08
	styrene	0.57	1.01	1.47	0.37	0.07	0.56	0.02
	benzene	6.83	5.61	8.18	1.98	0.37	0.07	0.63
	C9	3.12	4.21	6.14	0.78	0.14	1.17	0.25
	C10		3.07	4.48				
	C>13	6.01	3.46	5.04	13.37	2.47	20.37	
TOTALS (all NMVOC species)		**99.98**	**99.65**	**97.30**	**99.42**	**68.90**	**96.71**	**99.98**

NO_x speciation

Nitrogen oxides (NO_x) in vehicle exhausts mainly consist of NO and NO_2. The NO_2 mass fraction of total NO_x (primary NO_2) is of particular importance due to the higher toxicity of NO_2 compared to NO. This mass fraction is quoted as f-NO_2, in consistency with the AQEG (2006) report. Table 3-91 provides the range of f-NO_2 values (expressed as a percentage) developed in the framework of two relevant studies in Europe. The AEAT (2007) study was performed on behalf of DG Environment within a project aiming at assessing air quality targets for the future. The TNO study refers to national data used for the NO_2 emission assessment in the Netherlands (Smit, 2007). The same Table includes the values suggested for use. These values correspond to the AEAT study for Euro 4 and previous vehicle technologies. In general, the TNO and AEAT studies do not differ significantly for older vehicle technologies. It could be considered that the difference is lower than the expected uncertainty in any of the values proposed, given the limited sample of measurements available and the measurement uncertainty for NO_2. The AEAT study was considered more up-to-date, given the detailed discussion within the UK concerning primary NO_2 emission rates (AQEG, 2006) and the NO_2/NO_x data provided to AEAT by LAT. The ranges proposed in the AEAT study for passenger cars have also been transferred to light commercial vehicles.

Table 3-91: Mass fraction of NO2 in NOx emissions (f-NO2)

Category	Emission standard	f-NO_2 (%)		
		AEAT Study	TNO Study	Suggested Value
Petrol PCs	pre-Euro	4	5	4
	Euro 1 — Euro 2	4	5	4
	Euro 3 — Euro 4	3	5	3
	Euro 5	3	5	3
	Euro 6 a/b/c	-	-	2
	Euro 6 d-temp	-	-	2
	Euro 6 d	-	-	2
	Euro 7	-	-	2
Diesel PCs	pre-Euro	11	20	11
	Euro 1 — Euro 2	11	20	11
	Euro 3	25	40	25
	Euro 3 with DPF	-	-	51
	Euro 4	55	40-70	55
	Euro 5	55	70	40
	Euro 6 a/b/c	-	-	30
	Euro 6 d-temp	-	-	20
	Euro 6 d	-	-	20
	Euro 7	-	-	20
LPG PCs	pre-Euro	5	5	5
	Euro 1 — Euro 3		5	5
	Euro 4		5	5
	Euro 5		-	5
	Euro 6		-	5
	Euro 7		-	5
E85 PCs	Euro 4	-	-	3
	Euro 5	-	-	3
	Euro 6	-	-	2
	Euro 7	-	-	2
CNG PCs	Euro 4	-	-	3
	Euro 5	-	-	3
	Euro 6	-	-	2
	Euro 7	-	-	2
Petrol LCVs	pre-Euro	-	5	4
	Euro 1 — Euro 2	-	5	4
	Euro 3 — Euro 4	-	5	3
	Euro 5	-	5	3
	Euro 6 a/b/c	-	-	2
	Euro 6 d-temp	-	-	2
	Euro 6 d	-	-	2
	Euro 7	-	-	2
Diesel LCVs	pre-Euro	-	20	11
	Euro 1 — Euro 2	-	20	11
	Euro 3	-	40	25
	Euro 4	-	40-70	55
	Euro 5	-	70	40
	Euro 6 a/b/c	-	-	30
	Euro 6 d-temp	-	-	20
	Euro 6 d			20
	Euro 7	-	-	20
HDVs (ETC)	pre-Euro	11	10	11
	Euro I — Euro II	11	10	11

	Euro III	14	10	14
	Euro IV	10	10	14
	Euro V	-	10	10
	Euro VI	-	-	10
	Euro VII	-	-	10
	Euro III+CRT	35	-	35

With regard to Euro 5 and, in particular, Euro 6 diesel passenger cars, the exact configuration of the exhaust after-treatment system is a decisive factor in the f-NO_2 values. The use of an LNT may lead to f-NO_2 values of above 40%, while the use of SCR limits f-NO_2 to a moderate 10-20% in real-world conditions. However, if a catalysed DPF follows the SCR, then this could increase f-NO_2 levels to up to 50%. A Euro 6 diesel passenger car without any deNO$_x$ aftertreatment has demonstrated f-NO_2 values that are at petrol car levels (2.5%). This concept is not considered to be popular between individual manufacturers. Thus, a wide range of possible values for f-NO_2 exists for diesel Euro 6 cars, and the actual average value will depend on the share of each aftertreatment configuration to the total vehicle fleet. The suggested value in Table 3-91 assumes SCR to be the dominant de-NO$_x$ technology with some 70% of SCRs preceding the DPF and 30% of SCRs following the DPF.

With regard to petrol passenger cars, current evidence suggests that the NO_2 emissions from late vehicle technologies will remain minimal. The efficiency of the three-way catalyst has led to a reduction in NO_x emissions over the consecutive Euro-level vehicles, and at the same time kept f-NO_2 levels low, at 3%.

The f-NO_2 values for Euro V and Euro VI trucks remain relatively low. In all commercial applications, the SCR is installed downstream of the DPF, so NO remains well controlled. A special case is also presented in Table 3-91 for those earlier heavy-duty vehicles (Euro III) retrofitted with continuous regeneration particle filters (CRT). The DPF installed in this case disproportionally increases the f-NO_2.

PM speciation and black carbon

Exhaust PM mainly consists of elemental carbon (EC), organic carbon (OC) and inorganic components including metallic ash and ions. The PM speciation is important both because this affects the health and environmental impacts of the emitted particles and also because this is a necessary input to atmospheric modelling studies. Therefore, different literature values have been collected and average EC and OC values have been proposed (Ntziachristos et al., 2007).

The variability of the data collected from tunnel, roadway and dynamometer studies, and the uncertainties in the measurement of, in particular, organic carbon (OC), indicate that exhaust PM speciation is bound to be highly uncertain. Because of this uncertainty, mean EC and black carbon (BC) values are considered practically equal in this chapter (e.g. Battye & Boyer; May et al., 2010; Flanner et al., 2007). Although it is known that EC and BC definitions and determination methods differ, this is considered to be of inferior importance compared to the overall uncertainty in determining either of them per vehicle emission control technology.

Despite overall uncertainties, reliable BC/OC ratios can be developed, because there is a general agreement in the measurements from tunnel and laboratory studies with regard to the emission characteristics of diesel and petrol vehicles. The effect of different technologies (e.g. oxidation catalyst, diesel particle filter) on emissions is also rather predictable.

Table 3-92 suggests ratios between organic material (OM) and black carbon (OM/BC) and BC/$PM_{2.5}$ (both expressed as percentages) that can be applied to the exhaust PM emissions for different vehicle technologies. ‘Organic material’ is the mass of organic carbon corrected for the hydrogen content of the compounds collected. The sources of these data, and the methodology followed to estimate these values, are given in Ntziachristos et al. (2007). An uncertainty range is also proposed, based upon the values in the literature. The uncertainty is in percentage units and is given as a range for both ratios proposed. For example, if the OM/EC ratio for a particular technology is 50 % and the uncertainty is 20 %, this would mean that the OM/EC ratio is expected to range from 40 % to 60 %. This is the uncertainty expected on fleet-average emissions, and not on an individual vehicle basis; Individual vehicles in a specific category may exceed this uncertainty range. The ratios also correspond to hot operation.

The cold start PM and BC emissions of light-duty vehicles are revised since COPERT v5.8 based on data received from VTT Technical Research Centre of Finland Ltd (Aakko-Saksa, et al. 2020). VTT had recently conducted a study on BC emission factors for passenger cars in very cold temperatures. The focus is on the resulting exhaust emissions among the different fuels and Euro standards at -7°C. European chassis dynamometer driving cycle (NEDC) was used for the test. Regarding black carbon, the study concluded that they are about 50% of the total PM cold emissions for Euro 6 petrol cars and 20% for Euro 6 diesel cars.

Table 3-92: Split of hot PM in elemental (BC) and organic mass (OM)

Category	Euro standard	$BC/PM_{2.5}$ (%)	OM/BC (%)	Uncertainty (%)
Petrol PC and LCV	PRE-ECE	2	4900	50
	ECE 15 00/01	5	1900	50
	ECE 15 02/03	5	1900	50
	ECE 15 04	20	400	50
	Open loop	30	233	30
	Euro 1	25	250	30
	Euro 2	25	250	30
	Euro 3	15	300	30
	Euro 4 and later	15	300	30
Diesel PC and LCV	Conventional	55	70	10
	Euro 1	70	40	10
	Euro 2	80	23	10
	Euro 3	85	15	5
	Euro 4	87	13	5
	Euro 3, Euro 4, Euro 5 and later Equipped with DPF and fuel additive	10	500	50
	Euro 3, Euro 4, Euro 5 and later equipped with a catalysed DPF	20	200	50
Diesel HDV	Conventional	50	80	20
	Euro I	65	40	20
	Euro II	65	40	20
	Euro III	70	30	20
	Euro IV	75	25	20
	Euro IV	75	25	20
	Euro VI	15	300	30
L-category	Conventional 2 stroke	10	900	50
	Euro 1 2 stroke	20	400	50
	Euro 2 2 stroke	20	400	50
	Conventional 4 stroke	15	560	50
	Euro 1 4 stroke	25	300	50
	Euro 2 4 stroke	25	300	50
	Euro 3 4 stroke	25	250	50

The values in Table 3-92 originate from available data in the literature and engineering estimates of the effects of specific technologies (catalysts, DPFs, etc.) on emissions. The estimates are also based on the assumption that low-sulphur fuels (< 50 ppm t. S) are used. Hence, the contribution of sulphate to PM emissions is generally low. In cases where advanced aftertreatment is used (such as catalysed DPFs), then EC and OM do not add up to 100 %. The remaining fraction is assumed to be ash, nitrates, sulphates, water and ammonium salts.

4 Data quality

4.1 Completeness

It should be considered that all significant exhaust emissions from road transport must have been addressed by following the methodology described in the preceding sections. Non-exhaust emissions induced by vehicles' operation (fuel evaporation and PM from the wear of components) are addressed in separate chapters.

4.2 Avoiding double counting with other sectors

Petrol and, in particular, diesel fuel sold by gas stations may also be used for off-road machinery (e.g. agriculture tractors). Attention should be given so that the fuel consumption reported for road transport does not include sales for off-road use.

In addition, care should be given not to include CO_2 emissions produced by the combustion of biofuels (bioethanol, biodiesel, and biogas). Section 0.C explains how the calculation of total Greenhouse gas emissions should be reported when biofuels are blended with fossil fuels. According to the IPCC 2006 Guidelines, CO_2 emissions from the production of biofuels are reported in the Land Use, Land-Use Change and Forestry sector, while CO_2 from the combustion of biofuels should not be reported. This does not apply to other greenhouse gases produced when combusting biofuels (CH_4, N_2O). These should be included in the reporting of greenhouse gas emissions from road transport.

Finally, double-counting may occur in countries where gas used in CNG or LPG processes results from coal gasification. Also, in this case, coal-derived CO_2 is part of industrial procedures and the resulting CO_2 from the combustion of the derived gas should not be counted in road transport totals.

4.3 Verification

A few remarks on the verification of road transport emission inventories are presented in the following paragraphs. For a complementary discussion of these issues, refer to the chapter on 'Inventory management, improvement and QA/QC' in this Guidebook and the studies referenced therein. In general, these approaches can be categorised as either 'soft' or 'ground truth' verification methods. Some detail of methods applied to verify emission inventorying models is provided by Smit et al. (2010).

Soft verification: This mainly refers to a *comparison of alternative estimates*: alternative estimates can be compared with each other to infer the validity of the data, based on the degree of agreement. This process can help to homogenise the data collected with different methods. For example, a comparison of an inventory produced by a Tier 2 method (distance driven based) with an inventory produced by a Tier 1 method (fuel consumed based) can provide two alternative methods of estimating the same inventory. These two can be used to verify the calculations of either method. Depending on the reliability of the source of data, one may need to correct either the reported fuel consumption or the distance travelled.

Ground truth verification: This mainly refers to alternative scientific methods that can be used to physically verify the model calculations. These methods may be applied to verify either the complete inventory or the emission factors used to develop the inventory. For the verification of the emission factors, the following methods are most common:

- *Remote sensing studies*: In such studies, measurement devices are setup in specific areas (junctions, ramps to highways, …) and determine pollutant concentrations directly in the exhaust plume of the passing-by vehicles. Concentrations are converted to pollutant emissions per unit of fuel consumed, using the CO_2 concentration in the exhaust and the carbon balance between the engine inlet and exhaust. This technique has the advantage of producing results referring to several vehicles (a day-long sampling period may correspond to a few thousand vehicle samples for dense traffic conditions), including a representative portion of high and ultra emitters. However, momentary concentrations of pollutants are only measured, which are specific to particular vehicle operations in the sampling area. In addition, it is often cumbersome to know the emission control technology of passing-by vehicles and therefore to establish a link between emission levels and emission control technologies.

- *Tunnel studies*: In these studies, road tunnels are used as laboratories to study the emissions of vehicles in the tunnel. The difference in pollutant concentration between the inlet and the outlet of the tunnel is measured and converted to emission levels by combining with the air flowrate through the tunnel. This is associated with the flow of vehicles through the tunnel and emission factors are calculated. Tunnels offer a longer sampling period than remote sensing and provide average emission factors over this period. However, speed in tunnels is usually constant, therefore emission factors may not be representative of actual vehicle operation. In addition, emissions are a mix of vehicles of different fuel and emission control technology, hence it is not straightforward to distinguish between the different vehicle types. Tunnel verification usually provides emission factors for specific vehicle categories (e.g. petrol passenger cars) but not technologies (e.g. Euro 1, 2, …).

- *On-board and laboratory measurements*: These are the two methods that are primarily used to develop, rather than verify, emission factors. However, these can be also used for verification. In a laboratory, vehicles are driven over a predetermined driving pattern and emissions are measured with analysers. This provides a detailed measurement of emissions of a known vehicle over a specific driving cycle. This represents high-quality data to develop emission factors, as all conditions are known. On the other hand, these measurements are expensive and time-consuming and a relatively small dataset becomes available in this way. With on-board measurements, vehicles are equipped with on-board instrumentation and are driven on a road network. This can provide a detailed picture of emissions under real-world vehicle operation. On the other hand, equipping a vehicle with all instrumentation and data-logging is technically demanding. Also, some measurement problems still exist for such systems. However, these two methods result in the most detailed recording of emissions for single vehicles. Both methods can be used to verify emission factors. However, it should be noted that the emission factors used in this Guidebook correspond to the average emission value of a large number of cars. Single cars may significantly deviate from this average, even for the same technology level. It is recommended that emission factors are verified using the average values of a sufficient vehicle sample (at least 4-5 cars).

Different methods can be used for the verification of complete inventories, i.e. verifying both the emission factors and the activity data. In general, the difficulty in verifying a complete inventory increases with the area covered by the inventory. That is, it is almost impossible to verify a complete national inventory by ground truth methods. However, the principles of different methods may be used at varying degrees of success to attempt an independent verification. Methods that can be used for complete inventory verification include:

- *Inverse air quality modelling*: In these studies, ambient concentrations (mg/m^3) are converted back to emissions by taking into account the meteorological conditions and the physical location of the measuring station, the emission source(s) and the level of activity. This method has the advantage of being based on actual pollutant concentrations. Disadvantages include the mathematical complication of the problem and the uncertainty introduced by the contribution of emissions not taking place in the area being studied. For example, this method can be used to verify an emissions inventory for a road network in a city, with concentrations not only being affected by the particular roads but also by nearby domestic or industrial sources.

- *Mass-balance techniques*: In these studies, emission fluxes (kg/h) are determined through the measurement of ambient pollutant concentrations upwind and downwind of specific areas, where particular activity is taking place (i.e. upwind and downwind of a busy highway). These can be conducted at different heights and emissions over a differential volume can be calculated. The advantage of the technique is that emissions from other sources are, to a certain extent, corrected by taking into account the upwind concentrations. However, some uncertainty is introduced by the wind flow conditions which cannot be exactly determined through this differential volume section.

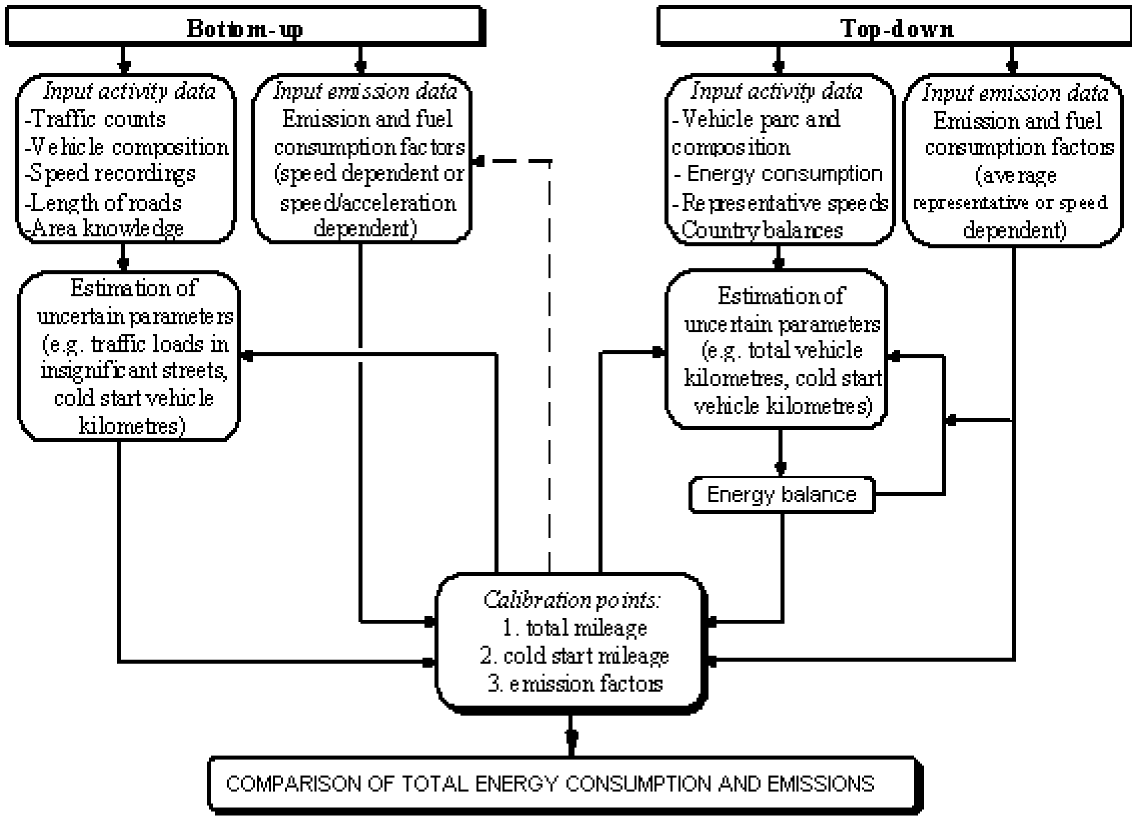
There is extensive scientific literature which deals with the verification of the emission factors and the methodology proposed in the Tier 3 method of this Guidebook chapter. Examples of such verification studies include the study of Broderick and O’Donoghue (2007), Librando et al. (2009), Johansson C et al. (2009), Beddows and Harrison (2008) and several others.

4.4 Bottom-up vs. top-down inventories

Spatially and temporally disaggregated emission inventories are necessary for reliable and accurate air quality predictions. For example, the ambient concentration of emissions in an urban hot-spot cannot be calculated using year-long average data, since concentrations depend both on the profile of emission rate and the meteorological conditions (temperature wind speed, direction). These follow a temporal profile. In addition, the concentration depends primarily on emissions produced in the nearby area and not the nation-wide or city-wide emissions. Traffic conditions may differ in various parts of the city given the hour of the day, because they may serve different transportation needs. Therefore, the spatial and temporal resolution of road transport emissions is particularly important in relation to air pollution assessments. This temporal profile may require a bottom-up rather than a top-down approach in order to address it.

Moreover, bottom-up inventories are important when trying to allocate national emissions to individual territories in the country. This is done most of the time by using proxies of transport activity to allocate aggregated emissions, such as the citizens’ population to different areas, the length of roads, etc. However, this approach may lead to higher or lower emissions for particular regions as such proxies are not always representative of real traffic activity. For example, the permanent population in the industrial district of a city may be very limited but traffic may be very dense. Moreover, industrial areas are linked to the activity of heavy commercial vehicles which are not present in the more domestic parts of the city. Using the citizens’ population as a proxy to estimate road transport activity in the industrial area would therefore significantly underestimate emissions. In such cases, bottom-up inventories need to be built in the different territories and any aggregated results (top-down) should be allocated in proportion to the bottom-up inventory calculations. Figure 4-1 illustrates a methodological approach that can be followed in order to make maximum use of both approaches in the creation of an emission inventory. In principle, the top-down and bottom-up estimates of motor vehicle emissions are carried out independently. In each case, the most reliable information (such as traffic counts, statistics of vehicle registrations and measured emission factors) forms the basis of the calculation. Uncertain parameters are then assessed according to relevant knowledge and reasonable assumptions. 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, annual cold-start vehicle kilometres, and emission factors) are compared, and any discrepancies which are identified are resolved. This reconciliation procedure leads to a re-estimation of the most uncertain parameters of each approach. After the activity and emission data have been reconciled, the next step is to calculate total energy consumption and emissions with both approaches and to compare the aggregated results. The calculated and statistical energy consumption should not greatly vary, otherwise, corrections may be necessary for one or both of the approaches.

Figure 4-1: Proposed reconciliation method in applying bottom-up and top-down approaches when building an urban emission inventory



The scheme shown in Figure 4-1 gives an overview of the required information for such an approach. Several of the required data are available in most European countries. 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.

It should be evident that national emission inventories are difficult to compile in a bottom-up approach. The reason is that this would require an immense amount of data which can be hardly found and reconciled for a complete country. It would also not offer a better calculation at this aggregated level. An exception to these is relatively small countries (e.g. Cyprus, Luxembourg) where the necessary data is easier to collect. However, if a country-wide road transport inventory should be developed with a bottom-up approach, then the following steps would have to be followed:

1. First, urban inventories should be compiled for the major cities (e.g. cities > 20000 inhabitants).

2. Second, emission inventories for the highway network should be developed. Traffic on highways is monitored both with respect to average speed and traffic counts during the day. This is input that can be directly used to calculate emissions with a high temporal profile.
3. Emissions in rural areas are more difficult to assess. These would require origin-destination matrices for different rural areas (city-village, village-village, …) and an estimate of the rural vehicle stock, which is not the same as the urban vehicle stock (different proportion of two-wheelers and busses, older car technologies, etc.). An approach would be to determine the length of roads according to service (e.g. major road connecting the city with village, secondary paved road, secondary unpaved road, etc.) and estimate vehicle road per service class. This can be used to estimate total activity in the rural network.

The amount of information is given in this report (statistical data and calculated values) is suitable for the compilation of national emission inventories. The application of the methodology at higher spatial resolution can be undertaken only when more detailed data are available to the user. As a general guideline, it can be proposed that the smallest area of application should be the one for which it can be considered that the fuel sold, and energy consumed in the region (statistical consumption) equals the actual consumption of the vehicles operating in the region. Zachariadis and Samaras (1997) and Moussiopoulos et al. (1996) have shown that the proposed methodology can be used with a sufficient degree of certainty at such high resolution (i.e. for the compilation of urban emission inventories with a spatial resolution of 1×1 km^2 and a temporal resolution of 1 hour).

One specific point is that the methodology provided as Tier 3 can be used to calculate cold-start emissions on a monthly basis (providing already a temporal resolution). However, special attention should be paid to the allocation of excess cold-start emissions to sub-national areas. In such a calculation, one should independently adjust the beta value (cold-start mileage) and not be based on the l_{trip} value discussed in section 0.B. This l_{trip} value and the beta equation quoted in Table 3-39 should only be used for national inventories because they are calibrated to l_{trip} distribution at a national and not a city level.

4.5 Uncertainty assessment

4.5.1 Uncertainty of emission factors

The Tier 1 and Tier 2 emission factors have been calculated from detailed emission factors and activity data using the Tier 3 method. The Tier 1 and Tier 2 emission factors will therefore have a higher level of uncertainty than those for Tier 3.

The Tier 1 emission factors have been derived from the Tier 3 methodology using 2010 fleet data for the EU-27. The upper limits of the stated ranges in the emission factors correspond to a typical uncontrolled (pre-Euro) technology fleet, and the lower limit of the range corresponds to the latest technology in 2010 (Euro 5). The suitability of these emission factors for a particular country and year depends on the similarity between the national fleet and the assumptions used to derive the Tier 1 emission factors.

The Tier 2 emission factors have been calculated based on average driving and temperature conditions for the EU-27 in 2018. These emission factors assume average urban, rural and highway driving mileage shares and speeds for the EU-27. Again, the suitability of these emission factors depends on the similarity between the national driving conditions and the average of EU-27.

The Tier 3 emission factors have been derived from experimental (measured) data collected in a range of scientific programmes. The emission factors for old-technology passenger cars and light commercial vehicles were taken from earlier COPERT/CORINAIR activities (Eggleston et al., 1989), whilst the emissions from more recent vehicles are calculated on the basis of data from the Artemis project. (Boulter and Barlow, 2005; Boulter and McCrae, 2007). The emission factors for mopeds and motorcycles are derived from the study on impact assessment of two-wheel emissions (Ntziachristos et al., 2004). Also, the emission factors of Euro 4 diesel passenger cars originate from an ad-hoc analysis of the Artemis dataset, enriched with more measurements (Ntziachristos et al., 2007).

Emission factors proposed for the Tier 3 methodology are functions of the vehicle type (emission standard, fuel, capacity or weight) and travelling speed. These have been deduced on the basis of a large number of experimental data, i.e. individual vehicles which have been measured over different laboratories in Europe and their emission performance has been summarised in a database. Emission factors per speed class are the average emission levels of the individual vehicles. As a result, the uncertainty of the emission factor depends on the variability of the individual vehicle measurements for the particular speed class. This uncertainty has been characterized in the report of Kouridis et al. (2009) for each type of vehicle, pollutant, and speed class. The tables are not repeated in this report due to their size. In general, the variability of the emission factors depends on the pollutant, the vehicle type, and the speed class considered. The standard deviations range from a few percentage units of the mean value to more than two times the emission factor value for some speed classes with limited emission information.

The distribution of individual values around the mean emission factor for a particular speed class is considered to follow a log-normal size distribution. This is because negative emission factor values are not possible and the log-normal distribution can only lead to positive values. Also, the lognormal distribution is highly skewed with a much higher probability allocated to values lower than the mean and a long tail that reaches high emission values. This very well represents the contribution of high and ultra emitters.

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

- the emission factors should only be applied within the speed ranges given in the respective Tables. These ranges have been defined according to the availability of the experimental data. Extrapolation of the proposed formulae to lower or higher speeds is therefore not advisable.
- the proposed formulae should only be used with average travelling speed, and by no means can be they considered to be accurate when only 'spot' or constant speed values are available.
- the 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 situations where the driving pattern differs substantially from the 'norm' (e.g. in areas with traffic calming).

4.5.2 Uncertainty about the emission inventory

In all cases of the application of the 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 accuracy, as long as the methodology used for estimating road traffic emissions represents a reliable image of reality. Errors when compiling an inventory may originate from two major sources:

1. Systematic errors of the emission calculation methodology. These may include errors in the determination of the emission factors and other emission-related elements (e.g. cold start modelling, default values of metals, etc.)

2. Errors in the input data provided by the inventory compiler. These refer to the activity data (vehicle parc, annual mileage, etc), fuel properties, and environmental conditions.

The uncertainty of the emission factors has been discussed in section 4.5.1. This has been mathematically determined based on the available experimental data. The most significant data input errors include:

- erroneous assumptions of vehicle usage. In many countries, the actual vehicle usage is not known. In others, data from only a few statistical investigations are available. Most important are errors in total kilometres travelled, the decrease in mileage with age, and the average trip length.
- erroneous estimates of the vehicle parc. The Tier 3 methodology proposes emission factors for 241 individual vehicle types. Detailed statistics for all the vehicle types are not available in all countries and sometimes they have to be estimated. For example, assessing the number of petrol and diesel vehicles > 2.5 t which belong to the category 'light commercial vehicles' and those which belong to the category 'heavy-duty vehicles' involves much uncertainty, since the exact numbers are not available. The same may hold for splitting a certain category into different age and technology groups, as the real numbers are again not always known.

Table 4-1 provides qualitative indications of the 'precision' which can be allocated to the calculation of the different pollutants.

Table 4-1: Precision indicators of the emission estimate for the different vehicle categories and pollutants

Vehicle Category	Pollutant							
	NO_x	CO	NMVOC	CH_4	PM	N_2O	NH_3	CO_2
Petrol passenger cars								
Without catalyst	A	A	A	A	-	C	C	A
With catalyst	A	A	A	A	-	A	A	A
Diesel passenger cars								
All technologies	A	A	A	A	A	B	B	A
LPG passenger cars	A	A	A	-	-	--	-	A
Without catalyst	A	A	A	A	D	C	C	A
With catalyst	D	D	D	D	D	D	D	A
2-stroke passenger cars	B	B	B	D	-	D	D	B
Light commercial vehicles								
Petrol	B	B	B	C	-	B	B	A
Diesel	B	B	B	C	A	B	B	A
Heavy-duty vehicles								
Petrol	D	D	D	D	-	D	D	D
Diesel	A	A	A	B	A	B	B	A
Two-wheel vehicles								
< 50 cm³	A	A	A	B	-	B	B	A
> 50 cm³ 2-stroke	A	A	A	B	-	B	B	A
> 50 cm³ 4-stroke	A	A	A	B	-	B	B	A
Cold-start emissions								
Pass. Cars conventional	B	B	B	-	-	-	-	B
Pass. Cars Euro 1 and later	B	B	B	A	-	-	-	A
Pass. Cars diesel Conv.	C	C	C	-	C	-	-	B
Pass. Cars diesel Euro I	A	A	A	A	A	-	-	A
Pass. Cars LPG	C	C	C	-	-	-	-	B
Gas. Light commercial vehicles	D	D	D	-	-	-	-	D
Diesel light commercial vehicles	D	D	D	-	D	-	-	D

Note: A: Statistically significant emission factors based on a 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.

In order to assess the uncertainty of a complete emission inventory, Kouridis et al. (2009) performed an uncertainty characterisation study of the Tier 3 emission methodology, using the COPERT 4 emission model which encompasses this methodology. Global sensitivity and uncertainty analysis was performed by characterising the uncertainty of the emission factors and the input data and by performing Monte Carlo simulations. The report of Kouridis et al. (2009) presents in detail the steps followed in this process. It is not the intention to repeat here the methodology followed in that study. However, some key points and recommendations may prove useful in quantifying and, more significantly, reducing the uncertainty of road transport inventories.

The study quantified the uncertainty of the 2005 road transport inventory in two countries. These two countries were selected as examples of a country in southern Europe with good knowledge of the stock and activity data and one country in northern Europe with poor statistics on the stock description. The difference in the territories selected (north vs south) affects the environmental conditions considered in each case.

For the compilation of the uncertainty and sensitivity analysis, the uncertainty of the input data was assessed based on available information and justified assumptions in case of no data. The uncertainty in the effect of vehicle age on the annual mileage driven was assessed by collecting information from different countries. The variability in other input data (fuel properties, temperatures, trip distance distributions, etc.) was quantified based on justified assumptions. In total, the variability of 51 individual variables and parameters was assessed. Some of these parameters were multi-dimensional.

As a first step of the uncertainty characterisation methodology, a screening test was performed. This screened the significant variables and parameters and separated them from the non-significant ones. 'Significant' in this case means that the expected variance of the particular variable affects the variance of the result by a significant amount. The significant variables in the case of the two countries are given in Table 4-2. It is evident from the table that there is a certain overlap of variables which are significant in both cases (hot emission factors, mean trip distance etc) but there are also other variables which are important only to each of the countries. For example, the country with good stock statistics has a very large number of two-wheelers. As a result, even a small uncertainty in their mileage or total stock will significantly add to the uncertainty of the final result. This is not the case in a country with weak stock statistics where two-wheelers are relatively fewer. In contrast, this second country has only a rough knowledge of the allocation of vehicles to different technologies and this shows up as a significant variable.

The 16 variables in the case of the country with good statistics can explain 78% (CO_2) to 91% (VOC) of the total uncertainty. This means that the remaining 35 variables can only explain ~10% of the remaining uncertainty of the result. In a country with poor statistics, the 17 variables can explain from 77% (CH_4) to 96% (NO_x) of the total uncertainty. This means that even by zeroing the uncertainty of the remaining 34 variables, the uncertainty in the case of that country would be reduced by less than 15% of its current value. Evidently, an effort should be made to reduce the uncertainty of the variables shown in Table 4-2. Reducing the uncertainty of other variables would have limited effect on the end result.

Some examples can be given to identify differences between the two countries examined: In the country with good statistics, the uncertainty in NO_x emissions is dominated by the uncertainty in the emission factor, which explains 76% of the total model uncertainty. This means that even if that country had perfect input data of zero uncertainty, the NO_x calculation would not be more than 24% less uncertain that the current calculation. In this instance, the variable that individually explains most of the uncertainty of the inventory is the hot emission factor, followed by either the heavy-duty vehicles mileage or the cold-start overemission. Other variables that are affected by the user (motorcycle and moped mileage, l_{trip}, speeds, etc.) affect the total uncertainty by 10-25%. This means that this country is an example where the uncertainty in the calculation of total emissions depends mostly on the inherent uncertainty of the model (emission factors) rather than on the uncertainty of the data provided by the inventory compiler.

Table 4-2: Variables significant for the quantification of the total emission inventory uncertainty (not by order of significance)

Variable	Significant for country with good stock statistics	Significant for country with weak stock statistics
Hot emission factor	☑	☑
Cold overemission	☑	☑
Mean trip distance	☑	☑
Oxygen to carbon ratio in the fuel	☑	☑
Population of passenger cars	☑	-
Population of light commercial vehicles	☑	☑
Population of heavy-duty vehicles	☑	☑
Population of mopeds	☑	-
Annual mileage of passenger cars	☑	☑
Annual mileage of light commercial vehicles	☑	☑
Annual mileage of heavy-duty vehicles	☑	☑
Annual mileage of urban busses	-	☑
Annual mileage of mopeds/motorcycles	☑	-
Urban passenger car speed	☑	☑
Highway passenger car speed	☑	-
Rural passenger car speed	☑	-
Urban speed of light commercial vehicles	☑	-
Urban share of passenger cars	☑	-
Urban speed of light commercial vehicles	-	☑
Urban speed of busses	-	☑
Annual mileage of vehicles at the year of their registration	-	☑
The split between diesel and petrol cars	-	☑
The split of vehicles to capacity and weight classes	-	☑
The allocation of vehicles to different technology classes	-	☑

In the case of the country with poor stock statistics, the situation is quite different. In this case, the uncertainty was estimated using all available information and building submodels to estimate the distribution of vehicles to classes and technologies. This is because the allocation of vehicles to different fuels and technology classes is hardly known in this case. The uncertainty of the emission factors still remains as one of the most important variables in estimating the total uncertainty. However, other variables, such as the initial vehicle mileage and the distribution of vehicles to different types are equally important. For example, the hot and cold-start emission factor uncertainty explains only ~30% of the total VOC and CO uncertainty. The remainder is determined by values introduced by the inventory compiler. This is also true to a lesser extent also for the other pollutants. As a result, the quality of the inventory can significantly improve by collecting more detailed input data and by reducing their uncertainty.

The uncertainty analysis conducted in the study of Kouridis et al. (2009) also made possible to quantify the total uncertainty of the calculation. Table 4-3 shows the coefficient of variation (standard deviation over mean) for the different pollutants, for the two countries. In the table, pollutant CO_{2e} represents the equivalent CO_2 emission, when aggregating the greenhouse gases (CO_2, CH_4, and N_2O) weighted by their corresponding 100-year GHG GWPs. Two different uncertainty ranges are given per country. The first (w/o EC), is the uncertainty calculated without trying to respect the statistical energy consumption. This means that the calculated energy consumption can obtain any value, regardless of the statistical one. The second calculation (w. EC) filters the calculation to keep only these runs that provide energy consumption values which are within plus minus one standard deviation (7% for the country with good statistics, 11% for the country of poor statistics) of the statistical energy consumption. This is considered a reasonable filtering, as an inventory calculation which would lead to a very high or very low energy consumption value would have been rejected as non-valid.

Table 4-3: Summary of coefficients of variation Two cases are shown, one w/o correction for energy consumption, and one with correction for energy consumption.

Case	CO	VOC	CH_4	NO_x	N_2O	$PM_{2.5}$	PM_{10}	PM_{exh}	FC	CO_2	CO_{2e}
Good statistics w/o EC	30	18	44	15	33	13	13	14	7	7	7
Good statistics w. EC	19	12	34	10	26	9	8	9	3	4	4
Poor statistics w/o EC	20	18	57	17	28	18	17	19	11	11	12
Poor statistics w. EC	17	15	54	12	24	13	12	14	8	8	8

The following remarks can be made by comparing the values in Table 4-3:

1. the most uncertain emissions calculations are for CH_4 and N_2O followed by CO. For CH_4 and N_2O it is either the hot or the cold emission factor variance which explains most of the uncertainty. However, in all cases, the initial mileage value considered for each technology class is a significant user-defined parameter, that explains much of the variance. Definition of mileage functions of age is therefore significant to reduce the uncertainty in the calculation of those pollutants.
2. CO_2 is calculated with the least uncertainty, as it directly depends on fuel consumption. It is followed by NO_x and $PM_{2.5}$ which are calculated with a coefficient of variance of less than 15%. The reason is that these pollutants are dominated by diesel vehicles, with emission factors which are less variable than petrol ones.
3. the correction for energy consumption within plus/minus one standard deviation of the official value is very critical as it significantly reduces the uncertainty of the calculation in all pollutants. Therefore, good knowledge of the statistical energy consumption (per fuel type) and comparison with the calculated energy consumption is necessary to improve the quality of the inventories. Particular attention should be given when dealing with the black market of fuel and road transport fuel used for other uses (e.g. off-road applications).
4. the relative level of variance in the country with poor stock statistics appears lower than the country with good stock statistics in some pollutants (CO, N_2O), despite the allocation to vehicle technologies in the former being not well known. This is for three reasons, (a) the stock in the country with poor statistics is older and the variance of the emission factors of older technologies was smaller than new technologies, (b) the colder conditions in the former country make the cold-start of older technologies to be dominant, (c) partially this is an artefact of the method as the variance of some emission factors of old technologies was not possible to quantify. As a result, the uncertainty of the old fleet calculation may have been artificially reduced.
5. despite the relatively larger uncertainty in CH_4 and N_2O emissions, the uncertainty in total greenhouse gas emissions (CO_{2e}) is dominated by CO_2 emissions in both

countries. Therefore, improving the emission factors of N_2O and CH_4 would not offer a substantially improved calculation of total GHG emissions. This may change in the future as CO_2 emissions from road transportation decrease.

4.6 Gridding

Gridding of national road transport inventories is required when trying to assess local air quality or to have a better allocation of national emissions to particular areas. The gridding of road transport emissions data basically means to allocate national emissions to sub-national level. In other words, starting from an aggregated inventory, move in a top-down fashion to allocate emissions at a higher spatial level. The discussion and guidance provided in streamlining top-down and bottom-up approaches in section 4.4 is useful in such a process. Some additional points that need to be clarified in such a procedure are:

- urban emissions should be allocated to urban areas only, e.g. by geographically localising 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.
- 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.
- highway emissions should be allocated to highways only, in other words all roads on which vehicles are driven in accordance with the 'highway' driving pattern, not necessarily what is termed '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 the national statistics are more detailed.

4.7 Weakest aspects/priority area for improvement in current methodology

The improvement of the emission factors for road transport is an ongoing task. The most important issues that need to be improved are considered to be:

- cold-start modelling, in particular for new vehicle technologies;
- improving emission factors for hybrid and PHEV vehicles;
- improving emission factors for light commercial vehicles;
- improving emission factors of non-exhaust emissions;
- better assessment of energy consumption from new vehicle concepts, to better describe CO_2 emissions;
- introduction of alternative fuel and vehicle concepts into the methodology;
- speciation of NMVOC.

Furthermore, it should be mentioned that the estimation of emissions from road traffic might be considered a task which requires more frequent reviewing and updating than in the case of other inventory source categories. This is due to the relatively large and rapid changes in this sector over short time periods — 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 and activity data, but also the continual adaptation of the methodology.

5 Glossary

5.1 List of abbreviations

Artemis	Assessment and Reliability of Transport Emission Models and Inventory Systems
BC	Western Balkan countries: AL, BA, HR, MK, ME, RS
BEV	Battery Electric Vehicles
CAI	Controlled auto-ignition
CC (cc)	Cylinder capacity of the engine
CH_4	Methane
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2	Carbon dioxide
COPERT	Computer programme to calculate emissions from road transport
CRDPF	Continuously regenerating diesel particle filter
CVS	Constant volume sampler
DI	Direct injection
DPF	Diesel particulate filter
E85	An ethanol fuel blend of up to 85% denatured ethanol fuel and petrol by volume
EC	Elemental carbon
EEA-32	Member countries of the European Environment Agency (EU+EFTA4+TR)
EFTA-4	European Free Trade Association Countries (CH, IS, LI, NO)
ETBE	Ethyl tert-butyl ether
FC	Fuel consumption
EC	Energy consumption
GDI	Gasoline direct injection
GVW	Gross vehicle weight
HCCI	Homogeneous charge compression ignition
HDV	Heavy-duty vehicle
I&M	Inspection and maintenance
IDI	Indirect injection
IRF	International Road Federation
JRC	DG Joint Research Centre of the European Commission
LC	Lubricant consumption
LCV	Light commercial vehicle
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
MEET	Methodologies to Estimate Emissions from Transport
MTBE	Methyl tert-butyl ether
N_2O	Nitrous oxide
NATO-CCMS	NATO Committee on the Challenges to Modern Society

NGV	Natural gas vehicle
NH_3	Ammonia
NIS	Newly Independent States (AM, AZ, BY, EE, GE, KZ, KG, LV, LT, MD, RU, TJ, TM, UA, UZ)
NMVOCs	Non-methane volatile organic compounds
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
OC	Organic carbon
OM	Organic matter
Pb	Lead
PC	Passenger car
PHEV	Plug-in Hybrid Electric Vehicle
RDE	Real Driving Emissions
SCR	Selective catalyst reduction
SNAP	Selective nomenclature for air pollution
THC	Total hydrocarbons
SO_x	Sulphur oxides
VOC	Volatile organic compounds
WMTC	World motorcycle test cycle

5.2 List of symbols

A^M	emission performance degradation per kilometre
B^M	relative emission level of brand-new vehicles
bc	correction coefficient for the β-parameter for improved catalyst vehicles
E_{HOT}	total emissions during thermally stabilised (hot) engine and exhaust aftertreatment conditions
E^{CALC}	emission of a fuel-dependent pollutant (CO_2, SO_2, Pb, HM), estimated on the basis of the calculated fuel consumption
E^{CORR}	corrected emission of a fuel dependent pollutant (CO_2, SO_2, Pb, HM) on the basis of t the statistical fuel consumption
e^{COLD}/e^{HOT}	ratio of emissions of cold to hot engines
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’
FC^{CALC}	calculated fuel consumption
EC^{CALC}	calculated energy consumption
Fce_{HOT}	hot emission factor corrected for the use of improved fuel
Fcorr	emission correction for the use of conventional or improved fuel
FC^{STAT}	statistical (true) fuel consumption

EC^{STAT}	statistical (true) energy consumption
FC^{BIO}	statistical fuel consumption of biofuel
k	weight related content of any component in the fuel [kg/kg fuel]
LP	the actual vehicle load factor (expressed as a percentage of the maximum load. i.e., LP = 0 denotes an unloaded vehicle and LP = 100 represents a totally laden one)
l_{trip}	average trip length [km]
M	average mileage in [km]
Mce_{HOT}	hot emission factor corrected for degraded vehicle performance due to mileage
Mcorr	correction coefficient for emission performance degradation due to mileage
M^{MEAN}	mean fleet mileage [km]
N	number of vehicles [veh.]
$r_{H:C}$	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

5.3 List of indices

a	monthly mean
Base	referred to the base fuel quality
c	cycle (c= UDC, EUDC)
C	correction
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
j	vehicle category
k	vehicle technology
m	fuel type
Pb	lead content in fuel
r	road type (urban, rural, highway)
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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7 Point of enquiry

Enquiries concerning this chapter should be directed to the relevant leader(s) of the Task Force on Emission Inventories and Projection's expert panel on Transport. Please refer to the TFEIP website (www.tfeip-secretariat.org/) for the contact details of the current expert panel leaders.

Appendix 1 Bulk Tier 1 emission factors for selected European countries

The Tier 1 approach uses general emission factors which are averaged over a number of key parameters. A more detailed alternative would be to use data at a national level. This has been achieved by *a priori* introducing a large number of data and estimates to come up with aggregated emission factors. The production of these emission factors has been performed using the activity data from New Mobility Patterns Study: insights into passenger mobility and urban logistics[10].

In principle, for the Tier 1 method any energy consumption-related figure can substitute $FC_{j,m}$ value in equation (1). 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 an understanding of. We also propose to group the vehicle categories in Table 2-1 to come up with simplified emission factors. The split adopted is shown in Table A1-0-1, together with the range of SNAP codes included for each vehicle category j. The simplified methodology does not deal with LPG vehicles, two-stroke cars, and petrol heavy-duty vehicles because of their small contribution to a national inventory. Table A1-0-2 to Table A1-0-31 provide fuel consumption-specific emission factors for the main pollutants for a number of countries, and also for countries classified as CC4, BC and NIS. These emission factors should be combined with fuel consumption data by vehicle category to provide total emission estimates. In particular for CO_2, the emission factor corresponds to the exhaust emission and not ultimate CO_2. For definitions and a conversion between the two, refer to subsection 0. The emission factor production is based on a large number of assumptions concerning vehicle technology mix (e.g. share of passenger cars in different ECE and Euro classes), 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 these emission factors; most of the shortcomings are thoroughly discussed by Ntziachristos et. al. (2002):

- they have not been calculated strictly on the basis of national submitted data. Hence, combination with the activity data also proposed in this chapter should not be expected to provide consistent results with the official data reported by countries;
- they correspond to a fleet composition in 2010. Their accuracy deteriorates forward from this point because new technologies appear and the contribution of older technologies decreases;
- they correspond to national applications, including mixed driving conditions (urban congestion to free flow highway).

Their range of application can include:

- simplified inventories, where rough estimate of the transport contribution is required;
- calculation of emissions when a particular vehicle type is 'artificially' promoted or discouraged from circulation (e.g. dieselisation, promotion of two-wheel vehicles in urban areas, etc);

[10] New Mobility Patterns Study: insights into passenger mobility and urban logistics - European Commission (europa.eu)

- demonstration of the emission reduction potential when shifting the balance with other modes of transport.

Table A1-0-1: Vehicle categories for application of the simplified methodology and respective SNAP-like ranges from Table 2-1.

Vehicle category — j	SNAP-like code ranges included from Table 2-1
Petrol 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
Petrol light commercial vehicles < 3.5 t	07 02 01 01–07 02 01 03
Diesel light commercial 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
Two-wheel vehicles	07 04 01 00–07 05 05 03

Table A1-0-2: Bulk emission factors (g/kg fuel) (for CO2 kg/kg fuel) for Austria, year 2010

Category	Austria						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	37.39	2.35	5.05	0.25	0.82	0.02	3.16
Diesel PC	2.14	12.16	0.50	0.02	0.02	0.74	3.18
Petrol LCV	68.20	2.00	2.96	0.19	0.55	0.02	3.16
Diesel LCV	6.12	12.46	1.09	0.04	0.01	1.04	3.18
Diesel HDV	5.53	23.09	0.65	0.10	0.02	0.45	3.18
Buses	2.26	9.71	0.12	2.68	0.00	0.03	2.74
Mopeds	225.77	9.76	150.04	8.81	0.05	1.91	3.27
Motorcycles	288.66	7.23	33.50	1.97	0.06	0.55	3.14

Table A1-0-3: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Belgium, year 2010

Category	Belgium						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	48.27	4.61	7.67	0.38	0.76	0.02	3.16
Diesel PC	2.14	11.76	0.45	0.02	0.02	0.74	3.18
Petrol LCV	113.01	6.77	8.40	0.54	0.55	0.02	3.15
Diesel LCV	6.10	12.68	1.12	0.04	0.01	1.05	3.18
Diesel HDV	6.27	25.58	0.80	0.12	0.02	0.51	3.17
Buses	8.00	24.82	0.25	5.73	0.00	0.02	2.75
Mopeds	201.46	11.75	129.89	7.63	0.05	1.56	3.29
Motorcycles	219.11	5.63	23.77	1.40	0.05	0.48	3.15

Table A1-0-4: Bulk emission factors (g/kg fuel) (for CO2 kg/kg fuel) for Bulgaria, year 2010

Category	Bulgaria						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	66.52	4.96	9.83	0.49	1.16	0.02	3.17
Diesel PC	4.52	12.19	0.81	0.04	0.02	1.00	3.18
Petrol LCV	70.94	2.18	2.81	0.18	0.62	0.02	3.17
Diesel LCV	6.88	14.42	1.59	0.06	0.01	1.27	3.18
Diesel HDV	6.82	30.65	1.38	0.21	0.02	0.73	3.17
Buses	9.36	26.57	0.28	6.34	0.00	0.02	2.75
Mopeds	283.08	8.02	168.48	9.89	0.05	2.39	3.25
Motorcycles	400.81	7.60	43.66	2.56	0.06	0.62	3.15

Table A1-0-5: Bulk emission factors (g/kg fuel) (for CO2 kg/kg fuel) for Cyprus, year 2010

Category	Cyprus						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	30.87	3.95	6.38	0.32	0.99	0.02	3.17
Diesel PC	3.27	10.97	0.74	0.04	0.02	0.76	3.18
Petrol LCV	59.37	4.23	4.76	0.31	0.64	0.02	3.17
Diesel LCV	7.77	16.08	1.37	0.05	0.01	1.34	3.18
Diesel HDV	6.97	31.88	1.54	0.24	0.02	0.77	3.18
Buses	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mopeds	217.80	11.45	139.26	8.18	0.05	1.72	3.29
Motorcycles	98.25	4.07	15.44	0.91	0.06	0.40	3.15

Table A1-0-6: Bulk emission factors (g/kg fuel) (for CO2 kg/kg fuel) for Czech Republic, year 2010

Category	Czech Republic						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	88.21	8.34	12.64	0.63	0.72	0.02	3.16
Diesel PC	4.33	11.65	1.08	0.05	0.02	1.26	3.18
Petrol LCV	153.60	5.85	6.68	0.43	0.80	0.03	3.16
Diesel LCV	10.86	15.92	1.59	0.06	0.01	2.28	3.18
Diesel HDV	6.80	28.89	1.62	0.25	0.02	0.77	3.18
Buses	9.67	27.55	0.32	7.31	0.00	0.02	2.75
Mopeds	361.52	6.25	227.08	13.33	0.04	3.40	3.22
Motorcycles	323.88	7.90	34.43	2.02	0.06	0.63	3.14

Table A1-0-7: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Denmark, year 2010

Category	Denmark						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	47.50	3.15	6.54	0.32	0.92	0.02	3.17
Diesel PC	1.76	11.12	0.45	0.02	0.02	0.66	3.18
Petrol LCV	98.42	5.27	6.47	0.42	0.55	0.02	3.17
Diesel LCV	6.20	12.68	1.13	0.04	0.01	1.07	3.18
Diesel HDV	5.47	23.82	0.65	0.10	0.02	0.47	3.17
Buses	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mopeds	185.73	12.45	121.75	7.15	0.05	1.39	3.30
Motorcycles	229.36	5.53	26.18	1.54	0.06	0.50	3.16

Table A1-0-8: Bulk emission factors (g/kg fuel) (for CO2 kg/kg fuel) for Estonia, year 2010

Category	Estonia						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	58.70	3.45	8.02	0.40	0.88	0.02	3.17
Diesel PC	3.56	11.37	0.89	0.04	0.02	0.90	3.18
Petrol LCV	115.91	3.49	5.48	0.35	0.61	0.02	3.17
Diesel LCV	6.25	13.07	1.40	0.05	0.01	1.13	3.18
Diesel HDV	6.01	26.94	0.95	0.15	0.01	0.58	3.17
Buses	2.23	9.68	0.09	1.97	0.00	0.03	2.74
Mopeds	216.99	8.36	104.01	6.11	0.05	1.52	3.25
Motorcycles	320.25	7.04	42.28	2.48	0.05	0.61	3.13

Table A1-0-9: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Finland, year 2010

Category	Finland						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	60.49	3.84	7.94	0.39	0.80	0.02	3.16
Diesel PC	2.73	11.28	0.71	0.04	0.02	0.84	3.18
Petrol LCV	210.91	8.20	10.53	0.68	0.85	0.03	3.16
Diesel LCV	7.34	13.71	1.51	0.05	0.01	1.42	3.18
Diesel HDV	6.51	27.94	1.18	0.18	0.02	0.64	3.17
Buses	2.22	15.86	0.08	1.82	0.00	0.02	2.75
Mopeds	247.40	10.58	132.59	7.79	0.05	1.91	3.29
Motorcycles	239.84	5.55	25.68	1.51	0.05	0.49	3.15

Table A1-0-10: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for France, year 2010

Category	France						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	49.91	4.67	8.11	0.40	0.89	0.02	3.15
Diesel PC	2.16	12.15	0.43	0.02	0.02	0.73	3.18
Petrol LCV	63.55	1.82	2.07	0.13	0.63	0.02	3.16
Diesel LCV	6.32	13.07	1.14	0.04	0.01	1.08	3.18
Diesel HDV	6.11	24.94	0.77	0.12	0.02	0.49	3.18
Buses	3.19	21.72	0.17	3.88	0.00	0.02	2.75
Mopeds	186.03	9.20	130.03	7.63	0.05	1.62	3.28
Motorcycles	153.11	5.11	17.66	1.04	0.06	0.45	3.15

Table A1-0-11: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Germany, year 2010

Category	Germany						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	37.12	2.30	5.15	0.26	0.75	0.02	3.16
Diesel PC	1.66	11.13	0.41	0.02	0.02	0.66	3.18
Petrol LCV	77.92	2.97	3.91	0.25	0.59	0.02	3.16
Diesel LCV	6.16	12.51	1.13	0.04	0.01	1.06	3.18
Diesel HDV	5.75	23.70	0.72	0.11	0.02	0.51	3.18
Buses	3.35	18.98	0.12	2.83	0.00	0.02	2.75
Mopeds	294.66	6.97	184.83	10.85	0.05	2.72	3.26
Motorcycles	264.16	6.37	29.61	1.74	0.06	0.52	3.14

Table A1-0-12: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Greece, year 2010

Category	Greece						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	41.12	4.30	7.05	0.35	0.95	0.02	3.17
Diesel PC	3.63	12.84	0.68	0.03	0.02	0.99	3.18
Petrol LCV	112.08	8.55	8.38	0.54	0.88	0.02	3.17
Diesel LCV	7.34	14.79	1.28	0.05	0.01	1.27	3.18
Diesel HDV	7.93	34.71	1.81	0.28	0.01	0.90	3.18
Buses	9.97	28.25	0.32	7.38	0.00	0.02	2.75
Mopeds	211.63	8.63	126.89	7.45	0.05	1.69	3.29
Motorcycles	255.39	7.09	27.15	1.59	0.06	0.53	3.16

Table A1-0-13: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Hungary, year 2010

Category	Hungary						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	56.67	4.25	8.12	0.40	0.86	0.02	3.16
Diesel PC	3.23	11.89	0.65	0.03	0.02	0.88	3.18
Petrol LCV	174.88	8.35	9.19	0.59	0.97	0.03	3.16
Diesel LCV	7.90	14.37	1.36	0.05	0.01	1.50	3.18
Diesel HDV	6.50	28.22	1.01	0.16	0.01	0.60	3.18
Buses	10.10	29.01	0.35	8.08	0.00	0.02	2.75
Mopeds	302.04	8.26	182.84	10.74	0.05	2.75	3.29
Motorcycles	229.22	5.09	24.89	1.46	0.05	0.48	3.15

Table A1-0-14: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Ireland, year 2010

Category	Ireland						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	43.96	3.26	6.08	0.30	0.89	0.02	3.17
Diesel PC	2.43	11.49	0.53	0.03	0.02	0.78	3.18
Petrol LCV	107.74	6.52	8.32	0.54	0.49	0.02	3.16
Diesel LCV	5.94	12.06	0.97	0.04	0.01	0.99	3.18
Diesel HDV	5.24	24.51	0.66	0.10	0.02	0.53	3.17
Buses	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mopeds	331.89	8.53	198.30	11.64	0.05	3.01	3.28
Motorcycles	346.87	5.73	36.44	2.14	0.05	0.56	3.15

Table A1-0-15: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Italy, year 2010

Category	Italy						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	39.77	3.52	6.75	0.34	0.94	0.02	3.16
Diesel PC	2.18	11.89	0.42	0.02	0.02	0.72	3.18
Petrol LCV	84.86	4.33	4.66	0.30	0.67	0.03	3.17
Diesel LCV	6.83	13.92	1.18	0.04	0.01	1.20	3.18
Diesel HDV	6.53	28.02	1.02	0.16	0.01	0.59	3.18
Buses	2.20	9.66	0.06	1.29	0.00	0.03	2.74
Mopeds	299.39	8.13	164.18	9.64	0.05	2.59	3.27
Motorcycles	213.04	5.89	25.24	1.48	0.06	0.51	3.15

Table A1-0-16: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Latvia, year 2010

Category	Latvia						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	85.61	9.23	12.10	0.60	0.75	0.02	3.16
Diesel PC	5.65	11.56	1.50	0.07	0.02	1.52	3.18
Petrol LCV	96.83	2.60	3.46	0.22	0.65	0.02	3.17
Diesel LCV	7.38	13.99	1.60	0.06	0.01	1.42	3.18
Diesel HDV	6.26	28.33	1.04	0.16	0.01	0.61	3.17
Buses	2.38	17.18	0.08	1.86	0.00	0.02	2.75
Mopeds	243.78	7.11	127.37	7.48	0.05	1.69	3.19
Motorcycles	319.08	8.06	45.00	2.64	0.06	0.59	3.11

Table A1-0-17: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Lithuania, year 2010

Category	Lithuania						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	81.95	5.89	13.23	0.66	1.09	0.02	3.16
Diesel PC	7.65	11.75	2.18	0.11	0.02	2.11	3.18
Petrol LCV	182.25	5.79	7.43	0.48	0.87	0.03	3.16
Diesel LCV	8.71	14.88	1.66	0.06	0.01	1.77	3.18
Diesel HDV	6.22	28.31	1.07	0.17	0.02	0.64	3.17
Buses	6.75	24.71	0.24	5.57	0.00	0.02	2.75
Mopeds	202.78	20.16	120.02	7.05	0.06	0.91	3.24
Motorcycles	141.91	4.74	27.50	1.61	0.06	0.42	3.12

Table A1-0-18: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Luxembourg, year 2010

Category	Luxemburg						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	40.25	3.09	4.70	0.23	0.78	0.02	3.17
Diesel PC	1.91	11.16	0.44	0.02	0.02	0.67	3.18
Petrol LCV	92.32	3.07	3.98	0.26	0.70	0.02	3.17
Diesel LCV	5.78	12.11	1.03	0.04	0.01	0.97	3.18
Diesel HDV	5.44	23.46	0.61	0.09	0.02	0.44	3.17
Buses	2.26	9.70	0.12	2.66	0.00	0.03	2.74
Mopeds	290.27	7.48	186.21	10.93	0.05	2.61	3.24
Motorcycles	139.40	4.08	21.15	1.24	0.05	0.41	3.15

Table A1-0-19: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Malta, year 2010

Category	Malta						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	50.15	6.90	9.54	0.47	0.97	0.02	3.16
Diesel PC	4.06	12.67	0.69	0.03	0.02	0.95	3.18
Petrol LCV	100.23	7.98	7.74	0.50	0.84	0.02	3.17
Diesel LCV	8.53	16.60	1.49	0.05	0.01	1.53	3.18
Diesel HDV	7.08	31.51	1.75	0.27	0.02	0.83	3.17
Buses	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mopeds	147.44	9.24	121.64	7.14	0.05	1.30	3.29
Motorcycles	254.78	6.93	28.79	1.69	0.06	0.55	3.15

Table A1-0-20: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Netherlands, year 2010

Category	Netherlands						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	42.29	2.86	5.76	0.29	0.81	0.02	3.16
Diesel PC	2.24	11.53	0.50	0.03	0.02	0.73	3.18
Petrol LCV	73.08	2.40	3.60	0.23	0.60	0.02	3.16
Diesel LCV	6.08	12.70	1.19	0.04	0.01	1.06	3.18
Diesel HDV	5.65	24.05	0.65	0.10	0.02	0.46	3.17
Buses	2.22	9.67	0.09	1.95	0.00	0.03	2.74
Mopeds	279.67	10.70	133.97	7.87	0.05	2.10	3.29
Motorcycles	275.42	5.66	31.27	1.84	0.05	0.51	3.15

Table A1-0-21: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Norway, year 2010

Category	Norway						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	60.21	3.44	7.56	0.38	1.00	0.02	3.17
Diesel PC	2.28	11.23	0.53	0.03	0.02	0.78	3.18
Petrol LCV	76.44	1.66	2.94	0.19	0.54	0.02	3.17
Diesel LCV	6.08	12.73	1.29	0.05	0.01	1.07	3.18
Diesel HDV	5.78	24.91	0.79	0.12	0.02	0.51	3.18
Buses	2.26	9.71	0.12	2.68	0.00	0.03	2.74
Mopeds	273.91	10.00	154.45	9.07	0.05	2.28	3.30
Motorcycles	216.93	5.09	24.08	1.41	0.05	0.48	3.16

Table A1-0-22: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Poland, year 2010

Category	Poland						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	80.40	6.38	13.14	0.65	1.11	0.02	3.15
Diesel PC	5.89	11.59	1.32	0.07	0.02	1.41	3.18
Petrol LCV	226.42	10.19	12.31	0.79	1.04	0.03	3.16
Diesel LCV	10.00	15.84	1.67	0.06	0.01	2.07	3.18
Diesel HDV	6.82	30.69	1.42	0.22	0.01	0.73	3.18
Buses	2.22	9.67	0.09	1.95	0.00	0.03	2.74
Mopeds	265.66	11.21	122.07	7.17	0.05	1.80	3.26
Motorcycles	252.26	7.43	31.81	1.87	0.06	0.57	3.13

Table A1-0-23: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Portugal, year 2010

Category	Portugal						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	46.26	5.27	8.64	0.43	1.15	0.03	3.16
Diesel PC	2.33	11.65	0.42	0.02	0.02	0.71	3.18
Petrol LCV	79.74	3.77	4.97	0.32	0.96	0.02	3.17
Diesel LCV	6.26	13.99	1.27	0.05	0.01	1.06	3.18
Diesel HDV	6.52	27.97	1.04	0.16	0.02	0.61	3.18
Buses	9.10	27.30	0.30	6.79	0.00	0.02	2.75
Mopeds	401.54	5.33	241.04	14.15	0.04	3.84	3.26
Motorcycles	276.84	6.44	30.49	1.79	0.06	0.55	3.16

Table A1-0-24: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Romania, year 2010

Category	Romania						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	69.89	6.04	12.33	0.61	0.89	0.02	3.15
Diesel PC	4.44	11.48	0.81	0.04	0.02	1.08	3.18
Petrol LCV	187.62	8.47	11.06	0.71	1.04	0.03	3.16
Diesel LCV	6.95	14.46	1.70	0.06	0.01	1.31	3.18
Diesel HDV	6.18	27.32	0.97	0.15	0.01	0.60	3.17
Buses	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mopeds	199.80	20.64	115.61	6.79	0.06	0.90	3.27
Motorcycles	181.53	5.60	26.48	1.55	0.06	0.46	3.13

Table A1-0-25: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Slovakia, year 2010

Category	Slovakia						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	61.95	4.51	9.52	0.47	0.91	0.02	3.16
Diesel PC	3.66	12.03	0.85	0.04	0.02	1.04	3.18
Petrol LCV	196.01	9.53	11.47	0.74	0.97	0.03	3.16
Diesel LCV	7.06	12.76	1.02	0.04	0.01	1.27	3.18
Diesel HDV	6.73	28.01	1.36	0.21	0.02	0.67	3.18
Buses	9.82	26.74	0.30	6.88	0.00	0.02	2.75
Mopeds	240.78	8.64	153.88	9.04	0.05	2.04	3.24
Motorcycles	287.75	6.25	35.99	2.11	0.06	0.54	3.13

Table A1-0-26: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Slovenia, year 2010

Category	Slovenia						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	61.53	5.50	8.65	0.43	0.87	0.02	3.17
Diesel PC	2.94	11.87	0.66	0.03	0.02	0.90	3.18
Petrol LCV	113.40	7.20	7.64	0.49	0.45	0.02	3.17
Diesel LCV	5.96	12.02	0.99	0.04	0.01	1.01	3.18
Diesel HDV	5.62	26.10	0.88	0.14	0.02	0.56	3.17
Buses	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mopeds	235.44	10.33	145.57	8.55	0.05	1.95	3.28
Motorcycles	190.82	5.23	23.33	1.37	0.06	0.49	3.15

Table A1-0-27: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Spain, year 2010

Category	Spain						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	59.00	7.62	15.45	0.77	0.60	0.02	3.14
Diesel PC	2.25	11.96	0.41	0.02	0.02	0.76	3.18
Petrol LCV	104.36	7.26	16.23	1.05	0.61	0.02	3.13
Diesel LCV	6.44	13.27	1.19	0.04	0.01	1.12	3.18
Diesel HDV	5.64	24.48	0.73	0.11	0.02	0.49	3.18
Buses	5.10	23.19	0.20	4.52	0.00	0.02	2.75
Mopeds	285.97	6.99	183.67	10.78	0.05	2.66	3.25
Motorcycles	205.16	5.54	27.69	1.63	0.06	0.50	3.13

Table A1-0-28: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for Sweden, year 2010

Category	Sweden						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	55.08	2.94	6.57	0.33	0.79	0.02	3.15
Diesel PC	1.71	10.46	0.37	0.02	0.02	0.62	3.18
Petrol LCV	111.52	4.08	6.07	0.39	0.58	0.02	3.15
Diesel LCV	5.91	12.33	1.18	0.04	0.01	1.02	3.18
Diesel HDV	5.83	24.94	0.75	0.12	0.02	0.49	3.18
Buses	2.25	13.79	0.06	1.31	0.00	0.03	2.75
Mopeds	187.43	17.58	116.23	6.82	0.06	1.07	3.28
Motorcycles	163.08	4.63	21.65	1.27	0.05	0.43	3.14

Table A1-0-29: Bulk emission factors (g/kg fuel) (for CO2 kg/kg fuel) for Switzerland, year 2010

Category	Switzerland						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	35.14	2.07	4.29	0.21	0.72	0.02	3.17
Diesel PC	1.52	10.94	0.36	0.02	0.02	0.65	3.18
Petrol LCV	101.67	3.67	4.51	0.29	0.72	0.02	3.17
Diesel LCV	5.79	12.29	1.08	0.04	0.01	0.97	3.18
Diesel HDV	5.96	25.27	0.79	0.12	0.02	0.52	3.17
Buses	2.20	9.66	0.06	1.28	0.00	0.03	2.74
Mopeds	310.66	8.46	187.51	11.01	0.05	2.77	3.27
Motorcycles	260.78	7.79	27.84	1.63	0.06	0.56	3.15

Table A1-0-30: Bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for UK, year 2010

Category	UK						
	CO	NOx	NMVOC	CH_4	NH_3	PM_{10}	CO_2 kg/kg fuel
Petrol PC	37.27	2.33	5.09	0.25	0.74	0.02	3.17
Diesel PC	1.89	11.27	0.42	0.02	0.02	0.69	3.18
Petrol LCV	119.97	4.58	5.03	0.32	0.87	0.03	3.17
Diesel LCV	6.07	12.69	1.18	0.04	0.01	1.03	3.18
Diesel HDV	5.65	24.17	0.72	0.11	0.02	0.50	3.17
Buses	2.23	11.66	0.08	1.83	0.00	0.03	2.74
Mopeds	178.04	11.77	112.00	6.58	0.05	1.27	3.29
Motorcycles	163.35	4.96	20.57	1.21	0.06	0.44	3.15

Table A1-0-31: Suggested bulk emission factors (g/kg fuel) (for CO_2 kg/kg fuel) for BC, NIS and CC4 countries, year 2002. Calculated with rough fleet composition estimations.

Category	BC, NIS and CC4 countries					
	CO	NOx	NMVOC	CH_4	PM	CO_2 [kg/kg fuel]
Petrol 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
Petrol LCV	305.63	26.58	32.61	1.51	0.00	2.59
Diesel LCV	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

Appendix 2 History of the development of the road transport chapter

This chapter presents the latest update of the initial methodology used in the Corinair 1985 emissions inventory (Eggleston et al., 1989), and firstly updated in 1991 for the Corinair 1990 inventory (Eggleston et al., 1993). The Corinair 1990 methodology was used 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 (**Co**mputer **P**rogramme to calculate **E**missions from **R**oad **T**ransport) and a further update of the Guidebook was prepared. The next methodology was fully embodied in the COPERT III tool (Ntziachristos and Samaras, 2000a). The present methodology is the most recent revision (version 2008) of the methodology fully incorporated in the software tool COPERT 4, which is available at http://www.emisia.com/copert. Several methodological issues were introduced in the 2006 revision and have been retained in this version (hot emission factors for post Euro 1 vehicles, PM emission information, emission factors for two-wheel vehicles). Some of these have been corrected, and new items have been included to cover new emission technologies and pollutants.

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 versions 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, as well as new PM, N_2O, NH_3 emission information and new emission factors for passenger cars including hybrids, heavy-duty vehicles and two-wheel vehicles. These mainly originated from the European Commission (DG Transport) projects Artemis (Assessment and Reliability of Transport Emission Models and Inventory Systems*)* and Particulates, a study of Euro 3 two-wheel vehicle emissions conducted on behalf of DG Enterprise, and specific Aristotle University studies on N_2O and NH_3 emissions. The present version includes additional refinements and new calculation elements across recent years. Those revisions and extensions mainly originate from the following sources:

- continuous work on the European Commission (DG Transport) Artemis project, which developed a new database of emission factors of gaseous pollutants from transport (www.trl.co.uk/artemis);
- Aristotle University studies and literature reviews, aiming at developing new information for the PM split in elemental carbon and organic carbon, NO_x split in NO and NO_2, emission factors for CNG buses, emission with the use of biodiesel, etc. These dedicated studies were funded by the European Topic Centre (2007 Budget);
- the European Topic Centre on Air Pollutino and Climate Change Mitigation of the European Environment Agency work relating to the assessment of the local contribution to air pollution at urban hotspots;
- the European Commission research project (DG Environment) on the further improvement and application of the transport and environment Tremove model;
- the joint EUCAR/JRC ([11])/Concawe programme on the effects of Petrol vapour pressure and ethanol content on evaporative emissions from modern cars.

([11]) DG Joint Research Centre of the European Commission

Appendix 3 Controls

Legislation classes for petrol 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').

Between 1970 and 1985 all EC Member States followed the UNECE Regulation 15 amendments as regards the emissions of pollutants from vehicles lighter than 3.5 tonnes GVW. According to the relevant EC Directives, the approximate implementation dates — which varied from one Member State to another — of these regulations were as follows:

- pre ECE vehicles up to 1971
- ECE-15.00 and ECE 15.01 1972 to 1977
- ECE-15.02 1978 to 1980
- ECE-15.03 1981 to 1985
- ECE-15.04 1985 to 1992

The regulations were applicable to vehicles registered in each Member State — either produced in the Member State or imported from elsewhere in the world.

During the period 1985–1990, two intermediate technologies appeared in some countries for passenger cars < 2.0 l engine capacity. The two technologies were:

for petrol passenger cars < 1.4 l

- 'Improved conventional', which took into account German (Anl.XXIVC — effective date: 1.7.1985) and Dutch (NLG 850 — effective date: 1.1.1986) incentive programmes. The emission standards called for improved engine technology, but without the use of aftertreatment. This type of emission control technology also started to appear in Denmark from 1.1.1988.
- 'Open loop', which took into account German, Danish, Greek and Dutch incentive programmes in which the required emission standards were 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.

for petrol passenger cars 1.4–2.0 l

- 'Improved conventional', which took into account vehicles which met 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 were: Denmark 1.1.1987, Germany 1.7.1985, the Netherlands 1.1.1987.
- 'Open loop', which took into account vehicles which met the limit values of Directive 88/76/EEC by means of open-loop catalysts (three-way, but no lambda control). In practice, these were only relevant to the national incentive programmes. Effective dates: Denmark 1.1.1987, Germany 1.7.1985, Greece 1.1.1990, the Netherlands 1.1.1986.

After 1992, the so-called 'Euro' standards became mandatory in all Member States, and a new type-approval test was introduced. In some countries, again based on national incentives, the new standards were introduced earlier than their official implementation date. The following paragraphs provide a summary of the various stages, and the associated vehicle technology.

- Euro 1: these vehicles were officially introduced by Directive 91/441/EEC in July 1992, and were the first to be equipped with a closed-loop, three-way catalyst. They also necessitated the use of unleaded fuel. Euro 1 vehicles were introduced earlier in some countries by means of incentives. These included the voluntary programmes in Germany, introduced after 1.7.1985, which called for compliance with the US 83 limits for cars < 2.0 l. For cars with engines larger than 2.0 l, some additional voluntary measures were introduced. These were Directive 88/76/EEC (relevant for all countries), with implementation date for new vehicles 1.1.1990 and US 83 (only relevant for Denmark, Germany, Greece, the Netherlands) with the following implementation dates: Denmark 1.1.1987, Germany 1.7.1985, Greece 1.1.1989, and the Netherlands 1.1.1987.
- Euro 2: these vehicles had improved, closed-loop, three-way catalyst control, and complied with lower emission limits compared with Euro 1 (30 % and 55 % reduction in CO and HC+NO_x respectively, relative to Euro 1). They were introduced by Directive 94/12/EC in all Member States in 1996.
- Euro 3: this emission standard was introduced with Directive 98/69/EC (Step 1) in January 2000, and introduced a new type-approval test (the New European Driving Cycle) and reduced emission levels compared with Euro 2 (30 %, 40 % and 40 % for CO, HC and NO_x respectively). The same Directive also introduced the need for On-Board Diagnostics (OBD) and some additional requirements (aftertreatment durability, in-use compliance, etc.). Euro 3 vehicles were equipped with twin lambda sensors to comply with emission limits.
- Euro 4: this has been introduced by Directive 98/69/EC (Step 2) in January 2005. It required additional reductions of 57 % for CO and 47 % for HC and NO_x compared with Euro 3, by means of better fuelling and aftertreatment monitoring and control.
- Euro 5 and 6: the European Council adopted the Euro 5 and 6 emission standards proposed by the European Commission in May 2007. Euro 5, that came into effect in January 2010 (September 2009 for new type approvals), leads to further NO_x reductions of 25 % compared with Euro 4, and a PM mass emission limit for GDI cars which is similar to that for diesel cars. No further reductions for petrol vehicles have been proposed for the Euro 6 legislation. Euro 6 vehicles have been further split based on their year of registration: Euro 6 registered up to 2016, Euro 6 registered between 2017-2019 and Euro 6 registered from 2020 onwards. These coincide with the individual steps in Euro 6 regulation, namely Euro 6c, Euro 6d-temp and Euro 6d/e, which correspond to the same emission limits but increasingly stringent emission control procedure.
- Euro 7: The European Council adopted the Euro 7 regulation on 12th of April 2024, which keeps the existing Euro 6 exhaust emission limits for petrol cars and vans but introduces stricter requirements for solid particles with a diameter starting from 10 nm (PN10), instead of 23 nm as in Euro 6. The co-legislators introduced stricter lifetime requirements for all vehicles in terms of both mileage and lifetimes; that now goes up to 200 000 km or 10 years for cars and vans. Moreover, the Euro 7 regulation changes monitoring from on-board diagnostics to on-board monitoring (OBM) which will provide continuous monitoring of emissions and urge the user for repairs and maintenance.

Legislation classes for diesel passenger cars

Diesel vehicles of pre-1992 production are all grouped together under the ‘conventional’ vehicle class. This includes non-regulated vehicles launched prior to 1985, and vehicles complying with Directive ECE 15/04 (up to 1992). Diesel vehicles in this class are equipped with indirect injection engines. In 1992, the ‘Consolidated Emissions Directive’ (91/441/EEC) introduced Euro standards for diesel cars.

The Euro standards of diesel cars correspond to those for petrol cars. These include Directives 91/441/EEC (Euro 1, 1992-1996), 94/12/EC (Euro 2, valid from 1996 for indirect injection and 1997 for direct injection up to 2000), regulation 98/69/EC Stage 2000 (Euro 3), and the current regulation 98/69/EC Stage 2005 (Euro 4). Euro 1 vehicles were the first to be regulated for all four main pollutants CO, HC, NO_x and PM. Few of the vehicles were equipped with oxidation catalysts. Directive 94/12/EC required reductions of 68 % for CO, 38 % for HC+NO_x and 55 % for PM relative to Euro 1, and oxidation catalysts were used in almost all vehicles. Euro 3 required further reductions relative to Euro 2: 40 %, 60 %, 14 % and 37.5 % for CO, NO_x, HC and PM respectively. These reductions were achieved with exhaust gas recirculation (NO_x reduction) and optimisation of fuel injection with use of common-rail systems (PM reduction). Refinements to the fuel (mainly a reduction in sulphur content) also played an important role in reducing PM emissions. In addition, due to national incentives and competition between manufacturers, some Euro 3 vehicles were equipped with a diesel particle filter to reduce the PM emissions to levels well below the emission standard. Therefore, a special PM emission factor is required for these vehicles. The Euro 4 standard required vehicles to emit 22 % less CO and 50 % less HC, NO_x and PM than the Euro 3 standard. Further to the voluntary introduction particle filters, such significant reductions have been made possible with advanced engine technology and aftertreatment measures, such as cooled EGR, and NO_x reduction - PM oxidation techniques.

As in the case of petrol vehicles, a Euro 5 proposal was put in place in 2010. Euro 6 became effective for new types of vehicles in September 2014, with full implementation for all type approvals starting January 2015. For diesel vehicles, reductions in NO_x emissions relative to Euro 4 of 28 % and 68 % are required for Euro 5 and Euro 6 respectively. However, the most important reduction will be for PM: 88 % relative to Euro 4. A particle number emission limit has also been agreed (5×10^{11} km^{-1}) which makes mandatory the use of a diesel particle filter.

Euro 5 diesel vehicles have been found to be very high emitters of NOx under real-world driving, many times above their type-approval emission levels. This has been the result of tuneable emission control systems which may alter their performance depending on operation conditions. In order to limit such practices, regulators have introduced an additional package of rules to the Euro 6 limits, the so-called real driving emissions (RDE) regulation. Euro 6 RDE-approved vehicles will need to comply with emission limits with a conformity factor when tested on the road using portable emissions measurement systems (PEMS). The RDE emission limits will be introduced in two steps. The first should apply from September 2017 for new models and from September 2019 for new vehicles and the second one from January 2020 for new models and from January 2021 for new vehicles. The second step comprises a lower conformity factor and additional provisions for testing conditions. Whereas the original Euro 6 regulation (EU) 715/2007 only introduced more strict limits compared to Euro 5, Euro 6 RDE (Regulation (EU) 646/2016) is expected to lead to some significant NOx emissions reductions for diesel passenger cars and light commercial vehicles. Due to these developments, Euro 6 vehicles have been further split based on their year of registration: Euro 6 registered up to 2016, Euro 6 registered between 2017-2019 and Euro 6 registered from 2020 onwards. Similar to petrol cars, these correspond to three individual steps within the Euro 6 regulation (Euro 6c, Euro 6d-temp, Euro 6d/e). Like petrol cars, the recently adopted Euro 7 regulation keeps the existing Euro 6 exhaust emission limits for diesel cars and vans but introduces stricter requirements for solid particles, lifetime requirements, and OBM.

Legislation classes for LPG and CNG passenger cars

LPG and CNG vehicles constitute a small fraction of the European fleet. LPG cars which were compliant with the legislation prior to 91/441/EEC are grouped together as 'conventional'. Otherwise, the same

Euro classes as those relating to petrol and diesel cars are used. For CNG cars only Euro classes 4, 5, 6 and 7 have been introduced in the methodology as they were not relevant for earlier emission control levels.

Legislation classes for two-stroke passenger cars

This type of vehicles is today disappearing and may be only relevant for some Eastern European countries. Very few vehicles are still in circulation, and no emission standards are applicable. Therefore, all such vehicles are grouped in a common 'conventional' class.

Legislation classes for petrol-hybrid vehicles

Petrol-hybrid vehicles offered today by manufacturers comply with the Euro 6 emission limits. Due to their advanced technology, some hybrid vehicles (HEV) may have actual emission levels which are actually much lower than the Euro 6 limits. Specific emission and energy consumption values are therefore provided for hybrid cars in this chapter. The emission factors are appropriate for the so-called 'full' hybrid vehicles, i.e. vehicles that can be started solely with their electric motor, as opposed to 'mild' hybrids, i.e. vehicles where the electric motor is only complementary to the internal combustion engine.

Legislation classes for rechargeable vehicles

There are three vehicle concepts, offered already in the market today, which can be recharged by power from the electrical grid. These are the plug-in hybrid vehicle (PHEV), the electric vehicle with range-extender (EREV) and the battery electric vehicle (BEV). All three vehicle types can be connected to the electrical grid and recharge their on-board batteries with electrical power, which they then use for propulsion. These vehicle types should not be confused with a full or mild hybrid vehicle. The hybrid vehicle cannot be recharged from the grid; only its own engine may recharge its batteries. A hybrid vehicle therefore uses fuel as the only power source. On the contrary, the PHEV and the EREV use two power sources (fuel and electricity from the grid) while the BEV uses only electricity from the grid for propulsion.

In a battery electric vehicle, electricity from the grid is stored in on-board batteries. The batteries power an electrical motor which provides propulsion. PHEV and EREV vehicles are equipped both with an electrical motor and an internal combustion engine. In a PHEV, power to the wheels is provided both by the electrical motor and the engine. In an EREV, power to the wheels is provided only by the electrical motor. The engine is only used to recharge the batteries through an electrical generator, when the batteries are depleted. This significantly extends the range of these vehicles (hence their name).

All electric vehicles are considered to comply with the petrol Euro 6 emission limits. However, they differ with respect to their carbon dioxide emissions. The recent Euro 7 regulation introduces minimum performance requirements for battery durability as well as monitoring of battery state of health.

Legislation classes for petrol light commercial vehicles < 3.5 t

In the EU, the emissions of these vehicles were covered by the various ECE steps up to 1993, and all such vehicles are again termed 'conventional'. From 1993 to 1997, Euro standards were applicable. Directive 93/59/EEC (Euro 1) required catalytic converters on petrol vehicles. In 1997, Directive 96/69/EC (Euro 2) introduced stricter emission standards for light commercial vehicles. Euro 2 was valid up to 2001. Two more legislation steps have subsequently been introduced: Directive 98/69/EC (Euro 3, valid 2001–2006) and Directive 98/69/EC (Euro 4, valid from 2006 onwards). These introduced even stricter emission limits. The Euro 5, Euro 6 and Euro 6 RDE proposals for passenger cars also covers this vehicle category, although the actual limits vary according to the vehicle weight. The emission-control technology used in light commercial vehicles generally follows the technology of passenger cars with a delay of 1–2 years. Euro 6 vehicles have been further split based on their year of registration, Euro 6 up to 2017, Euro 6 registered between 2018-2020 and Euro 6 registered from 2021 onwards. Similarly to petrol passenger cars, no emission reduction is expected from Euro 7 regulation and the only changes regard particle number, lifetime requirements and emission monitoring.

Legislation classes for diesel light commercial vehicles < 3.5 t

The legislation classes for petrol light commercial vehicles are also applicable to diesel light commercial vehicles (with different values, of course, plus a PM emission standard). Again, the engine technologies used in diesel light commercial vehicles tend to follow those used in diesel cars with 1–2 year delay. Specifically for the Euro 6 and Euro 6 RDE steps there is a one-year delay compared to diesel passenger cars (Euro 6 up to 2017, Euro 6 2018-2020 and Euro 6 2021+). Similarly to diesel passenger cars, no emission reduction is expected from Euro 7 regulation and the only changes regard particle number, lifetime requirements and emission monitoring.

Legislation classes for petrol heavy-duty vehicles > 3.5 t

Heavy-duty petrol vehicles > 3.5 t play a negligible role in European emissions from road traffic. Any such vehicles are included in the ‘conventional’ class. There is no legislative distinction as no specific emission standards have been set for such vehicles.

Legislation classes for diesel heavy-duty vehicles > 3.5 t

Emissions from diesel engines used in vehicles of GVW over 3.5 t were first regulated in 1988 with the introduction of the original ECE 49 Regulation. Vehicles (or, rather, engines) complying with ECE 49 and earlier are all classified as ‘conventional’. Directive 91/542/EEC, implemented in two stages, brought two sets of reduced emission limits, valid from 1992 to 1995 (Stage 1 — Euro I) and from 1996 to 2000 (Stage 2 — Euro II). Directive 1999/96/EC Step 1 (Euro III) was valid from 2000, and introduced a 30 % reduction of all pollutants relative to Euro II. The same Directive included an intermediate step in 2005 (Euro IV), and a final step in 2008 (Euro V). The Euro V standards are very strict, requiring a reduction in NO_x of more than 70 % and a reduction in PM of more than 85 % compared with the Euro II standards. This will be achieved with engine tuning and oxidation catalysts for PM control, and selective catalytic reduction (SCR) for NO_x control.

Latest emission limits at a Euro VI level have enforced since the 2013/14 period. These call for 50 % reduction in PM and a further 80% reduction in NO_x over Euro V, with the addition of a cold start cycle. This will necessitate the use of diesel particle filters, engine tuning and EGR for low engine-out NO_x, and specific NO_x exhaust aftertreatment to meet the regulations.

The recently adopted Euro 7 regulation, establishes more stringent Euro VII limits for various pollutants for heavy-duty vehicles, including for pollutants that were not regulated in Euro VI, such as nitrous oxide (N_2O). For example, NO_x limit is reduced by more than 50% (WHTC) compared to Euro VI while exhaust PM limit is further reduced by 20%, CO by 70% and VOCs by 50%.

Legislation classes for two-stroke and four-stroke mopeds < 50 cm³

In June 1999, multi-directive 97/24/EC (Step 1 — Euro 1) introduced emission standards which, in the case of mopeds < 50 cm³, were equal to CO of 6 g/km and $HC+NO_x$ at 3 g/km. An additional stage of the legislation came into force in June 2002 (Euro 2) with emission limits of 1 g/km CO and 1.2 g/km $HC+NO_x$. New Euro 3 emission standards for such small vehicles were prepared by the European Commission in 2013. The limit values are the same as those for Euro 2, but a new type of certification test will be introduced. This will be conducted with an engine start at the ambient temperature, as opposed to the hot engine start currently defined for Euro 2. Due to the strict emission limits, it is expected that few two-stroke mopeds will survive into the Euro 3 limits, and those that will conform with the regulations will have to be equipped with precise air-fuel metering devices, and possibly direct injection and secondary air injection in the exhaust line. In addition, Euro 4 levels have been regulated for the 2017/18 period and Euro 5 levels for the 2020/21 period. These new levels will lead to a further substantial decrease of emissions and are associated with additional measures, including evaporation control and durability requirements.

Legislation classes for two-stroke and four-stroke motorcycles > 50 cm³

Emissions regulations for 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 imposed different emission standards for two- and four-stroke vehicles respectively, and separate limits were set for HC and NO_x to allow for a better distinction between different technologies (two-stroke: CO 8 g/km, HC 4 g/km, NO_x 0.1 g/km; four-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) standards for motorcycles, with differentiated limits depending on the engine size. Regulation 168/2013 introduced Euro 4 and Euro 5 limits for motorcycles that gradually lead their emission levels to become similar to passenger cars. This Regulation also mandates evaporation control, durability requirements, OBD requirements, and CO_2 measurement. Possible additional future steps include in-use compliance, off-cycle emission control and particle emission number control for direct injection vehicles.

Appendix 4 Accompanying files

The accompanying hot emission function parameters are available as an electronic annex alongside the main Guidebook files at http://eea.europa.eu/emep-eea-guidebook.

Appendix 5 HDV correspondence

The current CO2 emission standards for new heavy-duty vehicles are the first of their kind in the European Union and were officially adopted in 2019 (The European Parliament and the Council of the European Union, 2019). The CO2 standards for heavy-duty vehicles are based on the new segmentation introduced by the European Commission in 2017 (The European Parliament and the Council of the European Union, 2017). One year later, Regulation (EU) 2018/956 establishes the requirements for the monitoring and reporting of CO2 emissions from and fuel consumption of new heavy-duty vehicles registered in the Union (The European Parliament and the Council of the European Union, 2018). The Regulation refers both to the Member States and manufacturers and applies to all new heavy-duty vehicles reported after 1st January 2019. Member States report trucks, buses and trailers registered in their territory. Manufacturers report trucks of specific types that are subject to certification requirements.

The new classification of the heavy-duty vehicle groups is mentioned in Annex I of Regulation 2017/2400 (The European Parliament and the Council of the European Union, 2017). The new classification system is in alignment with the one used in VECTO. Trucks are distinguished based on axle type, chassis configuration, gross vehicle weight and regulatory cycles and payloads used in VECTO. It is noted that not all vehicle groups are considered by the regulation yet.

Heavy-duty diesel trucks are classified in COPERT based on their chassis configuration and weight. Heavy-duty trucks are distinguished into rigid and articulated vehicles. An articulated vehicle is a tractor coupled to a semi-trailer. A rigid truck may also carry a trailer, but this is not considered an articulated vehicle. Similarly, buses are distinguished into their type (urban buses and coaches) and weight. Weight classes of heavy-duty vehicles correspond to Gross Vehicle Weight, i.e. the maximum allowable total weight of the vehicle when loaded, including fuel, passengers, cargo, and trailer tongue weight.

After consultation with the users, it was concluded that the best option (for COPERT users) is the user to have the possibility to import/export data for heavy-duty vehicles (for the moment, only for trucks) both in the current COPERT classification and the new classification proposed by the Regulation (EU) 2018/956. This can be done by implementing back-end calculations within COPERT and remapping data for heavy-duty trucks from one classification system to the other and vice versa. The remapping will be done automatically during each COPERT calculation and for all indicators (both input data and results). With this option, users will be still able to import/export data in both classification systems, whereas a full revision of the emission factors for heavy-duty trucks is avoided. All relevant input data of heavy-duty vehicles can be imported from excel to COPERT in the new classification format. Similarly, both input data and results can be exported in the new classification format from COPERT to excel by the user according to the following tables. This feature is available since COPERT v5.7.

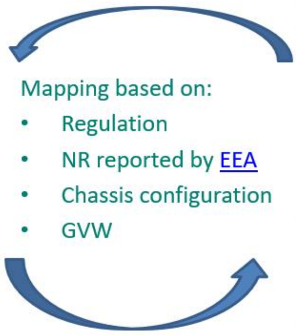
Note

Weight classes of heavy-duty vehicles correspond to Gross Vehicle Weight, i.e. the maximum allowable total weight of the vehicle when loaded, including fuel, passengers, cargo, and trailer tongue weight.

Heavy-duty vehicles are distinguished into rigid and articulated vehicles. An articulated vehicle is a tractor coupled to a semi-trailer. A rigid truck may also carry a trailer, but this is not considered an articulated vehicle.

HDTs groups based on REG EU 2017/2400

Description of elements relevant to the classification in vehicle groups			Vehicle group
Axle configuration	Chassis configuration	Technically permissible maximum laden mass (tons)	
4x2	Rigid lorry	> 3,5 –7,5	(0)
	Rigid lorry (or tractor)**	> 7,5 – 10	1
	Rigid lorry (or tractor)**	> 10 – 12	2
	Rigid lorry (or tractor)**	> 12 – 16	3
	Rigid lorry	> 16	4
	Tractor	> 16	5
	Rigid lorry	> 16	4v***
	Tractor	> 16	5v***
4x4	Rigid lorry	> 7,5 – 16	(6)
	Rigid lorry	> 16	(7)
	Tractor	> 16	(8)
6x2	Rigid lorry	all weights	9
	Tractor	all weights	10
	Rigid lorry	all weights	9v***
	Tractor	all weights	10v***
6x4	Rigid lorry	all weights	11
	Tractor	all weights	12
6x6	Rigid lorry	all weights	(13)
	Tractor	all weights	(14)
8x2	Rigid lorry	all weights	(15)
8x4	Rigid lorry	all weights	16
8x6 8x8	Rigid lorry	all weights	(17)



COPERT

Heavy-Duty Vehicles	
Petrol	>3,5 t
Diesel	Rigid <=7,5 t
Diesel	Rigid 7,5 - 12 t
Diesel	Rigid 12 - 14 t
Diesel	Rigid 14 - 20 t
Diesel	Rigid 20 - 26 t
Diesel	Rigid 26 - 28 t
Diesel	Rigid 28 - 32 t
Diesel	Rigid >32 t
Diesel	Articulated 14 - 20 t
Diesel	Articulated 20 - 28 t
Diesel	Articulated 28 - 34 t
Diesel	Articulated 34 - 40 t
Diesel	Articulated 40 - 50 t
Diesel	Articulated 50 - 60 t

REG EU 2017/2400 groups → COPERT HDTs groups

				axles	4X2						4X4			6X2
				Sales	123	3,121	13,327	12,031	32,608	283,107				66,283
Category	Fuel	GVW Segment			0	1	2	3	4	5	6	7	8	9
Heavy Duty Trucks	Petrol	>3,5 t	-->	% sales number inside the class	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Duty Trucks	Diesel	Rigid <=7,5 t	-->		100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Rigid 7,5 - 12 t	-->		0%	100%	100%	0%	0%	0%	33%	0%	0%	0%
Heavy Duty Trucks	Diesel	Rigid 12 - 14 t	-->		0%	0%	0%	8%	0%	0%	33%	0%	0%	0%
Heavy Duty Trucks	Diesel	Rigid 14 - 20 t	-->		0%	0%	0%	92%	61%	0%	33%	61%	0%	0%
Heavy Duty Trucks	Diesel	Rigid 20 - 26 t	-->		0%	0%	0%	0%	39%	0%	0%	39%	0%	3%
Heavy Duty Trucks	Diesel	Rigid 26 - 28 t	-->		0%	0%	0%	0%	0%	0%	0%	0%	0%	75%
Heavy Duty Trucks	Diesel	Rigid 28 - 32 t	-->		0%	0%	0%	0%	0%	0%	0%	0%	0%	22%
Heavy Duty Trucks	Diesel	Rigid >32 t	-->		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 14 - 20	-->		0%	0%	0%	0%	0%	49%	0%	0%	49%	0%
Heavy Duty Trucks	Diesel	Articulated 20 - 28	-->		0%	0%	0%	0%	0%	51%	0%	0%	51%	0%
Heavy Duty Trucks	Diesel	Articulated 28 - 34	-->		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 34 - 40	-->		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 40 - 50	-->		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 50 - 60	-->		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
				TOTAL	200%	200%	200%	200%	200%	200%	200%	200%	200%	200%

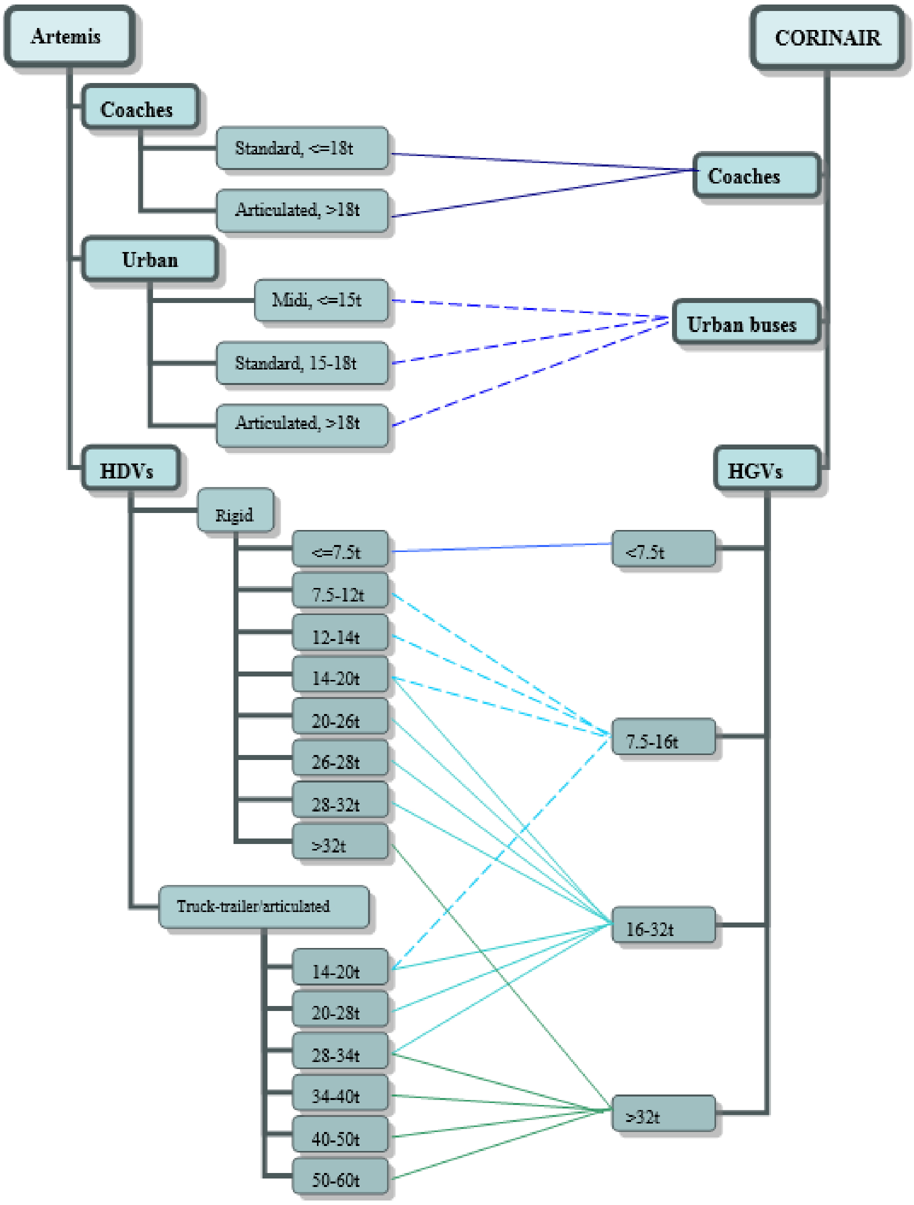
			6X2	6X4		6X6		8X2	8X4	8X6 8X8	8 axled tractor	5 axles
			13,613	2,377	1,314				3,576			
Category	Fuel	GVW Segment	10	11	12	13	14	15	16	17	18	19
Heavy Duty Trucks	Petrol	>3,5 t	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Duty Trucks	Diesel	Rigid <=7,5 t	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Rigid 7,5 - 12 t	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Rigid 12 - 14 t	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Rigid 14 - 20 t	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Rigid 20 - 26 t	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Rigid 26 - 28 t	0%	7%	0%	7%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Rigid 28 - 32 t	0%	67%	0%	67%	0%	3%	3%	3%	0%	0%
Heavy Duty Trucks	Diesel	Rigid >32 t	0%	26%	0%	26%	0%	97%	97%	97%	0%	100%
Heavy Duty Trucks	Diesel	Articulated 14 - 20	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 20 - 28	81%	0%	7%	0%	7%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 28 - 34	19%	0%	71%	0%	71%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 34 - 40	0%	0%	22%	0%	22%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 40 - 50	0%	0%	1%	0%	1%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 50 - 60	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
		TOTAL	200%	200%	200%	200%	200%	200%	200%	200%	200%	200%

COPERT HDTs groups → REG EU 2017/2400 groups

				axles	4X2						4X4			6X2
											Veh Groups in to be updated based on REG 2017/2400/EU			
Available in COPERT					0	1	2	3	4	5	6	7	8	9
Category	Fuel	GVW Segment		Sales	123	3,121	13,327	12,031	32,608	283,107				66,283
Heavy Duty Trucks	Petrol	>3,5 t	-->	% sales number inside the class	0.03%	0.72%	3.09%	2.79%	7.56%	65.61%	0.00%	0.00%	0.00%	15.36%
Heavy Duty Trucks	Diesel	Rigid <=7,5 t	-->		100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Rigid 7,5 - 12 t	-->		0%	19%	81%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Rigid 12 - 14 t	-->		0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Rigid 14 - 20 t	-->		0%	0%	0%	36%	64%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Rigid 20 - 26 t	-->		0%	0%	0%	0%	86%	0%	0%	0%	0%	14%
Heavy Duty Trucks	Diesel	Rigid 26 - 28 t	-->		0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
Heavy Duty Trucks	Diesel	Rigid 28 - 32 t	-->		0%	0%	0%	0%	0%	0%	0%	0%	0%	89%
Heavy Duty Trucks	Diesel	Rigid >32 t	-->		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 14 - 20	-->		0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 20 - 28	-->		0%	0%	0%	0%	0%	93%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 28 - 34	-->		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 34 - 40	-->		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 40 - 50	-->		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 50 - 60	-->		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

			6X2	6X4		6X6		8X2	8X4	8X6 8X8	8 axled tractor	5 axles
Category	Fuel	GVW Segment	10	11	12	13	14	15	16	17	18	19
		Sales	13,613	2,377	1,314				3,576			
Heavy Duty Trucks	Petrol	>3,5 t	3.15%	0.55%	0.30%	0.00%	0.00%	0.00%	0.83%	0.00%	0.00%	0.00%
Heavy Duty Trucks	Diesel	Rigid <=7,5 t	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Rigid 7,5 - 12 t	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Rigid 12 - 14 t	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Rigid 14 - 20 t	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Rigid 20 - 26 t	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Rigid 26 - 28 t	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Rigid 28 - 32 t	0%	10%	0%	0%	0%	0%	1%	0%	0%	0%
Heavy Duty Trucks	Diesel	Rigid >32 t	0%	15%	0%	0%	0%	0%	85%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 14 - 20	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 20 - 28	7%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 28 - 34	74%	0%	26%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 34 - 40	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 40 - 50	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
Heavy Duty Trucks	Diesel	Articulated 50 - 60	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%

Correspondence between the previous Corinair classification for HDVs and buses, and the new system of classification (Boulter and Barlow, 2005):


Artemis
CORINAIR
Coaches
Standard, <=18t
Articulated, >18t
Coaches
Urban
Midi, <=15t
Urban buses
Standard, 15-18t
Articulated, >18t
HDVs
HGVs
Rigid
<=7.5t
<7.5t
7.5-12t
12-14t
14-20t
20-26t
7.5-16t
26-28t
28-32t
>32t
Truck-trailer/articulated
16-32t
14-20t
20-28t
28-34t
34-40t
>32t
40-50t
50-60t