Category		Title
NFR	1.A.3.b.v	Gasoline evaporation
SNAP	0706	Gasoline evaporation from vehicles
ISIC		
Version	Guidebook 2023	
Updated	2025 (with a minor adjustment)	

Lead authors

Giorgos Mellios, Leonidas Ntziachristos

Contributing authors (including to earlier versions of this chapter)

Zissis Samaras, Les White, Giorgio Martini, Ken Rose

Contents

1 Overview ... 3
2 Description of sources ... 3
2.1 Process description ... 3
2.2 Controls ... 5
2.3 Contribution of evaporative emissions to total emissions ... 5
3 Calculation methods ... 6
3.1 Choice of method ... 6
3.2 Tier 1 method ... 7
3.3 Tier 2 method ... 9
3.4 Tier 3 method ... 14
3.5 Species profile for NMVOC from evaporative emissions ... 26
4 Data quality ... 28
4.1 Completeness ... 28
4.2 Avoiding double counting with other sectors ... 28
4.3 Verification ... 28
4.4 Developing a consistent time series and recalculation ... 28
4.5 Uncertainty assessment ... 28
4.6 Inventory quality assurance/quality control (QA/QC) ... 28
4.7 Gridding ... 28
4.8 Reporting and documentation ... 29
4.9 Additional comments ... 29
4.10 Weakest aspects/priority areas for improvement in current methodology ... 29
5 Glossary and abbreviations ... 29
5.1 List of abbreviations ... 29
5.2 List of symbols ... 30
6 References and supplementary documents ... 32
6.1 References ... 32
6.2 Supplementary documents ... 33
7 Point of enquiry ... 34

1 Overview

This chapter provides the methodology, emission factors and relevant activity data to enable evaporative emissions ([1]) of NMVOCs ([2]) from gasoline vehicles (NFR code 1A3bv) to be calculated. The term 'evaporative emissions' refers to the sum of all fuel-related NMVOC emissions not deriving from fuel combustion. It should be noted that the second level of the NFR code for this emission source relates to 'combustion'. Clearly, evaporation is not a combustion process. However, this chapter has been assigned its NFR code as a matter of convenience, and to allow all emissions from road transport to be assessed together. For the present time, this anomaly has to be accepted by inventory compilers.

For various European countries in 2006, the contribution of evaporative emissions to total NMVOC emissions from road transport ranged from slightly less than 3 % to around 16.5 % ([3]) (see subsection 2.3 of the present chapter). However, the contribution has been decreasing in recent years as a result of the introduction of control systems. In current vehicles evaporative emissions are controlled by means of an activated carbon canister connected to the fuel tank. The canister adsorbs the fuel vapour escaping from the tank.

2 Description of sources

2.1 Process description

Most evaporative emissions of VOCs emanate from the fuel systems (tanks, injection systems and fuel lines) of petrol vehicles. Evaporative emissions from diesel vehicles are considered to be negligible due to the presence of heavier hydrocarbons and the relatively low vapour pressure of diesel fuel, and can be neglected in calculations.

The most important sources of evaporative emissions from a vehicle are the following:

- breathing losses through the tank vent. Breathing losses are due to evaporation of fuel in the tank during driving and parking, as a result of normal diurnal temperature variation;
- fuel permeation/leakage. Various studies (e.g. CRC, 2004; Reuter et al., 1994) indicate that liquid fuel seepage and permeation through plastic and rubber components of the fuel and vapour control system contribute significantly to the total evaporative emissions.

When modelling evaporative emissions due to breathing losses and fuel permeation, three separate mechanisms are usually considered:

- diurnal emissions,
- running losses,
- hot-soak emissions.

([1]) In the context of evaporation, emissions are sometimes referred to as 'losses'.
([2]) NMVOCs = non-methane volatile organic compounds.
([3]) Based on the methodology presented in this chapter and the activity data and exhaust emissions calculated using TREMOVE v2.5.

Both breathing losses and fuel permeation contribute to these mechanisms, and their relative significance depends on the vehicle configuration. The three mechanisms are described in more detail in the following sections.

The evaporation of gasoline also takes place during the delivery of fuel to service stations, and during vehicle refuelling. However, these processes are not included in this chapter, as they are considered elsewhere in the Guidebook.

The processes of evaporation are summarised in Figure 2-1.

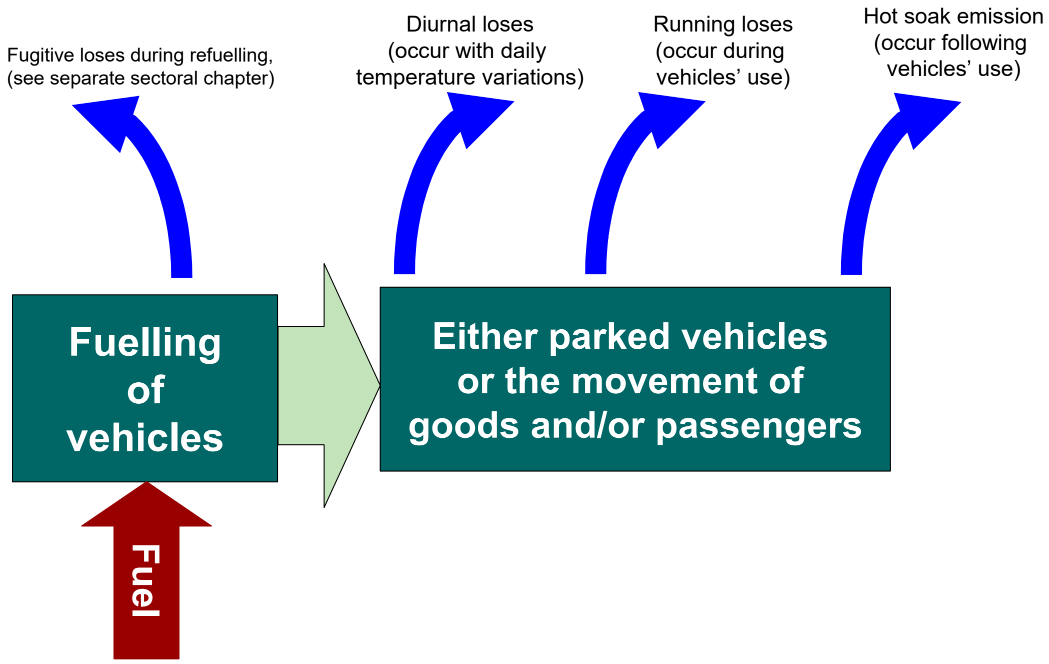


Figure 2-1 Processes resulting in evaporative emissions of NMVOCs

2.1.1 Diurnal emissions

The increase in ambient temperature which occurs during the daylight hours results in the thermal expansion of the fuel and vapour in the tank. Without an emission control system, some of the increased volume of fuel vapour is vented to the atmosphere. Emissions due to fuel permeation and/or leakage also contribute to the diurnal emissions.

2.1.2 Running losses

Running losses are the result of vapour generated in the fuel tank during vehicle operation. For older vehicles equipped with carburettor and/or fuel return systems, engine operation results in a significant temperature increase in the fuel tank and/or the carburettor (Morgan et al., 1993). For such vehicles, the combined effect of high ambient temperature and exhaust system heat can generate a significant amount of vapour in the fuel tank. For gasoline vehicles with fuel injection and returnless fuel systems, the fuel temperature in the tank is not affected by engine operation, and thus no additional fuel vapour is generated in the tank. The running losses of these vehicles are therefore very low and may be attributed to fuel permeation and/or leakage.

2.1.3 Hot-soak emissions

Hot-soak emissions are the emissions caused when a hot engine is turned off. Heat from the engine and exhaust system increases the temperature of the fuel in the system (which is no longer flowing). Carburettor float bowls are a particularly significant source of hot-soak emissions. For vehicles with fuel injection and returnless fuel systems, no additional fuel vapour is generated in the tank when a hot engine is turned off, and thus hot-soak emissions are mainly due to fuel permeation and/or leakage.

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

2.2 Controls

Until 1993 evaporative emissions of gasoline passenger cars were not controlled in Europe, with the exception of Austria, Denmark, Finland, Sweden and Switzerland, which adopted the US Environmental Protection Agency (USEPA) SHED (Sealed Housing for Evaporative Determination) test procedure. In the EU, a limit value of 2.0 g of NMVOC per test was first introduced by Directive 91/441/EEC (Euro 1 and Euro 2 vehicles). In order to meet this emission limit, the installation of small on-board carbon canisters was necessary. Directive 91/441/EC was superseded by Directive 98/69/EC, applicable to Euro 3 and Euro 4 vehicles, and by Regulation 715/2007/EC for Euro 5 and 6 vehicles. According to this, the limit value for evaporative emissions remained at the same level. However, the test procedure for evaporative emissions increased in its stringency. The fitting of larger carbon canisters was necessary for compliance with these more stringent requirements. Regulation (EU) 2017/1221 has subsequently introduced a new procedure for evaporative emissions, applicable to Euro 6d-temp and Euro 6 vehicles. Whereas the emission limit remains at 2.0 g of NMVOC per test, the testing procedure became stricter, specifically now addressing also the aging of the carbon canister and the permeability of the fuel system.

2.3 Contribution of evaporative emissions to total emissions

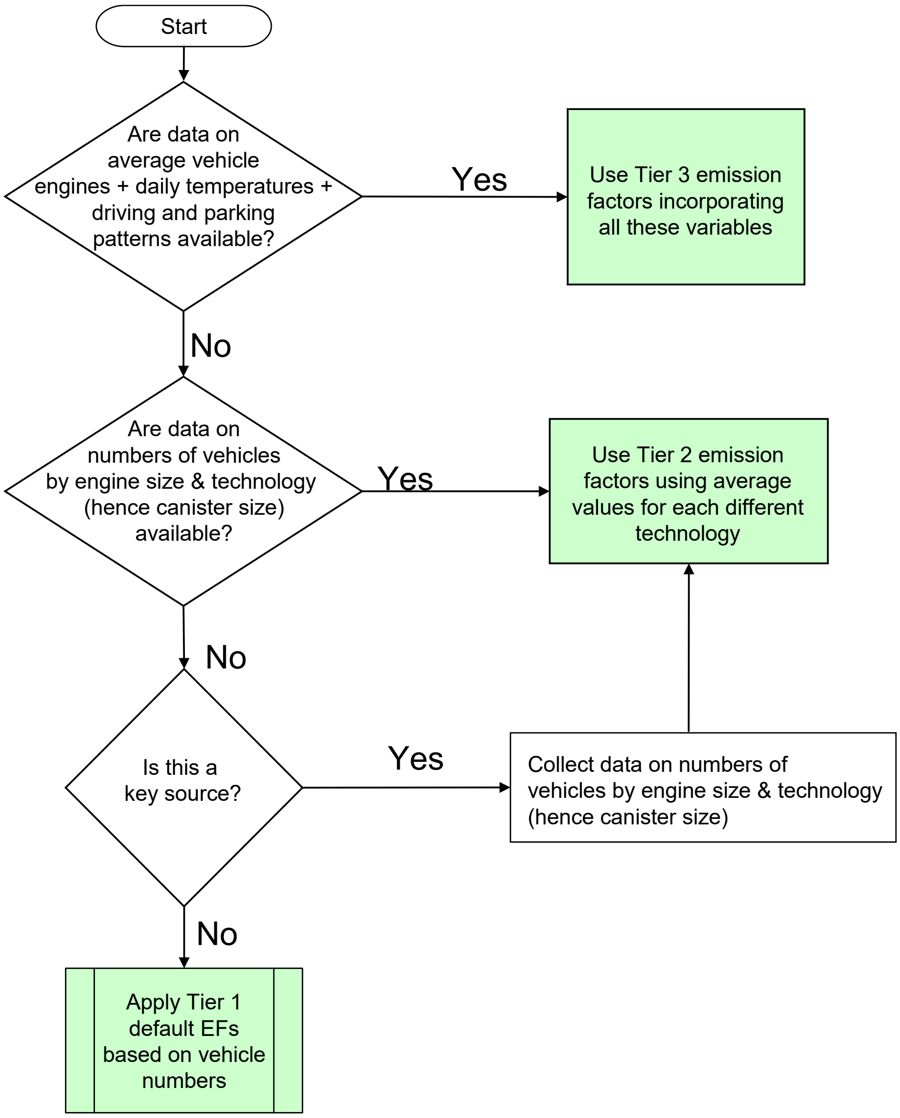
The contribution of evaporative emissions to total NMVOC emissions from road transport has decreased considerably since the introduction of carbon canisters. The observed differences are due to the combined effects of ambient temperatures (minimum and maximum), the volatility of the fuel used in different countries, the vehicle usage (annual mileage), the technology mix (share of older vehicles without a carbon canister), as well as the share of diesel vehicles on the national car fleet.

3 Calculation methods

3.1 Choice of method

Figure 3-1 schematically shows the process to be followed to select the method for estimating evaporative emissions from road transport. This decision tree is applicable to all countries. If evaporation is a key emission source, then a Tier 2 or Tier 3 method must be used for estimating the emissions.

Figure 3-1 Decision tree for evaporative emissions



3.2 Tier 1 method

This is a very basic method where all three main phases of evaporative emissions are combined into a single emission factor for the broad vehicle categories.

3.2.1 Algorithm

The Tier 1 approach for calculating evaporative emissions uses the general equation:

$$E_{VOC} = \sum_{j} N_j \times EF_{VOC,j} \times 365 \quad (1)$$

Where:

E_{VOC}	=	the emissions of VOC (g/year),
N_j	=	the number of vehicles in category *j,*
$EF_{VOC,\,j}$	=	the emission factor of VOC for vehicle category *j* (g/vehicle/day),
j	=	the vehicle category (passenger cars, light-duty vehicles and two-wheel vehicles, i.e. mopeds and motorcycles). No HDVs and busses are considered, as the share of gasoline fuelled vehicles in these categories is too low to be considered for evaporative emissions.

This equation is applied at the national level, using national statistics for the numbers of vehicles in each vehicle category within the country.

3.2.2 Emission factors

The Tier 1 method applies an average emission factor to each vehicle category within a country. These emission factors vary markedly according to the 24-hour temperature range, being larger for higher temperatures. Consequently, four different emission factors are provided to cover the different 24-hour temperature ranges 20 to 35 °C, 10 to 25 °C, 0 to 15 °C and -10 to 5 °C.

Emission factors were developed by taking the Tier 2 emission factors and combining these with some typical fleet technology and vehicle size distributions. These were summed and averaged per vehicle category (and for given temperature ranges) to give the Tier 1 averages. Hence, Tier 1 emission factors are approximate values of the more detailed Tier 2 methodology (which, as will be shown, has been derived from the Tier 3 method).

Table 3-1 Tier 1 evaporative emissions emission factors for gasoline fuelled road vehicles — when daily temperature range is around 20 to 35 °C

Tier 1 emission factors						
		Code	Name			
NFR Source Category		1.A.3.b.v	Road transport, gasoline evaporation			
Fuel		Gasoline dry vapour pressure equivalent (DVPE) 60 kPa				
Daily temperature range		20 to 35 °C				
Not estimated		POPs, hexachlorobenzene, polychlorinated biphenyls, dioxins and furans, polyaromatic hydrocarbons				
Pollutant	Vehicle type	Value	Unit	95% confidence level		Reference
				Lower	Upper	
NMVOC	Gasoline PCs	14.6	g/vehicle/day	10.5	19.2	Tier 2 method with typical fleet technology distributions
NMVOC	Gasoline LDVs	22.2	g/vehicle/day	9.9	27.9	
NMVOC	Two-wheels vehicles	7.5	g/vehicle/day	5.8	9.1	

Table 3-2 Tier 1 evaporative emissions emission factors for gasoline fuelled road vehicles — when daily temperature range is around 10 to 25 °C

Tier 1 emission factors						
		Code	Name			
NFR Source Category		1.A.3.b.v	Road transport, gasoline evaporation			
Fuel		Gasoline dry vapour pressure equivalent (DVPE) 70 kPa				
Daily temperature range		10 to 25 °C				
Not estimated		POPs, hexachlorobenzene, polychlorinated biphenyls, dioxins and furans, polyaromatic hydrocarbons				
Pollutant	Vehicle type	Value	Unit	95% confidence level		Reference
				Lower	Upper	
NMVOC	Gasoline PCs	7.8	g/vehicle/day	5.4	10.9	Tier 2 method with typical fleet technology distributions
NMVOC	Gasoline LDVs	12.7	g/vehicle/day	5.2	19.4	
NMVOC	Two-wheels vehicles	4.6	g/vehicle/day	3.6	5.5	

Table 3-3 Tier 1 evaporative emissions emission factors for gasoline fuelled road vehicles — when daily temperature range is around 0 to 15 °C

Tier 1 emission factors						
		Code	Name			
NFR Source Category		1.A.3.b.v	Road transport, gasoline evaporation			
Fuel		Gasoline dry vapour pressure equivalent (DVPE) 90 kPa				
Daily temperature range		0 to 15 °C				
Not estimated		POPs, hexachlorobenzene, polychlorinated biphenyls, dioxins and furans, polyaromatic hydrocarbons				
Pollutant	Vehicle type	Value	Unit	95% confidence level		Reference
				Lower	Upper	
NMVOC	Gasoline PCs	5.7	g/vehicle/day	3.9	8.0	Tier 2 method with typical fleet technology distributions
NMVOC	Gasoline LDVs	9.3	g/vehicle/day	3.8	14.1	
NMVOC	Two-wheels vehicles	3.4	g/vehicle/day	2.7	4.1	

Table 3-4 Tier 1 evaporative emissions emission factors for gasoline fuelled road vehicles — when daily temperature range is around -5 to 10 °C

Tier 1 emission factors							
		Code	Name				
NFR Source Category		1.A.3.b.v	Road transport, gasoline evaporation				
Fuel		Gasoline dry vapour pressure equivalent (DVPE) 90 kPa					
Daily temperature range		-5 to 10 °C					
Not estimated		POPs, hexachlorobenzene, polychlorinated biphenyls, dioxins and furans, polyaromatic hydrocarbons					
Pollutant	**Vehicle type**	**Value**	**Unit**	**95% confidence level**		**Reference**	
				Lower	**Upper**		
NMVOC	Gasoline PCs	4.0	g/vehicle/day	2.8	5.7	Tier 2 method with typical fleet technology distributions	
NMVOC	Gasoline LDVs	6.5	g/vehicle/day	2.6	9.9		
NMVOC	Two-wheels vehicles	2.6	g/vehicle/day	2.1	3.1		

3.2.3 Activity data

The Tier 1 approach necessitates statistics on the numbers of vehicles in each vehicle category within a country. Such data are most probably available from national vehicle licensing bodies or international organisations (e.g. Eurostat). These data are also those required for the Tier 2 methodology in Chapter 1.A.3.b Exhaust emissions from road transport (encompassing NFR codes 1.A.3.b.i to 1.A.3.b.iv).

3.3 Tier 2 method

3.3.1 Algorithm

The Tier 2 approach extends the Tier 1 approach by further sub-dividing the vehicle categories by engine size and the size of the canister fitted. The main equation for estimating the evaporative emissions using this methodology is:

$$E_{voc} = \sum_{s} D_s \times \sum_{j} N_j \times (HS_j + e_{d,j} + RL_j) \quad (2)$$

where:

E_{voc} = annual VOC emissions due to evaporative emissions (g),

D_s = the number of days for which the seasonal emission factor should be applied ($\sum_s D_s$ = total number of days in a particular year),

N_j = number of gasoline vehicles in category *j*,

HS_j = average daily soak emissions (hot, warm and cold) of vehicle category *j* (g/day),

$e_{d,j}$ = average diurnal emissions of vehicle category *j* (g/day),

RL_j = average daily running losses (hot, warm and cold) of vehicle category *j* (g/day);

and

$$HS_j = x \{c [p\ e_{s,hot,c} + (1 - p)\ e_{s,warm,c}] + (1 - c)\ e_{s,hot,fi}\} \quad (3)$$

$$RL_j = x \{c [p\ e_{r,hot,c} + (1 - p)\ e_{r,warm,c}] + (1 - c)\ e_{r,hot,fi}\} \quad (4)$$

where:

x	=	mean number of trips per vehicle per day, averaged over the year (trips/day),
c	=	fraction of gasoline powered vehicles equipped with carburettor and/or fuel return systems,
p	=	fraction of trips finished with hot engine, i.e. an engine that has reached its normal operating temperature and the catalyst its light-off temperature (dependent on the average monthly ambient temperature),
$e_{s,hot,c}$	=	mean hot-soak emission factor of gasoline powered vehicles with carburettor and/or fuel return systems (dependent on fuel volatility and average monthly ambient temperature) (g/parking),
$e_{s,warm,c}$	=	mean cold- and warm-soak emission factor of gasoline powered vehicles with carburettor and/or fuel return systems (dependent on fuel volatility and average monthly ambient temperature) (g/parking),
$e_{s,hot,fi}$	=	mean hot-soak emission factor of gasoline powered vehicles with fuel injection and returnless fuel systems (dependent on fuel volatility and average monthly ambient temperature) (g/parking),
$e_{r,hot,c}$	=	mean emission factor for hot running losses of gasoline powered vehicles with carburettor and/or fuel return systems (dependent on fuel volatility and average monthly ambient temperature) (g/trip),
$e_{r,warm,c}$	=	mean emission factor for cold and warm running losses of gasoline powered vehicles with carburettor and/or fuel return systems (dependent on fuel volatility and average monthly ambient temperature) (g/trip),
$e_{r,hot,fi}$	=	mean emission factor for hot running losses of gasoline powered vehicles with fuel injection and returnless fuel systems (dependent on fuel volatility and average monthly ambient temperature) (g/trip).

Where there are large seasonal (winter-summer) temperature variations it is advisable to use the above equation (2) in two parts applying summer and winter temperature emission factors (see Tables 3–5 and 3–6) separately to the relevant number of summer/winter days in the year.

The number of trips per day, if not known from statistical data, can be estimated by the expression:

$$x = \frac{M_j}{365 \times l_{trip}} \quad (5)$$

where M_j is the average annual mileage of gasoline vehicles of category *j*.

The fraction of trips finished with cold and warm engine, (1-*p*), is linked to the *β*-parameter, also used in the calculation of cold-start emissions in the chapter on exhaust emissions from road transport. Both (1-*p*) and *β* depend on, amongst other things, ambient temperature. In the absence of better data, the assumed relation between (1-*p*) and *β* is (1-*p*) ≈ *β*. Parameter *β* also depends on the average trip length l_{trip}. This indicates that, for the calculation of the cold start emissions and soak emissions, the average trip length is of great importance.

3.3.2 Emission factors

In order to apply equation 2, Table 3-5 provides emission factors for gasoline passenger cars in three different size classes and Table 3-6 for L-category vehicles. For gasoline light commercial vehicles it is assumed that the emission factors are equivalent to those for comparatively sized passenger cars. Emission factors are given for typical temperature ranges in winter and summer, and for typical fuels which are produced with seasonally different vapour pressures.

Table 3-5 Tier 2 evaporative emissions emission factors for passenger cars, summary of emission factors for typical summer and winter conditions

	summer		winter		summer		winter		summer		winter	
T. variation (°C)	20−35	10−25	0−15	-5−10	20−35	10−25	0−15	-5−10	20−35	10−25	0−15	-5−10
Fuel DVPE (kPa)	60	70	90	90	60	70	90	90	60	70	90	90
	Gasoline passenger cars < 1.4 l — uncontrolled				Gasoline passenger cars 1.4–2.0 l — uncontrolled				Gasoline passenger cars > 2.0 l — uncontrolled			
e_d (g/day)	20.7	12.4	9.1	6.4	24.8	14.9	11.0	7.7	31.1	18.6	13.7	9.6
$e_{s,hot,fi}$ (g/proced.)	0.09	0.06	0.04	0.03	0.09	0.06	0.04	0.03	0.09	0.06	0.04	0.02
$e_{s,warm,c}$ (g/proced.)	4.44	2.67	1.96	1.28	5.31	3.19	2.35	1.65	6.61	3.97	2.92	2.05
$e_{s,hot,c}$ (g/proced.)	5.65	3.40	2.5	1.75	6.76	4.06	2.99	2.09	8.43	5.06	3.72	2.61
$e_{r,hot,fi}$ (g/trip)	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01
$e_{r,warm,c}$ (g/trip)	1.83	1.10	0.81	0.57	2.20	1.31	0.97	0.68	2.73	1.64	1.21	0.84
$e_{r,hot,c}$ (g/trip)	5.42	3.25	2.39	1.67	6.5	3.9	2.87	2.01	8.11	4.87	3.58	2.51
	Gasoline passenger cars < 1.4 l — small canister				Gasoline passenger cars 1.4– 2.0 l — small canister				Gasoline passenger cars > 2.0 l — small canister			
e_d (g/day)	2.92	1.31	0.96	0.75	2.61	1.02	0.74	0.60	4.40	1.29	0.86	0.66
$e_{s,hot,fi}$ (g/proced.)	0.09	0.06	0.04	0.03	0.09	0.06	0.04	0.03	0.09	0.06	0.04	0.03
$e_{s,warm,c}$ (g/proced.)	0.92	0.36	0.24	0.15	1.01	0.38	0.23	0.14	1.36	0.45	0.28	0.16
$e_{s,hot,c}$ (g/proced.)	1.27	0.46	0.30	0.17	1.33	0.48	0.30	0.17	1.88	0.60	0.36	0.20
$e_{r,hot,fi}$ (g/trip)	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01
$e_{r,warm,c}$ (g/trip)	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01
$e_{r,hot,c}$ (g/trip)	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01
	Gasoline passenger cars < 1.4 l — medium canister				Gasoline passenger cars 1.4–2.0 l—– medium canister				Gasoline passenger cars > 2.0 l — medium canister			
e_d (g/day)	2.25	1.17	0.89	0.73	1.83	0.89	0.68	0.58	2.67	1.06	0.77	0.62
$e_{s,hot,fi}$ (g/proced.)	0.09	0.06	0.04	0.03	0.09	0.06	0.04	0.03	0.09	0.06	0.04	0.03
$e_{s,warm,c}$ (g/proced.)	0.68	0.28	0.18	0.12	0.72	0.30	0.18	0.12	0.92	0.35	0.22	0.13
$e_{s,hot,c}$ (g/proced.)	0.91	0.36	0.23	0.14	0.93	0.37	0.23	0.14	1.26	0.45	0.28	0.15
$e_{r,hot,fi}$ (g/trip)	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01
$e_{r,warm,c}$ (g/trip)	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01
$e_{r,hot,c}$ (g/trip)	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01
	Gasoline passenger cars < 1.4 l — large canister				Gasoline passenger cars 1.4–2.0 l — large canister				Gasoline passenger cars > 2.0 l — large canister			
e_d (g/day)	1.71	1.04	0.83	0.70	1.24	0.76	0.63	0.55	1.55	0.85	0.68	0.59
$e_{s,hot,fi}$ (g/proced.)	0.09	0.06	0.04	0.03	0.09	0.06	0.04	0.03	0.09	0.06	0.04	0.03
$e_{s,warm,c}$ (g/proced.)	0.42	0.19	0.13	0.09	0.43	0.20	0.13	0.09	0.53	0.22	0.15	0.09
$e_{s,hot,c}$ (g/proced.)	0.55	0.24	0.16	0.10	0.55	0.24	0.16	0.10	0.70	0.28	0.18	0.11
$e_{r,hot,fi}$ (g/trip)	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01
$e_{r,warm,c}$ (g/trip)	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01
$e_{r,hot,c}$ (g/trip)	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01

For canister-equipped passenger cars, three different carbon canister sizes (small, medium, large) were considered, depending on vehicle engine size and technology as indicated in Table 3-5.

It has to be stressed that emission factors are provided for all possible vehicle configurations, although some of them are rather unlikely to be found in vehicles in the European market (e.g. passenger cars > 2.0 l with a large canister and a carburettor). However, such vehicle configurations might exist in vehicles circulating in other parts of the world.

Table 3-6 Tier 2 evaporative emissions emission factors for L-category vehicles — summary of simplified emission factors for typical summer and winter conditions

	summer		winter		Summer		winter		summer		winter	
Temp. variation (°C)	20–35	10–25	0–15	-5–10	20–35	10–25	0–15	-5–10	20–35	10–25	0–15	-5–10
Fuel DVPE (kPa)	60	70	90	90	60	70	90	90	60	70	90	90
	Mopeds <50 cm^3				Motorcycles 2-stroke >50 cm^3				Motorcycles 4-stroke <250 cm^3			
e_d (g/day)	2.07	1.24	0.91	0.64	3.31	1.99	1.46	1.02	4.14	2.48	1.83	1.28
$e_{s,hot,fi}$ (g/proced.)	0.23	0.14	0.10	0.07	0.37	0.22	0.16	0.11	0.46	0.27	0.20	0.14
$e_{s,hot,c}$ (g/proced.)	0.36	0.22	0.16	0.11	0.58	0.35	0.26	0.18	0.72	0.43	0.32	0.22
$e_{r,hot,fi}$ (g/trip)	0.18	0.11	0.08	0.06	0.29	0.17	0.13	0.09	0.36	0.22	0.16	0.11
$e_{r,hot,c}$ (g/trip)	0.30	0.18	0.13	0.09	0.48	0.29	0.21	0.15	0.61	0.36	0.27	0.19
	Motorcycles 4-stroke 250–750 cm^3				Motorcycles 4-stroke > 750 cm^3 — uncontrolled				Motorcycles 4-stroke > 750 cm^3 — small canister			
e_d (g/day)	7.45	4.47	3.29	2.30	8.28	4.97	3.66	2.56	1.56	0.99	0.85	0.79
$e_{s,hot,fi}$ (g/proced.)	0.82	0.50	0.36	0.26	0.92	0.55	0.40	0.28	0.37	0.20	0.16	0.11
$e_{s,hot,c}$ (g/proced.)	1.30	0.78	0.57	0.40	1.45	0.87	0.64	0.45	0.53	0.23	0.17	0.12
$e_{r,hot,fi}$ (g/trip)	0.65	0.39	0.29	0.20	0.72	0.43	0.32	0.22	0.39	0.22	0.17	0.12
$e_{r,hot,c}$ (g/trip)	1.10	0.65	0.48	0.34	1.21	0.73	0.54	0.37	0.58	0.24	0.17	0.12

3.3.3 Activity data

In order to apply equation 2, the data required are the number of gasoline vehicles in category *j* (data that are already available and used in Tier 2 of the chapter on Exhaust emissions from road transport), an estimate of the average daily temperature variation for the country (standard meteorological data), and the average number of trips per day. If the number of trips per day is not known from statistical data, it can be estimated using equation 5, as described in subsection 3.3.1 of the present chapter, or using the data in Table 3-7.

In addition to these data, the fraction of vehicles equipped with a carburettor and/or fuel return systems is required in order to apply equations (3) and (4). In Europe, the fraction of passenger cars and LDVs equipped with a carburettor is approximately 99 % for pre-Euro 1 vehicles (i.e. only 1 % equipped with fuel injection) and 0 % for post-Euro 1 vehicles. For motorcycles this fraction is 100 % for conventional and Euro 1 vehicles, 20 % for Euro 2 and 0 % for Euro 3. These figures could be used where there is a lack of detailed national statistical data.

Table 3-7 Average daily usage of vehicles and average trip characteristics

	Number of trips/day	Driving duration (min)	Daily distance (km)	Average length (km)	Average duration (min)	Average speed (km/h)
Germany	5.8	75	66.0	10.6	12.3	51.4
France	4.8	60	36.8	7.6	12.4	36.8
UK	4.7	58	41.0	8.4	12.1	41.5
Average	5.1	64	46.4	8.9	12.3	43.4

3.4 Tier 3 method

The Tier 3 approach is an extension of the Tier 2 approach, and uses the same starting equation (equation 2). In this case, detailed emission factors can be used depending on the temperature profile and the driving and parking pattern over the day.

3.4.1 Algorithms and methodology

The starting algorithm for the Tier 3 methodology is the same as that for the Tier 2 methodology:

$$E_{voc} = \sum_{s} D_s \times \sum_{j} N_j \times (HS_j + e_{d,j} + RL_j) \quad (6)$$

where:

E_{voc} = annual VOC emissions due to evaporative emissions (g),

D_s = the number of days for which each specific temperature-dependant emission factor should be applied ($\sum_{s} D_s$ = total number of days in a particular year),

N_j = number of gasoline vehicles in category *j,*

HS_j = average daily soak emissions (hot, warm and cold) of vehicle category *j* (g/day), as per equation 3,

$e_{d,j}$ = average diurnal emissions of vehicle category *j* (g/day),

RL_j = average daily running losses (hot, warm and cold) of vehicle category *j* (g/day), as per equation 4.

The Tier 3 method is based on a number of input parameters, which include (i) fuel vapour pressure, (ii) vehicle tank size, (iii) fuel tank fill level, (iv) canister size, (v) diurnal temperature variation and (vi) cumulative mileage. Since a parking event may occur anytime during the day, a daily parking pattern is suggested, and a function is provided for estimating the temperature variation during the parking event. In order to estimate the canister status going into a parking event, the distance driven prior to each parking event is also taken into account in the calculations. Based on these, intermediate calculations for the estimation of fuel vapour generation and the canister load are performed for each parking event. Then, breakthrough emissions (for canister-equipped vehicles) or tank emissions (for carburetted vehicles) are calculated, as well as emissions due to fuel permeation and/or leakage. The total evaporative emissions for each evaporation process (diurnal emissions, hot-soak emissions and running losses) are determined by the sum of breakthrough or tank emissions and emissions due to fuel permeation and/or leakage.

The following sections describe the general processes and provide detailed equations and emissions factors.

Diurnal temperature variation

Diurnal emissions take place during vehicle parking as the ambient temperature varies during the day. In order to calculate diurnal emissions, both the temperature variation and the parking distribution during the day need to be known.

The diurnal temperature variation between the minimum and the maximum ambient temperatures is given by the following equation, and is in line with the diurnal temperature profile introduced in the type approval SHED test procedure (Directive 91/441/EEC):

$$T = T_{min} + T_{rise}\ e^{-0.0247\,(t-14)^2} \quad (7)$$

where

t	=	hour of the day (h),
T_{min}	=	minimum daily temperature (°C),
T_{max}	=	maximum daily temperature (°C),
T_{rise}	=	rise in the daily temperature, calculated as $T_{max} - T_{min}$ (°C).

Note

The T_{min} and T_{max} temperatures correspond to the average minimum daily and maximum daily temperatures over a defined period of time, e.g. one month. The maximum temperatures are usually observed in the early afternoon and the minimum temperature during the first morning hours.

As an example, when the minimum temperatures over two consecutive days are 2°C and 5°C and the maximum ones are 15°C and 19°C, the T_{min} and T_{max} values are 3.5°C and 17°C respectively.

These two values define the average temperature difference during a day, which is a key determinant of diurnal evaporation emissions.

The minimum and maximum temperatures need to be calculated over a complete parking period. A parking period can be defined from the end-time of the parking period and the parking duration t_{park}. In order to estimate diurnal emissions in detail, the parking duration can be distributed into 24 time bands ranging from < 2 to > 46 h. Each combination of parking duration and parking end-time has a probability factor f_k, as shown in Table 3-8. The sum of f_k values in Table 3-8 equals 1.

Table 3-8 Parking time distribution as a function of parking end-time

Parking end-time t_2 (hh:mm)	Parking duration t_{park} (h)				
	< 2	4	6	...	>46
1:00	f_1	f_2	f_3	...	f_{24}
2:00	f_{25}	f_{26}	f_{27}	...	f_{48}
3:00	f_{49}	f_{50}	f_{51}	...	f_{72}
...	...	...	...	...	...
24:00	f_{553}	f_{554}	f_{555}	...	f_{576}

The start time of parking may be calculated as $t_1 = t_2 - t_{park}$.

Canister status

The amount of fuel vapour loaded to the canister at the start of a parking event depends on the distance travelled before the vehicle is parked. In order to estimate the canister status going into a parking event, the trip distance is distributed into 4 distance bands ranging from 5 km to > 15 km. Each trip distance has a probability factor f_n, as shown in Table 3-9. The sum of f_n values in Table 3-9 equals 1.

Table 3-9 Trip distribution

Distance (km)	5	10	15	> 15
Frequency	0.59	0.19	0.09	0.13

A purge volume over each trip is then calculated. To this aim, two standard purge rates are used to calculate the purge volume: a rate of 9.66 litres per kilometre for small cars, and a rate of 16.68 litres per kilometre for medium and large cars. For Euro 6d-temp and Euro 6d, a more intense purging strategy is needed, hence the purge rates assumed are 16.77 for small cars, and 28.97 litres per kilometre for medium and large cars.

The Gasoline Working Capacity (GWC) of the canister is then calculated at the start and the end of each trip based on a typical purge curve. The canister status going into a parking event is thus estimated.

Fuel tank vapour generation

The vapour generation in the fuel tank (g) may be calculated as a function of fuel volatility, temperature variation, fuel tank size and fill level by the following equation (Reddy, 1989):

$$m_{tank}(T_{min,k}, T_{max,k}) = (1 - h/100)\ v_{tank}\ \left(0.025\ e^{0.0205\ vp}\left(e^{0.0716\ T_{max,k}} - e^{0.0716\ T_{min,k}}\right)\right) \quad (8)$$

where:

h	=	fuel tank fill level (%),
v_{tank}	=	fuel tank, fuel system and vapour control system volume (lt),
vp	=	fuel vapour pressure (DVPE) (kPa),

$T_{min,k}$ = minimum tank temperature during parking period *k* (°C),

$T_{max,k}$ = maximum tank temperature during parking period *k* (°C).

The equation above is valid only for the fraction of the parking period for which temperature increases. In the occasion of a continuous temperature decrease (e.g. after daily maximum value) there is no vapour generated in the fuel tank (m_{tank}=0).

> Note
>
> The Fuel Quality Directive (2009/30/EC) sets out a maximum permitted vapour pressure of 60 kPa for summer grade petrol while allowing the possibility of derogations for Member States with low ambient temperatures. Member States are required under the Directive to report annually on the quality of petrol and diesel for the preceding calendar year. Annual reports summarising this information can be found on the EEA website: https://www.eea.europa.eu/publications/fuel-quality-in-the-eu

Canister breakthrough emissions

Based on experimental work on carbon canisters (Mellios and Samaras, 2007) it was found that the canister weight gain during loading with fuel vapour is best described by the following equations:

$$m_{ads} = \left(m_{load} - e^{(a + b \times s \times m_{load})}\right) deg \qquad (9)$$

and

$$a = -3.2786 - 0.01052\ vp + 0.0229\ T \qquad (10)$$

$$b = 0.03247 + 0.00054\ vp + 0.00056\ T \qquad (11)$$

$$deg = 1 - 0.01\ (M_{cum,j} / M_{eff}) \qquad (12)$$

where:

m_{ads} = cumulative fuel vapour adsorbed on the carbon canister during loading (g),

m_{load} = cumulative fuel vapour loaded to the carbon canister (g),

s = canister size (equal to 1/canister size in litres), *s* = 1.25 for small, *s* = 1 for medium and *s* = 0.625 for large canister),

$M_{cum,j}$ = cumulative mileage (km) of the vehicle category *j*,

M_{eff} = mileage (km) at which the efficiency of the activated carbon decreases by 1%.

Two classes of durability of carbons are currently used in Europe:

- Low Degradation Carbons: these carbons lose about 4% to 9% of their capacity over the lifetime of the vehicle, due to repeated cycling with gasoline.

- High Degradation Carbons: these carbons lose about 12% to 20% of their capacity over the lifetime of the vehicle, due to repeated cycling with gasoline.

For non-ethanol containing fuels the efficiency of the activated carbon decreases by 1% every 12 000 km for small cars (i.e. about 13% decrease over vehicle lifetime), and by 1% every 40 000 km for medium and large cars (i.e. about 4% decrease over vehicle lifetime). For low ethanol blends the efficiency of the activated carbon decreases by 1% every 8 000 km for small cars and by 1% every 32 000 km for medium and large cars (i.e. 20% and 5% over vehicle lifetime respectively). Low degradation carbon is expected to be used in all Euro 6d-temp and Euro 6d cars (regardless of vehicle size) as a result of the stricter aging procedure of the carbon canister laid down in Regulation (EU) 2017/1221.

Equation (9) is valid for $0 \leq m_{load} \leq m_{sat}$, where m_{sat} is the cumulative fuel vapour that saturates the canister. For $m_{load} > m_{sat}$, $m_{ads} = m_{max}$, where m_{max} is the saturated capacity of the canister.

The initial canister weight is determined from the purge rate and the distance travelled by a vehicle going into a parking event as:

$$m_{ads,1} = \left(0.08476\ e^{(-0.05755 V_{purge,\ fin})} + 0.1272\ e^{(-0.002579 V_{purge,\ fin})}\right) \times 350\ /\ s \qquad (13)$$

where $V_{purge,fin}$ (l) is the total purge volume needed to purge the canister from saturation to its status at the beginning of parking and it is calculated as:

$$V_{purge,fin} = d_{trip} \times r_{purge} + 30 \qquad (14)$$

where:

d_{trip} = the distance travelled prior to a parking event (km)

r_{purge} = canister purge rate during driving (l/km) (r_{purge} = 9.66 for small, r_{purge} = 16.68 for medium and large canister, increased to r_{purge} = 16.77 for small, r_{purge} = 28.97 for medium and large canisters in Euro 6d-temp and Euro 6d).

The initial amount of vapour loaded on the canister $m_{load,1}$ is calculated using equations 9 to 12 for the vapour pressure and the initial temperature of the fuel in the tank, and canister degradation. This vapour load corresponds to the amount of vapour needed to increase the canister weight from dry to its initial weight at the beginning of the parking period. The amount of fuel vapour generated over the parking period is calculated by equation 8, and it is then added to $m_{load,1}$ to give the final vapour load $m_{load,2}$. The canister breakthrough emissions (g) are then calculated as:

$$m_{break}(T_{min,\ k}, T_{max,\ k}) = e^{(a+b \times s \times m_{load,2})} - e^{(a+b \times s \times m_{load,1})} \qquad (15)$$

Permeation emissions

For passenger cars and light commercial vehicles standard permeation rates are used for fluorinated mono-layer (0.6 g/day) and for multi-layer (0.2 g/day) fuel tanks containing non-ethanol fuels. For ethanol containing fuels (E5 – E10), 0.3 g/day additional permeation emissions from the fuel and vapour control system are assumed.

For mopeds and all-terrain vehicles (ATVs) up to Euro 4 a permeation rate of 0.01 g/h/l (grams per hour per litre of fuel tank) is assumed. For an average fuel tank volume of 7.5 litres for mopeds and 22 litres for ATVs the resulting permeation rates are 1.8 and 5.28 g/day respectively. For Euro 5 a reduced permeation rate of 0.0029 g/h/l is assumed, resulting in permeation rates of 0.52 and 1.53 g/day for mopeds and ATVs respectively. The same permeation rate of 0.0029 g/h/l is also suggested for motorcycles of all sizes and Euro classes. There is no distinction for ethanol and non-ethanol containing fuels.

The following table summarises the permeation rates m_{perm} (in g/h) for the different vehicle categories and combinations of fuel tank structure and fuel type.

Table 3-10 Permeation rates (g/h)

	Fuel tank type	Non-ethanol-containing	Ethanol-containing
Passenger cars and LCVs	Mono-layer	0.0250	0.0375
Passenger cars and LCVs	Multi-layer	0.0083	0.0205
Mopeds up to Euro 4	All	0.0750	
ATVs up to Euro 4	All	0.2200	
Mopeds Euro 5	All	0.0218	
ATVs Euro 5	All	0.0638	
Motorcycles 4-stroke <250 cm^3	All	0.0145	
Motorcycles 4-stroke 250−750 cm^3	All	0.0290	
Motorcycles 4-stroke >750 cm^3	All	0.0609	

The fraction of new light duty vehicles (passenger cars and LCVs) equipped with fluorinated tanks is decreasing over the years. It is estimated to be about 35% in 2012 and is expected to be lower than 1% after 2020. L-category vehicles are mostly equipped with mono-layer fuel tanks.

The above permeation emission rates may also include emissions due to small leakages of fuel vapour and/or liquid fuel.

Hence, non-canister emissions (g/parking) (also referred to as resting losses) over a parking period are calculated as:

$$m_{rest} = m_{perm}\, t_{park} \tag{16}$$

3.4.2 Emission factors

Gasoline passenger cars

Diurnal emissions

For any parking period *k* the vapour generated in the tank — and the associated breakthrough emissions — are calculated using equations 8–15 as described above. The permeation and leakage emissions are calculated by equation 18. The diurnal emissions for each parking period *k* (in g/parking) are thus calculated as:

$$m_{break}\left(T_{min,k}, T_{max,k}\right) + m_{rest} \tag{17}$$

Taking into account all parking periods, the average diurnal emissions (in g/day) are calculated as:

$$e_d = \sum_k f_k \cdot \left(m_{break}\left(T_{min,k}, T_{max,k}\right) + m_{rest}\right) \tag{18}$$

For gasoline vehicles without carbon canister all vapour generated in the fuel tank is released in the atmosphere. Thus, the mean emission factor for uncontrolled vehicles (in g/day) is given by the following equation:

$$e_d = \sum_k f_k \cdot \left(m_{tank}\left(T_{min,k}, T_{max,k}\right) + m_{rest}\right) \tag{19}$$

Hot-soak emissions

For gasoline vehicles with fuel injection and returnless fuel systems, the fuel temperature in the tank is not affected by engine operation, and thus no fuel vapour is generated in the tank when a hot engine is turned off. Hot-soak emissions are mainly due to fuel permeation and/or leakage. The mean hot-soak emission factor for gasoline vehicles (both canister-equipped and uncontrolled) with fuel injection and returnless fuel systems (in g/parking) is given by the following equation:

$$e_{s,hot,fi} = m_{rest} \tag{20}$$

For vehicles equipped with carburettor and/or fuel return systems, engine operation results in significant temperature increase in the fuel tank and/or the carburettor (Morgan et al., 1993). The additional fuel vapour that is generated loads the carbon canister causing breakthrough emissions which are calculated using equations 8–13 as described above. For the warm-soak emissions a 4.5 °C increase in the fuel temperature in the tank is used, while a 6 °C increase is used for hot-soak emissions. The mean warm and hot-soak emission factors for canister-equipped gasoline vehicles with carburettor and/or fuel return systems (in g/parking) are thus given by the following equations:

$$\begin{aligned} e_{s,hot,c} &= \sum_k f_k \cdot m_{break}(T_{1,k}, T_{1,k} + 6) + e_{s,hot,fi} \\ e_{s,warm,c} &= \sum_k f_k \cdot m_{break}(T_{1,k}, T_{1,k} + 4.5) + e_{s,hot,fi} \end{aligned} \tag{21}$$

For uncontrolled vehicles the above equations are rewritten as follows:

$$\begin{aligned} e_{s,hot,c} &= \sum_k f_k \cdot m_{tank}(T_{1,k}, T_{1,k} + 6) + e_{s,hot,fi} \\ e_{s,warm,c} &= \sum_k f_k \cdot m_{tank}(T_{1,k}, T_{1,k} + 4.5) + e_{s,hot,fi} \end{aligned} \tag{22}$$

Running losses

As mentioned above, for vehicles with fuel injection and a returnless fuel system the fuel temperature in the tank is not affected by engine operation, and thus the running losses are attributed to fuel permeation and/or leakage. The mean running losses emission factor for gasoline vehicles (both canister-equipped and uncontrolled) with returnless fuel systems (in g/trip) is calculated as:

$$e_{r,hot,fi} = t_{trip} \cdot m_{perm} \tag{23}$$

where t_{trip} is the mean driving duration per trip, average over the year (h/trip).

For vehicles equipped with a carburettor and/or fuel return system, the additional fuel vapour that is generated in the fuel tank loads the carbon canister. However, the canister is being purged with air at certain time intervals and thus no significant breakthrough emissions are observed (except for long periods of idling when the purge valve, controlling the amount of air that is used for purging, remains shut). For canister-equipped vehicles with a carburettor and/or fuel return system, equation 22 can be used for calculating hot and warm running losses, i.e.:

$$e_{r,hot,c} = e_{r,warm,c} = e_{r,hot,fi} \tag{24}$$

For uncontrolled vehicles the fuel vapour generated in the tank due to temperature increase also contributes to the running losses. For the warm running losses, a 1 °C increase in the fuel temperature in the tank is used, while a 5 °C increase is used for hot running losses. The mean warm and hot running losses factors for uncontrolled gasoline vehicles with fuel return systems (in g/trip) are thus given by the following equation:

$$\begin{aligned} e_{r,hot,c} &= \sum_k f_k \cdot m_{tank}(T_{2,k}, T_{2,k} + 5) + e_{r,hot,fi} \\ e_{r,warm,c} &= \sum_k f_k \cdot m_{tank}(T_{2,k}, T_{2,k} + 1) + e_{r,hot,fi} \end{aligned} \tag{25}$$

Light commercial vehicles

The same emission factors as for passenger cars may be applied.

L-category vehicles

Diurnal emissions for canister-equipped and uncontrolled L-category vehicles are calculated by equations 17 and 18, respectively.

The mean warm and hot-soak emission factors for controlled motorcycles equipped with fuel injection and those equipped with carburettor (in g/parking) are given by the following equations:

$$\begin{aligned} e_{s,hot,fi} &= \sum_k f_k \cdot m_{break}(T_{1,k}, T_{1,k} + 1.5) \\ e_{s,hot,c} &= \sum_k f_k \cdot m_{break}(T_{1,k}, T_{1,k} + 3.5) \end{aligned} \tag{26}$$

For uncontrolled vehicles equipped with fuel injection, and motorcycles equipped with carburettor, the mean warm and hot-soak emission factors (in g/parking) are:

$$\begin{aligned} e_{s,hot,fi} &= \sum_k f_k \cdot m_{tank}(T_{1,k}, T_{1,k} + 1.5) \\ e_{s,hot,c} &= \sum_k f_k \cdot m_{tank}(T_{1,k}, T_{1,k} + 3.5) \end{aligned} \tag{27}$$

The mean warm and hot running losses factors for controlled motorcycles equipped with fuel injection and those equipped with carburettor (in g/trip) are given by the following equations:

$$e_{r,hot,fi} = \sum_k f_k \cdot m_{break}(T_{2,k}, T_{2,k} + 1)$$
$$e_{r,hot,c} = \sum_k f_k \cdot m_{break}(T_{2,k}, T_{2,k} + 2.5) \qquad (28)$$

For uncontrolled vehicles equipped with fuel injection and those equipped with carburettor, the mean warm and hot running losses factors (in g/trip) are:

$$e_{r,hot,fi} = \sum_k f_k \cdot m_{tank}(T_{2,k}, T_{2,k} + 1)$$
$$e_{r,hot,c} = \sum_k f_k \cdot m_{tank}(T_{2,k}, T_{2,k} + 2.5) \qquad (29)$$

Summary

The basic emission factors, which are necessary to apply the methodology, are listed in Table 3-11.

Table 3-11 Summary of emission factors for estimating evaporative emissions of passenger cars, light commercial vehicles and L-category vehicles

Emission factor	Uncontrolled vehicle	Canister-equipped vehicle
Passenger cars and light-duty vehicles		
e_d (g/day)	$\sum_k f_k \cdot (m_{tank}(T_{min,k}, T_{max,k}) + m_{rest})$	$\sum_k f_k \cdot (m_{break}(T_{min,k}, T_{max,k}) + m_{rest})$
$e_{s,hot,fi}$ (g/parking)	m_{rest}	m_{rest}
$e_{s,warm,c}$ (g/parking)	$\sum_k f_k m_{tank}(T_{1,k}, T_{1,k} + 4.5) + e_{s,hot,fi}$	$\sum_k f_k m_{break}(T_{1,k}, T_{1,k} + 4.5) + e_{s,hot,fi}$
$e_{s,hot,c}$ (g/parking)	$\sum_k f_k \cdot m_{tank}(T_{1,k}, T_{1,k} + 6) + e_{s,hot,fi}$	$\sum_k f_k \cdot m_{break}(T_{1,k}, T_{1,k} + 6) + e_{s,hot,fi}$
$e_{r,hot,fi}$ (g/trip)	$t_{trip} \cdot m_{perm}$	$t_{trip} \cdot m_{perm}$
$e_{r,warm,c}$ (g/trip)	$\sum_k f_k \cdot m_{tank}(T_{2,k}, T_{2,k} + 1) + e_{r,hot,fi}$	$e_{r,hot,fi}$
$e_{r,hot,c}$ (g/trip)	$\sum_k f_k \cdot m_{tank}(T_{2,k}, T_{2,k} + 5) + e_{r,hot,fi}$	$e_{r,hot,fi}$
L-category vehicles		
e_d (g/day)	$\sum_k f_k \cdot (m_{tank}(T_{min,k}, T_{max,k}) + m_{rest})$	$\sum_k f_k \cdot (m_{break}(T_{min,k}, T_{max,k}) + m_{rest})$

$e_{s,hot,fi}$ (g/parking)	$\sum_k f_k \cdot m_{tank}(T_{1,k}, T_{1,k} + 1.5)$	$\sum_k f_k \cdot m_{break}(T_{1,k}, T_{1,k} + 1.5)$
$e_{s,hot,c}$ (g/parking)	$\sum_k f_k \cdot m_{tank}(T_{1,k}, T_{1,k} + 3.5)$	$\sum_k f_k \cdot m_{break}(T_{1,k}, T_{1,k} + 3.5)$
$e_{r,hot,fi}$ (g/trip)	$\sum_k f_k \cdot m_{tank}(T_{2,k}, T_{2,k} + 1)$	$\sum_k f_k \cdot m_{break}(T_{2,k}, T_{2,k} + 1)$
$e_{r,hot,c}$ (g/trip)	$\sum_k f_k \cdot m_{tank}(T_{2,k}, T_{2,k} + 2.5)$	$\sum_k f_k \cdot m_{break}(T_{2,k}, T_{2,k} + 2.5)$

3.4.3 Activity data

In addition to the emission factors, the proposed methodology requires statistical data which is unlikely to be available in many countries (e.g. the parameters p, c, x, t_{park}, t_{trip} and l_{trip}). This data can be obtained from detailed national statistics or various experimental studies (e.g. André et al., 1994). Examples for some countries are shown in Table 3-7 and Table 3-8 (in subsection 3.3.3 of the present chapter). Table 3-10 and Table 3-11 suggest input data for the parking time distribution and vehicle design characteristics respectively. An estimation of the fraction of vehicles equipped with a carburettor and/or fuel return systems is provided in subsection 3.3.3 of the present chapter.

Table 3-12 Parking time distribution

Parking end-time (hh:mm)	Parking duration t_{park} (h)																								
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	>46	
02:00	0.64%	0.31%	0.17%	0.07%	0.03%	0.02%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	**1.3%**
04:00	0.29%	0.12%	0.10%	0.07%	0.06%	0.03%	0.02%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	**0.7%**
06:00	0.55%	0.03%	0.07%	0.17%	0.25%	0.39%	0.19%	0.08%	0.05%	0.03%	0.01%	0.01%	0.00%	0.00%	0.00%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.06%	**2.0%**
08:00	4.16%	0.05%	0.09%	0.44%	0.79%	1.21%	1.94%	0.65%	0.22%	0.19%	0.12%	0.07%	0.02%	0.01%	0.01%	0.03%	0.04%	0.05%	0.09%	0.05%	0.03%	0.04%	0.03%	0.33%	**10.7%**
10:00	7.58%	0.30%	0.06%	0.12%	0.34%	0.42%	0.58%	0.67%	0.30%	0.13%	0.14%	0.11%	0.03%	0.01%	0.00%	0.01%	0.02%	0.02%	0.04%	0.06%	0.04%	0.02%	0.03%	0.33%	**11.3%**
12:00	8.94%	1.36%	0.95%	0.10%	0.12%	0.20%	0.20%	0.26%	0.28%	0.13%	0.07%	0.08%	0.04%	0.01%	0.01%	0.00%	0.01%	0.01%	0.01%	0.02%	0.03%	0.02%	0.01%	0.27%	**13.2%**
14:00	7.00%	1.17%	1.04%	0.50%	0.15%	0.07%	0.10%	0.11%	0.12%	0.17%	0.10%	0.05%	0.04%	0.03%	0.01%	0.01%	0.00%	0.00%	0.01%	0.01%	0.02%	0.03%	0.02%	0.27%	**11.1%**
16:00	7.98%	1.72%	0.65%	0.48%	0.31%	0.07%	0.07%	0.09%	0.09%	0.12%	0.18%	0.10%	0.04%	0.05%	0.04%	0.02%	0.01%	0.00%	0.00%	0.01%	0.01%	0.02%	0.04%	0.35%	**12.4%**
18:00	10.31%	1.77%	1.28%	0.43%	0.82%	0.49%	0.06%	0.04%	0.07%	0.07%	0.10%	0.14%	0.06%	0.03%	0.04%	0.03%	0.02%	0.01%	0.00%	0.01%	0.01%	0.02%	0.02%	0.32%	**16.1%**
20:00	7.61%	1.34%	0.93%	0.48%	0.27%	0.38%	0.16%	0.02%	0.03%	0.05%	0.06%	0.06%	0.06%	0.03%	0.02%	0.02%	0.02%	0.01%	0.01%	0.00%	0.00%	0.01%	0.02%	0.25%	**11.9%**
22:00	3.04%	1.27%	0.29%	0.17%	0.17%	0.07%	0.04%	0.03%	0.02%	0.02%	0.03%	0.03%	0.02%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%	0.01%	0.14%	**5.4%**
00:00	2.07%	1.12%	0.35%	0.11%	0.07%	0.04%	0.02%	0.02%	0.01%	0.00%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.06%	**3.9%**
	58.1%	**9.4%**	**5.6%**	**3.0%**	**3.3%**	**3.4%**	**3.4%**	**2.0%**	**1.2%**	**0.9%**	**0.8%**	**0.6%**	**0.3%**	**0.2%**	**0.2%**	**0.1%**	**0.1%**	**0.1%**	**0.2%**	**0.2%**	**0.2%**	**0.2%**	**0.2%**	**2.4%**	**100%**

Table 3-13 Suggested (typical) fuel-tank and canister sizes for various vehicle categories

Category	Segment / fuel	Euro standard	Fuel tank size (litres)	Canister size (litres)
Passenger Cars	Petrol Mini	All Euro	35	0.8
Passenger Cars	Petrol Small	Pre Euro	50	---
Passenger Cars	Petrol Small	Euro 1 - Euro 2	50	0.5
Passenger Cars	Petrol Small	Euro 3 - Euro 6c	50	0.8
Passenger Cars	Petrol Small	Euro 6d-temp / 6d	50	1.6
Passenger Cars	Petrol Medium	Pre Euro	60	---
Passenger Cars	Petrol Medium	Euro 1 - Euro 2	60	0.67
Passenger Cars	Petrol Medium	Euro 3 - Euro 6c	60	1
Passenger Cars	Petrol Medium	Euro 6d-temp / 6d	60	2
Passenger Cars	Petrol Large-SUV-Executive	Pre Euro	75	---
Passenger Cars	Petrol Large-SUV-Executive	Euro 1 - Euro 2	75	1
Passenger Cars	Petrol Large-SUV-Executive	Euro 3 - Euro 6c	75	1.5
Passenger Cars	Petrol Large-SUV-Executive	Euro 6d-temp / 6d	75	3
Passenger Cars	Petrol 2-Stroke	Conventional	50	---
Light Commercial Vehicles	Petrol N1-I, N1-II	Conventional	60	---
Light Commercial Vehicles	Petrol N1-I, N1-II	Euro 1 - Euro 2	60	0.67
Light Commercial Vehicles	Petrol N1-I, N1-II	Euro 3 - Euro 6c	60	1
Light Commercial Vehicles	Petrol N1-I, N1-II	Euro 6d-temp / 6d	60	2
Light Commercial Vehicles	Petrol N1-III	Conventional	75	---
Light Commercial Vehicles	Petrol N1-III	Euro 1 - Euro 2	75	1
Light Commercial Vehicles	Petrol N1-III	Euro 3 - Euro 6c	75	1.5
Light Commercial Vehicles	Petrol N1-III	Euro 6d-temp / 6d	75	3
Heavy Duty Trucks	Petrol >3.5 t	Conventional	300	---
L-Category	Mopeds	All	7.5	---
L-Category	Motorcycles 2-S	All	5	---
L-Category	Motorcycles 4-S <250 cm³	All	5	---
L-Category	Motorcycles 4-S 250-750 cm³	Conventional	10	---
L-Category	Motorcycles 4-S 250-750 cm³	Euro 1 - Euro 2	10	---
L-Category	Motorcycles 4-S 250-750 cm³	Euro 3 - Euro 5	10	0.15
L-Category	Motorcycles 4-S >750 cm³	Conventional	18	---
L-Category	Motorcycles 4-S >750 cm³	Euro 1 - Euro 4	18	0.2
L-Category	Motorcycles 4-S >750 cm³	Euro 5	18	0.25
L-Category	ATVs	All	22	---

The parking time distribution table (Table 3-12) has been based on real-world data from GPS recordings from a sample fleet of about 20 000 vehicles over a period of one month. The dataset includes parking events extending over several days, which have a significant impact on diurnal emissions.

Other sources of information on parking statistics include the Artemis and the Auto-Oil I projects.

Parking duration data were collected in the framework of the Artemis project (Andrè and Joumard, 2005) and are shown in Table 3-14. Parking duration is shown in italic characters while percentage values give the frequency. This can be considered typical for an average European condition, unless better data are available.

Table 3-14 Parking duration frequency (italic characters: parking duration, percentage values: frequency)

Parking duration t_{park} (h)											
<0.5	*1*	*1.5*	*2*	*2.5*	*3*	*3.5*	*4*	*4.5*	*5*	*5.5*	*6*
42 %	14 %	2.0 %	4.9 %	5.9 %	2.0 %	2.9 %	1.5 %	1.5 %	1.0 %	1.0 %	0.5 %
6.5	*7*	*7.5*	*8*	*8.5*	*9*	*9.5*	*10*	*10.5*	*11*	*11.5*	*>12*
1.0 %	0.5 %	0.5 %	0.5 %	0.5 %	0.5 %	0.5 %	0.5 %	0.5 %	0.5 %	0.5 %	13 %

In order to assess the frequency of parking end-time, one can consider that this coincides with the traffic intensity. Table 3-15 provides an averaged traffic profile from seven European cities (Athens, Cologne, London, Lyon, Madrid, Milan, and The Hague) derived from a study conducted in the framework of the Auto-Oil I project. The italic characters correspond to hour of day and percentage values show the fraction of total daily traffic that occurs in the particular hour of day. Of course, there may be a difference between traffic intensity and end-of-parking hour, but one can consider that averaging effects reduce this difference. By combining (multiplying) Table 3-14 with Table 3-15 one can get similar values to those of Table 3-11.

Table 3-15 Parking-end time as a function of time of day (italic characters: time of day, percentage values: frequency)

Parking end-time t_2 (h)											
0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
2.2 %	1.2 %	0.7 %	0.4 %	0.7 %	2.2 %	4.6 %	5.5 %	5.2 %	5.2 %	5.3 %	5.5 %
12	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*
4.6 %	5.2 %	5.6 %	5.8 %	6.4 %	6.5 %	6.3 %	5.1 %	4.4 %	4.2 %	3.9 %	3.1 %

3.5 Species profile for NMVOC from evaporative emissions

Based on the composition (speciation) of evaporative emissions analysed by means of gas chromatography, evaporative emissions are reported as $CH_{2.1}$. This corresponds to the mass content of carbon and hydrogen in the fuel vapour, and is specified in test protocols.

Almost all petrol sold in the EU in 2016 contains oxygenates. The distribution of NMVOCs by compound is given in Table 3-16 for two different types of oxygenated fuels, gasoline blended with ethanol (typically E5 or E10) or fuel ethers (MTBE or ETBE). An important difference in the speciation of vapours from the two oxygenated fuels is in the benzene concentration which is about 15% higher for ethanol blends. The proposed fractions have been obtained from different studies, including Harley et al., (1999), Kirchstetter et al. (1999) and a European test programme on evaporative emissions from canister-equipped gasoline passenger cars (JRC, 2007). It should be noted that the speciation of evaporative emissions depends on the fuel composition. Light fuel components tend to be more volatile than heavy ones. Hence, the profile of species evaporating may be shifted to lighter components.

Table 3-16 Composition of NMVOC in evaporative emissions

Group	Species	NMVOC fraction (% wt) Ethanol blends	NMVOC fraction (% wt) Fuel ether blends
Alkanes	ethane	0.27	0.26
	propane	4.60	4.34
	i-butane	3.91	3.69
	n-butane	5.24	4.93
	i-pentane	9.56	9.00
	n-pentane	6.90	6.50
	2-methylpentane	12.54	11.81
	3-methylpentane	22.49	21.18
	n-hexane	1.81	1.70
	n-heptane	1.48	1.39
Alkenes	ethene	0.06	0.05
	propene	0.30	0.26
	1-butene	0.79	0.68
	trans-2-butene	1.30	1.12
	isobutene	0.13	0.11
	cis-2-butene	1.15	0.99
	1,3 butadiene	0.00	0.00
	trans-2-pentene	1.75	1.50
	cis-2-pentene	0.82	0.71
	isoprene	0.00	0.00
Alkines	propyne	0.08	0.07
	acetylene	0.01	0.01
Aromatics	benzene	0.80	0.70
	toluene	4.36	4.12
	ethylbenzene	3.90	3.68
	m-xylene	6.40	6.05
	o-xylene	2.79	2.63
	1,2,4-trimethylbenzene	0.55	0.52
	1,3,5-trimethylbenzene	0.00	0.00
Oxygenates	ethanol	6.00	12.00
	ethers	0.00	0.00
Totals (all NMVOC species)		100.00	100.00

4 Data quality

4.1 Completeness

See the discussion in the chapter on Exhaust emissions from road transport.

4.2 Avoiding double counting with other sectors

See the discussion in the chapter on Exhaust emissions from road transport.

4.3 Verification

See the discussion in the chapter on Exhaust emissions from road transport.

4.4 Developing a consistent time series and recalculation

No specific issues

4.5 Uncertainty assessment

Using the indicators introduced in the chapter on road transport, Table 4-1 provides qualitative estimates of the precision which can be allocated to the calculation of evaporative emissions.

Table 4-1 Summary of precision indicators of the evaporative emission estimates

Vehicle category	NMVOC
Passenger cars, conventional	B
Passenger cars, canister-equipped	A
Light-duty vehicles, conventional	D
Light-duty vehicles, canister-equipped	D
L-category vehicles, conventional	B
L-category vehicles, canister-equipped	B

Legend:
A: statistically significant emission factors based on sufficiently large set of measured and evaluated data;
B: emission factors non statistically significant based on a small set of measured re-evaluated data;
C: emission factors estimated on the basis of available literature;
D: emission factors estimated applying similarity considerations and/or extrapolation. See text for later than Euro 1 vehicles.

4.6 Inventory quality assurance/quality control (QA/QC)

No specific issues.

4.7 Gridding

Evidently the principles of the approaches outlined for exhaust emission spatial allocation apply equally to evaporative emissions. In particular, as regards the top-down approach, the following hints may be useful:

- diurnal emissions: as diurnal emissions occur at any time, their spatial allocation to urban/rural/highway conditions depends on the time spent by the vehicles on the different road classes. Therefore, for those vehicles that are used by city inhabitants, one can assume that 11/12 of their diurnal emissions occur in urban areas, the rest being split between rural and highway driving proportionally to the ratio of (rural mileage x highway speed) / (highway mileage x rural speed);
- soak emissions: the majority of these emissions occur in the area of residence of the car owner, as they are associated with short trips;
- running losses: running losses are proportional to the mileage driven by the vehicles. Therefore, their allocation to urban areas, rural areas and highways has to follow the mileage split assumed for the calculation of exhaust emissions.

4.8 Reporting and documentation

No specific issues.

4.9 Additional comments

The evaporation emissions calculation scheme presented above is fully integrated into COPERT 4 (Computer Programme to Calculate Emissions from Road Traffic), which substantially facilitates the practical application of the methodology (see Ntziachristos et al. 2000).

4.10 Weakest aspects/priority areas for improvement in current methodology

The proposed methodology has been based on results from a range of canister-equipped gasoline vehicles representative of current Euro 3 and Euro 4 technology, and typical summer and winter fuels and temperatures. Although large numbers of hot-soak and diurnal tests have been carried out, running losses were not measured and therefore the proposed emission factors need further improvement. Other areas requiring additional consideration include:

- evaporative emission factors for light-duty vehicles; and
- evaporative emission factors for fuels containing bio components (e.g. ethanol).

5 Glossary and abbreviations

5.1 List of abbreviations

ATV	All-Terrain Vehicles
DVPE	Dry Vapour Pressure Equivalent at a temperature of 37.8 °C
NMVOC	Non-Methane Volatile Organic Compounds
VOC	Volatile Organic Compounds

5.2 List of symbols

c	fraction of gasoline powered vehicles equipped with carburettor and/or fuel return systems
d_{trip}	distance travelled prior to a parking event (km)
deg	carbon canister degradation
e_d	average diurnal emissions of vehicle category j (g/day)
$e_{r,hot,c}$	mean emission factor for hot running losses of gasoline powered vehicles with carburettor and/or fuel return systems (g/trip)
$e_{r,hot,fi}$	mean emission factor for hot running losses of gasoline powered vehicles with fuel injection and returnless fuel systems (g/trip)
$e_{r,warm,c}$	mean emission factor for cold and warm running losses of gasoline powered vehicles with carburettor and/or fuel return systems (g/trip)
$e_{s,hot,c}$	mean hot-soak emission factor of gasoline powered vehicles with carburettor and/or fuel return systems (g/parking)
$e_{s,hot,fi}$	mean hot-soak emission factor of gasoline powered vehicles with fuel injection and returnless fuel systems (g/parking)
$e_{s,warm,c}$	mean cold- and warm-soak emission factor of gasoline powered vehicles with carburettor and/or fuel return systems (g/parking)
$E_{eva,voc,j}$	VOC emissions due to evaporative emissions caused by vehicle category j (g)
f_k	probability factor for combination of parking duration and ending hour of parking
h	fuel tank fill level (%)
HS_j	average daily hot- and warm-soak emissions of vehicle category j (g/day)
l_{trip}	average trip length (km)
m_{ads}	cumulative fuel vapour adsorbed on the carbon canister during loading (g)
m_{load}	cumulative fuel vapour loaded to the carbon canister (g)
m_{tank}	fuel vapour generation (g)
m_{break}	canister breakthrough emissions (g)
m_{perm}	emissions due to fuel permeation (g)
m_{rest}	resting losses (emissions due to permeation and small leakages) (g)

M_j	total annual mileage of gasoline vehicles of category j (km)
$M_{cum,j}$	total cumulative mileage of gasoline vehicles of category j (km)
M_{eff}	mileage at which the efficiency of the activated carbon decreases by 1% (km)
N_j	number of gasoline vehicles of category j
p	fraction of trips finished with hot engine, i.e. an engine that has reached its normal operating temperature and the catalyst its light-off temperature
r_{purge}	canister purge rate during driving (l/km)
RL_j	average daily hot and warm running losses of vehicle category j (g/day)
s	canister size (s=2 for small, s=1 for medium and s=0.5 for large canister)
t	hour of the day (h)
t_1	hour of the day at the beginning of a parking period (h)
t_2	hour of the day at the end of a parking period (h)
t_{park}	mean parking duration (h)
t_{trip}	mean driving duration per trip, average over the year (h/trip)
T	ambient temperature (°C)
$T_{1,k}$	initial tank temperature during parking period k (°C)
$T_{2,k}$	final tank temperature during parking period k (°C)
T_{min}	minimum daily temperature (°C)
T_{max}	maximum daily temperature (°C)
$T_{min,k}$	minimum tank temperature during parking period k (°C)
$T_{max,k}$	maximum tank temperature during parking period k (°C)
T_{rise}	rise in the daily temperature, calculated as $T_{max} – T_{min}$ (°C)
v_{tank}	fuel tank, fuel system and vapour control system volume (lt)
vp	fuel vapour pressure (DVPE) (kPa)
$V_{purge,fin}$	total volume of purge air needed to purge the canister from saturation to its status at the beginning of a parking event
x	mean number of trips per vehicle per day, average over the year (trips/day)

6 References and supplementary documents

6.1 References

André M., Joumard R., Hickman J., Hassel D. (1994), 'Actual car use and operating conditions as emission parameters: derived urban driving cycles,' *Science of the Total Environment*, Vol. 146/147, pp. 225–233.

André J.-M., Joumard, R. 2005, 'Modelling of cold start excess emissions for passenger cars', INRETS Report LTE0509, Second Version, Bron Cedex, France.

Coordinating Research Council (2004), 'Fuel permeation from automotive systems', Final Report, CRC Project No E-65. Prepared for: California Environmental Protection Agency.

Harley R.A. (1999), 'Review of Organic Gas Speciation Profiles of Exhaust and Evaporative Emissions from Alternate Gasoline Formulations', personal communication ed: University of Berkeley California, 1999.

Itakura H., Kato N., Kohama T., Hyoudou Y., Murai T. (2000), 'Studies on Carbon Canisters to Satisfy LEVII EVAP Regulations', SAE Technical Paper Series 2000-01-895.

Joint Research Centre (2007). Joint EUCAR/JRC/CONCAWE Programme on: Effects of gasoline vapour pressure and ethanol content on evaporative emissions from modern cars. Final report to DG Joint Research Centre. EUR 22713 EN, Luxembourg: Office for Official Publications of the European Communities.

Kirchstetter, T. W., Singer, B. C., Harley, R. A., Kendall, G. R. and Hesson, J. M. (1999), 'Impact of California Reformulated Gasoline on Motor Vehicle Emissions. 2. Volatile Organic Compound Speciation and Reactivity', Environmental Science & Technology, vol. 33, pp. 329-336.

Mellios G. and Samaras Z. (2007), 'An empirical model for estimating evaporative hydrocarbon emissions from canister-equipped vehicles', *Fuel*, Vol. 86 (15), pp. 2254–2261.

Morgan T.B.D., Betts W.E., Hutcheson R.C., McArragher J.S., Schmiedel H.P., Snelgrove D.G. (1993), 'A Study of VOC Running Losses from European Canister-Equipped Vehicles', SAE Technical Paper Series 930945.

Ntziachristos L. and Samaras Z. (2000), *COPERT III Computer programme to calculate emissions from road transport — Methodology and emission factors (Version 2.1)*, Technical Report No 49, European Environment Agency, Copenhagen, Denmark, (https://www.eea.europa.eu/publications/Technical_report_No_49), accessed 19 July 2019.

Reddy R.S. (1989), 'Prediction of Fuel Vapor Generation from a Vehicle Fuel Tank as a Function of Fuel RVP and Temperature', SAE Technical Paper Series 890289.

Reuter R.M., Benson J.D., Brooks D.J., Dunker A.M., Gorse R.A., Koehl W.J. (1994), 'Sources of Vehicles Emissions in Three Day Diurnal Shed Tests — Auto/Oil Air Quality Improvement Research Program', SAE Technical Paper Series 941965.

6.2 Supplementary documents

CONCAWE (1987), 'An investigation into evaporative hydrocarbon emissions from European vehicles', Report No 87/60, The Hague, the Netherlands.

CONCAWE (1990), 'The effects of temperature and fuel volatility on vehicle evaporative emissions', Report No 90/51, The Hague, the Netherlands.

Egglestone S., Gaudioso D., Gorißen N., Joumard R., Rijkeboer R.C., Samaras Z., Zierock K.H. (1993), 'CORINAIR Working Group on emission factors for calculating 1990 emissions from road traffic Vol. 1: Methodology and emission factors'. European Commission, ISBN 92-826-5571-X, Final report, Luxembourg.

Hausberger S., Wiesmayr J., Bukvarevic E. (2005), 'ARTEMIS: Assessment and reliability of transport emission models and inventory systems', WP600: Evaporative emissions of vehicles. Final Report, Graz, Austria.

Heine P., Baretti A. (1987), 'Emissionsfaktoren für die Verdampfungsemissionen von Kraftfahrzeugen mit Ottomotoren'. Im Auftrag des Umweltbundesamtes Berlin, Germany.

Heine P. (1993). 'RWTÜV: Luftschadstoffemissionen des Straßenverkehrs in der Schweiz 1990–2010 — Verdampfungs- und Verdunstungsemissionen', Arbeitsunterlage 13, Bern, Switzerland.

Keller M., Evéquoz R., Heldstab J., Kessler H. (1995), 'Luftschadstoffemissionen des Straßenverkehrs 1950–2010', Schriftenreihe Umwelt Nr. 255 des BUWAL — Bundesamt für Umwelt, Wald und Landschaft, Bern, Switzerland.

Martini G., Manfredi U., Mellios G., Krasenbrink A., De Santi G., McArragher S., Thompson N., Baro J., Zemroch P., Boggio F., Celasco A., Cucchi C., Cahill G.F. (2007), 'Effects of gasoline vapour pressure and ethanol content on evaporative emissions from modern European cars', SAE Technical Paper Series 2007-01-1928.

Mellios G., Samaras Z., Martini G., Manfredi U., McArragher S., Rose K (2009). A vehicle testing programme for calibration and validation of an evaporative emissions model. Fuel, Volume 88, Issue 8, pp 1504-1512.

Samaras Z., Zachariadis T., Aslanoglou M. (1997), 'Methodologies for estimating air pollutants emissions from transport: Evaporative emissions'. Task 1.9, deliverable 14 of the MEET project, LAT Report No 9717, Thessaloniki, Greece.

United States Environmental Protection Agency (1990), 'Volatile Organic Compounds from On-Road Vehicles — Sources and Control Options', Draft report.

United States Environmental Protection Agency (1991), 'Supplement A to Compilation of Air Pollutant Emission Factors (AP-42) — Volume II: Mobile Sources'. Test and Evaluation Branch, Office of Air and Radiation, (https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors), accessed 19 July 2019.

United States Environmental Protection Agency (2003), 'User's Guide to MOBILE6.1 and MOBILE6.2 — Mobile source emission factor model'. Assessment and Standards Division, Office of Transportation and Air Quality.

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 expert panel's website (https://tfeip-secretariat.org/expert-panels/expert-panels-transport/) for the contact details of the current expert panel leaders.