HBEFA-Group

ERMES LDV emission measurements Database

Internal documentation
Bern, 25. April 2017

Mario Keller

Until 2014: INFRAS, Sennweg 2, CH-3012 Bern/Switzerland
Since 2015: MK Consulting GmbH, Distelweg 5, CH-3012 Bern/Switzerland (mario.keller@mkconsulting.ch)

MKC

Content

Summary

This document describes the ERMES LDV database – its history, its structure and its content (type of information as well as number of vehicles and tests) – and provides some indicative emission results.

The origin of the ERMES LDV DB is the ARTEMIS project (2002-2007), a research project of the 4th EU Framework Programme. A considerable amount of vehicle emission measurement data was collected and stored in a database, then called "A300DB" managed by INRETS and transferred to INFRAS after the end of ARTEMIS in 2007. Since then the database was regularly used in the context of the updates of HBEFA (last version 3.3 in April 2017). One of the DB's main objectives is the calibration and validation of the emission factors of HBEFA. In the meantime the DB was renamed into "ERMES LDV DB" to signalize its more widespread use – not only for HBEFA but also for the whole ERMES group.

The DB consists in principle of three main data tables:

- Vehicles, providing information about the tested vehicles, such as test-lab, make, model, year of registration, size of engine, fuel type, emission concept etc.
- Tests, providing information about the measurement test condittions, such as driving cycle, starting conditions (cold/hot), ambient temperature, test fuel, dynamometer settings, test date etc.
- Emission data, i.e. the measurement results of regulated and/or unregulated pollutants and fuel consumption.

Data are delivered by laboratories in general based on an 'input data sheet' (in Excel) and transferred to the DB by particular import procedures. A main challenge for the analysis is the comparability ot the data since pollutant emission measurements depend on a huge number of influencing factors (as e.g. type of vehicle and its technology, its emission concept, test cycles, start conditions, ambient temperatures, fuel qualities, settings of the chassis dynamometers etc.).

The focus of the ERMES LDV DB so far was on "bag data" (i.e. aggregate emissions per cycle). In 2016 the DB was extended with new data structures:

- for the integration of motorcycle emission measurements (in addition to passenger cars and light commercial vehicles),
- with the capability to store instantaneous data (or 'modal' data, i.e. second-per-second data)
  - of chassis dynamometer measurements (as basis for emission factor models which use instantaneous emission data for the elaboration of emission factors, as e.g. the PHEM-model of the TU Graz which provides the base emission factors for HBEFA),
  - of PEMS data (Portable Emission Measurement Systems): On-road measurements based on PEMS will become more prominent in the future due to the Real-Driving Emissions (RDE) regulation which is mandatory from Sept. 2017 for type approvals, but also independent emission monitoring campaigns are likely to contribute additional inputs for determining real world emission behavior of vehicles.

Presently the ERMES LDV DB contains measurements of ca. 4’300 vehicles, about 305’000 measurements measured in ca. 50’600 tests. The latter figures are of limited use for emission factor development though, since they include many tests in the type approval cycles which are not representative for real world behavior. More relevant is the number of newer vehicles measured in real world cycles (Euro-5 and Euro-6): the present DB (April 2017) contains measurements of real world cycles measured on chassis dynamometers in labs of ca. 120 diesel and ca. 60 petrol cars, and data of ca. 100 vehicles measured on the road (almost all of them diesel cars).

The access to the data is ruled in a non-disclosure agreement (NDA) of the ERMES group which specifies the conditions under which the data are made available. These conditions are (in short):

- A recipient first has to sign the NDA, available from the ERMES secretariat at JRC in Ispra (I).
- The principle is “data for data”, i.e. the data are available to those who provide their own input data to the ERMES DB.
- In case of publication of results by a data recipient the data have to be made anonymous.

Technically the results are made available in a standardized format (in Excel), i.e. emission measurement results per vehicle and test. For the time being it is open whether in the future periodically fact sheets shall be published for the ERMES group presenting the newest measurement results and new findings.

Acknowledgements

The continuing development of the ERMES LDV Database (based on the original ARTEMIS “A300DB”) would not have been possible without the financial support by the “HBEFA-countries” (Germany, Austria, Switzerland, Sweden, Norway and France), and in particular by the Swiss Federal Office of Environment. Thanks also go to all vehicle emission laboratories which regularly provide their measurement results.

1. Introduction

1.1. History

The "ERMES LDV Database[1]" has its origin in the ARTEMIS-project[2]. The aim of the ARTEMIS project was to develop a harmonized emission model for road, rail, air and ship transport and to provide consistent emission estimates at the national, international and regional level. The work package 300 entitled "Improved methodology for emission factor building and application to passenger cars and light duty vehicles" aimed to improve exhaust emission factors for the passenger cars (PC) and light commercial vehicles (LCV) by investigating the accuracy of the emission measurements, by enlarging the emission factor data base for regulated as well as non-regulated pollutants of recent passenger cars and light commercial vehicles, and by building emission factors according to the different purposes of the ARTEMIS project. Within the project a considerable amount of vehicle emission measurement data was collected and stored in a database, then called "A300DB". The data sources were measurements made within the project ARTEMIS itself, but the data also came from other databases and measurement campaigns available in Europe, as e.g. the previous European research project MEET, several national or European projects (as HBEFA, PARTICULATES) and from different laboratories throughout Europe (as e.g. EMPA, INRETS [today IFSTTAR], LAT, RWTueV resp. TueV Nord, TNO, TRL, TU Graz, ADAC, AVL-MTC and more.). The emission measurements were mostly generated by driving the vehicles on a vehicle test bench in well defined 'driving cycles'. Since emission models should represent real world behavior of the vehicles, the focus was put from the beginning on measurements performed in 'real world driving cycles'. In order to improve the representativeness and the comparability of the measurements made in different laboratories during the project, a reference set of real-world driving cycles was developed for use by all the project partners: the 'ARTEMIS cycle' or equivalent the 'Common Artemis Driving Cycle' (CADC, André M. 2004). The CADC was and still is extensively used in European research projects and national programmes for the measurement and modelling of pollutant emissions. In order to know the relationship of the real world behavior of the vehicles to the official legislative cycles, also measurements of the legislative cycles were integrated into the DB, namely the NEDC (New European Driving Cycle) and the US FTP 75.

Originally the "A300DB" was setup jointly by INRETS and INFRAS, and managed by INRETS (today IFSTTAR). After the end of the ARTEMIS project in 2007 the DB was handed over to INFRAS. The content of the "A300DB" and its status in the ARTEMIS project are described in André JM (2005).

---

[1] ERMES: European Research for Mobile Emission Sources (www.ermes-group.eu)
LDV: Light Duty vehicles (= passenger cars + light commercial vehicles)
DB: Database

[2] ARTEMIS: Assessment and Reliability of Transport Emission Models and Inventory Systems (Final report, ARTEMIS [2007]), a research project of the 4th EU Framework Programme.

1.2. Recent developments

The DB has continuously been updated over the last 10 years in the context of the updates of HBEFA[3]. The original ARTEMIS-DB was very ambitious concerning the level of detail of the data. So it was possible (and expected) to describe the vehicles with a huge amount of attributes (e.g. number and types of catalysts, tyre dimensions and manufacturer, number and alignment of cylinders, engine control manufacturer, charging system, airflow measurement, type of air-flow sensing, gearbox details, official type approval fuel consumption and pollutant emission values etc.). Similarly a detailed description of the tests was expected; in addition to cycle and fuel description additional attributes should or could be provided (e.g. the sampling methods for the different pollutants, oil/water/catalyst temperatures before and after the tests, chassis dynamometer and fan settings, CVS flow etc.). All these details could be provided by the laboratories with a particular “LDV Input DataSheet” (an Excel template). After the ARTEMIS project which ended in 2007 it turned out that hardly any of the labs provided these details. Hence a simplified “LDV Input DataSheet” was developed – while keeping the structure of the database. So all previous details are still available and could be added also for new measurements if needed, but the focus is now on a reduced set of information. In parallel, the objective of the emission measurements (and hence the DB) changed to a certain extent: the original focus was accuracy of emission factors (EF) and the identification of special influencing factors on the EF. Therefore, many (similar) tests were performed by changing singular factors as e.g. chassis dynamometer settings, gear change strategies, fuel composition, ambient temperature etc. Today, the focus is more on representativeness of measurements, i.e. during usual measurement campaigns several vehicles are measured under the same conditions (e.g. same cycles, same fuel etc.). Only in few additional ‘special programmes’ selected parameters are varied (e.g. ambient temperature, fuel [e.g. different biofuel-mixes). This change of objectives makes it necessary in the analysis of the data to identify comparable tests particularly if a vehicle has been tested under variable conditions.

The cycles used in the measurement program remain a key component of all measurement campaigns. In the “After-ARTEMIS” measurement programmes the CADC still plays a central role and provides a good basis for comparing the emission behavior of the different vehicles and emissions concepts. However, due to the fact that the CADC is comparatively long (3x20 minutes), that the CADC does not include any of the actual traffic situations of the HBEFA and that it does not cover high and full load engine operation for cars with higher power to mass ratio, an alternative cycle was developed in 2011/2012, the so called “ERMES cycle” (TUG 2013 [3.1.1]). In addition, in the most recent measurements programs also the new legislative cycle WLTC (World Harmonized Light Duty Test Cycle) becomes more and more part of regular measurement campaigns.

One of the main objectives of the ERMES LDV DB today is the calibration and validation of the emissions factors of HBEFA. Since HBEFA version 3.1 (2010) the HBEFA LDV emission factors are produced by the PHEM (Passenger car and Heavy duty Emission Model) of TU Graz. This model requires

[3] HBEFA: Handbook emission factors for road transport (www.hbefa.net), since 1995. Latest versions are HBEFA 3.1 (2010), HBEFA 3.2 (2014), HBEFA 3.3 (25.4.2017).

as input instantaneous emission measurements (TUG 2009, TUG 2013, TUG 2017) in order to derive useful engine maps. The availability of instantaneous emission measurements is much smaller than the number of bag measurements. Therefore, the bag measurements of the LDV DB are used to calibrate the PHEM LDV emission factors for HBEFA since its version 3.1 (2010) until today (HBEFA 3.3, Keller et.al. 2017). During this process the name of the DB was changed into "ERMES LDV DB" in order to signalize its continuous and more widespread use – not only for HBEFA but also for the whole ERMES group and other emission models like e.g. the COPERT model.

1.3. Extensions 2016

In 2016 three extensions were initiated:

- **Motorcycle data**: the DB was extended to store also motorcycle emission measurements, due to the need for updated emission factors in the light of new emission regulations for 2- and 3-wheelers. For the time being the newest measurements performed in recent years (by AFHB Biel) are integrated in the DB only. It is planned to integrate also the measurements performed prior to, during and after the ARTEMIS project as well as presently ongoing projects (e.g. at TUG and BASt). This extension did not change the basic structure of the DB, it only extended the content of particular items (e.g. MC specific cycles, the list of lab's).
- **Instantaneous data**: The DB now is also capable to include (as option) modal data, i.e. second-per-second measurements. There are two reasons for this extension:
  - *Chassis dynamometer instantaneous data*: As indicated above the PHEM model needs modal data for building engine maps. The data collection becomes more efficient if labs can provide 'bag data' (as done over the last 10/15 years) and – as new option – 'modal data' at the same time. This concerns particularly the measurements performed on chassis dynamometers.
  - *PEMS data*: On-road measurements will become more prominent in the future using PEMS (Portable Emission Measurement Systems). This is particularly due to the Real-Driving Emissions (RDE) regulation which is mandatory from Sept. 2017 for type approvals and is expected to improve the effectiveness of emissions control in the real world. Such PEMS measurement campaigns were also started by independent third parties to monitor emission behavior of the vehicles (e.g. DUH/EKI 2016, DUH/EKI 2017[4]). TU Graz proposed recently a test description for cars and LCV for chassis dyno tests and RDE tests as basis for emission factors (Matzer and Rexeis, 2016).

  In order to integrate the instantaneous data the "LDV Input DataSheet" is now complemented with the two options to provide chassis dynamometer instantaneous data as well as PEMS data. In parallel the DB structure was adjusted to store these data sets.
- **Special measurement programs in the context of 'Dieselgate'**: after the emission control failures of diesel cars became public several investigations and measurement programs in different coun-

[4] only aggregate data are publicly available and stored in the DB

tries were performed. Many of the tests aimed – e.g. by varying the NEDC cycle slightly – to detect cycle recognition which eventually change the emissions control management system. Additional on-road tests with PEMS were performed. The measurement results – as far as publicly available (by vehicle and test) – were integrated in the DB in 2016 :

- Germany: BMVI/KBA 2016,
- France: MEEM 2016,
- UK: DfT 2016,
- Wallonia: CTA 2016.

1.4. Structure of this report

This paper documents the status of the ERMES LDV DB in April 2017 and is structured as follows:

- Chapter 2 describes the structure of the data base
- Chapter 3 shows the 'LDV input data sheets' and explains the data expected (descriptions of the vehicle attributes, tests and emission measurement results)
- Chapter 4 gives a few key figures about the present content [status April 2017], as e.g. number of vehicles in the DB, number of tests etc.
- Chapter 5 gives a few selected results (mean emission values of petrol and diesel passenger cars as well as diesel LCV, differentiated by Euro-classes, for selected cycles and pollutants.
- Chapter 6 explains the access to the data.

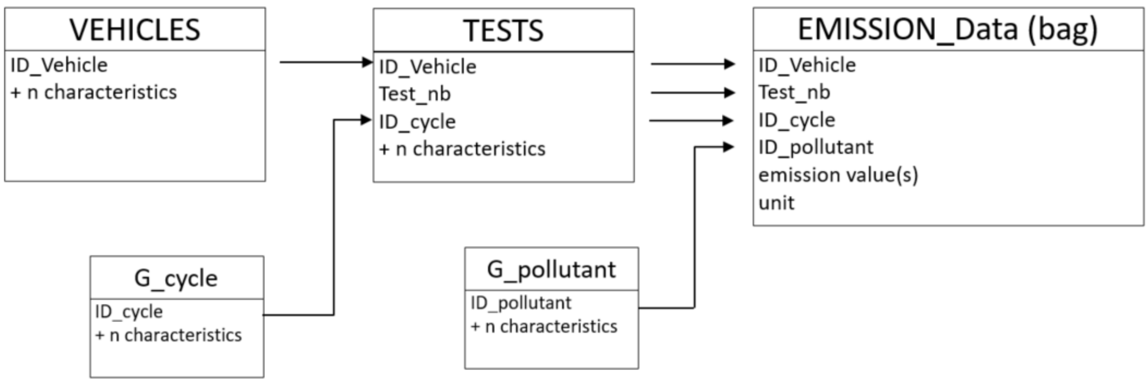
2. Structure of the database

2.1. The original A300 DB

The original A300 DB, now renamed into "ERMES LDV DB", is based on Microsoft Access 2010 databases and consists of a front-end DB ("Prog-DB", with modules for data import, data handling, analysis, visualisation etc.) and a backend-DB with the data. This "BagData-DB" contains three main data tables and several tables providing additional information about the definitions of the characteristics used (Figure 1). The three main tables are

- Vehicles: provides information on the tested vehicles, such as testing laboratory, make, model, year of registration, size of engine, fuel type, emission concept etc.
- Tests: provides information on the measured tests, such as driving cycle, starting conditions (cold/hot), ambient conditions, test fuel, test date, technical details of the test procedure as dynamometer settings etc.
- Emission data (bag data): contains the actual emission data for all measured regulated and unregulated pollutants, including units used.

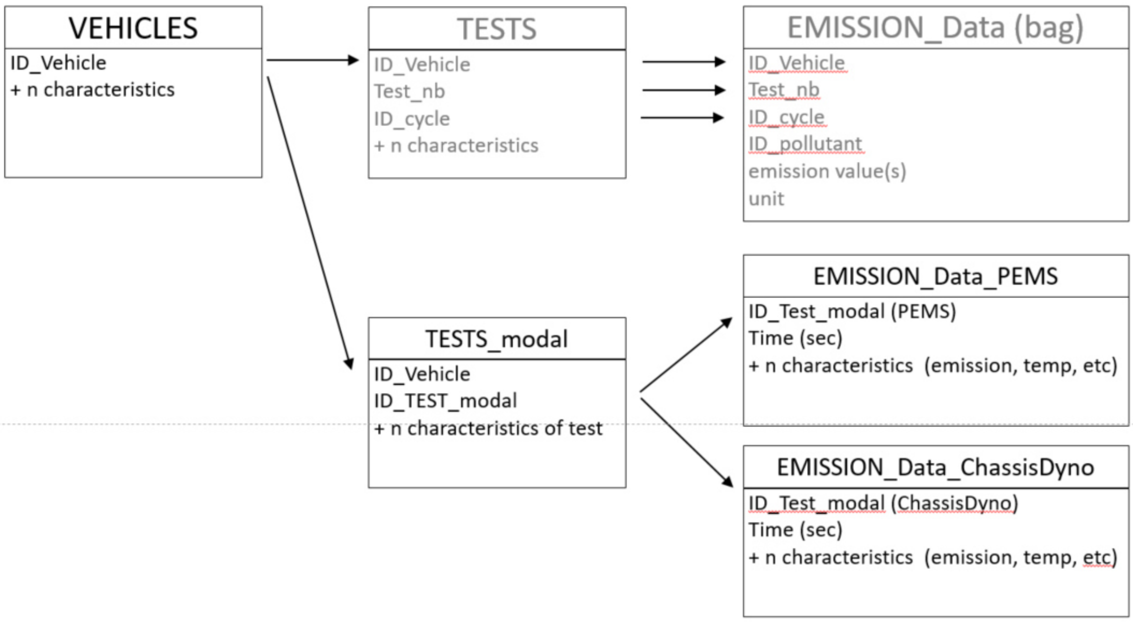
Figure 1: Main tables of the ERMES-LDV-DB ("BagData-DB")



2.2. The extended ERMES LDV DB

The need to integrate instantaneous data required an extension of the DB by three additional tables for describing the tests as well as two emission data tables (for PEMS resp. ChassisDyno-data, as illustrated in Figure 2. These data are stored in a separate “ModalData-DB”.

Figure 2: Extensions to integrate modal data in the ERMES-LDV-DB (“ModalData-DB”)



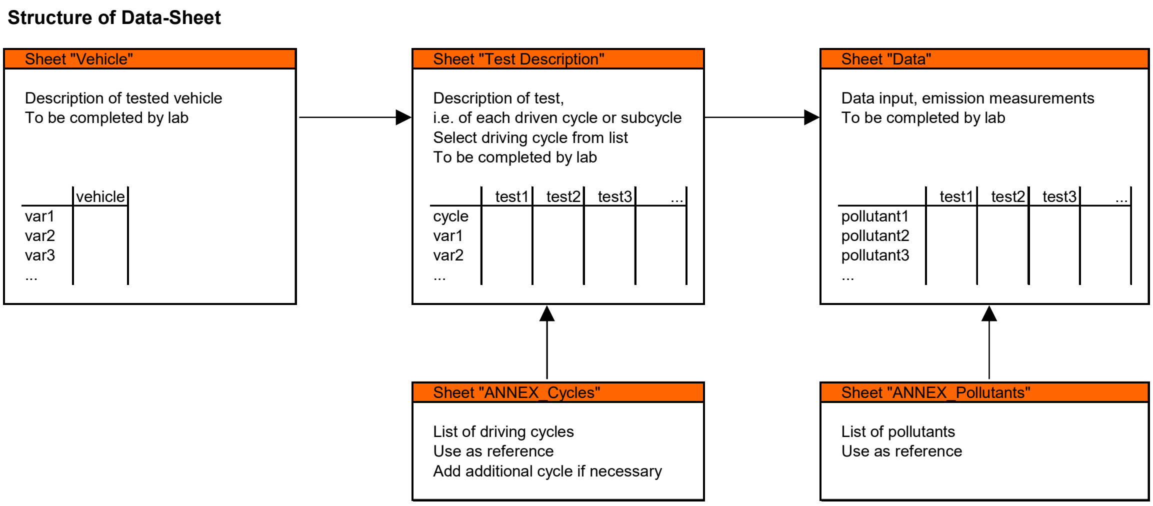
3. The ERMES LDV Input Data

The input data for the ERMES LDV database can be explained most appropriately by referring to the Excel-templates which was created for data suppliers. The actual version dates from 16. dec. 2016.

3.1. The original "LDV input data sheet" (ARTEMIS)

Figure 3 shows the structure of the original ARTEMIS input data sheet, expecting one file for one vehicle and describing the vehicle attributes, the tests and the corresponding emissions measurement results in separate sheets. DB structure and input data sheet correspond directly.

Figure 3: The structure of the original "input data sheet"

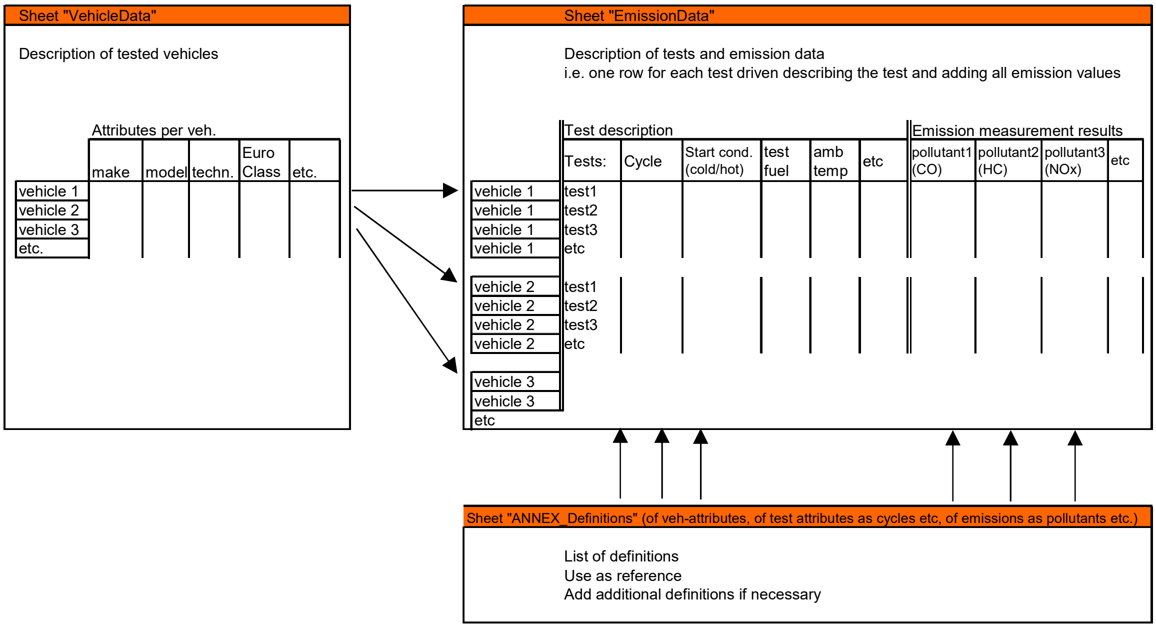


3.2. The actual "LDV Input Data Sheet"

3.2.1. Overview

It turned out that for production oriented measurement programs a more simplified and more compact structure could be more appropriate, in particular to allow the transmission of emission data of several vehicles at the same time (Figure 4).

Figure 4: The structure of the actual "input data sheet" for bag data



This file contains the following sheets:

- Sheet 'ReadMe': gives some general information and explains the procedure how to input data.
- Sheet 'VehicleData': for describing the vehicle(s) and its attributes
- Sheet 'EmissionData': for describing the test(s) and its attributes as well as the emission measurement results
- Sheet 'ANNEX_Definitions': describes the definitions used, e.g. for emission categories, cycles etc.

Several of the data sets are predefined in the sheet 'Annex_Definitions' and hence should be used by the data providers in order to guarantee consistency within the database (e.g. cycle names, pollutants etc.); the corresponding list can also be extended by the users. Other data specifications can be selected freely (e.g. make, model, comments etc.). Some of the predefined datasets are explained below.

Extensions 2016

The newest template (dec 2016) includes two additional options:

- Sheet 'ChassisDyno_Inst'[5] (=optional): for describing instantaneous emission data of tests performed on the chassis dynamometer
- Sheet 'PEMS_Inst' (=optional): for describing instantaneous emission data of tests performed with PEMS instruments (in general on the road)

[5] This option was already part of a previous "input data sheet" (since 2011), but used by 2 lab's only.

Data categories

The input data are categorized as 'mandatory', 'very welcome', and 'optional' (see Figure 5). The following subchapters list the data expected (or suggested) differentiated by these three categories.

Figure 5: Colours for distinguishing the character of input data

(orange)	= Mandatory (for useful analysis)
(green)	= Very welcome
(blue)	= Optional
(grey)	= Automatically assigned by Look-up-tables

Minimal set of data required

It turned out that the differentiation according to Figure 5 is "wishful thinking" since also the 'mandatory' inputs are not always available. The absolutely **minimal set of data** required for being integrated in the DB is smaller and contains the following elements:

- Minimal vehicle data: 1. Data source (lab), 2. Technology (P, D etc.), 3. Euro-Class
- Minimal test description: 1. CycleName
- Minimal emission data: 1. Pollutant (at least one), 2. Unit, 3. Emission value

3.2.2. Sheet 'VehicleData'

Table 1: Sheet 'VehicleData'

Vehicle attributes	Vehicle-No. (internal nr or name used by Lab to identify veh)	[text]
	Laboratory name	[predefined]
	Manufacturer	[text]
	Trade Name / Model	[text]
	Additional model specification (optional)	[text]
	Vehicle Category	[predefined]
	Size Class	[predefined]
	Technology	[predefined]
	EU Emission standard / Euro-Class / Emission Approval	[predefined]
	EC_TypeApproval (optional)	[text]
	Engine Capacity	[ccm]
	Power	[kW]
	Rated Engine Speed	[rpm]
	Idling Speed	[rpm]
	Max Torque	[Nm]
	Max Torque Speed	[rpm]
	Max Vehicle Speed	[km/h]
	Empty mass	[kg]
	Test weight	[kg]
	Comment Test weight	[text]
	Mileage	[km]
	Vehicle provenance	[predefined]
	State (new/used)	[text]
	Gearbox type	[predefined]
	Number of speeds	[nr]
	Injection System	[predefined]
Exhaust Gas Aftertreatment	DPF ["yes" if applicable, else: empty]	["yes" or empty]
	DPF type	[text]
	Three-Way Catalyst	["yes" or empty]
	Oxidation Catalyst	["yes" or empty]
	SCR (Selective catalytic reduction)	["yes" or empty]
	NOx-trap / NSK (NOx-Speicher-katalysator)	["yes" or empty]
	EGR (Exhaust Gas Recirculation)	["yes" or empty]
	Other Exhaust Gas Aftertreatment Systems	[text]
Vehicle attributes	OEM (for alternative fuel veh. only (CNG, LPG etc)	[text]
	Tyre - dimension	[text]
	Axle drive ratio	[nr]
	Transmission ratio gear 1	[nr]
	Transmission ratio gear 2	[nr]
	Transmission ratio gear 3	[nr]
	Transmission ratio gear 4	[nr]
	Transmission ratio gear 5	[nr]
	Transmission ratio gear 6	[nr]
	VIN (Vehicle identification number)	[text]
	Certificaton nr	[text]
	Registration (Year)	[nr]
	Registration (Month)	[nr]
	Registration (Day)	[nr]
	Test (Year)	[nr]
	Test (Month)	[nr]
	Test (Day)	[nr]
	Name of measurement campaign	[text]
	power ICE	[kW]
	power EM	[kW]
	battery type	[text]
	battery capacity	[kWh]
	nom. volt.	[V]
	no. of cells	[nr]
	level of hybr.	[text]
	hybrid type	[text]
Type Approval Info	Type Approval (NEDC) CO2	[g/km]
	Type Approval (NEDC) CO	[g/km]
	Type Approval (NEDC) HC	[g/km]
	Type Approval (NEDC) NOx	[g/km]
	Type Approval (NEDC) HC+NOx	[g/km]
	Type Approval (NEDC) PM	[g/km]
	Type Approval (NEDC) Fuel Consumption	[l/100km]
	Any comment concerning the vehicle	[text]

3.2.3. Sheet 'EmissionData'

Table 2: Sheet 'EmissionData'

Vehicle Attributes	Vehicle-No. (internal nr or name used by Lab) -> refer to Col A in Sheet 'VehicleData'	[---]
	Lab_name	[---]
	Manufacturer	[---]
	Trade Name	[---]
	Vehicle Category	[predefined]
	Size Class	[predefined]
	fuel type of vehicle	[predefined]
	EuroClass (Emission Approval)	[predefined]
Test attributes	chronological Test Nr (unique nr. per test and veh)	[nr]
	RepeatTestNr (relevant onl if tests are repeated)	[nr]
	Any comment concerning the test	[text]
	Driving cycle or PEMS route	[predefined]
	Start condition	[predefined]
	Fuel type of test	[predefined]
	Payload (optional, for LCV)	[%]
	Fuel Density	[Kg/L]
	Fuel Energy density	[MJ/kg]
	Ambient temperature (if not standard)	[Degree Celsius]
	Range of Ambient temperature	[text]
	Ambient temperature Min	[Degree Celsius]
	Ambient temperature Max	[Degree Celsius]
	Inertia weight (car weight + driver + load)	[Kg]
	Road driving resistance (road coast down) - f0	[kg m s-2]
	Road driving resistance (road coast down) - f1	[kg s-1]
	Road driving resistance (road coast down) - f2	[kg m-1]
	Source for weight and road load	[text]
	Gear_change_strategy	[text]
	Distance	[km]
Emission data	CO	g/km
	HC	g/km
	NOx	g/km
	NO2	g/km
	HC+NOx	g/km
	CO2_without_SOC_correction	g/km
	FC_L/100km	L/100km
	FC_g/km	g/km
	FC_MJ/km	MJ/km
	FC_m3/100km	
	PM	g/km
	PM(PMP)	g/km
	PN	#/km
	CH4	g/km
	Formaldehyde	g/km
	Acetaldehyde	g/km
	Alcohols	g/km
	NH3	g/km
	N2O	g/km
	CO2_with_SOC_correction	g/km
PEMS evaluation result with EMROAD	Trip valid (yes/no)	[yes/no]
	CO	g/km
	HC	g/km
	NOx	g/km
	CO2	g/km
	PN	g/km
PEMS evaluation result with CLEAR	Trip valid (yes/no)	[yes/no]
	CO	g/km
	HC	g/km
	NOx	g/km
	CO2	g/km
	PN	g/km
PEMS Parameters (optional)	95Percentile (v*a_pos) total trip	m^2/s^3
	95Percentile (v*a_pos) urban part	m^2/s^3
	cumulated positive altitude gain total trip	m/100km
	cumulated positive altitude gain urban part	m/100km
	Mileage share Urban	%
	Mileage share rural	%
	Mileage share motorway	%
	RPA total trip	m/s^2
	RPA urban part	m/s^2
	EMROAD % of normal windows	%

3.2.4. Sheet 'ChassisDyno_Inst' (optional, since 2016)

These data refer to instantaneous data of tests performed on chassis dynamometers.

Table 3: Sheet 'ChassisDyno_Inst'

Modal values:		
Time	time	[s]
roller test bed	Measured vehicle speed	[km/h]
	road gradient	[%]
	simulated tractive force	[N]
	measured tractive force	[N]
modal values	measured fuel consumption	[g/s]
	CO2	[g/s]
	NOx	[g/s]
	NO	[g/s]
	CO	[g/s]
	HC	[g/s]
	Particle number	[#/s]
Current Clamp	Current from/to battery	[A] (+when to battery)
	Voltage at Battery	[V]
ECU data, if available	vehicle speed	[km/h]
	fuel consumption	[g/s]
	(effective!) engine torque	[Nm]
	engine speed (either from ECU or from external sensor)	[rpm]
	Gear	[#]
external sensors / measurement devices if available	engine speed from external sensor	[rpm]
	cardan torque - signal from telemetry analogue output	[V]
	cardan torque	[Nm]
	engine cooling fan speed	[rpm]
	ambient air temperature	[°C]
	air pressure	[bar] abs
	alternator loading current	[A]
	fuel consumption from mobile fuel cons meas.	[g/s]
PEMS system	Corrected Exhaust Mass Flow Rate	[kg/s]
	instantaneous mass CO_2	[g/s]
	Corrected Instantaneous Mass NO	[g/s]
	Corrected Instantaneous Mass NO2	[g/s]
	Corrected Instantaneous Mass NOx	[g/s]
	Corrected Instantaneous Mass CO	[g/s]
	Corrected Instantaneous Mass HC	[g/s]
	Instantaneous Mass AVL MSS	[g/s]
temperature sensors if available	temperature engine coolant	[°C]
	temperature engine oil	[°C]
	temperature transmission oil	[°C]
	temperature exhaust gas after turbocharger / before aftertreatment	[°C]
	temperature exhaust after aftertreatment	[°C]
other measured quantities	Bag number (1,2 or 3)	[#]
	SubCycle	[#]
	Reference vehicle speed	[km/h]
	please specify	[please specify]
	please specify	[please specify]
	please specify	[please specify]
	please specify	[please specify]

3.2.5. Sheet 'PEMS_Inst' (optional, since 2016)

These data refer to instantaneous data of on road tests performed with PEMS

Table 4: Sheet 'PEMS_Inst'

Modal values:		
Time	time	[s]
GPS 1 or PEMS system	Vehicle (ground) speed	[km/h]
	Altitude measured	[m] asl
	Altitude filtered according to RDE regulation	[m] asl
	Number of satellites in use	[#]
	Latitude	e.g. [deg]
	Longitude	e.g. [deg]
GPS 2, if available	Vehicle (ground) speed	[km/h]
	Altitude	[m] asl
	Number of satellites in use	[#]
	Latitude	e.g. [deg]
	Longitude	e.g. [deg]
Current Clamp	Current from/to battery	[A] (+when to battery)
	Voltage at Battery	[V]
ECU data, if available	vehicle speed	[km/h]
	fuel consumption	[g/s]
	(effective!) engine torque	[Nm]
	engine speed	[rpm]
	gear	[#]
external sensors / measurement devices if available	Engine speed from external sensor	[rpm]
	cardan torque - signal from telemetry analogue output	[V]
	cardan torque	[Nm]
	engine cooling fan speed	[rpm]
	ambient temperature	[°C]
	air pressure	[bar] abs
	alternator loading current	[A]
	fuel consumption from mobile fuel cons meas.	[g/s]
PEMS system	Exhaust Mass Flow Rate	[kg/s]
	instantaneous mass CO_2	[g/s]
	Instantaneous Mass NO	[g/s]
	Instantaneous Mass NO2	[g/s]
	Instantaneous Mass NOx	[g/s]
	Instantaneous Mass CO	[g/s]
	Instantaneous Mass HC	[g/s]
	Instantaneous Mass AVL MSS	[g/s]
temperature sensors if available	temperature engine coolant	[°C]
	temperature engine oil	[°C]
	temperature transmission oil	[°C]
	temperature exhaust gas after turbocharger / before aftertreatment	[°C]
	temperature exhaust after aftertreatment	[°C]
other measured quantities	please specify	[please specify]
	please specify	[please specify]
	please specify	[please specify]
	please specify	[please specify]
	please specify	[please specify]

3.3. Descriptions of 'vehicle data'

3.3.1. Vehicle categories

the present version differentiates 3 vehicle categories

- passenger cars
- LCV [light commercial vehicles

- MC [motorcycles][6])

3.3.2. Technologies

So far, emission measurements for the following technologies can be stored:

Table 5: Definition of technologies[7]

Technologies
petrol
diesel
CNG
bifuel CNG/petrol
LPG
bifuel LPG/petrol
flex-fuel E85
hybrid petrol/electric
hybrid diesel/electric
Plug-in Hybrid petrol/electric
Plug-in Hybrid diesel/electric

3.3.3. Emission concepts

The ERMES LDV DB distinguishes the following emission concepts

Table 6: Definition of emissions concepts

Emissions concepts
pre-EURO-1
EURO-1
EURO-2
EURO-3
EURO-4
EURO-5
EURO-6

It seems likely that the Euro-6-class should be split up (e.g. Euro-6/6d1/6d2) in the near future in order to allow a differentiation between vehicles which do not yet or do comply with the new RDE reulation.

[6] MC were added in dec 2016

[7] Electric vehicles can be stored as well. However, the ERMES LDV DB focused so far on pollutant emissions. Therefore, no measurements of electric vehicles (BEV: battery electric vehicles) are integrated yet but some data of a few PHEV (plug in hybrid vehicles) are already integrated, see chapter 4.1.

3.3.4. Size Classes

The differentiation between size classes is due to historical reasons (different emission standards for different size classes) and is still kept in the DB (and used as far as data providers deliver this information):

- for PC: according to the capacity (<1.4L, 1,4-<2L, >=2L)
- for LCV: according to N1-I, N1-II, N1-III
- for MC[8]: according to stroke and capacity, i.e.
    - Mopeds: 2 classes: 2S, <=50cc, v-max <30km/h resp. v-max <50km/h
    - MC 2 stroke: 2 classes: <=150cc resp. >150 cc
    - MC 4 stroke: 4 classes: <=150cc, 151-250cc, 251-750cc, >750cc

3.3.5. Exhaust gas aftertreatment systems

For the time being, the following aftertreatment technologies can be distinguished (single or jointly):

- DPF ["yes" if applicable, else: empty], and DPF type
- Three-Way Catalyst
- Oxidation Catalyst
- SCR (Selective catalytic reduction)
- NOx-trap
- EGR (Exhaust Gas Recirculation)
- Other Exhaust Gas Aftertreatment Systems

3.3.6. Year of registration

This parameter is considered as 'mandatory' but not always provided which limits the analysis of e.g. progress of an emission abatement technology of newer vehicles within the same Euro-Class (e.g. PC diesel Euro-6).

3.3.7. Mileage

Mileage is also considered as 'mandatory' but not always supplied by the data providers. Most vehicles are tested only once which also limits the analysis of e.g. deterioration. Due to the limited number of vehicles such an analysis of deterioration would be of limited use anyhow. In only singular special programmes about deterioration the same vehicle could be tested at different points in time where the mileage increased significantly (e.g. LAT 2004). Alternative methodologies (as e.g. remote sensing) seem to be more appropriate to get useful information about deterioration since they cover a much larger sample of vehicles.

[8] Differentiation as in HBEFA

3.3.8. Further attributes

For further vehicle data attributes (as gearbox, injection system, vehicle provenance etc.) refer to the template ERMES_DB_LDV_Input_DataSheet.xlsx.

3.4. Descriptions of 'tests'

The definition of a 'test' is not a priori clear and can be interpreted differently. The ERMES LDV DB accepts the data provider's definition. In general, a test consists of the emission measurement driven

- with a particular vehicle (make/model, technology, emission concept, weight, mileage, payload [for LCV] etc.)
- in a particular cycle,
- with specified start conditions (cold/intermediate/hot),
- under particular ambient conditions (temperature, humidity),
- with a specified fuel,
- driven with a specified gear change strategy and
- with a specified setting of the chassis dynamometer (road driving resistance parameters f0, f1, f2; fan settings).

3.4.1. Cycles (LDV)

An important distinction can be made along the cycles. The set of cycles was particularly abundant in the context of the ARTEMIS project (the DB contains a list of ca. 1000 cycles; see Annex A). In the meantime a certain harmonization with respect to the cycle definitions can be observed. The most common cycles for which data were gathered in the last 10 years are – apart from some legislative cycles (NEDC, FTP, and recently WLTC) – a few real world cycles (CADC, ERMES, BAB, IUFC). Details of these cycles are listed in Table 7 and visualized in Annex B.

Table 7: Definitions of most common cycles of LDV

Cycle	Type	Subcycle	Comment	Duration		Distance	Ø Speed	Start cond.
	L: legislative RW: RealWorld			t (sec)	t (min)	dist (km)	v (km/h)	(default)
NEDC	L	ECE		781	13	4.058	18.7	cold
		EUDC		401	7	6.955	62.4	hot
		NEDC		1'181	20	11.013	33.6	cold
FTP	L	FTP1		506	8	5.779	41.1	cold
		FTP2		871	15	6.211	25.7	hot
		FTP3		506	8	5.779	41.1	hot
		FTP (total)		1'376	23	17.769	31.4	cold
WLTC	L	WLTC Low		589	10	3.095	18.9	cold
		WLTC Medium		433	7	4.756	39.5	hot
		WLTC High		455	8	7.158	56.6	hot
		WLTC Extra high		323	5	8.254	92.0	hot
		WLTC (total)		1'800	30	23.263	46.5	cold
CADC	RW	CADC urban		922	15	4.472	17.5	hot
		CADC rural		863	14	14.724	61.4	hot
		CADC MW130	v max 130 km/h	737	12	23.822	116.4	hot
		CADC MW150	v max 150 km/h	737	12	24.632	120.3	hot
		CADC URM130 (total)		3'144	52	50.878	58.3	hot
		CADC URM150 (total)		3'144	52	51.687	59.2	hot
ERMES	RW	ERMES urban		418	7	3.674	32.6	hot
		ERMES rural		305	5	6.764	79.3	hot
		ERMES MW		384	6	11.530	107.8	hot
		ERMES (total)		1'107	18	21.969	72.0	hot
IUFC	RW	IUFC_I	Inrets urbain fluide court	945	16	4.997	18.9	cold
		IUFC_II		945	16	4.997	18.9	intermediate
		IUFC_III		945	16	4.997	18.9	hot
		IUFC (total)		2'835	47	14.991	18.9	cold
BAB	RW	-	Bundesautobahn (DE)	1'001	17	32.646	117.4	hot
TNO DYNA	RW	-	TNO DYNA	827	14	10.822	47.1	

Even if the cycle definitions seem to be clear, there arise some questions which may make the analysis not as straightforward as one would expect and may also limit the comparability:

- For some of the cycles the data providers deliver emission measurement results for the ‘cycle - total’, for ‘cycles’ and/or for ‘subcycles’ . E.g. the CADC has 3 cycles: CADC-urban, CADC-rural and CADC-Motorway (and the latter has two versions: MW 130 / MW 150). The CADC-urban can be splitted in 6 subcycles, the CADC-rural in 5 subcycles etc. (see Annex B). Some providers deliver the cycles in total (only), some in cycles (only), some in subcycles (only), some provide several of them (e.g. ‘cycle-total’ and ‘cycles’). Therefore, for making comparisons some cycles (e.g. ‘cycle-total’) have to be calculated in addition to the original inputs (if the total is missing).
- Some of the cycles have different versions (e.g. ERMES V6/V7/V8) or different “classes” (e.g. WLTC), or some cycles changed their definitions during the data collection phases (e.g. NEDC was adapted with Euro-3, in ca. 2000).
- Some labs pool data of some cycles into one bag (due to operational reasons[9]), which leads to an implicit new ‘singular’ cycle (e.g. the WLTC distinguishes 4 stages: low, medium, high, extra high; some lab pool the stages ‘high’ and ‘extra high’).

[9] availability of 3 bags

- Some data providers create their own cycles, e.g. the CADC with a special sequence of 4 cycles [urban (cold)/rural/Motorway/urban (hot)] as e.g. provided by TNO. This provides additional insights in its own but is limiting the comparability unless also the cycle-information is provided).
- Similarly if particular cycles are provided by one lab only as e.g. in the context of previous HBEFA versions, where the so called HBEFA cycles[10] were measured as basis for direct use as emission factors in HBEFA by EMPA, or the 'TNO-DYNA' cycle which was developed by TNO and is measured by TNO only[11].

3.4.2. Additional cycles (LDV) for PEMS and 'Dieselgate'

In 2016 the list of cycles was extended due to the extension to PEMS data and due to the inquiries in the context of 'Dieselgate'. The added cycles are categorised in four groups (Table 8):

- NEDC variations driven on the chassis dynamometer
- NEDC variations driven on road with PEMS
- PEMS-RDE, i.e. on-road tests complying with RDE conditions. Annex C gives more details about the requirements of the RDE regulation (RDE regulation 2016).
- PEMS-RWC (real world cycles), which do not necessarily comply with the RDE regulation. For the time being they are categorized by driving style and by the data source respectively. Not all of the specified PEMS cycles are already used.

[10] e.g. the cycles "AE1", "AE2" etc. as specified in HBEFA Version 2.1 (INFRAS 2004)
[11] The artificial TNO-Dynacycle was developed by TNO in 2008 for assessing emissions at strong and prolonged accelerations (for the definition see e.g. in TNO 2016).

Table 8: Additional cycles introduced in the ERMES LDV DB in 2016 in the context of 'Dieselgate' and due to the integration real world measurements (RWC) based on PEMS

Cycle-Group	Cycle	Cycle_Fullname	CycleSort
NEDC-Variations (Chassis-Dyno)	NEDC reverse UK	NEDC reverse track testing	691
	NEDC v+10% UK	NEDC +10%	692
	NEDC x2 UK	Cumul. value for 2 back-to-back, hot NEDC cycles	693
	EUDC_D1 FR	ChassisDyno with slightly modified procedure EUDC	694
	NEDC_D1 FR	ChassisDyno with slightly modified procedure NEDC	695
	EUDC_D2 FR	ChassisDyno, first part (ECE) modified, then EUDC	696
	NEDC_D3_track FR	Track test	697
	NEDC hot_after_cold_DE	VW Inq DE, Test 2 NEDC hot after a cold NEDC	698
PEMS-NEDC-Variations	PEMS NEDC	NEDC on-road	700
	PEMS NEDC v+10%	NEDC on-road	702
	PEMS NEDC v-10%	NEDC on-road	703
	PEMS NEDC reverse DE	NEDC on-road	705
PEMS-RDE	PEMS RDE	PEMS on road trip valid acc. RDE regulation	720
PEMS-RWC	PEMS Normal	PEMS trip Normal-driving	710
	PEMS Eco	PEMS trip Eco-driving	711
	PEMS Aggressive	PEMS trip Aggressive-driving	712
	PEMS Special	PEMS trip with special driving	713
	PEMS RWC BE	NOx emissions in mg/km - Belgium/Wallonia	731
	PEMS RWC DUH	NOx emissions in mg/km - Dt Umwelthilfe/EKI	732
	PEMS RWC EA	Real NOX emissions from PEMS - Emission Analytics	733
	PEMS RWC TUG	Real world cycle (ad hoc)	734

3.4.3. Cycles (MC)

In 2016 the DB was extended to be capable to store also motorcycle data. This implied a further extension of cycles typically used for motorcycles (this list is provisional; not for all cycles there are already data available, and the list is likely to be extended further once also the MC data of the ARTEMIS project and further measurement campaigns will be integrated).

Table 9: Definitions of most common MC cycles

CycleGroup	Cycle (ShortName)	Cycle (LongName)	CycleSort
Idle	idle	idle	10
MC Legislative	ECE	ECE	11
MC Legislative	EUDC	EUDC	12
MC Legislative	ECE+EUDC	ECE+EUDC	13
MC Legislative	ECE 15-00	ECE 15-00	14
MC Legislative	ECE R47	ECE R47	17
MC Legislative	WMTC-1	WMTC part 1	21
MC Legislative	WMTC-2	WMTC part 2	22
MC Legislative	WMTC-3	WMTC part 3	23
MC Legislative	WMTC-total	WMTC total	24
MC Legislative	WMTC-1-v-red	WMTC part 1 - reduced speed	31
MC Legislative	WMTC-2-v-red	WMTC part 2 - reduced speed	32
MC Legislative	WMTC-3-v-red	WMTC part 3 - reduced speed	33
MC Legislative	WMTC-total-v-red	WMTC total - reduced speed	34
MC Legislative	WMTC cl1-1	WMTC class 1 - part 1	41
MC Legislative	WMTC cl1-2	WMTC class 1 - part 2	42
MC Legislative	WMTC cl1-total	WMTC class 1 - total	43
MC Legislative	FTP75-1	FTP75 - part 1	51
MC Legislative	FTP75-2	FTP75 - part 2	52
MC Legislative	FTP75-1+2	FTP75 - part 1+2	53
MC Highway	Highway-1	Highway - part 1	54
MC Highway	Highway-2	Highway - part 2	55
MC Highway	Highway-1+2	Highway - part 1+2	56
MC FHB	FHB1-c1	FHB1 center 1	61
MC FHB	FHB1-c2	FHB1 center 2	62
MC FHB	FHB1-c3	FHB1 center 3	63
MC FHB	FHB1-ctotal	FHB1 center total	64
MC FHB	FHB2-p1	FHB2 periphery 1	65
MC FHB	FHB2-p2	FHB2 periphery 2	66
MC FHB	FHB2-p3	FHB2 periphery 3	67
MC FHB	FHB2-ptotal	FHB2 periphery total	68
MC FHB	FHB3-c1	FHB3 center 1	71
MC FHB	FHB3-c2	FHB3 center 2	72
MC FHB	FHB3-c3	FHB3 center 3	73
MC FHB	FHB3-ctotal	FHB3 center total	74
MC FHB	FHB4-p1	FHB4 periphery 1	75
MC FHB	FHB4-p2	FHB4 periphery 2	76
MC FHB	FHB4-p3	FHB4 periphery 3	77
MC FHB	FHB4-ptotal	FHB4 periphery total	78
MC v constant	v max const	v max constant	81
MC v constant	v20 const	v20 constant	82
MC v constant	v30 const	v30 constant	83
MC v constant	v40 const	v40 constant	84
MC v constant	v50 const	v50 constant	85
MC-PEMS	MC-PEMS RDE	MC-PEMS trip valid acc. RDE regulation	91
MC-PEMS	MC-PEMS Eco	MC-PEMS trip Eco-driving	92
MC-PEMS	MC-PEMS Normal	MC-PEMS trip Normal-driving	93
MC-PEMS	MC-PEMS Aggr	MC-PEMS trip Aggressive-driving	94
MC-PEMS	MC-PEMS Special	MC-PEMS trip with special driving	95

3.4.4. Start conditions (cold/intermediate/hot)

Uncertainties arise sometimes with respect to the start conditions. E.g. the NEDC in general is considered to have a cold start. In some cases it is indeed a hot start though – often in order to reduce time and costs of the measurements. This limits the direct comparability. However, this is not very relevant with respect to the production of hot EF since for this case only real-world cycles are being used. For the analysis of cold start effects though this may be relevant.

However, in certain cases some data providers assign the start condition not only to the relevant first cycle (e.g. ECE), but to all of the cycles (e.g. to ECE, to EUDC as well as to the 'total-NEDC'). This requires that in the analysis some of the definitions have to be adjusted in order to get comparable results (see chapter 5.1.2).

3.4.5. Test fuel

If the fuel used during the test is not specified (which is the 'normal' case) we assume a 'standard' market fuel without any further distinction. this parameter is mostly used for multifuel vehicles,

- specifying the fuel during measurements of bifuel-vehicles (e.g. CNG/petrol)
- or distinguishing biofuel-shares (B5, B10, E5, E10, E85 etc.).

3.4.6. Ambient conditions (temperature, humidity)

In many tests ambient conditions are not specified explicitly. Then one can assume that the temperature is in the range of 20°C to 25°C. For the analysis we pool these tests to an 'ambient temperature class' of '>20°C'; the analysis then allows to pool or differentiate the measurements by ambient temperature or by ambient temperature classes (see chapter 5.1).

3.4.7. Gear change strategies

The standard case is that tests are performed using the gear change strategy as prescribed by the test definition. Tests with different gear change strategies (and leaving everything else equal) are comparably rare. They were performed mainly in the ARTEMIS project and in special programmes (e.g. JRC 2010). Therefore this parameter in general is not provided .

3.4.8. Chassis dynamometer settings

Chassis dynamometer settings should use resistance forces that are representative of those the vehicle would experience in real world operation. Ideally road load information should be derived from the coast down method performed by the laboratory. The official NEDC test regulation specifies such road loads. Very often they are also used for the measurements in real world cycles even if the road loads measured under realistic conditions, representative of in-use vehicles driven in realistic conditions are found to be substantially higher than those of the Type Approval road loads (e.g. TNO 2012). The parameters used in the measurement tests representing the forces of the vehicle rolling resistance and aerodynamic drag (F0, F1, F2) are not always provided. In some special programmes these settings are varied in order to identify its influence on the emissions.

NOTE: The ERMES LDV template expects the values F0, F1 and F2 in particular units while some labs use alternative units for these terms. Therefore this should be taken into account while importing the data from labs; it might request corrections for the parameters F1 and F2 in order to get consistency in the database[12] (Table 10):

Table 10: Road driving resistance parameters

Road driving resistance parameters	Units expected by template	Units used by some lab's
Road driving resistance (road coast down) - f0	[kg m s-2]	[N]
Road driving resistance (road coast down) - f1	[kg s-1]	[N/v]
Road driving resistance (road coast down) - f2	[kg m-1]	[N/v^2]

Additional settings (as e.g. vehicle cooling) were also looked at in the ARTEMIS project, but not considered as a relevant parameter (Joumard et.al. 2006), hence they do not show up in the actual 'input data sheet'.

3.5. Descriptions of 'emission data'

The template expects that the data provider specify the pollutants and the corresponding units (in general in g/km or mg/km). The providers however can add additional pollutants (particularly non regulated pollutants). Some particularities should be considered:

3.5.1. Names of pollutants

Pollutants are predefined in the template by dropdown fields. However, it turned out that different naming conventions are used (particularly for non-regulated pollutants). The import procedure identifies respectively adjusts discrepancies.

3.5.2. Units

Units have to be specified: in general g/km or mg/km, predefined by dropdown fields. In some cases the units have to be selected carefully:

- **NOx, NO, NO2**: In general NOx is given in 'g/km in NO2 equivalents'. For deriving NO2 (or NO2 as share of NOx) it is necessary to know how NO is specified (if a lab provides NO and NOx only), i.e. whether the lab provides NO in g/km ('true') or in 'g/km in NO2 equivalents', i.e. whether with molar mass of NO (30) or of NO2 (46)
- **CO2**: So far the CO2 values were not further specified. In the actual ERMES LDV template CO2 can be specified with or without SOC correction' (SOC: State of charge of battery).

[12] Corrections needed:
F1 (DB) = F1 (lab) * 3.6
F2 (DB) = F2 (lab) * 3.6^2
No correction is needed for F0 since N=kg m / sec^2.

- **Fuel consumption (FC):** Fuel consumption can be specified in different units (g/km, L/100km, MJ/km or m3/100km [for CNG]), i.e. one or several values can be provided which has to be considered in the analysis (see chapter 5.1.2).

3.5.3. Origin of the emission data

The origin of the emission data is not always clear, i.e. whether the resulting emission measurements are indeed bag-data, or whether they are derived from instantaneous measurements (i.e. the calculated integral value over subcycles and/or cycles). The DB in principle would allow to distinguish this type of origin. However, the majority of the data are provided without such a distinction[13]. This uncertainty about the origin of the data (bag or modal) should not influence the resulting analysis significantly, since in general the difference between bag result and corresponding integral of modal data is limited. However, in future, with increasing amounts of modal data this distinction might be taken into account again.

3.5.4. New options: PEMS evaluation results of EMROAD and CLEAR

The actual input data sheet now also allows to enter aggregate emission measurement results based on PEMS data, and differentiated by the software how the PEMS data are evaluated, i.e. by EMROAD (JRC) or by CLEAR (TU Graz). In addition, also PEMS parameters can be stored (see Table 2). For the time being (Status April 2017) these data were not used yet.

3.6. Descriptions of instantaneous data (‘ChassisDyno_Inst’, ‘PEMS_Inst’

In the sheet ‘ChassisDyno_Inst’ resp. sheet ‘PEMS_Inst’ instantaneous data can be stored, i.e. second-per-second data. The data structure should be self explaining (see chapter 3.2.4 and 3.2.5). Two aspects should be mentioned:

3.6.1. Engine parameters required for emission factor models

Emission factor models try to use instantaneous emission data for the elaboration of emission factors. A basic task is the time alignment between measured emissions and exhaust flow from the engine. This is an important topic in itself, but not relevant here; more relevant in the present context is the question what input data (apart from the instantaneous emissions) are needed for emission factor models.

Previous simplified methods used instantaneous followed an approach by creating “base emission functions” based on kinematic parameters only (TueV Rheinland 1995), i.e. on speed and speed*acceleration where acceleration can be derived out of the v-signal.

---

[13] in the early years of 2010ff this distinction was also made explicit in the LDV input data sheet by allowing to specify the origin of the emissions values as e.g. ‘NOx’ (=NOx measured as bag) and ‘NOx_modal’ respectively. In the meantime this distinction was given up since only one lab followed this logic.

More elaborated emission factor models as e.g. PHEM (e.g. TUG 2013) use instantaneous data as basis for creating engine emission maps. These assign the sec-per-sec emissions to engine parameters, i.e. to power and engine speed. A typical problem of instantaneous data (particularly PEMS data) is that no reliable load or torque signals are available. As a proxy method, TU Graz developed the "CO2 interpolation method" (Matzer C. et al. 2016). This method calculates engine power from the measured CO2 mass flow (or fuel flow) and engine speed based on generic engine efficiency map. This method requires engine speed on a second-per-second basis, hence at least engine speed has to be provided in order that the data can be used for engine map creation. If engine speed is missing a "second best" approach could be applied: the information about the selected gear (on a second-per-second basis) could replace engine speed; this signal would allow to approximate engine speed and then to derive the engine power.

3.6.2. An operational detail: Test ID

This comment refers to an operational aspect how data providers can store instantaneous data in the input data sheet: The most efficient way to store the instantaneous data is to use one sheet per cycle, and to store all data of a *total cycle* (e.g. the 'total CADC') in one sheet (instead of using one sheet per cycle or even one sheet per subcycle). In order to assign the instantaneous data to the corresponding test in the sheet 'emission data' it is necessary to specify first that 'total cycle' in the sheet 'emission data' as shown (as example) in Table 11. As a convention it is recommended to specify the 'total-cycle' as e.g. 'chronological test nr' 1, 2, 3 etc. and the corresponding cycles or subcycles as 1.1, 1.2 etc. resp. 2.1, 2.2 etc. resp. 3.1, 3.2 etc.

Table 11: Specifying the test nr in the sheet 'Emission data'

chronological Test nr	Cycle Name	Start condition	…	…	Fuel type	…	…	CO	…
3	CADC URM150 (total)	hot			petrol			0.327	
3.1	CADC urban	hot			petrol			0.347	
3.2	CADC rural	hot			petrol			0.161	
3.3	CADC MW150	hot			petrol			0.433	

In this manner one can assign the instantaneous data (of e.g. sheet 'ChassisDyno_Inst_03') to the appropriate cycle by simply referring to the relevant test number specified in the sheet 'emission data' (in this example to test nr "3")[14]. In addition, the instantaneous sheet allows to specify cycles or subcycles or bags (used in chassis dyno measurements) in separate columns (col. AO, AP).

3.7. Harmonization of the data

The ARTEMIS project made a considerable effort to 'harmonize' the data from different sources. Particular studies developed correction factors for different effects. Finally three aspects were taken

[14] This explanation refers the cells I9 in the instantaneous sheets, which allows to refer by a dropdown field to the tests already defined in the sheet 'emission data'.

into account: corrections for (1) gearshift strategy, (2) mileage, and (3) humidity and temperature for NOx. In general a ‘standard setting’ was identified which allows comparisons with measurements of other campaigns where comparable ‘standard settings’ were applied. While importing the measurement data from the different sources into the database, the data were ‘harmonized’ i.e. corrected for these three elements. The correction procedures are explained in Joumard et.al. (2006). These corrections were applied up to Euro-4 since the study provided corresponding factors for concepts up to Euro-4 (only). For the newer measurements (Euro-5ff) no ‘harmonization’ is applied any more. Operationally the DB stores the original measurement data as well as the harmonized values (harmonization per aspect as well as cumulated).

3.7.1. Gearshift strategies

Correction factors for gearshift strategies are used for CO2 only (Joumard et. al. (2006), chapter 4.4, p. 84, table 20). According to this source only the values for rural and motorway driving (with the NEDC gearshift strategy) are corrected[15].

3.7.2. Mileage correction

The mileage correction factors (Euro-1 up to Euro-4 for petrol cars only) refer to the Artemis Subtask 3123 (Investigation of the emission degradation of gasoline vehicles, [LAT 2004]). The factors are also summarized in Joumard et. al. (2006), chapter 4.4, p. 84, table 21 and 22. While importing the emission measurement results into the ERMED DB the emissions (of petrol cars, Euro-1 to Euro-4) are “harmonized” (or corrected) to a standard vehicle with a mileage of 50’000 km. This has to be taken into account if the ERMES DB values are used for comparisons resp. for calibration of EF for emission models as e.g. PHEM or HBEFA. For consistency reasons the same correction functions should be used in those emission models for taking into account mileage dependencies.

3.7.3. Humidity and temperature (for NOx).

Correction factors for the two laboratory related parameters – ambient air temperature and humidity – are specified in Joumard et. al. (2006), chapter 4.4, p. 85, table 23 and 24. The factors are specified for petrol and diesel vehicles from Euro-0 up to Euro-4.

3.7.4. Comments

As mentioned above, newer measurements imported into the ERMES DB are not ‘harmonized’ any more. This has to be taken into account particularly for the mileage correction as well as for ambient temperature corrections:

- The **mileage correction factors** (in ARTEMIS) were – necessarily – based on a comparatively small sample of vehicles since the resources for measuring the same vehicle at stepwise increasing odometer readings are obviously huge and could be performed for very few vehicles only. Newer

[15] Values in the DB going back to the ARTEMIS project of the cycles BAB and HighWay were corrected in the analogue manner assuming apparently the same gearshift strategy.

methods, in particular remote sensing measurement campaigns, seem to be more capable to provide appropriate correction factors since they cover a much wider range of vehicles of different ages (using age as a proxy for mileage). First studies (e.g. Chen et. al. 2016) provide newer data for all Euro-Classes as well as for diesel cars. Therefore this new data source should be taken into consideration for future mileage correction factors.

- **Temperature and humidity corrections**: It is not fully clear whether the laboratories provide 'uncorrected' or 'corrected' NOx emission values. From some labs we know that their 'modal values' are uncorrected, while their 'bag values' are corrected where 'corrected' means corrected according to the regulation (ECE R83, Annex 4a, nr 6.6.5). The correction factor may be considerable since the depend on the temperature: from a recent sample we know that the correction factor at 23°C is 0.969 (on average) and for -7°C on average 0.77 (diesel cars, Euro-5). In absence of more details it is assumed that the newer measurements (Euro-5ff) are already 'corrected' values since this corresponds to the standard procedures of the labs.

3.8. The import procedure

For transferring the data from the Excel 'input data sheets' to the MS ACCESS database, a particular import procedure was developed (in Visual Basic), originally for the first (complex) input datasheet, and then as a modified version for the simplified input data sheet. The procedure in principle performs the following tasks:

- It reads one or several Excel-sheets
- In a first step the procedure checks
  - whether all field names can be identified (e.g. names of pollutants or units etc.), and
  - whether all cell contents (e.g. vehicle technologies, Euro-standards, cycle names, start conditions etc.) can be identified.

  This step is necessary since the 'input data sheet' suggests (by dropdown fields) the names and conventions used in the database but it does not force the data providers to use those names. Therefore, data providers can use (and some do indeed) their own names. The import procedure produces error lists, and depending on the case either the DB has to be adjusted (e.g. extend the cycle list) or the input data sheets have to be corrected. With new data types (particularly PEMS) it is very likely that these lists (e.g. cycle names/types) will have to be extended in future.
- In a second step all data are stored in interim tables for easy control and plausibility with particular forms (e.g. check of vehicle attributes, start conditions etc.). This check is an operational check, not a check of the plausibility of the content. In this step each vehicle gets a unique ID, and each test gets a unique 'chronological test number, i.e. a unique test number per test and vehicle.
- In a third step data are – as far as appropriate (see chapter 3.7) – harmonized, i.e. the original emission data are multiplied with correction factors (according to the 'harmonization routines') and stored in additional fields.
- In a fourth step eventually the data are transferred from the interim tables to the final database, by adding date-of-entry, original Excel-filenames etc.

4. Content of the Database - status April 2017

This chapter gives a short overview about the number of vehicles, tests and measurements available in the DB (status April 2017). Presently it contains ca. 4’300 vehicles, ca. 50’600 tests and ca. 305’000 measurements.

4.1. Number of vehicles

4.1.1. Number of vehicles by category, technology and Euro-class

Table 12: Number of vehicles (ERMES LDV DB, status April 2017)

VehCat	Technology	SumNrOfVeh	pre-EURO-1	EURO-1	EURO-2	EURO-3	EURO-4	EURO-5	EURO-6
pass. car	petrol (4S)	2'876	878	1'191	164	156	315	146	26
pass. car	diesel	1'156	207	48	54	141	194	306	206
pass. car	CNG	5					4	1	
pass. car	bifuel CNG/petrol	31				1	25	5	
pass. car	LPG	12		7	3	2			
pass. car	bifuel LPG/petrol	1						1	
pass. car	flex-fuel E85	32					27	5	
pass. car	Hybrid petrol/electri	12					10	2	
pass. car	Plug-in Hybrid petrol	1						1	
pass. car	Plug-in Hybrid diesel/	2						2	
Sum		4'128	1'085	1'246	221	300	575	469	232
LCV	petrol (4S)	64	23	36	5				
LCV	diesel	117	24	20	30	7	7	28	1
Sum		181	47	56	35	7	7	28	1
motorcycle	petrol (4S)	16			1	14	1		

4.1.2. Number of vehicles by data provider and Euro-class

Table 13: Number of vehicles by data providers (ERMES LDV DB, status April 2017)

VehCat	Lab_VehGroup	SumNrOfVeh	pre-EURO-1	EURO-1	EURO-2	EURO-3	EURO-4	EURO-5	EURO-6
pass. car	ADAC	47			39			4	4
pass. car	AVLMTC	190			5	3	182		
pass. car	DUH-EKI	54						1	53
pass. car	EMPA	289	6	107	38	38	58	24	18
pass. car	FORD	1				1			
pass. car	IFP	4				4			
pass. car	IM	13	1	1	4	6	1		
pass. car	Innovhub	2					2		
pass. car	INRETS/IFSTTAR	167	67	54	32	6	2	4	2
pass. car	JRC	32				1	16	15	
pass. car	KTI	3			3				
pass. car	LAT	86	1	54	5	13	2	11	
pass. car	SHELL	4				4			
pass. car	TNO	1'694	687	892	14	25	18	31	27
pass. car	TRL	105	49	35	16	5			
pass. car	TU Vienna	5					5		
pass. car	TueV RL	198	156	42					
pass. car	TueVN	476	118	61	52	150	95		
pass. car	TueVN-SE	444				15	167	239	23
pass. car	TUG	72				15	24	23	10
pass. car	VTT	29			13	14	2		
pass. car	VW_Inq	213					1	117	95
Sum		4'128	1'085	1'246	221	300	575	469	232
LCV	DUH-EKI	1							1
LCV	EMPA	49		25	12		6	6	
LCV	Innovhub	2				2			
LCV	INRETS/IFSTTAR	21		4	17				
LCV	KTI	2		1	1				
LCV	TNO	30	2	15	3	1		9	
LCV	TRL	22	19	1	2				
LCV	TueV RL	19	9	10					
LCV	TueVN	20	17			3			
LCV	TueVN-SE	5						5	
LCV	TUG	5				1	1	3	
LCV	VW_Inq	5						5	
Sum		181	47	56	35	7	7	28	1
motorcycle	AFHB Biel	16			1	14	1		

4.2. Number of tests

Even if the table 'TESTS' in the ERMES DB contains more than 50'600 records, this number is not a priori meaningful since 'tests' can be specified very differently (e.g. how many cycles and/or sub-cycles, different test fuels, repeated tests etc.). Therefore, Table 14 lists the number of vehicles tested in different relevant cycle groups, measured on chassis dynamometers (with one or more pollutants, with one or several different ambient temperatures, with one or several different test fuels). Table 15 adds the number of vehicles tested with PEMS on chassis dynamometers (varying the NEDC cycle) and on road presently available in the DB.

Table 14: Number of vehicles tested in different cycle groups on chassis dynamometers (ERMES LDV DB, status April 2017)

			Legislative cycles			Real world cycles			
VehCat	Technology	EU_em_std	NEDC	FTP	WLTC	CADC	ERMES	BAB	TNO Dyna
pass. car	petrol (4S)	pre-EURO-1	834	310	-	7	-	241	-
pass. car	petrol (4S)	EURO-1	695	842	-	9	-	90	-
pass. car	petrol (4S)	EURO-2	114	110	-	33	-	59	-
pass. car	petrol (4S)	EURO-3	154	101	-	87	-	56	-
pass. car	petrol (4S)	EURO-4	313	77	-	229	-	29	-
pass. car	petrol (4S)	EURO-5	144	-	40	54	31	10	-
pass. car	petrol (4S)	EURO-6	20	-	17	8	16	1	-
pass. car	diesel	pre-EURO-1	177	82	-	2	-	35	-
pass. car	diesel	EURO-1	17	8	-	5	-	10	-
pass. car	diesel	EURO-2	48	26	-	31	-	17	-
pass. car	diesel	EURO-3	137	69	-	66	-	31	-
pass. car	diesel	EURO-4	187	45	-	129	-	16	-
pass. car	diesel	EURO-5	195	-	55	71	44	12	21
pass. car	diesel	EURO-6	84	-	32	47	18	7	10
pass. car	CNG	EURO-4	4	4	-	4	-	4	-
pass. car	CNG	EURO-5	1	1	-	1	-	1	-
pass. car	bifuel CNG/petrol	EURO-3	1	-	-	1	-	-	-
pass. car	bifuel CNG/petrol	EURO-4	25	16	-	23	-	13	-
pass. car	bifuel CNG/petrol	EURO-5	5	-	-	3	-	-	-
pass. car	LPG	EURO-1	7	-	-	-	-	-	-
pass. car	LPG	EURO-2	3	-	-	-	-	-	-
pass. car	LPG	EURO-3	2	-	-	2	-	-	-
pass. car	bifuel LPG/petrol	EURO-5	1	-	-	1	-	-	-
pass. car	flex-fuel E85	EURO-4	27	-	-	17	-	-	-
pass. car	flex-fuel E85	EURO-5	5	-	-	3	-	-	-
pass. car	Hybrid petrol/electric	EURO-4	8	5	-	8	-	2	-
pass. car	Hybrid petrol/electric	EURO-5	2	1	-	2	-	1	-
pass. car	Plug-in Hybrid petrol/e	EURO-5	1	-	1	1	1	-	-
pass. car	Plug-in Hybrid diesel/el	EURO-5	1	-	1	1	-	-	-
LCV	petrol (4S)	pre-EURO-1	23	19	-	-	-	19	-
LCV	petrol (4S)	EURO-1	24	19	-	-	-	20	-
LCV	petrol (4S)	EURO-2	5	5	-	-	-	5	-
LCV	diesel	pre-EURO-1	24	7	-	-	-	7	-
LCV	diesel	EURO-1	6	5	-	-	-	15	-
LCV	diesel	EURO-2	14	9	-	8	-	7	-
LCV	diesel	EURO-3	5	3	-	4	-	-	-
LCV	diesel	EURO-4	7	6	-	7	-	6	-
LCV	diesel	EURO-5	21	-	-	13	3	6	2
Total Veh.			3'341	1'770	146	877	113	720	33

Table 15: Number of vehicles tested with PEMS in different cycle groups (ERMES LDV DB, status April 2017)

			Modified NEDC	Real world cycles	
VehCat	Technology	EU_em_std	NEDC-Variations	RDE	RWC
pass. car	petrol (4S)	EURO-6			3
pass. car	diesel	EURO-5	40	40	39
pass. car	diesel	EURO-6	49	48	52
LCV	diesel	EURO-5	5	5	
LCV	diesel	EURO-6			1
Total Veh.			94	93	95

The vehicles tested in the cycle group “NEDC-variations” were measured on chassis dynamometers as well as with PEMS in the inquiries in the context of ‘Dieselgate’, some of these vehicles were also measured on road with PEMS. The vehicles tested in the cycle group “RWC” (real world cycles) were tested on road with PEMS in cycles which do not necessarily comply with the RDE regulation.

4.3. Number of measurements per pollutant

The following two tables show the number of measurements of “usually” measured components which are available in the ERMES LDV DB (status April 2017), first for petrol and diesel vehicles (Table 16), and in Table 17 for vehicles with alternative concepts (as CNG, LPG, bifuel, hybrids). Annex D shows also the number of measurements of non-regulated pollutants (differentiated VOC and PAH).

Table 16: Number of measurements of petrol/diesel vehicles and per pollutant (ERMES LDV DB, status April 2017)

VehCat	Technology	Group	pollutant	Family	pre-EURO-	EURO-1	EURO-2	EURO-3	EURO-4	EURO-5	EURO-6
pass. car	petrol (4S)	"regulated"/HBEFA	Benzene	aromatics	7	1	3	12	3	1	1
pass. car	petrol (4S)	"regulated"/HBEFA	CH4	alkanes	35	23	10	12	151	134	15
pass. car	petrol (4S)	"regulated"/HBEFA	CO		837	1'171	158	152	310	145	22
pass. car	petrol (4S)	"regulated"/HBEFA	HC		837	1'170	157	152	310	145	22
pass. car	petrol (4S)	"regulated"/HBEFA	HC+NOx		-	-	-	-	1	124	21
pass. car	petrol (4S)	"regulated"/HBEFA	N2O		17	-	-	-	-	-	-
pass. car	petrol (4S)	"regulated"/HBEFA	NMHC		-	-	-	-	68	1	-
pass. car	petrol (4S)	"regulated"/HBEFA	NO		-	-	-	-	86	7	6
pass. car	petrol (4S)	"regulated"/HBEFA	NO2		-	-	-	7	127	131	21
pass. car	petrol (4S)	"regulated"/HBEFA	NO2%		-	-	-	7	92	-	-
pass. car	petrol (4S)	"regulated"/HBEFA	NOx		837	1'170	158	152	310	145	22
pass. car	petrol (4S)	"regulated"/HBEFA	PM		1	7	16	15	190	130	17
pass. car	petrol (4S)	"regulated"/HBEFA	PM(PMP)		-	-	-	-	68	-	-
pass. car	petrol (4S)	"regulated"/HBEFA	PN		-	-	-	-	182	124	20
pass. car	petrol (4S)	"regulated"/HBEFA	Toluene	aromatics	7	1	3	10	3	1	1
pass. car	petrol (4S)	FC/CO2	CO2		837	1'171	158	152	309	144	13
pass. car	petrol (4S)	FC/CO2	CO2_without_SOC_		-	-	-	-	1	1	9
pass. car	petrol (4S)	FC/CO2	FC		308	323	155	109	224	8	7
pass. car	petrol (4S)	FC/CO2	FC_L/100km		-	-	-	-	95	136	22
pass. car	petrol (4S)	FC/CO2	FC_MJ/km		-	-	-	-	-	8	7
pass. car	diesel	"regulated"/HBEFA	Benzene	aromatics	-	-	7	1	1	3	1
pass. car	diesel	"regulated"/HBEFA	CH4	alkanes	12	11	2	23	64	136	15
pass. car	diesel	"regulated"/HBEFA	CO		198	30	45	132	178	171	46
pass. car	diesel	"regulated"/HBEFA	HC		198	30	45	132	178	171	46
pass. car	diesel	"regulated"/HBEFA	HC+NOx		-	-	13	23	22	153	43
pass. car	diesel	"regulated"/HBEFA	N2O		5	-	-	-	-	-	-
pass. car	diesel	"regulated"/HBEFA	NMHC		-	-	-	-	33	-	-
pass. car	diesel	"regulated"/HBEFA	NO		-	-	-	12	27	15	13
pass. car	diesel	"regulated"/HBEFA	NO2		-	-	-	24	75	158	37
pass. car	diesel	"regulated"/HBEFA	NO2%		-	-	-	19	33	-	-
pass. car	diesel	"regulated"/HBEFA	NOx		198	30	45	132	178	198	90
pass. car	diesel	"regulated"/HBEFA	PM		185	7	40	129	162	166	43
pass. car	diesel	"regulated"/HBEFA	PM(PMP)		-	-	-	-	38	-	-
pass. car	diesel	"regulated"/HBEFA	PN		-	-	-	23	118	146	36
pass. car	diesel	"regulated"/HBEFA	Toluene	aromatics	-	-	7	1	1	3	1
pass. car	diesel	FC/CO2	CO2		198	30	45	132	177	167	27
pass. car	diesel	FC/CO2	CO2_without_SOC_		-	-	-	-	1	4	19
pass. car	diesel	FC/CO2	FC		50	14	28	76	152	13	20
pass. car	diesel	FC/CO2	FC_L/100km		-	-	-	3	82	169	39
pass. car	diesel	FC/CO2	FC_MJ/km		-	-	-	-	-	13	20
LCV	petrol (4S)	"regulated"/HBEFA	CO		23	36	5	-	-	-	-
LCV	petrol (4S)	"regulated"/HBEFA	HC		23	36	5	-	-	-	-
LCV	petrol (4S)	"regulated"/HBEFA	NOx		23	36	5	-	-	-	-
LCV	petrol (4S)	FC/CO2	CO2		23	36	5	-	-	-	-
LCV	petrol (4S)	FC/CO2	FC		23	21	5	-	-	-	-
LCV	diesel	"regulated"/HBEFA	CH4	alkanes	-	-	-	-	6	11	-
LCV	diesel	"regulated"/HBEFA	CO		24	15	10	6	7	14	-
LCV	diesel	"regulated"/HBEFA	HC		23	15	10	6	7	14	-
LCV	diesel	"regulated"/HBEFA	HC+NOx		-	-	-	-	-	8	-
LCV	diesel	"regulated"/HBEFA	NO		-	-	-	-	-	6	-
LCV	diesel	"regulated"/HBEFA	NO2		-	-	-	-	6	14	-
LCV	diesel	"regulated"/HBEFA	NOx		24	15	10	6	7	21	-
LCV	diesel	"regulated"/HBEFA	PM		24	5	10	6	7	14	-
LCV	diesel	"regulated"/HBEFA	PN		-	-	-	2	6	8	-
LCV	diesel	FC/CO2	CO2		24	15	10	6	7	14	-
LCV	diesel	FC/CO2	FC		22	15	10	1	7	3	-
LCV	diesel	FC/CO2	FC_L/100km		-	-	-	2	-	14	-
LCV	diesel	FC/CO2	FC_MJ/km		-	-	-	-	-	3	-

Table 17: Number of measurements of alternative concepts and per pollutant in the ERMES DB (status April 2017)

VehCat	Technology	Group	pollutant	Family	pre-EURO-	EURO-1	EURO-2	EURO-3	EURO-4	EURO-5	EURO-6
pass. car	CNG	"regulated"/HBEFA	CO		-	-	-	-	4	1	-
pass. car	CNG	"regulated"/HBEFA	HC		-	-	-	-	4	1	-
pass. car	CNG	"regulated"/HBEFA	NMHC		-	-	-	-	4	1	-
pass. car	CNG	"regulated"/HBEFA	NOx		-	-	-	-	4	1	-
pass. car	CNG	FC/CO2	CO2		-	-	-	-	4	1	-
pass. car	bifuel CNG/petrol	"regulated"/HBEFA	CH4	alkanes	-	-	-	-	8	5	-
pass. car	bifuel CNG/petrol	"regulated"/HBEFA	CO		-	-	-	1	25	5	-
pass. car	bifuel CNG/petrol	"regulated"/HBEFA	HC		-	-	-	1	25	5	-
pass. car	bifuel CNG/petrol	"regulated"/HBEFA	HC+NOx		-	-	-	-	-	5	-
pass. car	bifuel CNG/petrol	"regulated"/HBEFA	NMHC		-	-	-	-	8	-	-
pass. car	bifuel CNG/petrol	"regulated"/HBEFA	NO2		-	-	-	-	5	-	-
pass. car	bifuel CNG/petrol	"regulated"/HBEFA	NO2%		-	-	-	-	5	-	-
pass. car	bifuel CNG/petrol	"regulated"/HBEFA	NOx		-	-	-	1	25	5	-
pass. car	bifuel CNG/petrol	"regulated"/HBEFA	PM		-	-	-	-	11	5	-
pass. car	bifuel CNG/petrol	"regulated"/HBEFA	PN		-	-	-	-	12	5	-
pass. car	bifuel CNG/petrol	FC/CO2	CO2		-	-	-	1	24	5	-
pass. car	bifuel CNG/petrol	FC/CO2	FC		-	-	-	1	16	-	-
pass. car	bifuel CNG/petrol	FC/CO2	FC_L/100km		-	-	-	-	10	5	-
pass. car	bifuel CNG/petrol	FC/CO2	FC_m3/100km		-	-	-	-	1	-	-
pass. car	LPG	"regulated"/HBEFA	CO		-	7	3	1	-	-	-
pass. car	LPG	"regulated"/HBEFA	HC		-	7	3	1	-	-	-
pass. car	LPG	"regulated"/HBEFA	NOx		-	7	3	1	-	-	-
pass. car	LPG	"regulated"/HBEFA	PM		-	-	1	-	-	-	-
pass. car	LPG	FC/CO2	CO2		-	7	3	1	-	-	-
pass. car	LPG	FC/CO2	FC		-	-	1	1	-	-	-
pass. car	bifuel LPG/petrol	"regulated"/HBEFA	CO		-	-	-	-	-	1	-
pass. car	bifuel LPG/petrol	"regulated"/HBEFA	HC		-	-	-	-	-	1	-
pass. car	bifuel LPG/petrol	"regulated"/HBEFA	HC+NOx		-	-	-	-	-	1	-
pass. car	bifuel LPG/petrol	"regulated"/HBEFA	NO2		-	-	-	-	-	1	-
pass. car	bifuel LPG/petrol	"regulated"/HBEFA	NOx		-	-	-	-	-	1	-
pass. car	bifuel LPG/petrol	FC/CO2	CO2		-	-	-	-	-	1	-
pass. car	bifuel LPG/petrol	FC/CO2	FC_L/100km		-	-	-	-	-	1	-
pass. car	flex-fuel E85	"regulated"/HBEFA	CH4	alkanes	-	-	-	-	15	5	-
pass. car	flex-fuel E85	"regulated"/HBEFA	CO		-	-	-	-	27	5	-
pass. car	flex-fuel E85	"regulated"/HBEFA	HC		-	-	-	-	27	5	-
pass. car	flex-fuel E85	"regulated"/HBEFA	HC+NOx		-	-	-	-	-	5	-
pass. car	flex-fuel E85	"regulated"/HBEFA	NMHC		-	-	-	-	15	-	-
pass. car	flex-fuel E85	"regulated"/HBEFA	NO2		-	-	-	-	6	-	-
pass. car	flex-fuel E85	"regulated"/HBEFA	NOx		-	-	-	-	27	5	-
pass. car	flex-fuel E85	"regulated"/HBEFA	PM		-	-	-	-	25	5	-
pass. car	flex-fuel E85	"regulated"/HBEFA	PM(PMP)		-	-	-	-	15	-	-
pass. car	flex-fuel E85	"regulated"/HBEFA	PN		-	-	-	-	25	5	-
pass. car	flex-fuel E85	FC/CO2	CO2		-	-	-	-	25	5	-
pass. car	flex-fuel E85	FC/CO2	FC		-	-	-	-	17	-	-
pass. car	flex-fuel E85	FC/CO2	FC_L/100km		-	-	-	-	27	5	-
pass. car	Hybrid petrol/elec	"regulated"/HBEFA	CH4	alkanes	-	-	-	-	5	1	-
pass. car	Hybrid petrol/elec	"regulated"/HBEFA	CO		-	-	-	-	8	2	-
pass. car	Hybrid petrol/elec	"regulated"/HBEFA	HC		-	-	-	-	8	2	-
pass. car	Hybrid petrol/elec	"regulated"/HBEFA	HC+NOx		-	-	-	-	-	1	-
pass. car	Hybrid petrol/elec	"regulated"/HBEFA	NMHC		-	-	-	-	2	1	-
pass. car	Hybrid petrol/elec	"regulated"/HBEFA	NO		-	-	-	-	3	-	-
pass. car	Hybrid petrol/elec	"regulated"/HBEFA	NO2		-	-	-	-	3	1	-
pass. car	Hybrid petrol/elec	"regulated"/HBEFA	NO2%		-	-	-	-	3	-	-
pass. car	Hybrid petrol/elec	"regulated"/HBEFA	NOx		-	-	-	-	8	2	-
pass. car	Hybrid petrol/elec	"regulated"/HBEFA	PM		-	-	-	-	3	-	-
pass. car	Hybrid petrol/elec	"regulated"/HBEFA	PN		-	-	-	-	3	1	-
pass. car	Hybrid petrol/elec	FC/CO2	CO2		-	-	-	-	8	2	-
pass. car	Hybrid petrol/elec	FC/CO2	FC		-	-	-	-	6	-	-
pass. car	Hybrid petrol/elec	FC/CO2	FC_L/100km		-	-	-	-	3	1	-
pass. car	Plug-in Hybrid pet	"regulated"/HBEFA	CO		-	-	-	-	-	1	-
pass. car	Plug-in Hybrid pet	"regulated"/HBEFA	HC		-	-	-	-	-	1	-
pass. car	Plug-in Hybrid pet	"regulated"/HBEFA	HC+NOx		-	-	-	-	-	1	-
pass. car	Plug-in Hybrid pet	"regulated"/HBEFA	NO2		-	-	-	-	-	1	-
pass. car	Plug-in Hybrid pet	"regulated"/HBEFA	NOx		-	-	-	-	-	1	-
pass. car	Plug-in Hybrid pet	"regulated"/HBEFA	PM		-	-	-	-	-	1	-
pass. car	Plug-in Hybrid pet	"regulated"/HBEFA	PN		-	-	-	-	-	1	-
pass. car	Plug-in Hybrid pet	FC/CO2	CO2		-	-	-	-	-	1	-
pass. car	Plug-in Hybrid pet	FC/CO2	FC_L/100km		-	-	-	-	-	1	-
pass. car	Plug-in Hybrid die	"regulated"/HBEFA	CH4	alkanes	-	-	-	-	-	1	-
pass. car	Plug-in Hybrid die	"regulated"/HBEFA	CO		-	-	-	-	-	1	-
pass. car	Plug-in Hybrid die	"regulated"/HBEFA	HC		-	-	-	-	-	1	-
pass. car	Plug-in Hybrid die	"regulated"/HBEFA	HC+NOx		-	-	-	-	-	1	-
pass. car	Plug-in Hybrid die	"regulated"/HBEFA	NO2		-	-	-	-	-	1	-
pass. car	Plug-in Hybrid die	"regulated"/HBEFA	NOx		-	-	-	-	-	1	-
pass. car	Plug-in Hybrid die	"regulated"/HBEFA	PM		-	-	-	-	-	1	-
pass. car	Plug-in Hybrid die	"regulated"/HBEFA	PN		-	-	-	-	-	1	-
pass. car	Plug-in Hybrid die	FC/CO2	CO2_without_SOC_		-	-	-	-	-	1	-
pass. car	Plug-in Hybrid die	FC/CO2	FC		-	-	-	-	-	1	-
pass. car	Plug-in Hybrid die	FC/CO2	FC_L/100km		-	-	-	-	-	1	-
pass. car	Plug-in Hybrid die	FC/CO2	FC_MJ/km		-	-	-	-	-	1	-

5. Selected emission measurement results

It is not the purpose of this report to provide a comprehensive picture of the emissions of the different vehicle types. This chapter only presents some selected average values in order to give indications about the possibilities of the ERMES LDV DB and how they are used in practice.

5.1. Analyses

5.1.1. Differentiation by key parameters

As explained in chapter 3 the emission measurements can be influenced by many different parameters. Therefore, one has to define the set of parameters before an analysis is made. In this context one should note that the purpose of the ERMES LDB DB has changed compared to its initial objective: in the ARTEMIS project the focus was on accuracy of the emission measurements and hence on the elaboration of key influencing parameters. Therefore, in special campaigns several tests were repeated varying singular parameters as e.g. chassis dyno settings, road load etc. In the meantime the focus has switched to get representative emission measurements. The usual measurement campaigns hence have a standard program focusing on a set of vehicles which are measured in some defined cycles. Only in singular cases some parameters are varied (e.g. ambient temperatures, or start conditions, or varying test fuels).

Standard analysis

Based on these considerations the 'standard analysis' of the ERMES LDV makes differentiations along the following parameters which can be selected:

- Vehicle type:
  - Vehicle category: PC, LCV, MC
  - Technology: petrol, diesel, alternative concepts (see Table 5)
  - Emission concepts: Euro-1, -2, -3 etc.
- Tests:
  - Cycles
  - Start conditions
  - Test fuels[16]
  - Dynamometer settings[17]
  - Ambient temperature: Can be selected in order to include or exclude respectively measurements below or above a certain temperature threshold [18]

[16] A market fuel is assumed as default (if test fuel is not particularly specified by the data providers)
[17] Standard settings are assumed as default (if not specified differently by the data providers). Varying settings are rare in recent measurement programs.
[18]Ambient temperature resp. temperature class so far was relevant in the context of cold start emissions; since 'Dieselgate' ambient temperature is getting relevant also for hot emissions (NOx of diesel vehicles). With PEMS data this might get more relevant in future.

- Pollutants

The standard analysis results will provide emission values differentiated by these parameters. They also allow to produce statistical indicators as e.g. standard deviations taking into account the (often limited) number of measurements. Theses analyses are not only useful for the final objective, i.e. describing the emission levels of different vehicle types. They are also helpful for plausibility checks, e.g. by comparing emission levels between labs, between size classes etc. In this manner one also can detect input errors, as e.g. wrong units (mg/km instead of g/km), typing errors etc.

Additional optional differentiation or pooling of the data

Since the data have more differentiation, one can analyze the data with more details (as far as the original data are available for further differentiation), or also pool the data further. One could differentiate e.g.

- by the data providers / laboratories,
- by vehicle parameters[19] as e.g. size class, registration years, or date of entry of the data (e.g. to analyze the emissions due to technological progress).

Or one could pool data e.g.

- pool the emission measurements of all temperature classes (assuming that the sample measured leads to a meaningful representative result),
- pool the emission measurements of all dynamometer settings.

Special analyses

In addition to the standard analyses some special analyses can be performed as

- **Outliers**
  Special DB queries allow to eliminate outliers which are defined as values which are < or > than the sample mean +/- 2*standard deviation. The diagrams in chapter 5.2 make use of this element.
- **Cold start**
  A few cycles are particularly designed for cold start behavior of vehicles (e.g. IUFC), ohter cycles too allow to infer information about cold start excess emissions, e.g. comparison of FTP 1 (=cold) and FTP 3 (=hot). The same holds for CADC if measured with and without cold start or e.g. in the TNO-format (urban-cold/rural/motorway/urban-hot). Special DB queries were developed to produce the relevant indicators.

5.1.2. Initialization

Due to the heterogeneity of the input data some procedures are performed[20] as basis for the standard analysis:

---

[19] as far as they are available

[20] These procedures are implemented in the ERMES LDV DB as ‘initialization’ before the analyses are performed.

- Some cycles are provided in different versions which differ often only marginally: Therefore, they can be pooled (optionally). This is the case for
  - ERMES cycle (version V6, V7, V8) : The 'initialization procedure' allows as option to pool the three versions.
  - CADC motorways: there are two versions (with v-max 130 km/h resp 150 km/). The 'initialization procedure' allows (optionally) to pool the two versions.
  - NEDC: The NEDC cycle depends on the Euro-Class: up to Euro-2 the ECE version contained 40 sec preconditioning. Since Euro-3 ff. the 40 sec. are not included. The 'initialization procedure' allows (optionally) to pool the two versions.
- Often cycles are provided in heterogeneous structures (e.g. with or without totals). In order to get a more complete and comparable measurement set, the 'totals' are (if missing) calculated and added. In the case of CADC an additional 'CADC-1/3-mix' is calculated since the standard distance-weighted CADC is dominated by the CADC-MW and hence not necessarily representative for an overall emission level.
- In the case of NO, NO2, NOx the emission values are – if needed – readjusted in order to have the same units (in NO2-equivalents) and to allow to calculate the indicator "NO2 in % of NOx".
- In order to produce comparable results some 'start conditions' are harmonized resp. corrected where they are likely to be mis-interpreted erroneous. E.g. the first part of a cycle may or may not be 'cold' while the following cycles are assumed to be 'hot' respectively they are replaced by the default values; see Table 7, col. 'start conditions (default)'.
- Heterogeneous inputs are also provided with respect to CO2 and fuel consumption (FC). As shown in chapter 3.2.3 (Table 2) the present input data sheet allows different ways of specifying FC (in g/km, in L/100 km or in MJ/km), and the previous specification for CO2 in the input data sheet is now replaced by a differentiated input (without and/or with SOC correction [state of charge of battery]). In the initialization step FC is transformed (if not provided already) into g/km. This transformation uses for fuel density (Kg/L) resp. fuel heating density (MJ/kg) the data provider's values; if these are missing, default values according to Table 18 are used. If FC is missing, it is calculated out of CO2, CO and HC (according to the regulation[21]) – or if CO and HC are missing – based on the CO2 factor according to Table 18.

[21] FC = f1*(g1*HC + g2*CO + g3*CO2),
with g1=0.866, g2=0.429, g3=0.273 and with f1=1.154 for petrol and 1.155 for diesel.

Table 18: Default values for Fuel density and fuel energy density

Fuel type	Fuel density (Kg/L)	Fuel energy density (lower heat value) (MJ/kg)	CO2 factor (kg CO2/kg Fuel)
Petrol	0.742	43.543	3.135
Diesel	0.832	42.960	3.179
Ethanol	0.789	26.658	-
Biodiesel	0.881	37.242	-
CNG	0.716	44.324	2.743

Values as used in HBEFA, data for Germany (source: AGEB: Arbeitsgemeinschaft Energiebilanzen e.V.).

5.2. Indicative results

The following diagrams (Figure 6, Figure 7 and Figure 8) give an overview of aggregate emission levels of **passenger cars,** differentiated by petrol and diesel, depicted as time series from Euro-1 up to Euro-6, for selected cycles (the three legislative cycles NEDC, FTP and WLTC[22] and two real-world cycles CADC[23] and ERMES). Only test measured at ambient temperatures >15° C are used. For NOx emissions of recent diesel cars some PEMS-measurements complying with the RDE regulation are shown as well. The diagrams show mean values including standard deviations and number of vehicles (the latter refer to the NOx emissions); the number of vehicles varies from cycle to cycle and often also from pollutant to pollutant due to the heterogeneity of measurement campaigns. These values represent average values without outliers, i.e. emission values below or beyond the mean value +/-2 x the standard deviation are excluded; in addition, each sample has to contain at least 2 vehicles The mean values are given also in Annex E (E1).

The figures show the well known fact that the emissions of real world cycles tend to be considerably higher than the emissions in the type approval cycles. The difference though depends on the pollutant as well as the vehicle emission class. Furthermore, the standard deviations are remarkable, indicating the importance of sample composition and sample size. The samples of Euro-1 and Euro-2 vehicles in the CADC are rather limited, due to the fact that the CADC was only developed in the period 2003/2005 when the interest was particularly high for the new Euro-3 and Euro-4 vehicles. Hence, if the interest is on full time series including older vehicles (until down to the Pre-Euro-vehicles) additional real world cycles should be taken into account (as e.g. the original HBEFA cycles).

Figure 9 and Figure 10 show the emissions of **diesel light commercial vehicles** (no figures for petrol vehicles are shown since measurements are available for Euro-1 and -2 vehicles only). However, the number of available measurements of diesel LCV is very limited (none for Euro-6), hence the uncertainty is relatively high. The mean values are given also in Annex E (E2).

[22] the appendix «c» means that these cycles include cold start excess emissions.
[23] For the CADC differentiated values are shown: three subcycles urban/rural/motorway, the distance weighted total CADC and the average 1/3mix.

Figure 6: HC, CO and NOx-emissions of petrol cars (Euro-1 to Euro-6) of selected cycles (mean values incl. standard deviation as well as nr of underlying vehicles of the NOx-emissions)

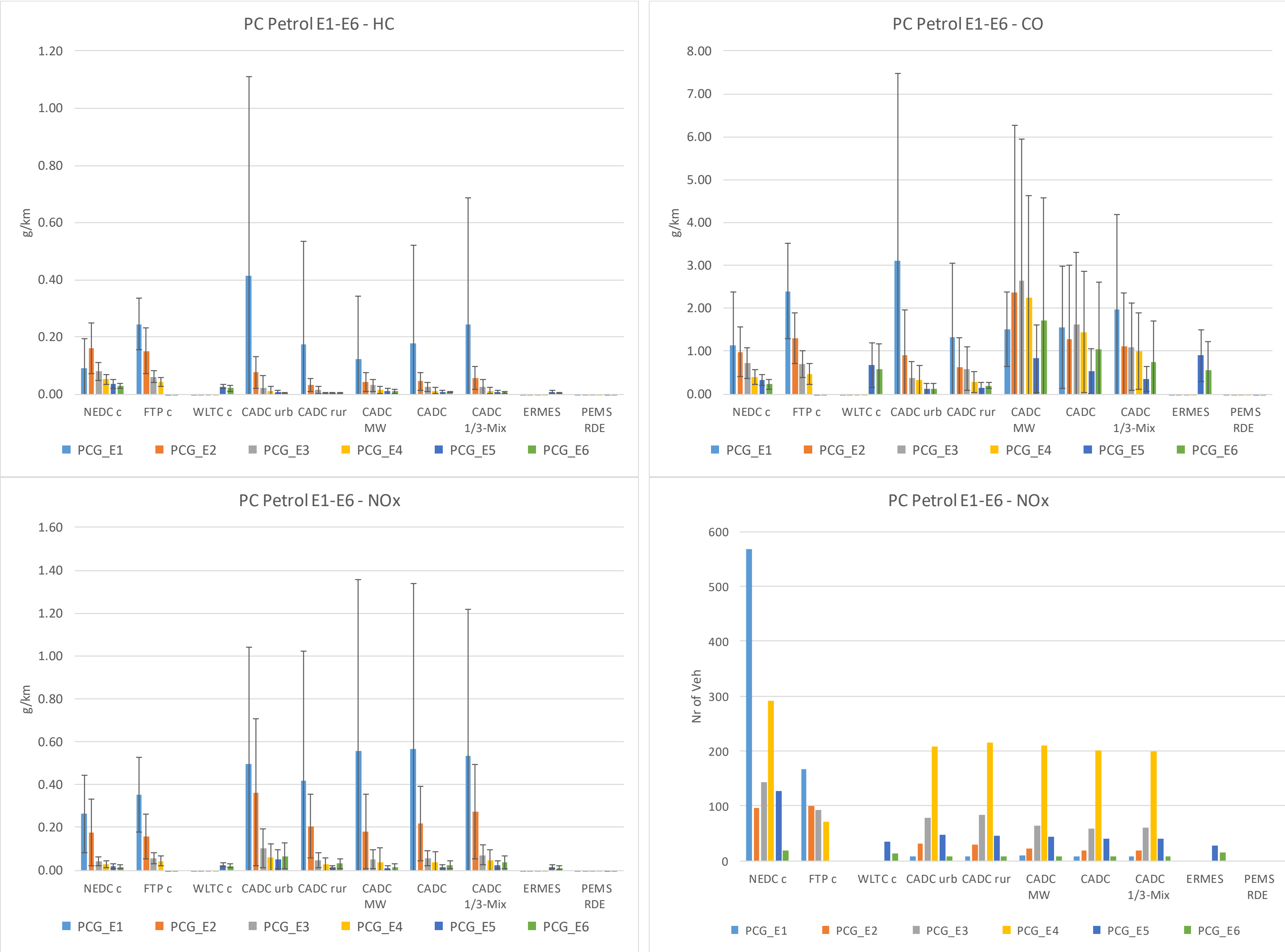


Figure 7: HC, CO and NOx-emissions of diesel cars (Euro-1 to Euro-6) of selected cycles (mean values incl. standard deviation as well as nr of underlying vehicles of the NOx-emissions)

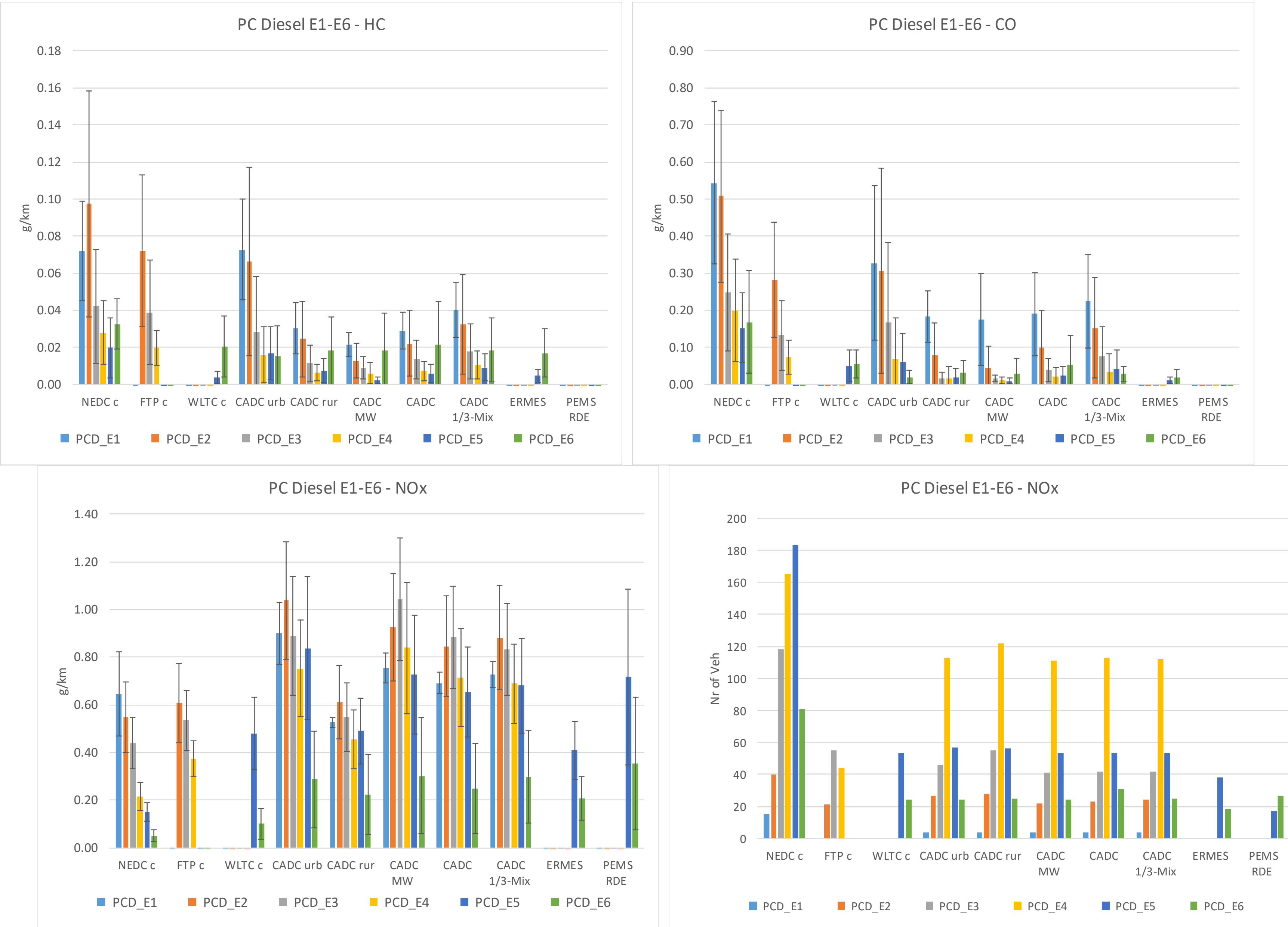
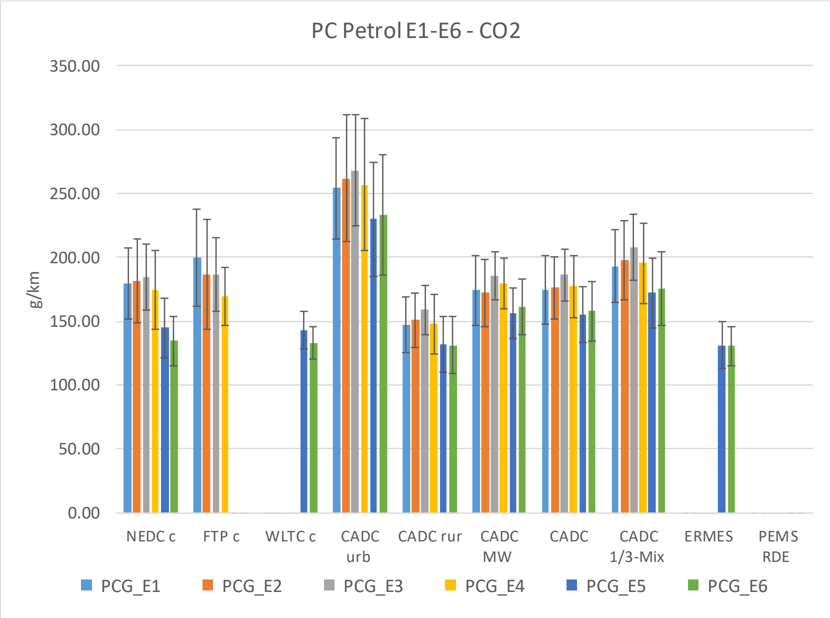


Figure 8: CO2-emissions of petrol and diesel cars (Euro-1 to Euro-6) of selected cycles (mean values incl. standard deviation)



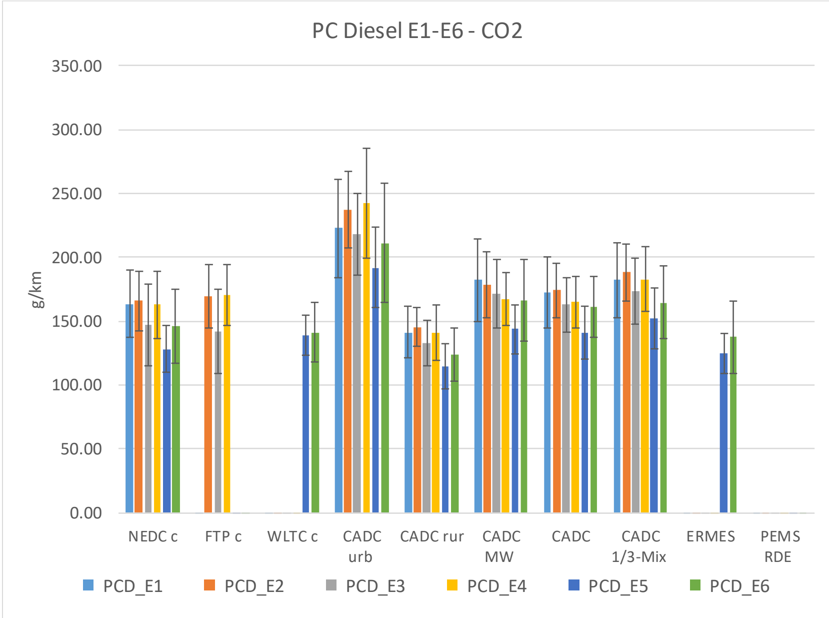


Figure 9: HC, CO and NOx-emissions of diesel LCV (Euro-1 to Euro-6) of selected cycles (mean values incl. standard deviation as well as nr of underlying vehicles of the NOx-emissions)

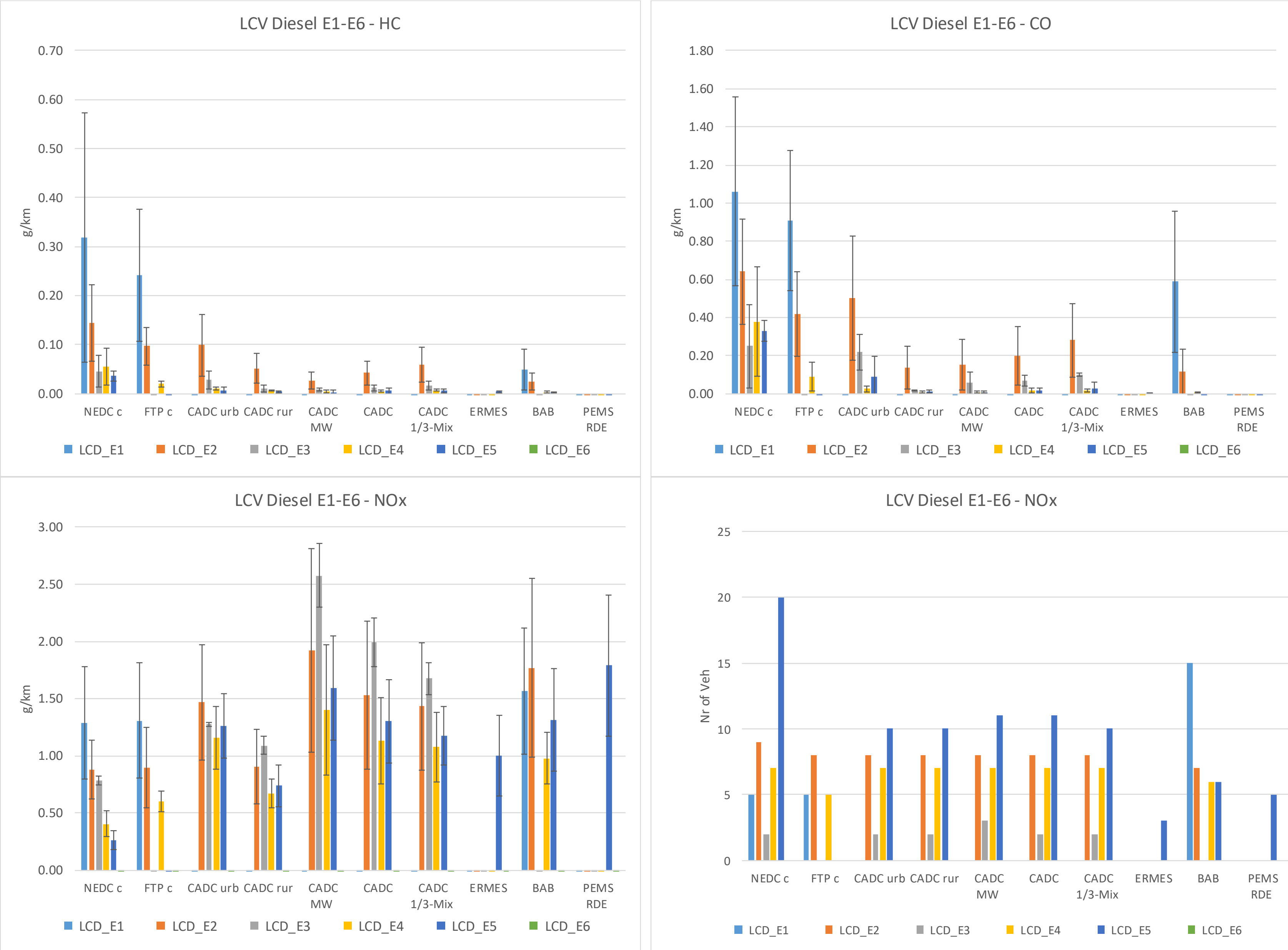
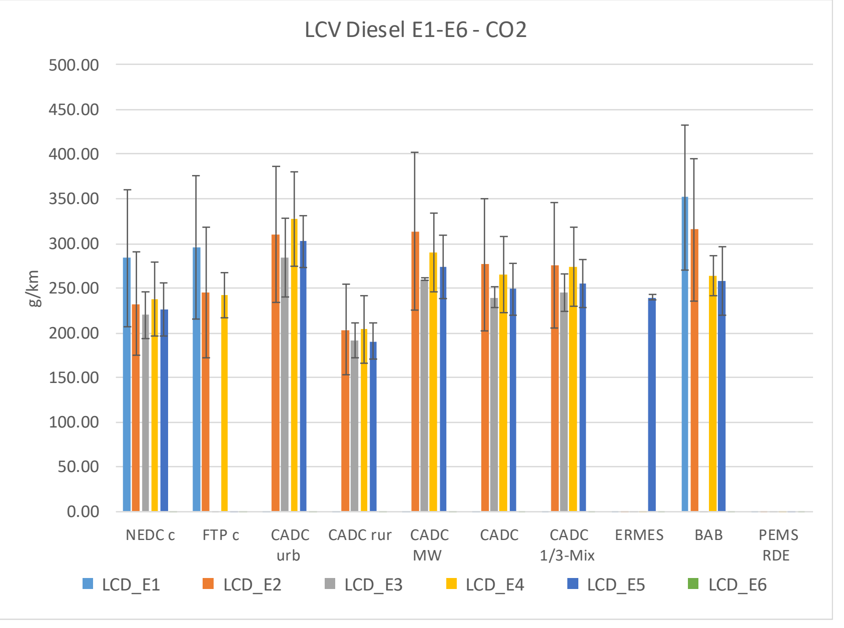


Figure 10: CO2-emissions of diesel LCV (Euro-1 to Euro-6) of selected cycles (mean values incl. standard deviation)



6. Access to the data

The access to the data is ruled in a non-disclosure agreement (NDA). Its scope is "to establish a confidential relationship between the parties to allow them to exchange the necessary Confidential Information for setting up the activities of the ERMES data group" (Paragraph 2). The content of the ERMES LDV DB is considered as "Confidential Information". Article 3 of the NDA rules the disclosure of the confidential information:

- "1. The Parties shall treat any Confidential Information exchanged in the performance of the present Agreement as strictly confidential. (…)
- 2. In case of publication of results obtained through use, processing or analysis of the Confidential Information exchanged between the Parties, any data related directly to *vehicles, vehicle brands and types, and time and location of the measurements shall be made anonymous*.
- 3. For a party to exercise its right to access and use Confidential Information of other Parties, said requesting party shall have to *share its own proprietary Confidential Information with the other Parties.*
- 4. The Disclosing Party shall have in place the internal means to ensure the quality of the Confidential Information before disclosure to the other Parties.
- 5. All Confidential Information exchanged among the Parties shall be encoded in a standard format to be agreed among the Parties."

In short, the results are made available to third parties under certain conditions:

- A recipient has to sign the NDA, available from the ERMES secretariat at JRC in Ispra (I)[24]
- The principle is "data for data", i.e. the data are available to those who provide substantial input data, i.e. their own data to the ERMES DB.
- In case of publication of results the data have to be made anonymous.

Technically, the database as such is not available to third parties. The main reasons are its complexity and heterogeneity and the fact that the management of the data (data collection, import of the data, plausibility tests, analyses etc.) is time consuming and – over the last ca. 10 years – is only partially financed by the mandate to update the HBEFA. However, the results are made available in a standardized format, i.e. emission measurement results

- per vehicle, including attributes – as far as available – as name of the data provider (test lab), make and model, size (capacity, weight), technology, emission class, mileage, registration data, exhaust gas after treatment techniques etc., and
- per test where 'test' includes the description of the pollutant, the cycle used and – as far as available – 'settings' as fuel type, start conditions, temperature, road load etc.

For the time being it is open whether in the future periodically short fact sheets shall be published for the ERMES group presenting the newest measurement results and new findings.

[24] Presently: Maria-Cristina.GALASSI@ec.europa.eu at JRC Ispra (I)

Annex

Annex A: Driving cycles in the ARTEMIS-project

Driving cycles in the database for the ARTEMIS project (André JM, 2005)

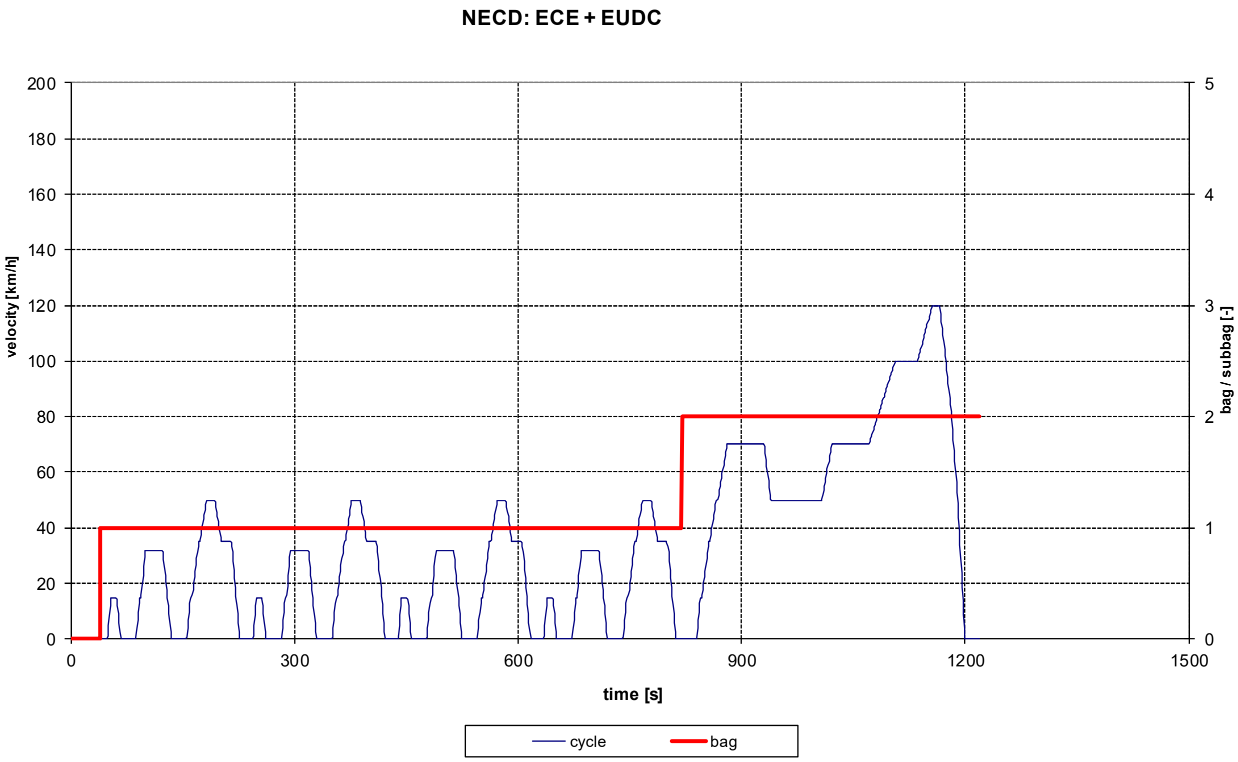
Number of driving cycles in the database per cycle family and per cycle type. The number between the brackets is the number of sub cycles in the category. These differentiations are still available in the present DB.

Cycle family	Cycle sub family	Cycle type						Total
		Artificial cycle (incl. ECE)	Representative cycle		Sum of bags (artificiel)	Parametric Test (incl. Cold start)	Transition (start, pre, post, transition)	
			Coherent set of cycles	Single cycle				
Artemis	Artemis		6 (16)		4		5	**15 (16)**
	VP_Faible_Mot[2]		6 (22)		6		7	**19 (22)**
	VP_Forte_Mot[3]		5 (20)		5		7	**17 (20)**
EMPA		15	4	47 (11)	26	18		**110 (11)**
Handbook	R[4]		12		8		12	**32**
	S[5]		12		4			**16**
Inrets	court[6]				9	15 (46)		**24 (46)**
	long[7]		10					**10**
LDV/PVU	2.5t fourgons[5]		9 (3)		4		7	**20 (3)**
	3.5t fourgons[8]		8 (7)		4		6	**18 (7)**
	Commercial cars		6		3		6	**15**
	Fourgonnette[9]		8		2		2	**12**
Legislative		3 (5)		5 (3)	3			**11 (8)**
modem				7 (17)				**7 (17)**
modemHyzem			9 (1)		5		8	**22 (1)**
modemIM			5					**5**
MTC				2				**2**
Napoli				3 (7)				**3 (7)**
OSCAR				11				**11**
Particulates		6						**6**
TRL	TRRL			6 (10)				**6 (10)**
	WSL			2				**2**
TUG		2						**2**
TUV		1						**1**
Other[10]	Artemis WP3142				29	29 (130)	42	**100 (130)**
	Artemis WP321				5	22 (25)	10	**37 (25)**
	Artemis WP324				3	4 (16)	5	**12 (16)**
Total		**27 (5)**	**100 (69)**	**83 (48)**	**120**	**88 (217)**	**117**	**535 (339)**

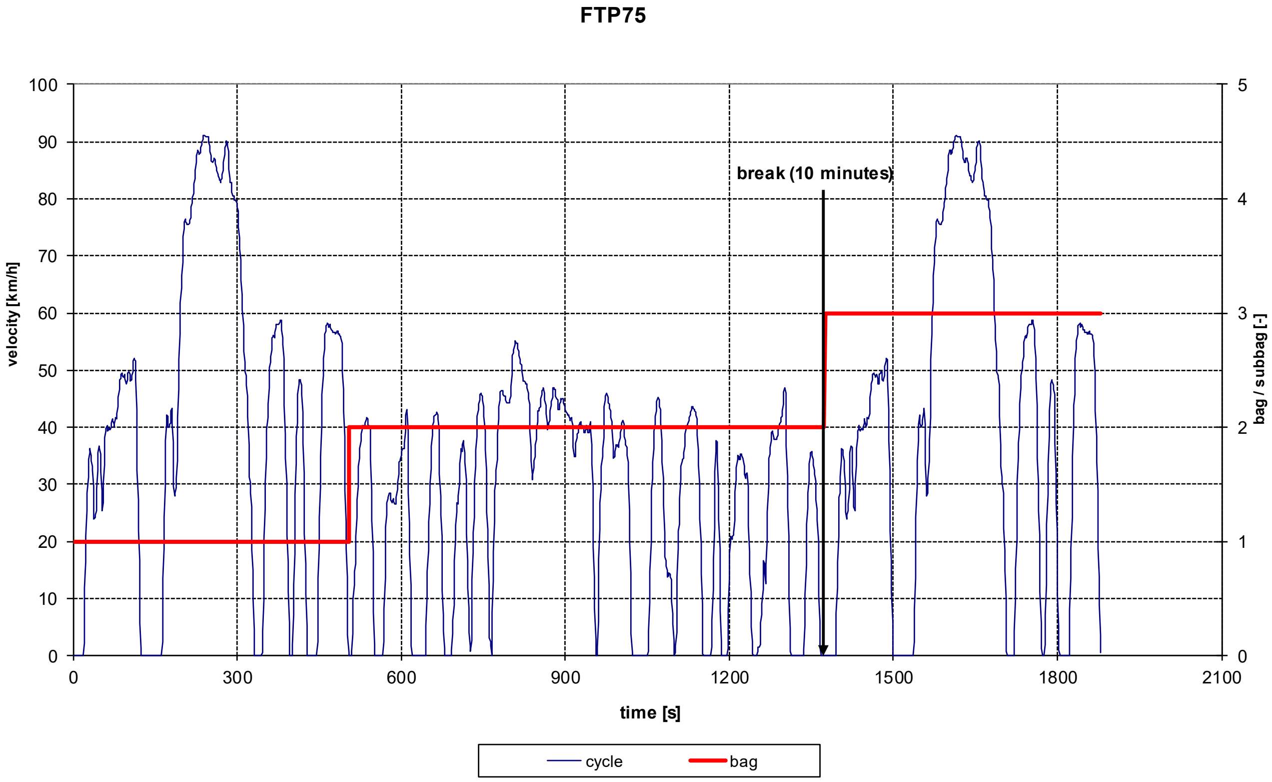
Annex B: Definitions of the most common cycles

See also Table 7 for the key parameters of the most common cycles.

1. NEDC (New European Driving Cycle)

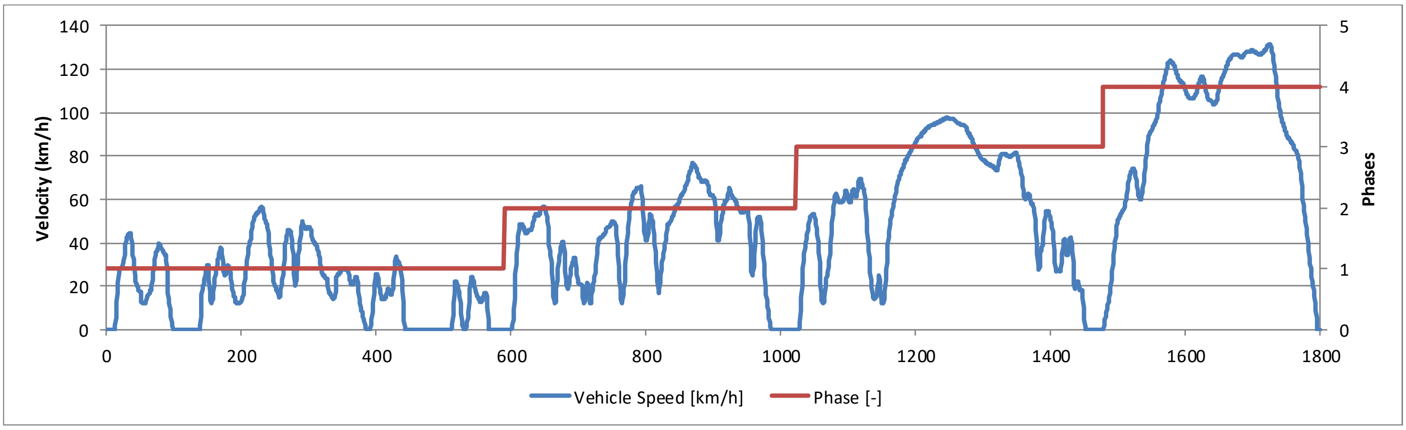


2. FTP 75 (Federal Test Procedure)



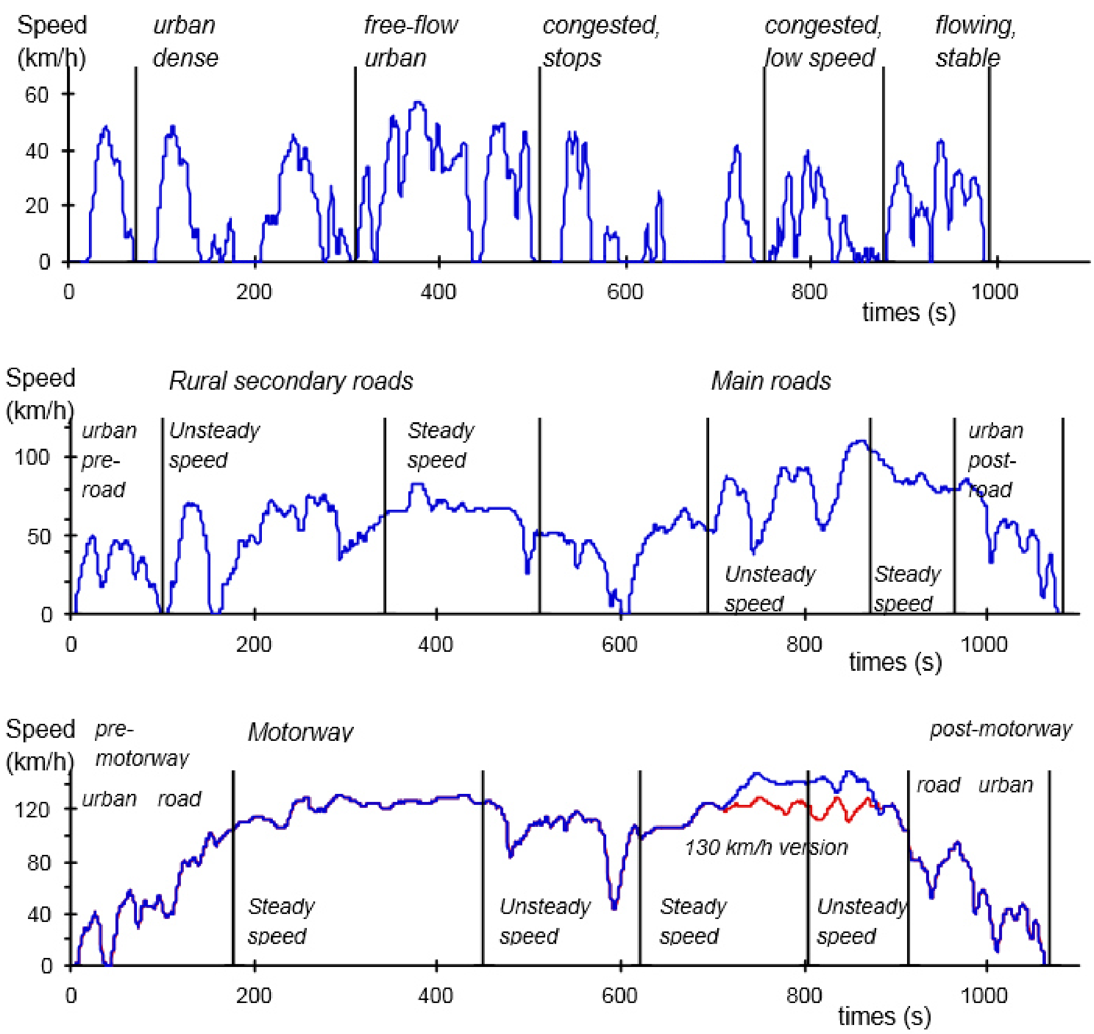
fi

3. WLTC



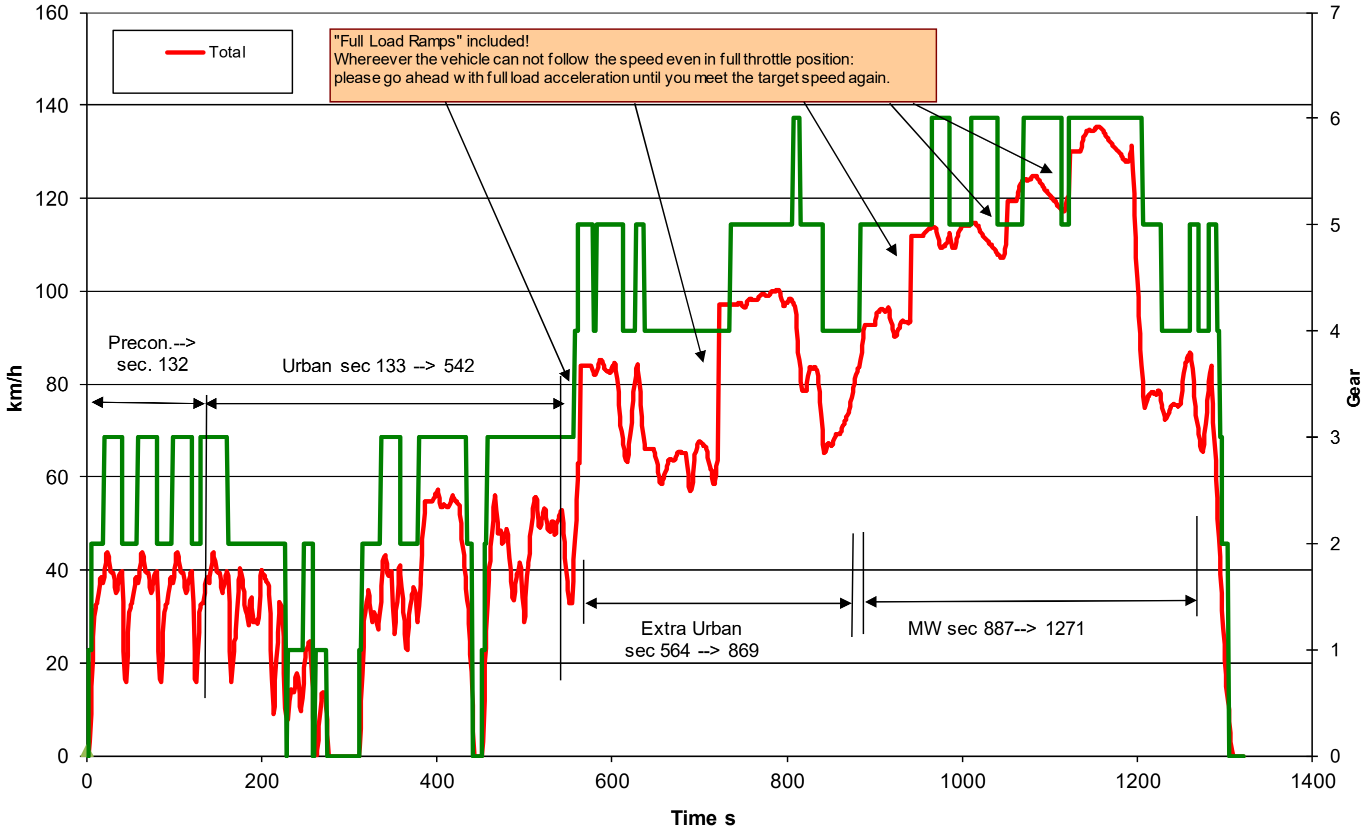
WLTC, Class 3b (power to unladen mass ratio >34W/kg and vmax >=120km/h)
with 4 phases: Low, Medium, High, ExtraHigh

4. CADC (Common ARTEMIS driving cycle)



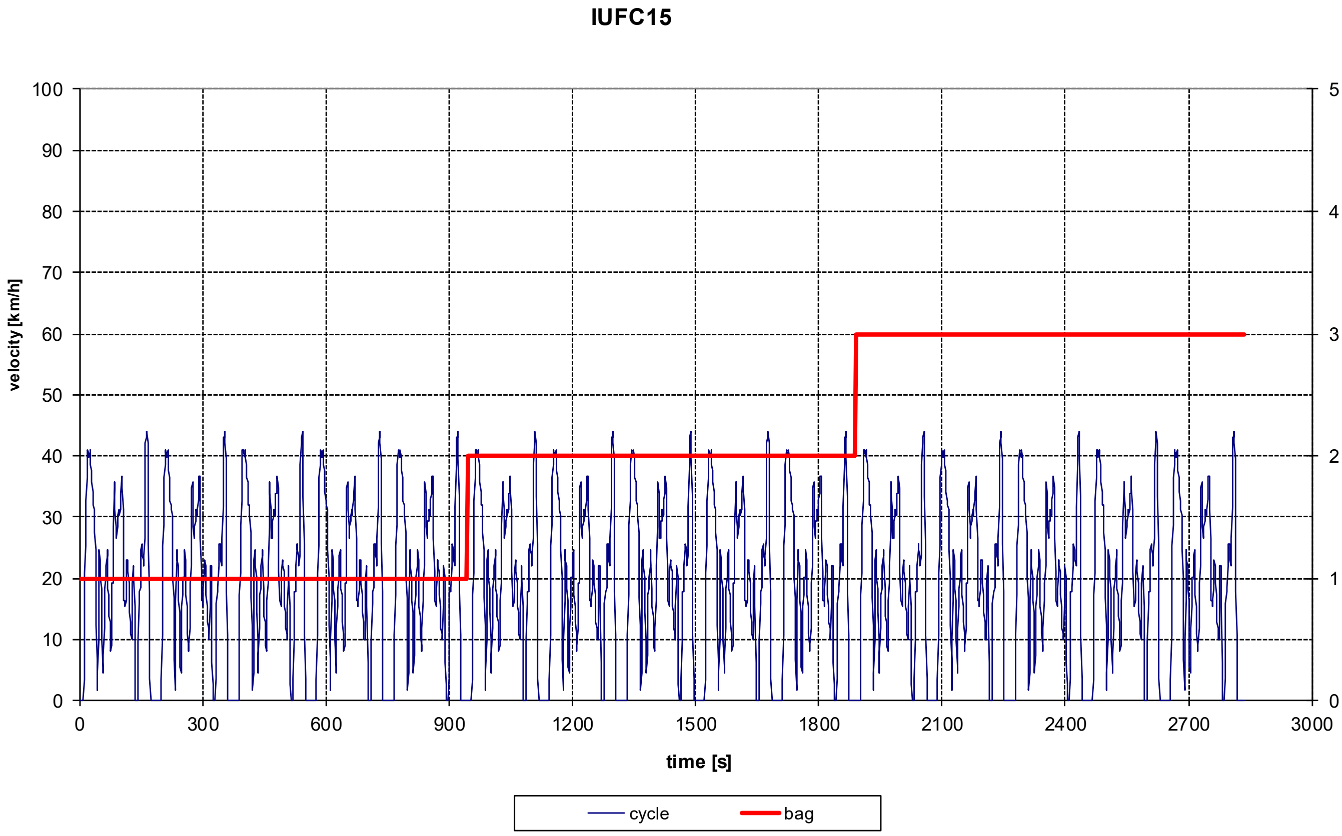
Source: The ARTEMIS urban, rural and motorway driving cycles, including sub-cycles and starting conditions (André M, 2005).

5. ERMES Cycle

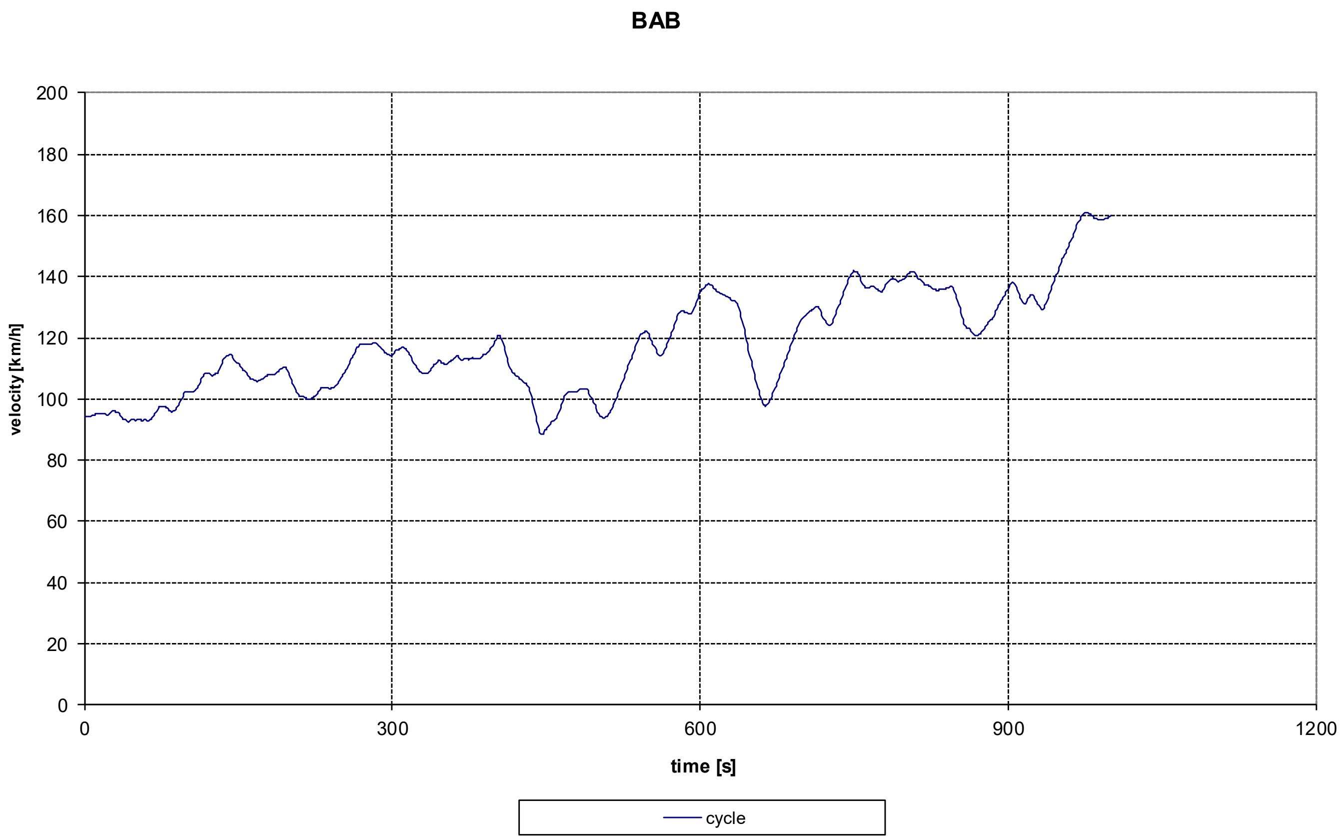


Source: TU Graz

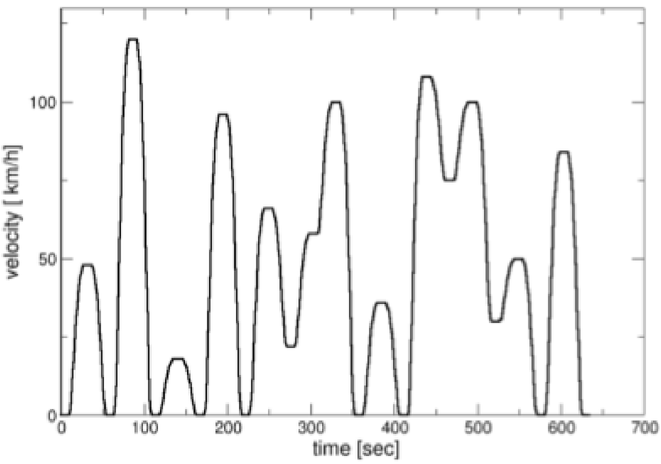
6. IUFC (Inrets Urbain Fluide Courte)



7. BAB (Bundesautobahn)



8. TNO-Dynacycle



See TNO 2016

Annex C: RDE requirements (Real-Driving Emissions)

For being accepted as 'RDE-test' according to the RDE regulation (2016) a test has to comply with different boundary conditions which should reduce the variability of the measurement results (source: Hausberger et.al. 2016).

RDE Road Category				
URBAN				$v \leq 60$ km/h
RURAL				$60 < v \leq 90$ km/h
MOTORWAY				$v > 90$ km/h
RDE Requirment Checks/Boundary Conditions				
Value	***Unit***	***MIN***	***MAX***	***Describtion***
trip length	*s*	5400	7200	
trip distance	*km*	16		*Each part (URBAN/RURAL/MW) > 16 km.*
share URBAN	%	29	44	*Distance based shares for the total trip distance.*
share RURAL	%	23	43	
share MW	%	23	43	
Stop periods	%	10		*6-30% of urban time with v < 1 km/h. time per stop < 180s*
avg. speed URBAN v_{KU}	*km/h*	15	40	*Stops included.*
avg. speed MW v_{KM}	*km/h*	90	145	*+15 km/h tolerance for < 3% time. v > 100 km/h for > 5 min.*
RDE Dynamic Parameter				
95 Perzentil v*apos	m^2/s^3	if v_k<=74.6 km/h		*95 Perz* $v{*}a_{pos} \leq (0.136{*}v_k + 14.44)$
	m^2/s^3	if v_k>74.6 km/h		*95 Perz* $v{*}a_{pos} \leq (0.0742{*}v_k + 18.966)$
RPA	m/s^2	if v_k<=94.05 km/h		*and* $RPA_k \geq (-0.0016{*}v_{average} + 0.1755)$
	m/s^2	v_k>94.05 km/h		*and* $RPA_k \geq 0.025$
RDE Moderate/Extended Conditions				
Altitude	m	@ periods with extended cond. emissions are		*moderate: ≤ 700 m above sea level; extended: 700 m < h ≤ 1300 m*
Temperature	°C			*Extended -7°C <t < 0°C or 30°C <t ≤ 35°C.*

Annex D: Number of measurements of non-regulated pollutants

VehCat	Technol.	Group	Pollutant	Poll. family	Euro Pre-1	E1	E2	E3	E4	E5	E6
pass.car	petrol(4S)	PAH	2,3-benzofluorene		1	1	1	3	-	-	-
pass.car	petrol(4S)	PAH	acenaphthene		1	1	1	3	-	-	-
pass.car	petrol(4S)	PAH	acenaphthylene		1	1	1	3	-	-	-
pass.car	petrol(4S)	PAH	anthanthrene		1	1	1	2	-	-	-
pass.car	petrol(4S)	PAH	anthracene		1	1	1	3	1	-	-
pass.car	petrol(4S)	PAH	benz[a]anthracene		1	1	1	3	1	-	1
pass.car	petrol(4S)	PAH	Benzo[a]pyrene		1	1	1	3	-	-	-
pass.car	petrol(4S)	PAH	benzo[b]chrysene + picene		1	1	1	3	-	-	-
pass.car	petrol(4S)	PAH	benzo[b]naphtho[1,2-d]thiophene		1	1	1	3	-	-	-
pass.car	petrol(4S)	PAH	benzo[b+k+j]fluoranthene		1	1	1	3	-	-	-
pass.car	petrol(4S)	PAH	benzo[c]phenanthrene		1	1	1	3	-	-	-
pass.car	petrol(4S)	PAH	benzo[e]pyrene		1	1	1	3	-	-	-
pass.car	petrol(4S)	PAH	benzo[g,h,i]fluoranthene		1	1	1	3	-	-	-
pass.car	petrol(4S)	PAH	benzo[g,h,i]perylene		1	1	1	3	-	-	-
pass.car	petrol(4S)	PAH	chrysene + triphenylene		1	1	1	3	-	-	-
pass.car	petrol(4S)	PAH	coronene		1	1	1	3	-	-	-
pass.car	petrol(4S)	PAH	cyclopenta[c,d]pyrene		1	1	1	3	-	-	-
pass.car	petrol(4S)	PAH	dibenz[a,c]anthracene		1	1	1	2	-	-	-
pass.car	petrol(4S)	PAH	dibenz[a,h]anthracene		1	1	1	2	-	-	-
pass.car	petrol(4S)	PAH	fluoranthene		1	1	1	3	-	-	-
pass.car	petrol(4S)	PAH	fluorene		1	1	1	3	-	-	-
pass.car	petrol(4S)	PAH	indeno[1,2,3-c,d]pyrene		1	1	1	3	-	-	-
pass.car	petrol(4S)	PAH	naphthalene		1	-	1	9	-	-	-
pass.car	petrol(4S)	PAH	perylene		1	1	1	2	-	-	-
pass.car	petrol(4S)	PAH	phenanthrene		1	1	1	3	1	-	-
pass.car	petrol(4S)	PAH	pyrene		1	1	1	3	1	-	-
pass.car	petrol(4S)	VOC	1,2,3,4-tetramethylbenzene	aromatics	-	-	-	1	-	-	-
pass.car	petrol(4S)	VOC	1,2,3,5-tetramethylbenzene	aromatics	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	1,2,3-trimethylbenzene	aromatics	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	1,2,4,5-tetramethylbenzene	aromatics	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	1,2,4-trimethylbenzene	aromatics	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	1,2-dimethyl-4-ethylbenzene	aromatics	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	1,3,5-trimethylbenzene	aromatics	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	1,3,5-triphenylbenzene	aromatics	1	1	1	3	-	-	-
pass.car	petrol(4S)	VOC	1,3-butadiene	alkenes	1	-	3	9	2	-	-
pass.car	petrol(4S)	VOC	1,3-diethylbenzene	aromatics	-	-	-	5	-	-	-
pass.car	petrol(4S)	VOC	1,3-dimethyl-4-ethylbenzene	aromatics	-	-	-	5	-	-	-
pass.car	petrol(4S)	VOC	1,3-dimethyl-5-ethylbenzene	aromatics	-	-	-	5	-	-	-
pass.car	petrol(4S)	VOC	1-butene	alkenes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	1-heptene	alkenes	-	-	-	1	-	-	-
pass.car	petrol(4S)	VOC	1-methylcyclopentene	alkenes	-	-	-	4	-	-	-
pass.car	petrol(4S)	VOC	1-pentene	alkenes	-	-	-	2	-	-	-
pass.car	petrol(4S)	VOC	2,2,4-trimethylpentane	alkanes	1	1	2	7	-	-	-
pass.car	petrol(4S)	VOC	2,2,5-trimethylhexane	alkanes	-	-	-	4	-	-	-
pass.car	petrol(4S)	VOC	2,2-dimethylbutane	alkanes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	2,2-dimethylhexane	alkanes	-	-	-	5	-	-	-
pass.car	petrol(4S)	VOC	2,2-dimethylpentane	alkanes	-	-	-	3	-	-	-
pass.car	petrol(4S)	VOC	2,3,4-trimethylpentane	alkanes	-	-	-	5	-	-	-
pass.car	petrol(4S)	VOC	2,3-dimethyl-1-ethylbenzene	aromatics	-	-	-	2	-	-	-
pass.car	petrol(4S)	VOC	2,3-dimethylbutane	alkanes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	2,3-dimethylhexane	alkanes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	2,3-dimethylpentane + 2-methylhexane	alkanes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	2,4-dimethylhexane	alkanes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	2,4-dimethylpentane	alkanes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	2,5-dimethylbenzaldehyde	aldehydes	1	-	1	-	-	-	-
pass.car	petrol(4S)	VOC	2,5-dimethylhexane	alkanes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	2-ethyltoluene	aromatics	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	2-methyl-1-butene	alkenes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	2-methyl-1-pentene	alkenes	-	-	-	2	-	-	-
pass.car	petrol(4S)	VOC	2-methyl-2-butene	alkenes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	2-methyl-2-pentene	alkenes	-	-	-	3	-	-	-
pass.car	petrol(4S)	VOC	2-methylheptane	alkanes	-	-	-	6	-	-	-

VehCat	Technol.	Group	Pollutant	Poll. family	Euro Pre-1	E1	E2	E3	E4	E5	E6
pass.car	petrol(4S)	VOC	2-methylpentane	alkanes	1	1	1	7	-	-	-
pass.car	petrol(4S)	VOC	2-methylpropane	alkanes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	2-methyl-propene	alkenes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	3-ethyltoluene	aromatics	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	3-methyl-1-butene	alkenes	-	-	-	3	-	-	-
pass.car	petrol(4S)	VOC	3-methyl-1-pentene	alkenes	-	-	-	2	-	-	-
pass.car	petrol(4S)	VOC	3-methylheptane	alkanes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	3-methylhexane	alkanes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	3-methylpentane	alkanes	1	1	1	7	-	-	-
pass.car	petrol(4S)	VOC	3-propyltoluene	aromatics	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	4-ethyltoluene	aromatics	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	4-methylheptane	alkanes	-	-	-	5	-	-	-
pass.car	petrol(4S)	VOC	4-methyl-t-2-pentene	alkenes	-	-	-	2	-	-	-
pass.car	petrol(4S)	VOC	4-propyltoluene	aromatics	-	-	-	3	-	-	-
pass.car	petrol(4S)	VOC	acetaldehyde	aldehydes	1	1	2	9	2	1	1
pass.car	petrol(4S)	VOC	acetone	ketones	-	-	-	6	1	1	1
pass.car	petrol(4S)	VOC	acetone + acrolein	ketones+aldehydes	1	1	2	3	-	-	-
pass.car	petrol(4S)	VOC	acrolein	aldehydes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	benzaldehyde	aldehydes	1	1	2	9	-	-	-
pass.car	petrol(4S)	VOC	butyraldehyde	aldehydes	1	1	2	6	-	-	-
pass.car	petrol(4S)	VOC	cis-2-butene	alkenes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	cis-2-pentene	alkenes	-	-	-	3	-	-	-
pass.car	petrol(4S)	VOC	crotonaldehyde	aldehydes	1	1	2	8	-	-	-
pass.car	petrol(4S)	VOC	cyclohexane	alkanes	-	-	-	5	-	-	-
pass.car	petrol(4S)	VOC	cyclopentane	alkanes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	cyclopentene	alkenes	-	-	-	1	-	-	-
pass.car	petrol(4S)	VOC	ethane	alkanes	1	1	3	12	2	-	-
pass.car	petrol(4S)	VOC	ethene	alkenes	1	1	2	9	2	-	-
pass.car	petrol(4S)	VOC	ethylbenzene	aromatics	-	-	1	9	3	1	1
pass.car	petrol(4S)	VOC	ethyne	alkynes	-	-	1	9	2	-	-
pass.car	petrol(4S)	VOC	formaldehyde	aldehydes	1	1	2	9	2	1	1
pass.car	petrol(4S)	VOC	heptane	alkanes	1	1	2	1	-	-	-
pass.car	petrol(4S)	VOC	hexaldehyde	aldehydes	1	-	1	-	-	-	-
pass.car	petrol(4S)	VOC	hexane	alkanes	1	1	2	7	-	-	-
pass.car	petrol(4S)	VOC	hexene	alkenes	-	-	-	1	-	-	-
pass.car	petrol(4S)	VOC	i-butene	alkenes	-	-	1	3	2	-	-
pass.car	petrol(4S)	VOC	indane	aromatics	-	-	-	5	-	-	-
pass.car	petrol(4S)	VOC	isobutane	alkanes	1	1	2	2	-	-	-
pass.car	petrol(4S)	VOC	isopentane	alkanes	1	1	2	8	-	-	-
pass.car	petrol(4S)	VOC	isopropylbenzene	aromatics	-	-	-	2	-	-	-
pass.car	petrol(4S)	VOC	isovaleraldehyde	aldehydes	-	1	2	2	-	-	-
pass.car	petrol(4S)	VOC	m+p+o-tolualdehyde	aldehydes	1	1	1	2	-	-	-
pass.car	petrol(4S)	VOC	Methacrolein	ketones	-	-	-	4	-	-	-
pass.car	petrol(4S)	VOC	methyl ethyl ketone	ketones	1	1	2	6	-	-	-
pass.car	petrol(4S)	VOC	methylcyclohexane	alkanes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	methylcyclopentane	alkanes	1	1	2	7	-	-	-
pass.car	petrol(4S)	VOC	m-tolualdehyde + p-tolualdehyde	aldehydes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	m-xylene	aromatics	-	-	1	3	2	-	-
pass.car	petrol(4S)	VOC	m-xylene + p-xylene	aromatics	-	-	-	6	1	1	1
pass.car	petrol(4S)	VOC	naphtalene	aromatics	-	-	-	-	1	1	1
pass.car	petrol(4S)	VOC	n-butane	alkanes	1	1	2	8	-	-	-
pass.car	petrol(4S)	VOC	n-decane	alkanes	-	-	-	1	-	-	-
pass.car	petrol(4S)	VOC	n-dodecane	alkanes	-	-	-	1	-	-	-
pass.car	petrol(4S)	VOC	n-heptane	alkanes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	n-nonane	alkanes	-	-	-	3	-	-	-
pass.car	petrol(4S)	VOC	n-octane	alkanes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	n-pentane	alkanes	1	1	2	9	-	-	-
pass.car	petrol(4S)	VOC	n-propylbenzene	aromatics	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	n-undecane	alkanes	-	-	-	3	-	-	-
pass.car	petrol(4S)	VOC	o-tolualdehyde	aldehydes	-	-	-	4	-	-	-
pass.car	petrol(4S)	VOC	o-Xylene	aromatics	-	-	1	9	3	1	1
pass.car	petrol(4S)	VOC	propadiene	alkenes	-	-	-	3	-	-	-
pass.car	petrol(4S)	VOC	propane	alkanes	1	1	3	11	2	-	-
pass.car	petrol(4S)	VOC	propene	alkenes	1	-	1	9	2	-	-
pass.car	petrol(4S)	VOC	propionaldehyde	aldehydes	1	1	2	9	-	-	-
pass.car	petrol(4S)	VOC	propyne	alkynes	-	-	-	4	-	-	-

VehCat	Technol.	Group	Pollutant	Poll. family	Euro Pre-1	E1	E2	E3	E4	E5	E6
pass.car	petrol(4S)	VOC	styrene	aromatics	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	trans-2-butene	alkenes	-	-	-	6	-	-	-
pass.car	petrol(4S)	VOC	trans-2-pentene	alkenes	-	-	-	4	-	-	-
pass.car	petrol(4S)	VOC	valeraldehyde	aldehydes	-	1	2	4	-	-	-
pass.car	diesel	PAH	2,3-benzofluorene		-	-	1	2	-	-	-
pass.car	diesel	PAH	acenaphthene		-	-	1	2	-	-	-
pass.car	diesel	PAH	acenaphthylene		-	-	1	2	-	-	-
pass.car	diesel	PAH	anthanthrene		-	-	1	2	-	-	-
pass.car	diesel	PAH	anthracene		-	-	1	2	-	2	-
pass.car	diesel	PAH	benz[a]anthracene		-	-	1	2	-	2	-
pass.car	diesel	PAH	Benzo[a]pyrene		-	-	1	2	-	-	-
pass.car	diesel	PAH	benzo[b]chrysene + picene		-	-	1	2	-	-	-
pass.car	diesel	PAH	benzo[b]naphtho[1,2-d]thiophene		-	-	1	2	-	-	-
pass.car	diesel	PAH	benzo[b+k+j]fluoranthene		-	-	1	2	-	-	-
pass.car	diesel	PAH	benzo[c]phenanthrene		-	-	1	2	-	-	-
pass.car	diesel	PAH	benzo[e]pyrene		-	-	1	2	-	-	-
pass.car	diesel	PAH	benzo[g,h,i]fluoranthene		-	-	1	2	-	-	-
pass.car	diesel	PAH	benzo[g,h,i]perylene		-	-	1	2	-	-	-
pass.car	diesel	PAH	chrysene + triphenylene		-	-	1	2	-	-	-
pass.car	diesel	PAH	coronene		-	-	1	2	-	-	-
pass.car	diesel	PAH	cyclopenta[c,d]pyrene		-	-	1	2	-	-	-
pass.car	diesel	PAH	dibenz[a,c]anthracene		-	-	1	1	-	-	-
pass.car	diesel	PAH	dibenz[a,h]anthracene		-	-	1	1	-	-	-
pass.car	diesel	PAH	fluoranthene		-	-	1	2	-	-	-
pass.car	diesel	PAH	fluorene		-	-	1	2	-	-	-
pass.car	diesel	PAH	indeno[1,2,3-c,d]pyrene		-	-	1	2	-	-	-
pass.car	diesel	PAH	naphthalene		-	-	1	2	-	-	-
pass.car	diesel	PAH	perylene		-	-	1	2	-	-	-
pass.car	diesel	PAH	phenanthrene		-	-	1	2	1	1	-
pass.car	diesel	PAH	pyrene		-	-	1	2	-	2	-
pass.car	diesel	VOC	1,3,5-triphenylbenzene	aromatics	-	-	1	2	-	-	-
pass.car	diesel	VOC	2,2,4-trimethylpentane	alkanes	-	-	1	-	-	-	-
pass.car	diesel	VOC	2,5-dimethylbenzaldehyde	aldehydes	-	-	1	1	-	-	-
pass.car	diesel	VOC	3-methylpentane	alkanes	-	-	1	-	-	-	-
pass.car	diesel	VOC	acetaldehyde	aldehydes	-	-	1	2	1	3	1
pass.car	diesel	VOC	acetone	ketones	-	-	-	-	1	2	1
pass.car	diesel	VOC	acetone + acrolein	ketones+ald ehydes	-	-	1	2	-	-	-
pass.car	diesel	VOC	benzaldehyde	aldehydes	-	-	1	2	-	-	-
pass.car	diesel	VOC	butyraldehyde	aldehydes	-	-	1	2	-	-	-
pass.car	diesel	VOC	crotonaldehyde	aldehydes	-	-	1	2	-	-	-
pass.car	diesel	VOC	ethane	alkanes	-	-	1	1	-	-	-
pass.car	diesel	VOC	ethylbenzene	aromatics	-	-	-	-	1	3	1
pass.car	diesel	VOC	formaldehyde	aldehydes	-	-	1	2	1	3	1
pass.car	diesel	VOC	heptane	alkanes	-	-	1	1	-	-	-
pass.car	diesel	VOC	hexaldehyde	aldehydes	-	-	1	2	-	-	-
pass.car	diesel	VOC	hexane	alkanes	-	-	1	1	-	-	-
pass.car	diesel	VOC	isobutane	alkanes	-	-	1	-	-	-	-
pass.car	diesel	VOC	isopentane	alkanes	-	-	1	1	-	-	-
pass.car	diesel	VOC	isovaleraldehyde	aldehydes	-	-	1	2	-	-	-
pass.car	diesel	VOC	m+p+o-tolualdehyde	aldehydes	-	-	1	2	-	-	-
pass.car	diesel	VOC	Methacrolein	ketones	-	-	-	-	-	2	-
pass.car	diesel	VOC	methyl ethyl ketone	ketones	-	-	1	2	-	-	-
pass.car	diesel	VOC	methylcyclopentane	alkanes	-	-	1	-	-	-	-
pass.car	diesel	VOC	m-xylene + o-xylene + p-xylene + ethylbenzene	aromatics	-	-	6	-	-	-	-
pass.car	diesel	VOC	m-xylene + p-xylene	aromatics	-	-	-	-	1	3	1
pass.car	diesel	VOC	naphtalene	aromatics	-	-	-	-	-	3	1
pass.car	diesel	VOC	n-butane	alkanes	-	-	1	1	-	-	-
pass.car	diesel	VOC	n-pentane	alkanes	-	-	-	1	-	-	-
pass.car	diesel	VOC	o-Xylene	aromatics	-	-	-	-	1	3	1
pass.car	diesel	VOC	propionaldehyde	aldehydes	-	-	1	2	1	1	-
pass.car	diesel	VOC	valeraldehyde	aldehydes	-	-	1	2	-	-	-
pass.car	bifuelCNG /petrol	VOC	acetaldehyde	aldehydes	-	-	-	-	2	-	-
pass.car	bifuelCNG /petrol	VOC	formaldehyde	aldehydes	-	-	-	-	2	-	-

VehCat	Technol.	Group	Pollutant	Poll. family	Euro Pre-1	E1	E2	E3	E4	E5	E6
LCV	diesel	VOC	acetaldehyde	aldehydes	-	-	-	2	-	-	-
LCV	diesel	VOC	formaldehyde	aldehydes	-	-	-	2	-	-	-

Annex E: Emission values of PC and LCV (Euro-1 to Euro-6)

E1: Emissions of passenger cars (PC)

The emission measurement results are grouped by PC Diese/Petrol[25] resp. Euro-Classes E1-E5.

Table 19: Emissions of cars (Euro-1 to Euro-6) of selected cycles

Veh-Group	Fuel	poll.	Unit	NEDC c	FTP c	WLTC c	CADC urb	CADC rur	CADC MW	CADC	CADC 1/3-Mix	ERMES	PEMS RDE
PCD_E1	diesel	CO	g/km	0.544			0.327	0.183	0.175	0.190	0.225		
PCD_E1	diesel	CO2	g/km	164			223	141	182	173	182		
PCD_E1	diesel	FC	g/km	52			71	45	58	55	58		
PCD_E1	diesel	HC	g/km	0.072			0.073	0.030	0.021	0.029	0.040		
PCD_E1	diesel	NOx	g/km	0.644			0.900	0.526	0.754	0.692	0.726		
PCD_E1	diesel	PM	g/km	0.058			0.073	0.057	0.156	0.114	0.095		
PCD_E2	diesel	CO	g/km	0.508	0.282		0.307	0.079	0.045	0.099	0.153		
PCD_E2	diesel	CO2	g/km	166	169		238	145	179	174	188		
PCD_E2	diesel	FC	g/km	53	55		75	46	57	55	60		
PCD_E2	diesel	HC	g/km	0.097	0.072		0.066	0.025	0.013	0.022	0.032		
PCD_E2	diesel	NOx	g/km	0.548	0.607		1.037	0.611	0.924	0.845	0.882		
PCD_E2	diesel	PM	g/km	0.039	0.036		0.076	0.051	0.074	0.065	0.064		
PCD_E3	diesel	CO	g/km	0.248	0.132		0.168	0.015	0.016	0.038	0.077		
PCD_E3	diesel	CO2	g/km	147	142		218	133	171	163	174		
PCD_E3	diesel	FC	g/km	47	45		68	42	54	52	54		
PCD_E3	diesel	HC	g/km	0.042	0.039		0.028	0.011	0.009	0.013	0.018		
PCD_E3	diesel	NOx	g/km	0.437	0.535		0.889	0.549	1.042	0.883	0.832		
PCD_E3	diesel	PM	g/km	0.027	0.030		0.034	0.024	0.044	0.037	0.036		
PCD_E3	diesel	PN	#/km	4.9E+13			5.6E+13	4.1E+13	4.9E+13	4.7E+13	4.8E+13		
PCD_E4	diesel	CO	g/km	0.200	0.074		0.068	0.017	0.011	0.021	0.035		
PCD_E4	diesel	CO2	g/km	163	170		243	141	168	165	183		
PCD_E4	diesel	FC	g/km	51	54		76	45	53	52	58		
PCD_E4	diesel	HC	g/km	0.028	0.020		0.016	0.006	0.006	0.007	0.010		
PCD_E4	diesel	NOx	g/km	0.216	0.374		0.752	0.453	0.839	0.713	0.689		
PCD_E4	diesel	PM	g/km	0.003	0.013		0.009	0.006	0.009	0.008	0.009		
PCD_E4	diesel	PN	#/km	1.4E+13	3.0E+13		1.5E+13	1.2E+13	1.9E+13	1.6E+13	1.5E+13		
PCD_E4	diesel	PN	g/km	4.3E+11			6.5E+11	7.2E+11	4.5E+11	5.8E+11	6.3E+11		
PCD_E5	diesel	CO	g/km	0.153		0.050	0.061	0.019	0.009	0.023	0.043	0	0
PCD_E5	diesel	CO2	g/km	128		139	192	115	144	141	152	125	
PCD_E5	diesel	FC	g/km	40		44	61	36	45	44	48	39	
PCD_E5	diesel	HC	g/km	0.020		0.004	0.017	0.007	0.002	0.006	0.009	0	
PCD_E5	diesel	NOx	g/km	0.152		0.480	0.838	0.490	0.726	0.653	0.681	0	0.7170
PCD_E5	diesel	PM	g/km	0.000		0.000	0.001	0.001	0.001	0.001	0.001	0	0
PCD_E5	diesel	PN	#/km	8.8E+10		9.0E+10	1.2E+11	1.1E+11	4.0E+10	5.3E+10	6.6E+10	4.8E+10	
PCD_E6	diesel	CO	g/km	0.168		0.055	0.019	0.032	0.029	0.053	0.028	0	
PCD_E6	diesel	CO2	g/km	146		142	211	124	166	161	165	138	

[25] the abbreviation used is D for Diesel and G for Gasoline (i.e. petrol).

Veh-Group	Fuel	poll.	Unit	NEDC c	FTP c	WLTC c	CADC urb	CADC rur	CADC MW	CADC	CADC 1/3-Mix	ERMES	PEMS RDE
PCD_E6	diesel	FC	g/km	46		45	67	39	52	48	52	42	
PCD_E6	diesel	HC	g/km	0.033		0.021	0.015	0.018	0.018	0.022	0.018	0	
PCD_E6	diesel	NOx	g/km	0.050		0.101	0.287	0.224	0.302	0.247	0.297	0	0.3520
PCD_E6	diesel	PM	g/km	0.000		0.000	0.001	0.000	0.001	0.001	0.001	0	0
PCD_E6	diesel	PN	#/km	6.7E+10		4.3E+10	3.2E+10	1.2E+10	2.4E+10	2.1E+10	2.3E+10	2.2E+10	
PCG_E1	petrol	CO	g/km	1.128	2.393		3.104	1.321	1.506	1.559	1.964		
PCG_E1	petrol	CO2	g/km	180	200		254	147	174	175	193		
PCG_E1	petrol	FC	g/km	57	64		83	48	57	57	63		
PCG_E1	petrol	HC	g/km	0.092	0.245		0.413	0.173	0.123	0.179	0.244		
PCG_E1	petrol	NOx	g/km	0.263	0.351		0.497	0.417	0.557	0.568	0.531		
PCG_E1	petrol	PM	g/km										
PCG_E2	petrol	CO	g/km	0.983	1.307		0.907	0.629	2.364	1.278	1.125		
PCG_E2	petrol	CO2	g/km	182	187		262	151	172	176	198		
PCG_E2	petrol	FC	g/km	58	61		83	48	56	56	63		
PCG_E2	petrol	HC	g/km	0.160	0.151		0.076	0.032	0.041	0.045	0.056		
PCG_E2	petrol	NOx	g/km	0.176	0.159		0.363	0.206	0.180	0.218	0.274		
PCG_E2	petrol	PM	g/km	0.002			0.003	0.016	0.022	0.019	0.015		
PCG_E3	petrol	CO	g/km	0.719	0.698		0.362	0.589	2.638	1.628	1.103		
PCG_E3	petrol	CO2	g/km	185	187		268	159	186	186	208		
PCG_E3	petrol	FC	g/km	59	60		86	51	60	60	66		
PCG_E3	petrol	HC	g/km	0.079	0.061		0.022	0.013	0.030	0.024	0.024		
PCG_E3	petrol	NOx	g/km	0.042	0.057		0.102	0.048	0.053	0.056	0.071		
PCG_E3	petrol	PM	g/km	0.005	0.000		0.005	0.003	0.008	0.006	0.006		
PCG_E4	petrol	CO	g/km	0.401	0.467		0.317	0.284	2.253	1.451	0.997		
PCG_E4	petrol	CO2	g/km	175	169		257	148	180	177	195		
PCG_E4	petrol	FC	g/km	55	54		81	47	58	56	62		
PCG_E4	petrol	HC	g/km	0.051	0.041		0.012	0.004	0.014	0.012	0.011		
PCG_E4	petrol	NOx	g/km	0.027	0.044		0.061	0.028	0.036	0.038	0.045		
PCG_E4	petrol	PM	g/km	0.001	0.001		0.001	0.001	0.004	0.003	0.002		
PCG_E4	petrol	PN	#/km	5.7E+11	8.1E+11		5.4E+11	4.9E+11	1.7E+12	1.1E+12	8.7E+11		
PCG_E4	petrol	PN	g/km	7.1E+11			6.6E+11	7.3E+11	1.3E+12	1.1E+12	1.1E+12		
PCG_E5	petrol	CO	g/km	0.317		0.672	0.120	0.133	0.827	0.537	0.353	1	
PCG_E5	petrol	CO2	g/km	145		143	230	132	156	155	172	131	
PCG_E5	petrol	FC	g/km	46		47	73	42	51	50	56	42	
PCG_E5	petrol	HC	g/km	0.035		0.025	0.006	0.003	0.010	0.007	0.007	0	
PCG_E5	petrol	NOx	g/km	0.018		0.025	0.052	0.013	0.011	0.016	0.026	0	
PCG_E5	petrol	PM	g/km	0.001		0.001	0.001	0.001	0.004	0.003	0.002	0	
PCG_E5	petrol	PN	#/km	5.2E+11		8.9E+11	1.4E+12	9.8E+11	1.8E+12	1.1E+12	1.5E+12	1.1E+12	
PCG_E6	petrol	CO	g/km	0.230		0.582	0.120	0.189	1.718	1.055	0.742	1	
PCG_E6	petrol	CO2	g/km	135		133	234	131	162	158	176	131	
PCG_E6	petrol	FC	g/km	43		43	74	41	53	45	56	40	
PCG_E6	petrol	HC	g/km	0.028		0.020	0.002	0.003	0.010	0.008	0.006	0	
PCG_E6	petrol	NOx	g/km	0.017		0.020	0.066	0.031	0.015	0.026	0.038	0	
PCG_E6	petrol	PM	g/km	0.000		0.000	0.001	0.001	0.001	0.001	0.001	0	
PCG_E6	petrol	PN	#/km	4.1E+11		6.8E+11	5.2E+11	3.4E+11	8.1E+11	7.2E+11	7.3E+11	3.0E+11	

E2: Emissions of light commercial vehicles (LCV)

Table 20: Emissions of LCV (Euro-1 to Euro-6) of selected cycles

Veh-Group	Fuel	poll.	Unit	NEDC c	FTP c	CADC urb	CADC rur	CADC MW	CADC	CADC 1/3-Mix	ERMES	BAB	PEMS RDE
LCD_E1	diesel	CO	g/km	1.062	0.910							0.588	
LCD_E1	diesel	HC	g/km	0.319	0.242							0.049	
LCD_E1	diesel	NOx	g/km	1.288	1.308							1.564	
LCD_E1	diesel	PM	g/km	0.407	0.127							0.176	
LCD_E2	diesel	CO	g/km	0.640	0.416	0.502	0.137	0.150	0.199	0.280		0.114	
LCD_E2	diesel	HC	g/km	0.144	0.097	0.099	0.052	0.026	0.042	0.059		0.025	
LCD_E2	diesel	NOx	g/km	0.876	0.898	1.468	0.904	1.921	1.533	1.431		1.769	
LCD_E2	diesel	PM	g/km	0.069	0.058	0.067	0.051	0.160	0.119	0.101		0.127	
LCD_E3	diesel	CO	g/km	0.248		0.217	0.015	0.057	0.068	0.102			
LCD_E3	diesel	HC	g/km	0.045		0.028	0.011	0.009	0.012	0.016			
LCD_E3	diesel	NOx	g/km	0.780		1.275	1.090	2.578	1.993	1.676			
LCD_E3	diesel	PM	g/km	0.061		0.076	0.043	0.077	0.065	0.065			
LCD_E4	diesel	CO	g/km	0.378	0.089	0.025	0.008	0.008	0.017	0.016		0.005	
LCD_E4	diesel	HC	g/km	0.055	0.020	0.010	0.006	0.004	0.005	0.007		0.003	
LCD_E4	diesel	NOx	g/km	0.403	0.600	1.157	0.671	1.400	1.130	1.076		0.978	
LCD_E4	diesel	PM	g/km	0.018	0.026	0.027	0.017	0.043	0.033	0.029		0.047	
LCD_E5	diesel	CO	g/km	0.328		0.088	0.010	0.007	0.014	0.028	0.001		
LCD_E5	diesel	HC	g/km	0.037		0.007	0.003	0.003	0.006	0.006	0.003	0.002	
LCD_E5	diesel	NOx	g/km	0.263		1.261	0.736	1.591	1.301	1.173	1.000	1.314	1.788
LCD_E5	diesel	PM	g/km	0.002		0.002	0.001	0.003	0.002	0.002	0.002	0.002	
LCD_E6	diesel	NOx	g/km										
LCG_E1	petrol	CO	g/km	3.474	3.884							21.932	
LCG_E1	petrol	HC	g/km	0.185	0.278							0.313	
LCG_E1	petrol	NOx	g/km	0.494	0.629							0.895	
LCG_E2	petrol	CO	g/km	2.063	3.287							14.120	
LCG_E2	petrol	HC	g/km	0.245	0.355							0.390	
LCG_E2	petrol	NOx	g/km	0.601	0.640							1.149	

Abbreviations

ADAC:	Allgemeiner Deutscher Automobil-Club (Germany)
ARTEMIS:	Assessment and Reliability of Transport Emission Models and Inventory Systems (EU project, 4th Framework program)
AWEL:	Amt für Abfall, Wasser, Energie und Luft (Zurich)
BAB:	German motorway driving cycle (Bundesautobahn)
BAFU:	Swiss Federal Office for the Environment (FOEN), Bundesamt für Um welt
BMVI:	Bundesministerium für Verkehr und digitale Infrastruktur (Germany)
CADC:	Common ARTEMIS driving cycle
CH:	Switzerland
CO2:	Carbon dioxide
CTA:	Centre de Technologie Avancée (Wallonie)
D:	Diesel
DB:	Database
DfT:	Department for Transport (UK)
DP:	Driving pattern
DPF:	Diesel Particle Filter
ECE:	Economic Commission for Europe
EFA, E-Factor:	Emissions factor
EGR:	Exhaust Gas recirculation
EMPA:	Federal Materials Testing and Research Institute, Dübendorf/Zurich
ERMES:	European Research for Mobile Emission Sources (Group)
EURO-1, -2, -3 etc:	European exhaust emissions regulations for passenger cars and light vehicles
EURO-I, -II, -III etc:	European exhaust emissions regulations for heavy vehicles
FRG:	Federal Republic of Germany
HB / HBEFA:	Handbook Emission Factors for Road Transport
HGV:	Heavy Goods Vehicles
IUFC:	Inrets Urbain Fluide Courte driving cycle
JRC:	Joint Research Center of the EU
KBA:	Kraftfahrt-Bundesamt (Germany)
LAT:	Laboratory of Applied Thermodynamics, Aristotle University of Thessaloniki

LCV:	Light commercial vehicle <3,5t (small buses, trucks, camper vans, other motor vehicles)
LDV:	Light duty vehicle, general term for passenger cars and light commercial vehicles
LNT:	Lean NOx trap
MEEM:	Ministère de l'Environnement, de l'Énergie et de la Mer (France)
NEDC:	New European Driving Cycle
NOx :	Nitrogen oxide
PC:	Passenger car
PEMS:	Portable Emission Measurement System
PHEM :	Passenger car and Heavy duty Emission Model (of the TU Graz)
RDE:	Real-Driving Emissions
RPA:	Relative positive acceleration
RS:	Remote Sensing
RWC:	Real world driving cycle
SCR:	Selective catalytic reduction (for NOx-reduction)
SOC:	State of charge of battery
TA:	Type Approval
TNO:	Netherlands Organisation for applied scientific research
TRL:	Transport Research Laboratory (UK)
TS:	Traffic situation
TÜV:	Technical inspection agencies (DE)
TUG:	Technical University, Graz
UBA:	Umweltbundesamt (Germany, Austria), Federal Environment Agency
v:	Speed, velocity (in km/h)
VDA:	Verband der Automobilindustrie e.V.
WLTC:	World-wide Harmonized Light duty Test Cycle

Literature

André JM 2005: Vehicle emissions measurement collection of the ARTEMIS database, Artemis 3312 report, Report n° LTE 0504**,** INRETS, Bron, France.

André M 2004: Real-world driving cycles for measuring cars pollutant emissions - Part A: The ARTEMIS European driving cycles. INRETS report LTE 0411. INRETS, Bron, France.

ARTEMIS 2007: Assessment and reliability of transport emission models and inventory systems, Final Report (DG TREN Contract No. 1999-RD.10429 Deliverable No. 15), edited by Paul Boulter and Ian McCrae, Oct. 2007.

BMVI/KBA 2016: Bericht der Untersuchungskommission „Volkswagen» des Bundesministeriums für Verkehr und digitale Infrastruktur und des Kraftfahrt-Bundesamtes, 2016.

Chen et.al. 2016: Yuche Chen and Jens Borken-Kleefeld: NOx Emissions from Diesel Passenger Cars Worsen with Age, Environ. Sci. Technol., 2016, 50 (7), pp 3327–3332.

CTA 2016: Centre de Technologie Avancée (Wallonie), Résultats de l'évaluation des rejets athmosphériques par les véhicules légers Diesel, mandaté par le le Ministre wallon de l'Environnement (Wallonie), Mons/Wallonie, Juin 2016.

DfT 2016: Department of Transport (UK), Vehicle Emissions Testing Programme, April 2016.

https://www.gov.uk/government/publications/vehicle-emissions-testing-programme-conclusions

DUH/EKI 2016: NOx- und CO2-Messungen an Euro 6 Pkw im realen Fahrbetrieb, Hintergrundpapier, Emissions-Kontroll-Institut der Deutschen Umwelthilfe e.V., Berlin, 7. September 2016.

http://www.duh.de/projekte/eki-kontrollen/

DUH/EKI 2017: NOx- und CO2-Messungen an Euro 6 Diesel-Pkw im realen Fahrbetrieb, Wintermessungen, September 2016 – März 2017, Emissions-Kontroll-Institut der Deutschen Umwelthilfe e.V., Berlin, 29. März 2017
http://www.duh.de/projekte/eki-kontrollen/

Hausberger et. al. 2016: Hausberger S., Lipp S, Matzer C.: Anforderungen durch die kommende 'Real Drive Emissions (RDE) Gesetzgebung für PKW, TU Graz, 9. März 2016

INFRAS 2004: HBEFA Version 2.1, Dokumentation (in German), 18. Aug. 2004

INFRAS 2005: Kljun N., Keller M. and DeHaan P.: Design of the A300 database, Deliverable WP3311, Infras- Bern.

Joumard et.al. 2006: ACCURACY OF EXHAUST EMISSIONS MEASUREMENTS ON VEHICLE BENCH Artemis deliverable 2, Report nr LTE 0522, dec. 2006

Keller et. al. 2017: Keller M., Hausberger S., Matzer C., Wüthrich P., Notter B.: HBEFA Version 3.3, Background documentation, Berne, 25. April 2017

LAT 2004: Investigation of the emission degradation of gasoline vehicles, Artemis Subtask 3123, Report No: 0415 Thessaloniki September 2004.

Matzer et.al. 2016: Matzer C., Hausberger S., Lipp S., Rexeis M.: A new approach for systematic use of PEMS data in emission simulation, 21st International Transport and Air Pollution Conference, Lyon 24. – 26. May 2016

Matzer and Rexeis 2016: Matzer Claus, Rexeis Martin: Proposal for test description for cars and LCV for chassis dyno tests and RDE tests as basis for emission factors, IVT, TU Graz Status: Draft version 3.0, 24.06.2016

RDE regulation 2016: Commission Regulation (EU) 2016/646 amending Regulation (EC) No 692/2008 as regards emissions from light passenger and commercial vehicles (Euro 6), 20 April 2016

TNO 2012: Road load determination of passenger cars, TNO Report 2012 R10237, October 29th, 2012

TNO 2016: NOx emissions of Euro 5 and Euro 6 diesel passenger cars – test results in the lab and on the road, TNO Report 2016 R10083, 9 March 2016.

TüV Rheinland 1995: Emissionsfaktoren von Leichten Motoragen in der Schweiz, commissioned by BAFU, Umweltmaterialien Nr. 27. Bern 1995.

TUG 2009: Emission Factors from the Model PHEM for the HBEFA Version 3, Report Nr. I-20/2009 Haus-Em 33/08/679, 07.12.2009 (www.hbefa.net).

TUG 2013: Update of Emission Factors for EURO 5 and EURO 6 vehicles for the HBEFA Version 3.2, Report No. I-31/2013/ Rex EM-I 2011/20/679, 06.12.2013 (www.hbefa.net).

TUG 2017: Update of Emission Factors for EURO 4, EURO 5 and EURO 6 Diesel Passenger Cars for the HBEFA Version 3.3, forthcoming (www.hbefa.net).

UBA 2015: IFEU, INFRAS AG, TU Graz, HS, IVU Umwelt GmbH, VMZ Berlin: Aktualisierung und Recherche zu Emissionsfaktoren von Euro 5- und Euro 6-Fahrzeugen und nachgerüsteten Kfz und Übertragung der Daten ins Handbuch für Emissionsfaktoren (HBEFA) und in TREMOD; UFOPLAN-3711 45 105, Berlin April 2015.
specifically AP 300: Weiterentwicklung und Validierung eines realitätsnahen und kompakten PkwPrüfzyklus (sog. ERMES-Zyklus) – by TU Graz.