HBEFA

Handbook of emission factors for road transport (HBEFA) 5.1
Quick reference

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Content

1. Introduction

The Handbook of Emission Factors for Road Transport (HBEFA) provides emission and energy consumption factors, i.e. the specific emission or energy consumption (e.g. g/km, MJ/km, #/km) for all relevant road vehicle categories (PC, LCV, HGV, buses, coaches, and motorcycles). Emission factors can be queried from very detailed level (by vehicle category, technology, size class, emission standard, age class, traffic situation, year) to aggregated levels (e.g. by vehicle category/year).

HBEFA strives to provide real-world emission factors, i.e. values that are representative for real-world driving behaviour (as opposed to test conditions) based on the current state of knowledge and data. Therefore, it is regularly updated (Table 1). The first version was published in December 1995 and contained emission factors for Germany and Switzerland; since then, comprehensive or selective updates followed in intervals of 3 to 6 years. The current version, HBEFA 5.1, was published in 2025 and provides emission factors for Germany [D], Austria [A], Switzerland [CH], Sweden [SE], Norway [N] and France [F].

Table 1: Overview of HBEFA versions.

Version	Publication year	Remarks
1.1	1995	Contents for Germany and Switzerland
1.1A	1998	Added contents for Austria
1.2	1999	"Light" update of 1.1A
2.1	2004	Comprehensive update; LCV size classes, fuel qualities, A/C and DPF influence
3.1	2010	Comprehensive update; current traffic situation scheme introduced; added contents for Norway and Sweden
3.2	2014	"Light" update of 3.1; added contents for France
3.3	2017	Update of Diesel PC emission factors incl. ambient temperature dependency after Diesel scandal
4.1	2019	Comprehensive update; focus on alternative drivetrains
4.2	2022	"Light" update; hot EF for Euro VI HDV, NO2/NOx ratios, additional software updates of Diesel PC etc.
5.1	2025	Comprehensive update; non-exhaust EF, cold start for HGV and BEV, new non-regulated pollutants, SCR tampering and malfunctions etc.

For the current HBEFA version 5.1, the structure of the present “Quick reference” document has been adapted based on user feedback: For previous versions, the “Quick reference” consisted mostly of the “Alphabetic reference” Chapter (currently, Chapter 4). In addition, the

current document provides an overview of the HBEFA methodology and an overview of operational aspects in Chapters 2 and 3.

2. Methodology

2.1. System boundaries

The system boundaries of HBEFA regarding different aspects are summarized below:

- Regarding **emission source**, HBEFA covers **road transport**, i.e. the vehicle categories that are relevant in road transport in the countries covered (see below)– i.e. passenger cars, light commercial vehicles, trucks, buses, coaches, and motorcycles.

  Please note:

  - Motorcycles include other L-category vehicle types such as ATVs or Mini-cars, as well as "fast" e-Bikes (those that require immatriculation and have a license plate; "slow" e-bikes, i.e. those <25 km/h that do not require a license plate, as well as bicycles, are not included);
  - Regarding **geographical coverage**, HBEFA provides emission factors for the countries that form part of the HBEFA workgroup and that contribute to updates, i.e. **Germany [D], Austria [A], Switzerland [CH], Sweden [SE], Norway [N] and France [F]**. For these countries, HBEFA contains fleet, energy, traffic, and ambient condition data that allow aggregation and corrections for energy efficiency, mileage, and ambient temperature. The base emission factors (i.e. uncorrected emission factors for new reference vehicles, see Chapter 2.3.1) provided by HBEFA are valid for Europe (i.e. the countries where the Euro emission standards apply). They are also applied outside Europe due to lack of alternative sources (e.g. in EcoTransIT, EcoTransIT World 2023, or for China, Sun et al. 2014, or Kenya, Notter and Füssler 2018).
- Regarding **time**, HBEFA covers a time series of at least 1990 – 2050 for the countries mentioned above.
- Regarding **life cycle stage** or emission scope, HBEFA covers **operational** emissions (also called direct, or tank-to-wheel, TTW) emissions. The HBEFA versions 4.x also included CO2e emissions of energy provision (well-to-tank, WTT); this has been discontinued in HBEFA 5.1 since it would have required continuous update of energy production type emission factors and shares, which is not the main focus of HBEFA and for which there are better sources (i.e. various LCA databases).

2.2. Classifications and aggregations

2.2.1. Pollutants

Currently, 44 **pollutants or "components"** are provided. Their definitions can be viewed in Menu *Definitions > pollutants*. They include greenhouse gases (such as CO2), air pollutants (such as NOx, PM10), pollutants that are both greenhouse gases and air pollutants (CH4, N2O), as well as energy consumption (EC) and positive engine work (WE-pos).

Please note the following:

- Some pollutants are subsets of others – e.g.:
  - CO2(total) refers to fossil and biogenic CO2 emissions, while CO2(rep) refers to fossil ("reported") CO2 emissions and is a subset of CO2(total).
  - CO2e contains CO2(rep) plus CH4 and N2O multiplied with their global warming potentials. NOTE: Since CO2e is based on CO2(rep), i.e. fossil CO2 only, it may be lower than CO2(total)!
  - PM2.5 is particulate matter with a diameter up to 2.5 micrometers and is a subset of PM10, which is particulate matter with a diameter up to 10 micrometers. The non-exhaust "pollutants" from brake, tyre, road wear and resuspension (e.g. can be summed up to the corresponding non-exhaust pollutant without process name. HC refers to total hydrocarbons, of which Methane (CH4), NMHC (non-methane hydrocarbons), Benzene, Toluene, and Xylene are subsets/members.
- Energy consumption ("EC") is final energy consumption (base unit MJ), while positive engine work ("WE-pos", base unit Wh) is work demand (not considering engine efficiency). The latter has been included with HBEFA version 5.1 to facilitate the conversion of HDV emission factors to g/kWh, i.e. the unit in which air pollutant limit values for HDV are expressed.
- **Some pollutants have been renamed** between HBEFA 4.2 (Microsoft Access version) and the HBEFA Versions migrated to Python, e.g. energy consumption is now "EC", but used to be "FC_MJ" in Access (for "fuel consumption in Megajoule"); or PM10-exhaust is now abbreviated "PM10-ex" but used to be just "PM" in Access. The column "pollutant_hb42" in the definition table under menu *Definitions > Pollutant definitions* contain the pollutant abbreviations used in older HBEFA versions up to HBEFA 4.2.

2.2.2. Emission categories

Emission factors for the following **emission categories** are provided:

- **Hot emissions**: These are emissions from a hot engine state. Hot emission factors are by default expressed per vehicle kilometre.

  - NOTE: In HBEFA, we classify **non-exhaust emissions** – i.e. particle emissions from brake, road, tyre wear, and resuspension – as "hot" emissions, because they are also expressed per vehicle kilometre.
- **Cold start excess emissions**: These are the added emissions after cold start. They are by default expressed per start. For most vehicle types and pollutants, emissions are higher when the engine is still cold. Negative cold start EF can occur for a few pollutants and vehicle types if emissions with cold engine are lower than with hot engine.
- **Gasoline evaporation**: These form when gasoline evaporates from the fuel tank – either due to daily temperature fluctuations ("evap-diurnal"), after stopping when the engine is still hot or warm ("evap-soak") or during driving ("evap-running losses" or "evap-rl"). They are only available for HC (hydrocarbons) or some HC components[1].

2.2.3. Vehicle classification

Emission factors in HBEFA are differentiated by **vehicle types** at different aggregation levels (see Menu *Definitions > Vehicles*):

- Vehicle family - e.g. LDV (light-duty vehicle)
- Vehicle category – e.g. PC (passenger car)
- Technology (i.e. drivetrain technology) – e.g. petrol, diesel, BEV, …

  Note that HBEFA differentiates two types of "technology":
  - "Base technology" – a single vehicle drivetrain technology, such as petrol, diesel, battery-electric etc.
  - "Multi-technology" – two "base technologies" in the same vehicle, e.g. in Plug-In hybrid vehicles (PHEV, electric plus petrol or diesel) or bi-fuel vehicles (CNG or LPG plus petrol). At the level of "subsegment" (see below), two subsegments exist for each segment and emission concept of multi-technology vehicles, i.e. one for each "base technology". These are denoted with an abbreviation of the respective base technology in brackets as a suffix of the subsegment name (e.g. "(El)" for the electric, or charge-depleting mode, and "(P)" for the petrol, or charge-sustaining mode of a petrol-electric PHEV)
- Size class (e.g. M+NI, NII, NIII for LCV, weight classes for HDV, capacity classes for MC)
- Emission concept (i.e. emission standard; in some cases further differentiated by exhaust aftertreatment technology, such as EGR vs. SCR HGV for Euro IV and V, or vehicles with/without DPF for emission standards with optional DPF)

[1] Note that Methane (CH4) is not included in evaporation emissions, since due to its low boiling temperature it does not occur in liquid form in gasoline. It only forms due to incomplete combustion in the engine. Therefore, evaporation emissions do not have to be considered for greenhouse gas emissions. Methane slip from gas or LNG tanks is included in the hot emission factors

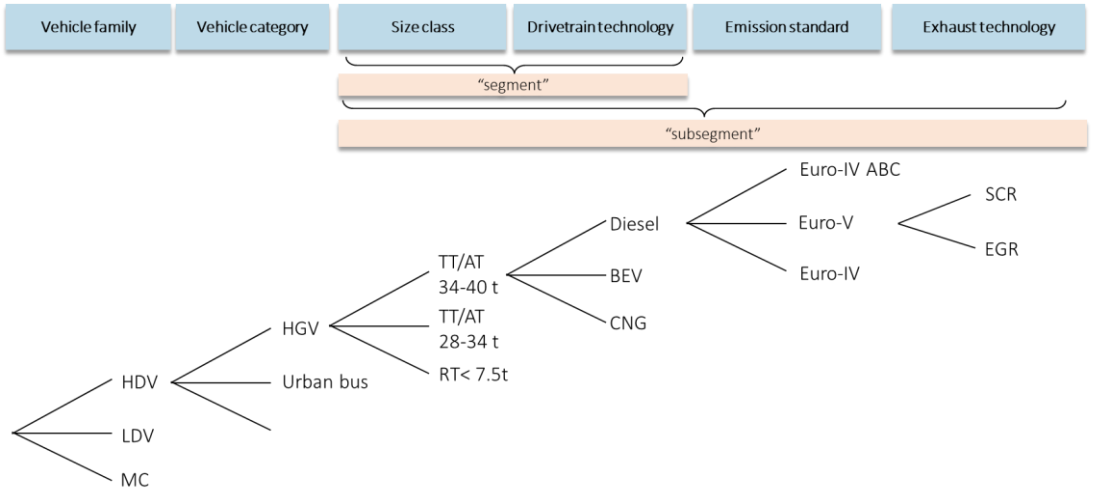
- Age class (new in HBEFA 5.1)

The following terms are HBEFA-specific for combinations of above characteristics:

- **"Segment"**: Combination of vehicle category, technology, and size class
- **"Subsegment"**: Combination of "segment" and emission concept

Under Menu *Definitions > Vehicles*, then select "vehicle aggregation levels" as "definition to view", all vehicle aggregation levels assigned to each subsegment can be viewed or copied.

Figure 1: Vehicle classification hierarchy in HBEFA (example of a Euro-V 40-ton truck).



Source: www.hbefa.net.

2.2.4. Energy

«Energy» in HBEFA refers to all used energy types for propulsion, i.e. liquid or gaseous fuels or electricity. All energy and fuel properties can be accessed under the menu *Fuel/Energy*.

HBEFA differentiates "main" and "base" energies. A "main" energy is linked to one or several drivetrain technologies, i.e. can be used to propel the respective vehicles. A "base" energy forms part of a fuel mix.

- Which "base energies" can be mixed together to form a "main" energy can be viewed under menu *Fuel/energy > Main and base energy definitions*;
- Which technologies use which "base energy" as reference energy can be viewed under menu *Fuel/energy > Link between technologies and fuels*;

2.2.5. Traffic Situations

Hot emission factors in HBEFA can be differentiated by individual or aggregate traffic situations (also abbreviated as "TS"; see menu *Definitions* > *Traffic situations*)[2]:

Individual, or single, traffic situations (menu *Definitions* > *Traffic situations* > *Individual traffic situations*) are defined by:

- Area type (rural/urban; see menu *Definitions* > *Traffic situations* > *Area*)
- Road type (functional hierarchy of road types; see menu *Definitions* > *Traffic situations* > *Road type*)
- Speed limit (see menu *Definitions* > *Traffic situations* > *Speed limit*)
- Level of service (LOS), i.e. traffic density or other conditions that influence the flow of traffic (see menu *Definitions* > *Traffic situations* > *Level of service*)

Not all combinations of these four traffic situation parameters exist in reality; HBEFA contains emission factors for the relevant combinations. The **"Traffic Situation Scheme"** (see menu *Definitions* > *Traffic situations* > *Traffic Situation Scheme*) defines which combinations form a valid Traffic Situation in the HBEFA context. It also shows by color shades which fleet composition is used by default to aggregate the respective emission factors. Fleet compositions are differentiated by road category (see menu *Definitions* > *Traffic situations* > *Road category*).

Each traffic situation is assigned a representative **speed profile** per vehicle category. These can be viewed under menu *Definitions* > *Traffic situations* > *Individual traffic situations* (see also Chapter 2.3.1).

Each individual traffic condition can be combined with a **gradient** class (menu *Definitions* > *Traffic situations* > *Gradient*).

The difference should be noted between the more fine-grained **"road type"** – which is part of the HBEFA TS definition (see above), and the more generalized **"road category"** (motorway/rural/urban), by which we can also query emission factors in HBEFA. "Road types" are NOT subsets of "road categories" – e.g. the road type "distributor" can occur in the rural or in the urban "road category". The **"road category" is used in two different ways in HBEFA**:

[2] For more details on the concept and use of the HBEFA Traffic Situations, please also refer to the "Traffic Situation Guidelines" available here: www.umweltbundesamt.de/publikationen/hbefa-traffic-situations

- To differentiate fleet compositions (see the “Traffic Situation Scheme” and above), and to form aggregate traffic situations (see below). In this case, a given road segment can be assigned one road category;
- To link HBEFA and the COPERT methodology for aspects that HBEFA adapts from COPERT: Since COPERT is based on the “average speed” approach – i.e. its emission factors are calculated from average speed – the road category classification in this context depends on average speed. E.g. the same physical road segment can belong to a different road category depending on the level of service and thus the average speed driven. For example, a rural distributor road segment with speed limit of 80 km/h is classified as “Rural” in most LOS, but in Stop+Go traffic, average speeds of only 15-20 km/h are possible. In this case, COPERT emission factors for “urban” roads are assigned. Which road category is assigned to which Traffic Situation by speed is shown in menu *Definitions > Traffic situations > Traffic Situation Definitions.*

Aggregate traffic situations (menu *Definitions > Traffic situations > Individual traffic situations*) define patterns of mileage shares of individual Traffic Situation/gradient combinations for a given vehicle category and geographical region. For every country covered, there is at least an urban, rural, motorway, and overall pattern available; for some countries there are more choices. They are useful to quickly query average emission factors – overall or by road type.

In HBEFA 5.1, the possibility to query emission factors by **“static traffic situations”** has been introduced. A “static TS” is defined by only the “static” TS parameters area, road type and speed limit, leaving out the dynamic (temporally changing) parameter LOS. To calculate emission factors for a “static TS”, a weighted average of the EF for the involved LOS is calculated. The weights are taken from the “aggregate traffic situation” that can be selected in the emission factor request (or the “default“aggregate traffic situation” for the respective country is used).

Cold start and evaporation emission factors are not differentiated by traffic situations. if an assignment is necessary, they should be assigned to the “urban” road category (because most cold starts and evaporation emissions take place in urban areas). The “evaporation running losses” emissions are differentiated by road category, since their methodology is based on the COPERT model (Mellios et al. 2024).

2.2.6. Years

The main temporal unit in HBEFA is the year. HBEFA differentiates two types of years:

- Reference year (often abbreviated as “yearref” in column titles): The year for which an emission factor, or a traffic or emission amount is valid.
- Construction year (often abbreviated as “yearconstr” in column titles): The construction year of vehicles of a certain age.

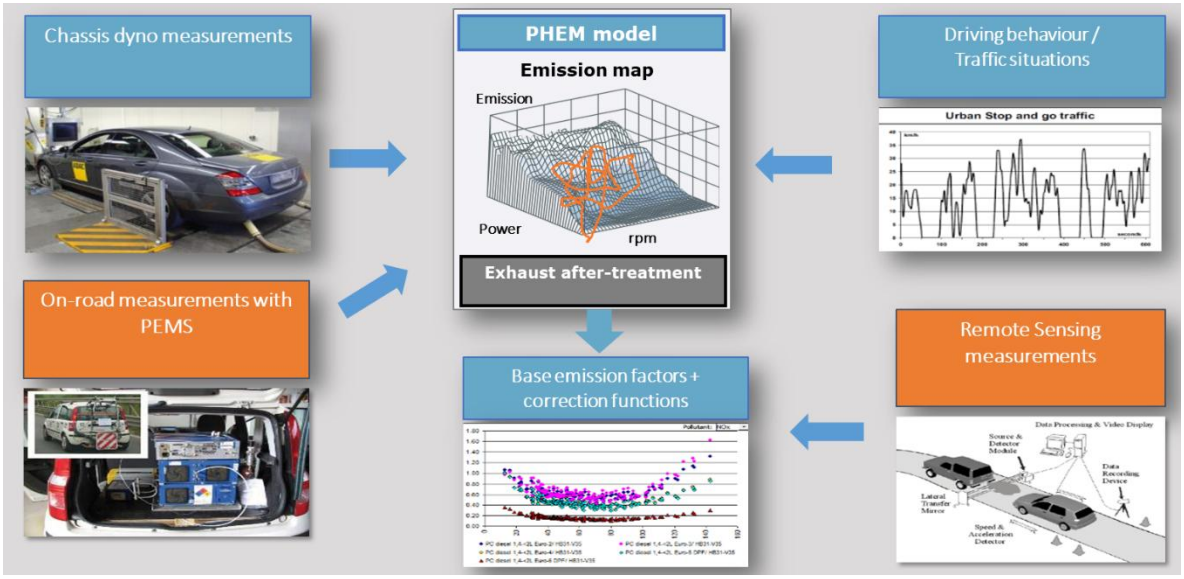
2.3. Hot emission factors

2.3.1. Base emission factors

“Base” emission factors are valid for new (up to 50’000 km of cumulative mileage) reference vehicles at about 20°C ambient temperature and using the standard fuel quality at the time of their registration. Most base EF in HBEFA are sourced from the PHEM model (“Passenger car and Heavy Duty Emission Model”) of the Technical University of Graz (Hausberger and Rexeis 2018).

In simplified terms, for hot exhaust emissions, PHEM derives engine emission maps, i.e. emission heights by power (torque) and number of revolutions (RPM), from chassis-dyno or PEMS measurements, see Figure 1. The real-world driving profiles that are assigned to each Traffic Situation (see menu *Definitions > Traffic situations > Individual traffic situations*) are then used as an input and converted to torque and RPM values using a gearshift model within PHEM. The emission values for each second of each driving profile (represented by the orange zig-zag line on the emission map in Figure 1 are then summed and normalized per kilometer to form the base emission factors in g/km for HBEFA. The concrete methodology can vary by pollutant or vehicle type; for more detailed information, please refer to the dedicated “Emission Factor reports” available for each HBEFA version on www.hbefa.net. Since not all base emission factors originate from the PHEM model, please refer to menu *Definitions > Pollutant definitions* to check the data source(s) per pollutant (column “source”).

Figure 2: Derivation of hot exhaust base emission factors and correction functions



Source: www.hbefa.net.

The emissions of some pollutants do not vary with the combustion conditions in the engine but mostly depend on **fuel properties**. These include **CO2, Pb, S, Zn** or **Cd**. Their emission factors in g/km are derived from the fuel content of the origin substances. These can be viewed in the menus *Emission factor inputs > EF <pollutant(s)>* in the HBEFA application.

Some **pollutants are calculated as a share of others**:

- HC components (CH4, NMHC, Benzene, Toluene, Xylene) are calculated as shares of HC: See menu *Emission factor inputs > EF HC components*
- NO2 is calculated as a share of NOx: See menu *Emission factor inputs > EF NO2 (% of NOx)*
- PM2.5 and BC (exhaust) are calculated as a share of PM10: See menu *Emission factor inputs > EF PM2.5 and BC (exhaust)*
- PM2.5 non-exhaust (PM2.5-nx) is calculated as a share of PM10-nx by process:
  - 40% for brake and tyre wear
  - 30% for road wear
  - 10% for resuspension

See menu *Emission factor inputs > Correction factor inputs > EF PM10 to PM2.5 (non-exhaust).*

2.3.2. Corrections

HBEFA corrects the hot "base" EF for the following influences:

- Mileage (i.e. catalyst aging): Due to deterioration of catalysts, emissions of regulated pollutants may increase with vehicle age, or cumulative mileage. HBEFA implements correction functions based mostly on remote sensing (RS) measurements (as shown in Figure 1) to account for this effect. The functions and resulting correction factor values can be viewed in menu Definitions > Correction factors > Mileage correction…. Up to HBEFA 4.x, multiplicative correction factors were used, i.e. they were multiplied with the base EF. In HBEFA 5.1, we use additive correction factors in the unit of the base EF, since these represent actual emission behavior better: Especially in the case of the very low base EF of modern vehicles, multiplicative values would add too little to lower base EF values and correct already high values upwards too much.
- NOx emissions of Diesel PC and LCV are corrected for **ambient temperature**, due to the optimization of NOx aftertreatment for the test conditions at 23°C under the NEDC test cycle). Also, the ambient temperature correction functions are largely based on remote sensing data.
- Energy and fuel consumption (and all pollutants derived from them, see previous subchapter) are corrected for **energy efficiency**. The energy efficiency correction factors reflect (where available):
  - EEA CO2 monitoring values (type approval CO2 emissions),
  - Real-world usage (based e.g. on Tietge et al. 2020 or www.spritmonitor.de),
  - Assumptions of future efficiency development.

  Please note that changes in vehicle weight/size are also reflected in the energy efficiency correction factors.

  The energy efficiency correction factors are defined for new registrations and are modelled for the entire fleet in the fleet model (see Chapter 2.6). They can be viewed under menu *Fleet > Analyse fleet composition*.
- Some regulated pollutants are corrected for **fuel quality**, i.e. if the fuel quality standard in the current reference year differs from the standard at the time of vehicle new registration. The correction factors can be viewed under menu *Fuel/Energy > Fuel quality (country-independent) > Correction factors (EPEFE)*.

  Please note that the fuel quality correction is only carried out for MC and HDV, even though LDV inputs are also displayed in the HBEFA application.

2.4. Cold start emission factors

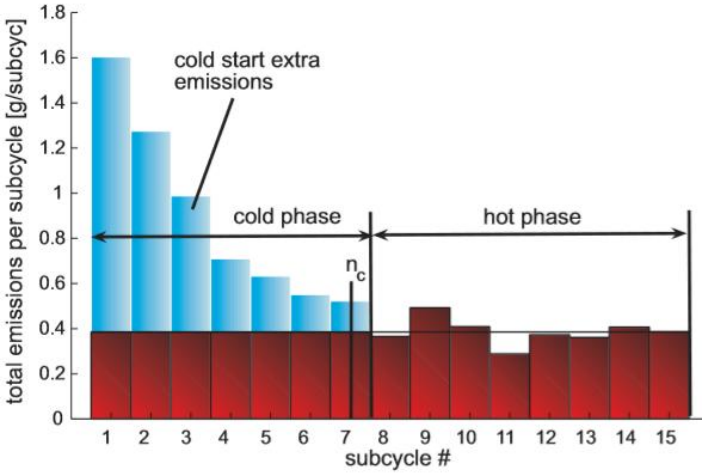
2.4.1. Approach up to HBEFA Version 4.2

Up to HBEFA Version 4.2, cold start extra emission (CSEE) factors in HBEFA were modelled for petrol and diesel LDV, with an approach developed by EMPA (Favez et al. 2009, Weilenmann et al. 2009) as a function of ambient temperature T, averaged velocity V (representing driving dynamics), trip distance d and stop time (=parking time) t:

$$\mathrm{EE}_{\mathrm{cold}}(T, V, \delta, t) = \mathrm{EE}_0 e(T) f(V) h(\delta) g(t)$$

where EE_0 is the standard CSEE at a temperature of 23° C (standard test temperature), V at 20 km/h, d at d_c (the vehicle warms up completely in the test) and t at12 h (the vehicles were completely cooled down before the test). The function e(T) expresses the influence of the ambient temperature, while f(V), h(d) and g(t) are the influence functions of averaged velocity, trip distance and stop time, respectively. The term f(V), i.e. the influence of averaged velocity, is ignored in this context, since there is only one empirical basis available for deriving the parameters for the model, the so-called IUFC cycle, developed by INRETS in the context of the ARTEMIS project (INFRAS 2007). The IUFC repeats a short base cycle 15 times; the cold start extra emissions are the excess emissions above the average emissions of the (hot) subcycles (those taking place after the vehicle is warmed up and a stabilized hot phase is reached) (Figure 3).

Figure 3: Emissions measured during the 15 subcycles of the IUFC and derivation of cold start extra emissions.



Graphics by INFRAS. Source: EMPA 2008

The main limitation of this approach is that only IUFC measurements could provide empirical input data for cold start emission factors, and therefore the empirical data base was inherently limited.

Please also note that with the cold start methodology up to HBEFA 4.2, only one trip length, parking time, and traffic volume distribution per country and season could be considered – i.e. they had to be assumed identical for all vehicle types. Since cold start EF were only available for LDV, this simplification was acceptable.

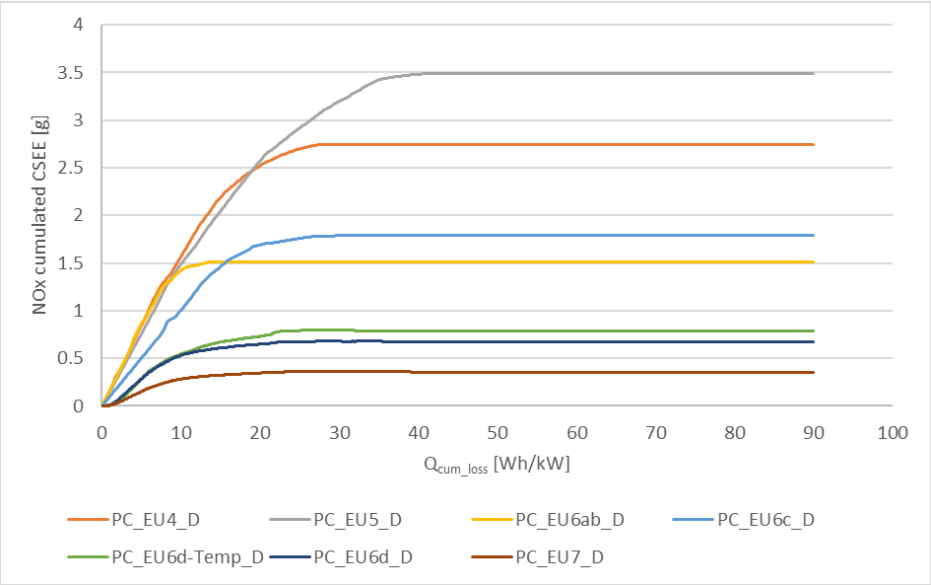
2.4.2. Current approach

As of HBEFA 5.1, cold start extra emission factors are available for LDV and HDV, including BEV[3]. A new cold start model elaborated by EMPA and TUG in the H2020 project "uCARe" and implemented in PHEM (Opetnik et al. 2025) produces the input CSEE.

The new model has the advantage that it can use any measurement data that include a cold start as empirical input: The hot exhaust emission model in PHEM (see Chapter 2.3.1) is used to model the theoretical hot emissions for the given cycle; the cold start extra emissions can then be calculated as the difference of the measured emissions and the modelled hot emissions. They are then characterized as averaged curves over the heat loss, i.e. the energy released into engine coolant and exhaust aftertreatment system (Figure 4).

[3] For BEV, the cold start extra energy consumption is required to heat the battery and the driver compartment, whereby battery heating requires most of the energy.

Figure 4: NOx CSEE curves at -20°C for Diesel PC.



Graphics by ITnA, TU Graz

Base cold start emission factors have been produced in PHEM in a matrix of the following variables:

- parking time (before the cold start) from 0 to 735 min
- ambient temperature from -20 to +30 degrees Celsius
- trip distance from 0.1 to 30 km

This leads to 4004 combinations for which cold start base EF are available. In an emission factor query, HBEFA application interpolates the values for the combination(s) of parking time, ambient temperature and trip distance requested by the user.

The **underlying ambient condition data** can be accessed via menu *Traffic conditions > Ambient condition patterns*.

Since driving behaviour patterns (parking time, trip length distributions, traffic volume distributions) can vary by vehicle type, we only use the climate and RVP data from most ambient condition patterns in HBEFA 5.1. Driving behaviour patterns patterns are linked to each subsegment in the fleet model output (see Chapter 2.6).

Which subsegment uses which pattern can be seen under menu *Fleet > Analyse fleet composition*, in the columns “idset_triplength”, “idset_parkingtime”, “iddistrib_trafficday”, and “triplength” of the data table view (right-click on a cell brings up the option to select the pattern and view it in a separate windows).

However, there are also ambient condition patterns available that allow querying cold start EF for given trip lengths, temperatures, or parking times. These ambient condition patterns carry the value “True” in one or several of the columns “distrib_traffic_from_pattern”, “parkingtime_from_pattern”, or “triplength_from_pattern” in menu *Traffic conditions > Ambient condition patterns*. This means that the respective pattern linked to the current ambient condition pattern via a seasonal subpattern is used, and NOT the pattern linked to the respective subsegments in the fleet model output.

2.5. Evaporation emission factors

Evaporation emissions occur from petrol-fuelled vehicles and only include hydrocarbons (i.e. HC and HC components). HBEFA fully implements the Tier 3 methodology described in the EMEP/EEA Emission Inventory Guidebook (Mellios et al. 2024) and developed for the COPERT model, to calculate evaporation EF.

The input data regarding ambient and traffic conditions are the same as those used for cold start extra emissions – see Chapter 2.4.2.

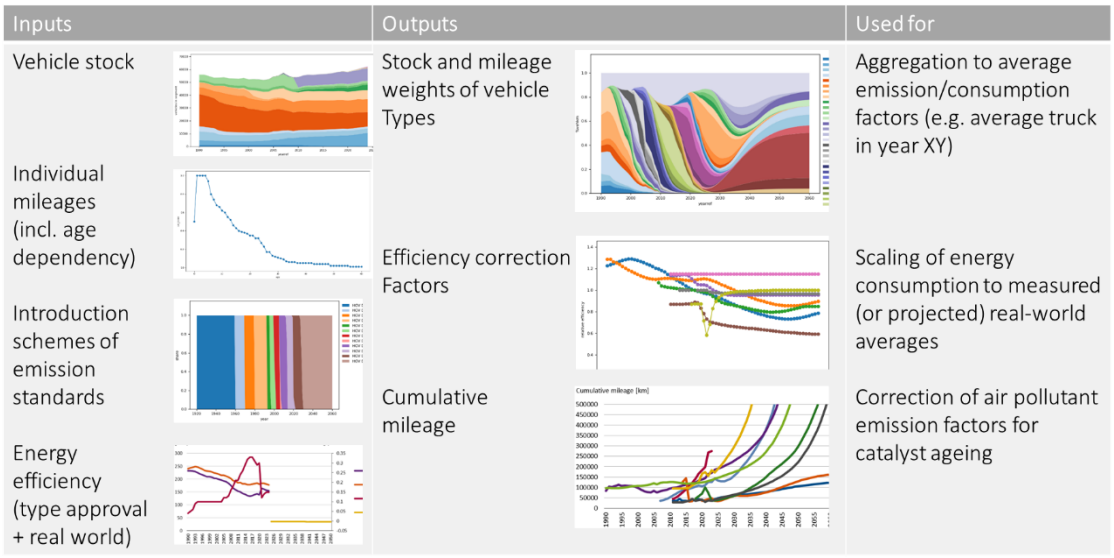
The shares of the HC components in total HC can be accessed in menu *Definitions > Emission factor inputs > EF HC components*. Please note that there are no evaporation emissions for methane (CH4) – see Footnote 1 on p. 8.

2.6. Fleet composition (traffic scenarios)

HBEFA uses so-called “traffic scenarios” to store fleet-related data. These are created by an internal fleet model. A simplified overview of the main inputs, outputs, and uses of the fleet model and the “traffic scenario” it creates is shown in Figure 5.

In the Public Version of the Handbook, we publish **one reference “traffic scenario” per country and HBEFA version**. This is due to the basic motivation of HBEFA to provide a standard data source for emission factors, which would be undermined if there were multiple scenarios to choose from.

Figure 5: Simplified overview of inputs, outputs, and uses of the HBEFA fleet model.



Graphics by INFRAS

Inputs into the fleet model include:

- Vehicle stock at "segment" level, typically from registration databases, for the historical period. For future periods, either an estimate of the entire vehicle stock or only new registrations, along with survival probabilities, can be provided as input;
- Individual mileages (i.e. km per vehicle and year), including
  - age dependency (since newer vehicles are typically driven more than older ones),
  - shares of the mileage by road category (motorway/rural/urban),
  - distributions of average trip length, parking time, and traffic volume over the day;
- Introduction schemes of emission standards (i.e. which percentage of new vehicles of a given segment complies with which Euro standard in a given reference year);
- Energy efficiency inputs: Either expressed as CO2 in g/km or energy consumption in MJ/km of new registrations, per segment and year. This should reflect real-world usage, therefore an "official" type approval value and a "real-world excess" in % can be specified;
- Sub-technology inputs:
  - Shares of mileage by base technology for multi-technology vehicles, per road category (i.e. which share of PHEVs is driven electrically on motorways in a given year and country)
  - Shares of Euro IV and V HGV equipped with EGR/SCR
  - Vehicles with software updates (mainly Diesel PC)
  - HGV with tampered or malfunctioning SCR catalyst

From these inputs, the following **outputs** are derived (see menu *Fleet > Analyse fleet composition*):

- Stock and mileage shares (adding up to 100% per vehicle category, road category, and year). These are used for the aggregation of emission factors.
- Efficiency correction factors (see Chapter 2.3.2)
- Cumulative mileages as an input to mileage correction functions (see Chapter 2.3.2)
- References to the distributions of average trip length, parking time, and traffic volume over the day (the distribution data themselves are also accessible via menu *Traffic conditions > Ambient condition patterns*.)

3. Operational aspects

3.1. HBEFA 5.1 vs. previous HBEFA versions

In previous versions (up to Version 4.2), HBEFA was implemented as a Microsoft Access database application. The memory limitations of Microsoft Access, which would have prevented adding more data – which has been necessary with every new version due to additional technologies, vehicle types, pollutants etc. – were the main driver for migrating the application to a Python-based client-server solution. Other reasons included the increasing complexity of deployment under MS Access (i.e. creating installers that work for a growing number of combinations of Windows versions, Office versions, Office license models etc.), lacking potential for automated queries and low user-friendliness.

HBEFA 5.1 is the first version to be published as a Python-based server-client solution.

Users now download a **desktop client program**, referred to in this document as the **(main) front-end**, that can only be double-clicked to run and doesn't require installation. All references to menus and other GUI elements in the HBEFA application in this document refer to this main front-end.

The main front-end communicates with the **server**, i.e. it converts requests entered by the user via the GUI (graphical user interface) to requests that it sends to the server API (Application Programming Interface), and converts the responses from the server back into tables or graphics that are displayed or can be copied or exported.

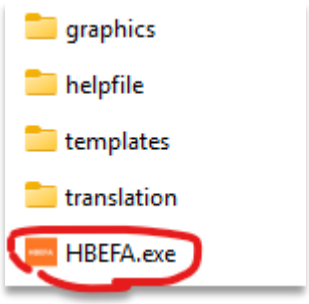
The main front-end currently only supports the Windows operating system (support for other operating systems would theoretically be possible but has not been prioritized).

The HBEFA API can also be accessed third-party scripts and clients. We request interested users to contact INFRAS directly for this option, and we reserve the right to charge for additional resources or support efforts necessary due to the use of third-party clients.

Please note that the Python HBEFA desktop client application shows a command line (terminal) window in the background. You can ignore this. In case of any errors, it may be helpful, however, to report the

3.2. Application start, user log-in and settings

- Download the HBEFA front-end (desktop client) from the download repository. The access link is provided upon user registration. It is a .zip archive called “hbefa51_py.zip” (or similar).
- Unzip the archive.
- Start the front-end by double-clicking on «HBEFA.exe»

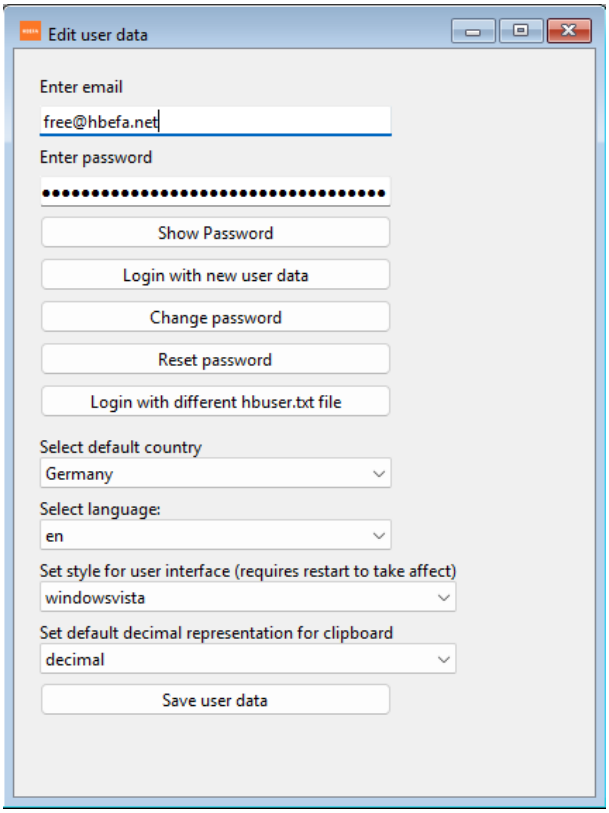


- In the freshly downloaded application, at first the user free@hhefa.net is logged in. As long as this is the case, you only have access to the free HBEFA contents that are also available via the “Online Version” on www.hbefa.net.

  IMPORTANT: To enable access to the full functionality of HBEFA, you have to log in with your e-mail address and the initial password you received after registration, by going to *Settings > user settings and log in.*

- After that, you can change anytime who is logged in with menu *Settings > user settings and log in*.
  This will open the “Edit user data” window.
  Besides the login info, this window also contains buttons

- to change your password (see further explanations below);
- to set the default country and language that the application starts with;
- to set the default style (appearance of frames, buttons etc.) of the front-end app;
- to set the default decimal representation for the clipboard.
  This affects how data copied from a table in the HBEFA front-end are saved in the clipboard, to be pasted into other applications (e.g. Excel).
  Available choices are “decimal” or “comma”. The recommendable choice depends on the Region settings of your Windows OS. If you use a dot to separate decimals from integer numbers, choose “decimal” (default e.g. in Switzerland); if you use a comma, choose “comma” (default e.g. in Germany).



- “Change password” will open a browser window where you can first log in with your old password, then change the password:

- "Reset password" will open a browser window where you can enter your e-mail address that a reset link will be sent to. When clicking this link, a page will be shown where a new password can be entered twice, and confirmed. After this, a confirmation e-mail containing the message "Your password has been reset" will be sent to the e-mail address specified.
- All information in the "Edit user data" window is saved in a text file called "hbuser.txt". This file can also be edited directly in any text editor, but the correct syntax has to be used (otherwise, the application may not be able to start).
  - The button "Login with diferent hbuser.txt file" facilitates logging in quickly with another text file in the same format as "hbuser.txt", which can be selected after clicking this button.

3.3. Selecting an HBEFA version

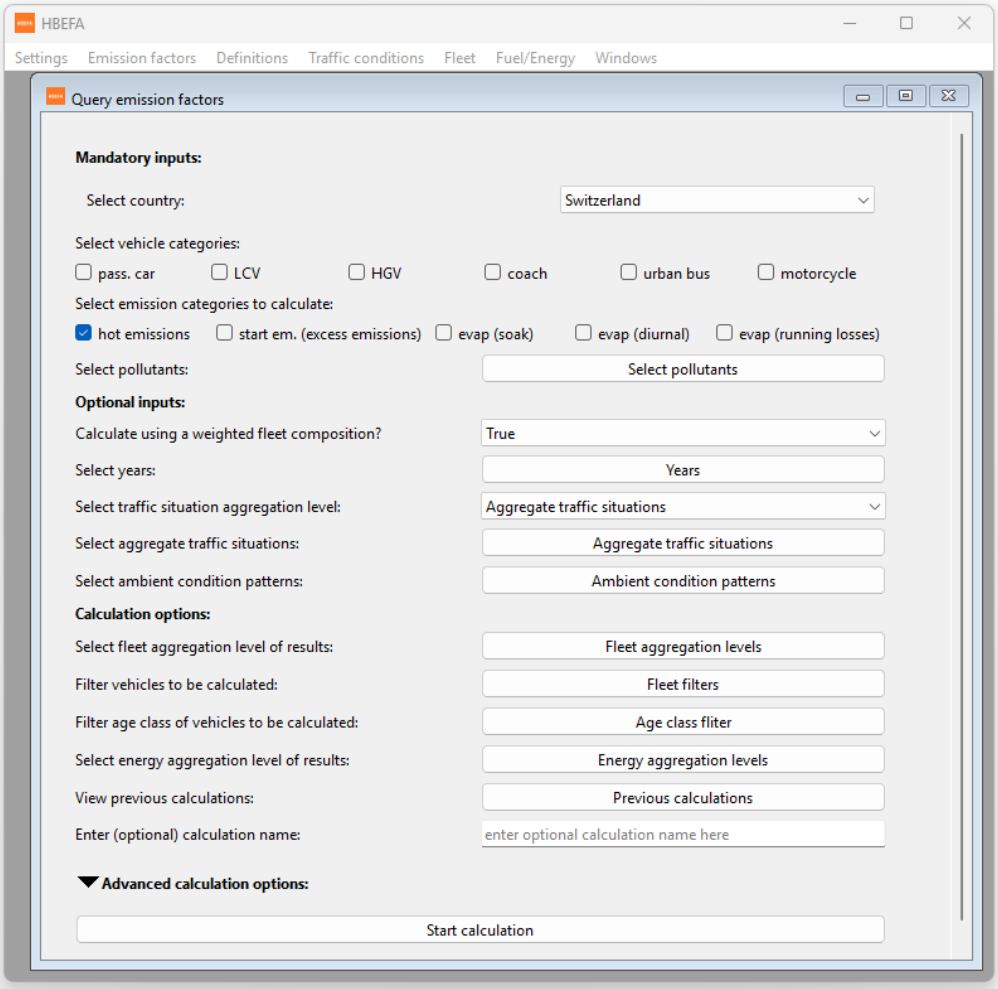
With the Python-based HBEFA, you can change the HBEFA version you want to use within the same application, via menu *Settings > Select HBEFA version*.

Currently, only HBEFA 4.2 can be selected besides HBEFA 5.1, but in the future, all new versions starting with HBEFA 4.2 should be available.

Please note, however, that only the current version should be used productively! Older versions represent an outdated state of knowledge and data and should only be used for comparison or pure informative purposes!

3.4. Querying emission factors

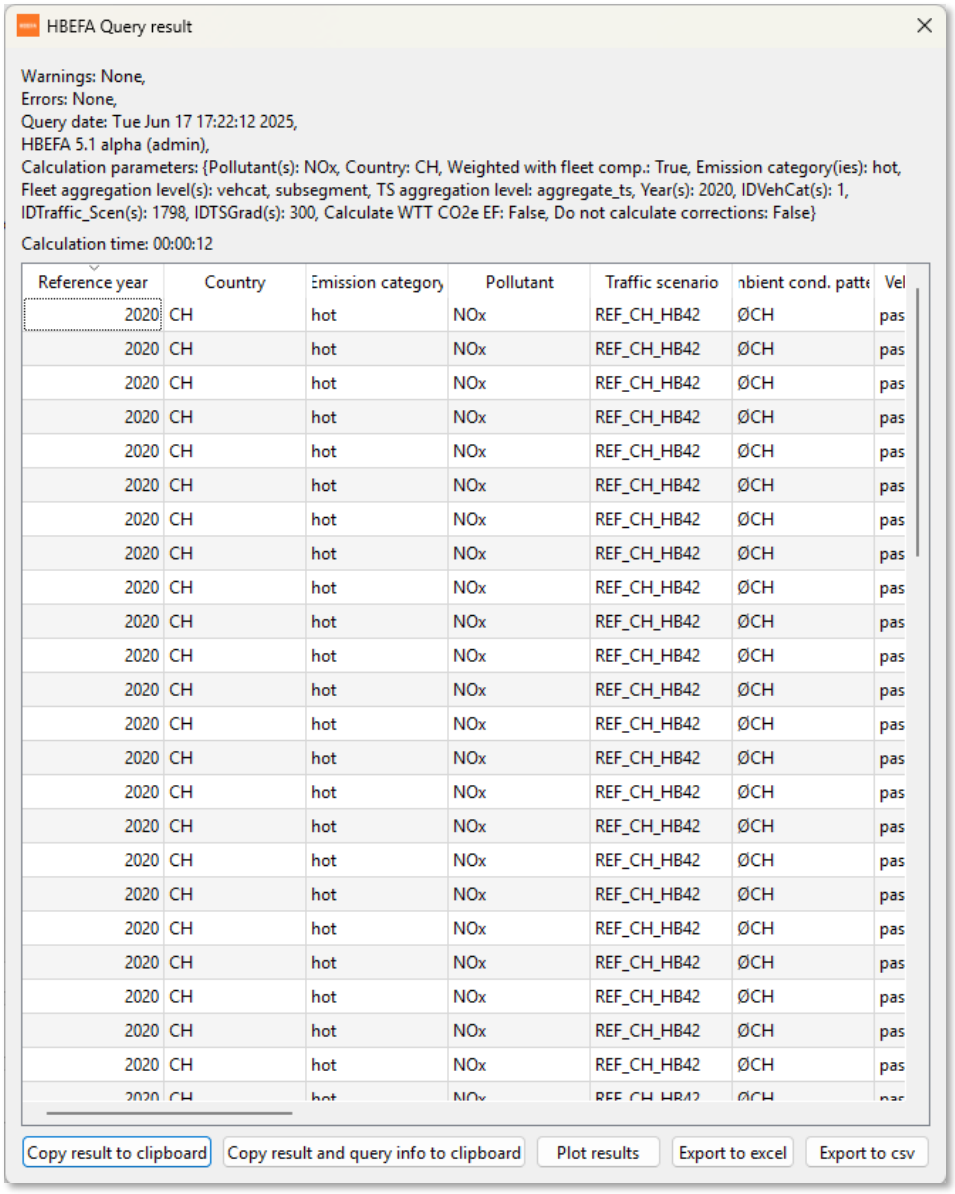
Emission factors can be queried/extracted by using menu *Emission factors > Query emission factors*.



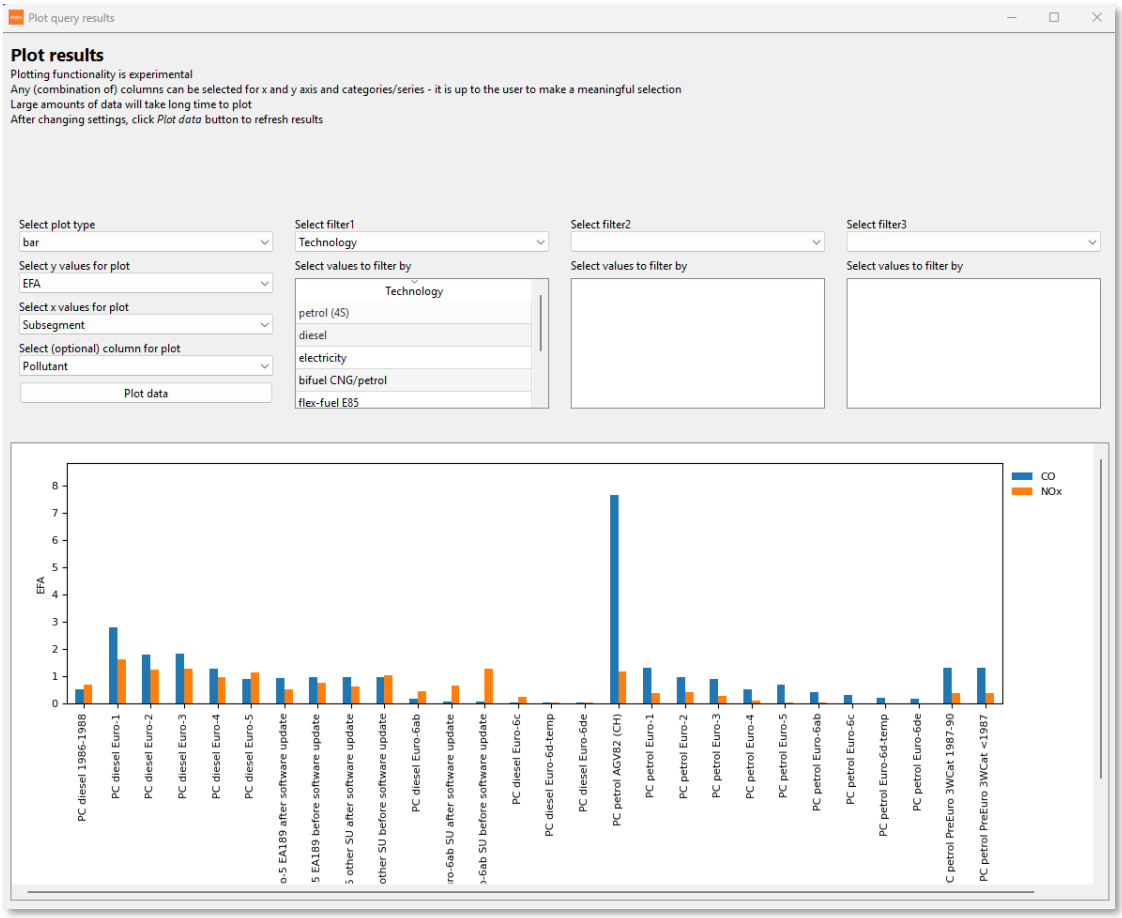
Please note:

- As a minimum, you have to select options in the section “Mandatory inputs”;

- "Calculate using a weighted fleet composition":
  - The default is "True" for a so-called "weighted" query → please see Weighting ("weighted" EF query)
  - You can choose "false" for a so-called "unweighted" query. For all "optional inputs" or "calculation options", default values apply if you don't select anything. The selected option(s) is/are shaded in blue (or yellow, depending on your computer settings);
- Some selection windows allow multiple selections (e.g. years, traffic situations, ambient condition patterns, fleet aggregation levels).
  Others allow only one option to be selected (e.g. traffic scenarios, energy aggregation levels);
- In the more complex filter windows (i.e. for individual traffic situations and the fleet filters), selecting entries in a table on the left limits the choices in the tables further to the right;
- Advanced calculation options: Click on the small black triangle to expand advanced calculation options. Some potentially useful options include:
  - "Calculating EF without correction factors": This will suppress mileage, ambient temperature, energy efficiency, and fuel quality corrections.
  - Some options influence the column structure of the emission factor query result – please see Chapter 3.5.
- "Start calculation" starts the calculation. A small status window will display the current calculation status until the result is shown in a new subwindow.



- The result subwindow shows the first 100 rows of the result as a maximum. To use or view the entire result,
  - copy the result to the clipboard to paste into another application (e.g. Excel); note that the option “Copy resultto clipboard” copies only the result table, “Copy result and query info to clipboard” also copies the metadata (query parameters, computation time etc.).
  - export the result to Excel or CSV.
- You can also plot results via the “Plot results” button on the result subwindow. This is still experimental, but it can help to give quick visual overview of results.



3.5. Emission factor query result

On top of the emission factor result window, some **meta-information** on the request is shown:

- Warnings and error messages: These should normally be “None”. Otherwise:
  - **Warnings** are rather informative, and in most cases directed to the user (e.g. informing that the request was large and therefore executed in iterations). The results are still valid even if there are warnings.
  - If **errors** are reported, the result of the query (if there is any) should be regarded as invalid. Optionally, INFRAS can be informed – we appreciate such reports.
- Query date (start time)
- HBEFA version (and user role, in brackets)
- Calculation parameters
- Calculation time (duration)
- Query end time (“produced” time)

This meta-information is copied to the clipboard along with the result table if you click the **button "Copy result and query info to clipboard"**, and inserted as first row above the result table if you paste the result to Excel.

The **columns** of the standard emission factor query output are shown in Table 2. Please note that this is a compilation of ALL columns that CAN BE shown in the standard output – but which ARE shown will depend on selections like the traffic situation or fleet aggregation level. In addition, some "advanced calculation options" influence the column output:

- "Select type of parameter columns in output": Here you can choose whether to output all result parameter columns (name columns AND ID columns), IDs only, or "standard" (this is as in HBEFA up to 4.2: Name columns are output, only for the Subsegment also the ID column is added).
- "Select option for results column titles": Here you can choose between "speaking" column titles or column titles as in the underlying database (option "db"). The latter may be preferrable if you want to postprocess results with tools that don't support upper- vs. lowercase or special characters in column titles.
- "Load parameter as rows instead of columns in results": If set to "True", results for the different loads will not appear in three columns, but "stacked" on different rows.
- "Include all aggregation columns in result": If set to "True", all aggregation columns will be output – i.e. if fleet aggregation level "subsegment" is selected, all aggregation columns (e.g. size class, technology, emission concept) will be output as well, or if individual traffic situations are selected, columns for the TS parameters area, road type, speed limit and LOS will be output as well.

Table 2: (Potential) columns in the standard emission factor output (the actual output depends on the query parameters selected).

Column	Description
Reference year	Year the EF results are valid for. For "unweighted" option: Default year (currently 2020)
Country	1- or 2-letter code for the country
Emission category	Emission category (hot, cold start, evap diurnal/soak/running losses)
Pollutant	Pollutant or "component" (i.e. energy consumption, positive engine work)
Traffic scenario	Traffic scenario (scenario for fleet composition/fleet data). Remains empty in case of an "unweighted" query.
Ambient cond. pattern	Ambient condition pattern (contains climate and RVP data; can also imply traffic/trip length/parking time distributions)
Vehicle category	Fleet aggregation level "vehicle category". This column is always included in the output
Technology	Fleet aggregation levels; these columns are included either if the option has been

Column	Description
Size class	selected as a fleet aggregation level, or if a lower level has been selected and "include all aggregation levels in results" has been set to True under "Advanced calculation options".
Segment	
Emission concept	
Subsegment	
IDSubsegment	The IDSubsegment is the only ID that is output in the "Standard" column output option. For all paramters, the inclusion of ID columns can be controlled with the "Select detail level of results columns" option under "Advanced calculation options".
Energy	Energy carrier. Left blank if not unique.
Aggr. traffic situation	Aggregated traffic situation. Shown if the traffic situation aggregation level has been set to "aggregated traffic situations".
Road category	Road category (MW/Rural/Urban or unspecified). Shown if the traffic situation aggregation level has been set to "aggregated traffic situations".
Traffic situation	Individual traffic situation. Shown if the traffic situation aggregation level has been set to "individual traffic situations".
Gradient	Gradient class. Shown if the traffic situation aggregation level has been set to "individual traffic situations".
Weight	Fleet weight - either mileage or stock share of the current vehicle type in the current vehicle category.
v	Average speed of the driving profile assigned to the traffic situation(s) [km/h].
v_0%	Average speed of the driving profile assigned to the traffic situation(s) at empty load (given for HDV only) [km/h]
v_100%	Average speed of the driving profile assigned to the traffic situation(s) at full load (given for HDV only) [km/h]
EFA	Emission factor
EFA_0%	Emission factor at empty load (given for HDV only)
EFA_100%	Emission factor at full load (given for HDV only)
EF unit	Emission factor unit
Cum. mileage	Cumulative mileage [km]

3.6. Query duration and large queries

Please note that due to the large data amounts potentially processed in HBEFA 5.1, **emission factor queries can take some time** (several minutes depending on the number of pollutants, years, vehicle types selected). To avoid unnecessary waiting time, it is therefore **recommended to only query the categories (pollutants, vehicle types, years, traffic situations, emission categories) actually needed**, instead of just selecting “all” categories.

3.6.1. Safeguards to prevent server overload

Due to limits of the server capacity, several **measures** are built-in **to prevent overload**:

- If a query is requested that requires the server to internally calculate with a large data amount, but the result is not too large to be stored or transmitted, the request is broken up into several iterations. In that case, the request will take a longer time to complete. A warning in the output will inform the user (retrospectively).

- If a query is requested that will create a very large output (which may be too large to store internally on the server or take too long to transmit to the client), the server will refuse the request and tell the user to break down the request into several smaller requests.
- The server periodically checks if the client that started the request is still querying the status of the request. If a query is cancelled (e.g. by hitting the “Esc” key while the calculation status is displayed), the server will stop the calculation at the next checkpoint.

In spite of these safeguards, a server overload cannot be ruled out if many users send large requests simultaneously. If this happens, an error message will be shown to the user. The same query can be tried again later.

3.6.2. Calculation times

The calculation times emission factors vary greatly and depend on the complexity of the request. The calculation time for emission factors is determined by the following parameters:

- **Number of base categories**: The runtime increases with the number of base categories requested, i.e.:
  - Number of subsegments
  - Number of individual traffic situations
  - Number of pollutants/components
  - Number of emission categories
  - Number of reference years
- **Aggregation**: The calculation time of aggregated results also depends on the number of base categories required (see above), even if the final result may be aggregated to few rows.
- **Size of the result**: Very large queries that generate millions of data rows require additional time to convert the data to JSON format and transfer it.
- **Server restart:** After a server restart, the first larger query (in terms of base categories) will trigger reading in all base emission factors, which takes several minutes. The read-in data are available to all subsequent requests, so they will be faster. Since the central server usually does not have to be restarted, this should only happen very rarely.
- **Caching of cold start emissions:** Cold start emission factors require a large amount of input data; however, at subsegment level, they do not vary with reference years, since they are not corrected for mileage. Therefore, they only need to be calculated in full for the first year; for subsequent years, the results from previous years are reused. As a consequence, a cold start EF query will take long for the first year in the request, but be much faster for the subsequent years.

Example calculation times:

- For few subsegments and traffic situations, and an individual emission category, a request typically takes 10-30 seconds;
- The combination of all emission categories (hot, start, evap-soak, etc.) and all pollutants for one year depends on the reference year: The later, the more complicated the fleet (due to more technologies, more emission standards etc.), and the higher the calculation time. A query for all pollutants, emission categories, and vehicle types for the year 2020 can take approximately 10 minutes. To avoid unnecessary waiting time, it is therefore advisable to only query the categories (pollutants, vehicle types, years, traffic situations, emission categories) for which you actually need results.
- For multiple reference years, the calculation time multiplies with the number of years – except for cold start, where emission factors do not depend on the year.

3.7. Saving outputs, re-running previous requests

In previous HBEFA versions, queries were saved as “cases” so they could be re-run later, and emission factor query results could be saved to a “user” database.

In the current, Python-based HBEFA, **previous requests can be re-run** by clicking the “Previous calculations” button on the Emission Factor Query form. This will display a table of all previous EF requests of the logged-in user with ID, request name, creation date, and query parameters. The column headers can be clicked on to sort or reverse-sort by the column contents (e.g. the date).

The ”request name” column is empty per default. A request name can optionally be entered BEFORE starting the calculation in the field “Enter optional calculation name” below the “previous calculations” button. It can help finding a certain result again later.

As opposed to previous HBEFA versions, **saving query outputs** within the application is not supported anymore. Instead, the user can copy-paste or export the outputs to Excel or a CSV file to save them.

3.8. Hints on application handling

3.8.1. Resizing GUI elements

- You can hover the mouse over separations between tables or graphics on HBEFA application subwindows. When the mouse arrow changes to a symbol with two arrows ( , ), you can drag the border to enlarge the element on one or the other side.

- If high table rows are displayed because of long texts in some columns, the respective columns can be made wider by:
  - Dragging the separators: Hover the mouse over the column separator in the header, then drag when the mouse changes to this symbol  symbol,
  - Double-clicking on the right column separator in the header – this will increase the column width so that the longest texts in it will have room in one row.

3.8.2. Getting additional info, filtering, sorting

- Right-click on an ID or dataset name brings up a “Select …” option. Clicking it will open the dataset in a separate window.
- Right-click on column headers brings up an option to filter the table by a substring. Python Regular Expressions (RegEx) are also supported.
- Left-click in column headers sorts the table by the contents of that column.

4. Alphabetic reference

Abbreviations (Glossary)

Abbreviation	Description
2S	2 stroke petrol engine
4S	4 stroke petrol engine
a	Acceleration
AC	Air conditioning
ACR	Active carbon reduction (for reducing the HC evaporation emissions)
API	Application Programming Interface: a set of rules and protocols that allows different software systems to communicate and exchange data. In the case of HBEFA, the HBEFA server provides an API that the main front-end can communiate with.
AT	Articulated truck
BAB	German motorway driving cycle (Bundesautobahn)
BAFU	Swiss Federal Office for the Environment (FOEN), Bundesamt für Umwelt
BEV	Battery-electric vehicle
Case	User-defined parameter combination for calculating emission factors
Cat	Catalytic converter
CH	Switzerland
CH4	Methane
CNG	Compressed natural gas
CO	Carbon monOxide
CO2	Carbon dioxide
CSEE	Cold start extra emissions
D	Diesel
DP	Driving profile
DPF	Diesel Particle Filter
DT	Distance travelled, mileage
ECE	Economic Commission for Europe
EEA	Exhaust Emissions Act. In the context of the Handbook, this term refers to Swiss regulations: EEA 1 = Light motorised vehicles, EEA 2 = Heavy motorised vehicles, EEA 3 = Motorcycles, EEA 4 = Mopeds
EF, EFA, E-Factor	Emission factor
EFA_weighted	Emission factor, weighted (according to fleet compositions)
EGR	Exhaust Gas recirculation
EMPA	Federal Materials Testing and Research Institute, Dübendorf
EU	European Union
EURO-1, -2, -3 etc	European emission standards for light duty vehicles
EURO-I, -II, -III etc	European emission standards for heavy duty vehicles (exception: for Euro-7, also the HDV standards carry an arabic number)
FEA	Federal Environmental Agency (=UBA: Umweltbundesamt)
FFV	Flex-fuel vehicle
HC	Hydrocarbons
HGV	Heavy goods vehicles {= general term for trucks, truck trailers (TT) and articulated trucks (AT)}
HDV	Heavy duty vehicle {= vehicles > 3.5 t total weight; = general term for heavy goods vehicles (HGV), coaches (RBus) and urban buses (LBus)}

Abbreviation	Description
HEV	Hybrid electric vehicle. Note that within HBEFA 5.1, HEVs are only differentiated from ICE vehicles for HDVs. For LDVs, HEV are included with ICE vehicles, since most modern ICE vehicles exhibit hybridisation to some degree.
IBA	In built-up area
IUFC	INRETS Urbain Fluide Court, driving cycle used to produce empirical input data for cold start extra emissions up to HBEFA 4.2.
Lbus	Bus, urban bus, public transport bus (German: Linienbus)
LEV	Low Emission Vehicle
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
LNG	Liquefied natural gas
MC	Motorcycle
NEDC	New European Driving Cycle. Driving cycle for LDV type approval tests in Europe until 2018, when it was replaced by the WLTP (Worldwide Harmonized Light Vehicles Test Procedure)
NMHC	Non-methane hydrocarbons
NMOG	Non-methane organic gases
NOx	Nitrogen oxide
OBA	Outside built-up area
Pb	Lead
PHEV	Plug-in Hybrid Electric Vehicle
PM	Particulate matter (weight)
PN	Particle number
PC	Passenger car
Rbus	Coach (German: Reisebus)
RPA	Relative positive acceleration[1]
RVP	Reid vapour pressure. Absolute vapor pressure exerted by a liquid at 100°F (37.8°C); a measure of a fuel's volatility, indicating how readily it evaporates at a specific temperature.
SCR	Selective catalytic reduction (for NOx-reduction)
SO2	Sulphur dioxide
TLEV	Transient Low Emission Vehicle
TLS	Traffic light system
Truck	Truck
TS	Traffic situation
TT	Truck-trailer, Trailer truck
TTW	Tank-to-wheel. Term for emissions from energy provision.
TUG	Technical University of Graz
TWV	Two-wheeled vehicle
UBA	Umweltbundesamt (Germany, Austria), Federal Environment Agency
ULEV	Ultra Low Emission Vehicle
v	Speed, velocity (in km/h)
VDA	Verband der Automobilindustrie e.V.
VOC	Volatile Organic Compounds
VS	Vehicle segment
WLTP	Worldwide Harmonized Light Vehicles Test Procedure. Type approval test procedure for LDV used in Europe since 2019.
WTT	Well-to-tank. Term for emission from vehicle operation/use

Abbreviation	Description
WTW	Well-to-wheel. Total emissions from energy provision and vehicle operation.
ZEV	Zero Emission Vehicle

Additional units

By default, HBEFA outputs emission factors in grams (for most pollutants), MJ (for energy consumption) or # (particle number PN) per traffic unit related to the respective emission category. This means:

- For hot and evap-running losses EF, the default output unit is .../vehkm;
- For cold start EF, the default output unit is .../start;
- For evap-soak EF, the default output unit is .../stop;
- For evap-diurnal EF, the default output unit is .../veh*day;

In HBEFA 5.1, the option to select additional output units has been added:

- EF per vehicle km for emission categories with other original activity units (cold start, evaporation)
- EF per MJ of final energy consumption (EC)
- EF per kg fuel consumption (FC)
- EF per kWh of positive engine work (WE-pos)
- Fuel consumption (FC) in l/100 km (for liquid fuels) or Nm3/100 km (for gaseous fuels)

If one of these options is selected, rows with the additional selected output units are added to the result. The rows with the original (default) units (see above) are always included as well. For requested output units that do not make sense or no input data is available, the unit conversion is skipped and a warning is issued This is the case e.g.

- if EC (energy consumption) is requested in combination with the output unit "…/MJ" – because MJ/MJ does not make sense, the EF value would always be 1 in this case;
- or if the output unit "…/kWh" is requested for cold start EF. This would theoretically be possible, but cold start extra positive engine work (WE-pos), which would be required to calculate this unit, is not available.

Please note:

- If you select "l/100 km" or "Nm3/100 km" in combination with vehicle category fleet aggregation level, the result will be disaggregated by liquid and gaseous fuels, since two different units per vehicle category may be involved. In this case, the row with unit "l/100 km" will be valid for all vehicles of the respective vehicle category with liquid fuels, and the row

with unit “Nm3/100 km” will be valid for all vehicles of the respective vehicle category with gaseous fuels.

Aggregate traffic situations

Aggregate traffic situations (sometimes also referred to as “average traffic situations”) define patterns of mileage shares of individual traffic situation/gradient combinations for a given vehicle category and geographical region. For every country covered, there is at least an urban, rural, motorway, and overall pattern available; for some countries there are more choices. They are useful to quickly query average emission factors – overall or by road type.

See menu *Definitions* > *Traffic situations* > *Individual traffic situations*) and Chapter 2.2.5.

Air conditioning

The option for the user to explicitly select whether air conditioning emissions are calculated or not has been deactivated in HBEFA 4.x. A/C excess consumption and emissions are now included in the base emission factors calculated by the PHEM model. The share of vehicles with A/C corresponds to the European average for the respective subsegment, and the usage has been calibrated to real-world fuel consumption data.

Ambient condition patterns

"Ambient condition patterns" in HBEFA refer to country-specific datasets of factors that influence emissions, i.e.:

- Climate data (mainly temperature distributions)
- Season-dependent fuel characteristics (i.e. Reid Vapour Pressure, RVP)
- Driving behaviour characteristics (traffic volume distribution over the day, trip length and parking time distributions)

Up to HBEFA 4.2, all these datasets were linked to ambient condition patterns. In HBEFA 5.1, the data model has been extended so that different driving behaviour patterns can be assigned to different vehicle types via the fleet model. Therefore, in HBEFA 5.1, the driving behaviour characteristics (traffic volume distribution over the day, trip length and parking time distributions) linked to the seasonal subambient condition patterns in menu *Traffic conditions* > *Subambient condition patterns* are only relevant if the corresponding if the corresponding ambient condition pattern (in menu *Traffic conditions* > *Ambient condition patterns*) has the value “True” in the corresponding column “distrib_traffic_from_pattern”, “parking-

time_from_pattern", or "triplength_from_pattern". For all other cases, the IDs of the relevant driving behaviour datasets/patterns can be looked up via menu *Fleet > Analyse fleet composition* in the columns "iddistrib_trafficday", "idset_parkingtime" and "idset_triplength".

Case

A "case" was the term for an emission factor query that could be created, saved, or re-run in HBEFA versions up to 4.2. Please refer to Chapter 3.7 for information on how to re-run previous queries or save your results in the current application.

Components

Another, more generic term for "pollutants" (more appropriate when referring to output components that are not pollutants, like EC (energy consumption) or WE-pos (positive engine work). Please see menu *Definitions > Pollutant definitions*.

Computing a "case"

"Case" was the term used in the MS Access HBEFA up to Version 4.2 for an emission factor query. Please refer to Chapter 3.4 (Querying emission factors).

Computing time

Please refer to Chapter 3.5 (query duration and large queries).

Concept

Or "Emission concept": Basically, another term for "emission standard" – but it can also include additional characteristics like aftertreatment technology. See menu *Definitions > Vehicles > Emission concepts*.

CUMKM

Another term for cumulative mileage. Relevant for mileage correction to account for catalyst ageing. See menu *Fleet > Analyse fleet composition*

Deleting a case

This is not possible or necessary anymore, since emission factor query results are not saved as data. Please refer to Chapter 3.7.

DPF – diesel particle filter

Diesel particle filters primarily reduce the particle emissions (mass and numbers). DPFs can be implicit part of an emission concept or they are optional devices (e.g. retrofitting). For emission concepts (emission standards) under which DPFs is optional, the respective vehicle fleet is split into vehicles with and without DPF, since particle emissions are very different for the two groups. In such cases, the emission concepts or subsegments carry the suffix "-DPF".
See e.g. menu *Fleet > Analyse fleet composition.*

Displaying results

Please refer to Chapters 3.4 (Querying emission factors) and/or 3.5 3.7 (Saving outputs, re-running previous requests).

Driving patterns

A "driving pattern" represents a typical driving behaviour and can be described with the help of kinematic parameters (typically average speed, dynamics). The emission factors are originally calculated for these driving patterns. However, for the practical application it is of more interest to know emission factors for different situations on the different types of roads. Therefore, the term "Traffic Situation" has been introduced, and the emission factors in the Handbook are given for different "traffic situations" by attributing the driving patterns to different traffic situations (based on statistical analyses). The term "traffic situation" is more flexible than e.g. a static term such as "road section" because different driving patterns in reality do occur on the same road (e.g. stop and go at peak times, fast driving during off-peak periods). At the same time the term "traffic situation" can be applied equally to all vehicle categories, whereas the "driving patterns" are defined differently for each vehicle category.

The menus *Definitions > Traffic situations > …* contain all information about traffic situations. Under menu *Definitions > Traffic situations > Individual traffic situations*, the driving profiles of all traffic situations can be viewed and exported.

Edit a case

Please refer to Chapter 3.53.7 (Saving outputs, re-running previous requests).

Emission concept

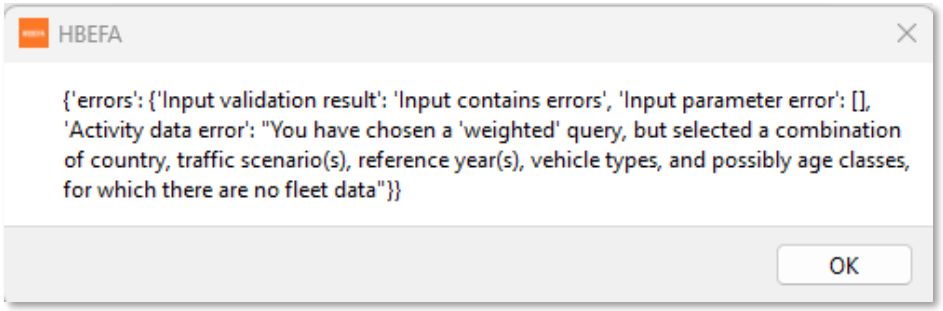
Please refer to Chapter 2.2.3.

Emission category

Please refer to Chapter 2.2.1.

Empty results tables

In most cases, if you query emission factors for a combination of parameters for which no emission factors exist (e.g. BEVs in the year 1990), the server will return an error message like:



There may, however, be some cases in which still an empty result table is returned because there are no EF results to display.

Energy

Please refer to Chapter 2.2.4.

Export to Excel

Please refer to Chapters 3.4 (Querying emission factors) and/or 3.53.7 (Saving outputs, re-running previous requests).

Fleet composition

Also: Traffic Composition. Please refer to Chapter 2.6.

Fuel

Please refer to Chapter 2.2.4 (Energy).

Fuel quality

Please refer to Chapter 2.3.2 (Corrections, fuel quality correction), and see the menus *Fuel/Energy > Fuel quality …*

Future vehicle concepts

The Handbook also contains emission factors for future concepts (in HBEFA 5.x, Euro-7 emission factors for petrol and diesel PC). The emission levels of these concepts were estimated on the basis of the future regulations. For details about limit values and assumed correction factors please check the underlying reports in www.hbefa.net (documents).

Gradient classes

See menu *Definitions > Traffic situations > Gradient*.

HBEFA versions

Please see Table 1 for a list of all published HBEFA versions.
For info how to select a version in the HBEFA front-end, please refer to Chapter 3.3 (Selecting an HBEFA version).

Installation

The HBEFA front-end (desktop client) does not require installation. See Chapter 3.2 on application download and start.

Literature

Please check www.hbefa.net:

- Technical documentation
- Reports

Load

Load (i.e. cargo load, not engine load) is mainly relevant, and explicitly modelled, for HDV. For these, EF values in the columns “EFA_0%” (empty) and “EFA_100%” (full load) are output. The “EFA” column contains for HDV:

- EF at 50% load in case of an “unweighted” query
- EF at average load (determined by the fleet model) in case of a “weighted” query

For all loads in between, the EF values can be linearly interpolated.

Regarding the output structure of the EF query, you can set the option “Load parameter as rows instead of columns in results” to “True” under “Advanced calculation options” on the EF query form. In that case, results for the different loads will not appear in three columns, but “stacked” on different rows.

Memory management

Please refer to Chapter 3.5 (Query duration and large queries).

Mileage

Please refer to Chapter 2.3.2 (Hot EF, corrections), and see menus *Definitions > Correction factors > mileage deterioration*.

Name conventions

As opposed to HBEFA Versions up to 4.2, any name (containing any characters) can be chosen for an EF query. It is optional anyway to name queries – but assigning a name may help to find a particular query again (see Chapter 3.7).

Online version

The website www.hbefa.net (> *Software > Online Version*) contains an "Online Version" of HBEFA, i.e. a web application that provides aggregated emission factors (for the 6 countries D, A, CH, SE, N, F). Please note the following differences between the full HBEFA application and the Online Version:

- The Online Version provides all emission factors (also cold start and evaporation) in g/km, while in the full HBEFA application, default units differ by emission category (see Chapter 2.2.2)
- Small differences between EF values of the Online Version and the full HBEFA application are possible due to the derivation methodology of the Online Version: For the latter, we perform an emissions calculation for all countries, i.e. we calculate all emissions in t/a by multiplication of EF with activities (mileages, starts, stops, vehicles), then divide the emissions by mileage. The EF in the Online Version are therefore "implied emission factors". Because the shares of motorway, rural, and urban mileages are inputs into this emission calculation and may slightly deviate from the shares used in the fleet model (which is used to aggregate emission factors in the full HBEFA application), also the implied emission factors in the Online Version may show small deviations from those in the full HBEFA application.
- As of HBEFA Version 4.2, the "CO_2" available in the Online Version includes *fossil* CO_2 only, i.e. it corresponds to "CO_2 (rep.)" in the full application. Previous Online Versions included CO_2 from fossil and renewable sources, which corresponded to "CO_2 (total)" in the full HBEFA version – but it was not what most users were expecting.

Parking times

Cold start emission factors and evaporation emissions (after the engine has been switched off; hot/warm soak) depend on the engine temperature. This in turn depends on the time the vehicle was parked previously.

See menus *Traffic conditions > Ambient conditions > Parking time distributions/Diurnal variation of parking time distributions*.

Particle filters, particle traps

[-> DPF – diesel particle filter]

Pollutants/Components

Please see Chapter 2.2.1 and menu *Definitions > pollutant definitions*.

Result tables

Please refer to Chapters 3.4 and 3.5.

Segment

Please refer to Chapter 2.2.3.

Software updates

HBEFA accounts for the software updates after the Dieselgate scandal. In HBEFA 4.1, emission factors for the Euro-5 diesel cars with an EA189 engine updated in the compulsory VW update round were made available based on the current availability of measurement data. Additional software updates (Euro-5 other than EA189 and Euro-6ab) have been included with HBEFA 4.2.

Software update EF are implemented in such a way that not only emission factors for the updated PC are available in addition to the “normal” emission factors, but also the effect of vehicles being updated on the non-updated rest of the fleet can be accounted for. This was achieved by differentiating three subsegments for every source subsegment in which software updates take place. These include:

- The vehicles not affected by the update: e.g. subsegment “PC diesel Euro-5”
- The affected vehicles before the update, e.g. subsegment “PC diesel Euro-5 EA189 before software update”
- The affected vehicles after the update, e.g. subsegment “PC diesel Euro-5 EA189 after software update”

Static traffic situation

An HBEFA traffic situation (TS) is defined by four parameters – area, road type, speed limit, and level of service. By leaving out the dynamic parameter "level of service" (LOS) that changes in time, we are left with the "static" parameters area, road type and speed limit. A "static traffic situation" is therefore a situation defined by these three parameters only.

In HBEFA 5.1, the possibility to query emission factors by static TS has been introduced. To this end, a weighted average of the EF for the involved LOS is calculated. The weights are taken from the "aggregate traffic situation" that can be selected in the emission factor request (or the default "aggregate traffic situation" for the respective country is used).

See also Chapter 2.2.5.

Subsegment

Please refer to Chapter 2.2.3.

Tampering, malfunctions, "tampered" subsegments (*)

Tampering and malfunctions of SCR (Selective Catalytic Reduction) catalysts result in severely higher NOx emission factors. For HDV, HBEFA contains emission factors for tampered vehicles. These can be recognized by the asterisk (*) at the end of the subsegment name. The NOx EF of these vehicles correspond to the engine-out emissions; the EF of all other pollutants are identical to their non-tampered counterparts.

Up to HBEFA 4.2, the "tampered" subsegments were not taken into account in the fleet compositions and were therefore available only in an "Unweighted" EF query. In HBEFA 5.1, high emitter rates have been estimated on plume-chasing studies and remote sensing (see the "HBEFA 5.1 Update documentation"[4]).

In LDV, SCR tampering may also occur; and in addition to SCR tampering, also DPF – diesel particle filters may be tampered. These effects, which also lead to high emitters, are taken into account on average for the entire fleet, since the mileage correction functions (see Chapter 2.3.2) are based on remote sensing data NOT excluding high emitters (for HDVs, high emitters have been excluded from the datasets used to derive the mileage correction functions for NOx such as not to double-count tampering/malfunctions).

[4] https://download.hbefa.net/reports/hb51/HBEFA5.1_Update_documentation.pdf

All in all, tampering and malfunctions lead to high uncertainty in emissions, which HBEFA users should remain aware of. The HBEFA workgroup will strive to improve the basis for EF affected by these effects by further research in the future.

Technology

The term "technology" in the vehicle/fleet classification of HBEFA refers to drivetrain technology (not aftertreatment technology). We further differentiate (see also menu *Definitions > Vehicles > Technology*):

- A "base technology" is a single technology, i.e. petrol (Otto engine), diesel, electric;
- A "multi-technology" refers to multiple base technologies in the same vehicle, e.g. electricity and diesel/petrol in PHEVs, or CNG and petrol in bi-fuel vehicles.
  Please note that **"multi-technology" vehicles are split into two subsegments!**
  The respective subsegment names carry a suffix "_(<BaseTechAbbreviation>)", e.g. for a Euro-6de petrol plug-in hybrid passenger car:
  - «PC PHEV petrol Euro-6de_(El)» - this represents the electric (or charge-depleting) driving mode, or the respective mileage
  - «PC PHEV petrol Euro-4_(P)» - this represents the combustion-engine (or charge-sustaining) driving mode, or the respective mileage

Temperature

The ambient temperature is required for calculating the cold start or evaporation factors (see Chapters 2.4 and 2.5) as well as air conditioning corrections (see Chapter 2.3.2).

Country-specific temperature input data can be accessed via menu *Traffic conditions > Ambient condition patterns > Diurnal variation of temperature and humidity*.
The temperature correction functions can be viewed in *menu Definitions > Correction factors > Ambient temperature In* (equations) / *Out* (resulting correction factors).

Traffic composition

Please refer to Chapter 2.6.

Traffic situation

Please refer to Chapter 2.2.5, and/or see the "Traffic Situation Guidelines" available on the Website of the German Environment Agency (http://www.umweltbundesamt.de/publikationen/hbefa-traffic-situations)

Trip lengths

Trip length distributions are used for calculating cold start emission factors and evaporation losses after the engine has been switched off (hot/warm soak).

See menus *Traffic conditions > Ambient conditions > Trip length distributions/Diurnal variation of trip length distributions*.

Uninstall

Since the HBEFA front-end does not require installation, it doesn't need to be uninstalled either – the application files can just be deleted. See Chapter 3.2.

"Unweighted" EF query

In an "unweighted" EF query, no "traffic scenario" or reference year can be selected and consequently, no information from the "traffic scenario" (such as fleet composition, mileage or energy efficiency correction factors) is used. Therefore:

- Results will also include subsegments that do not form part of the fleet composition
- No fleet aggregation can be performed and only the fleet aggregation level "subsegment" is possible.
- No correction for mileage, energy efficiency, or fuel quality is performed (ambient temperature correction for NOx is carried out, however)

What is not strictly consistent in the "unweighted" query is that everything that has to do with the fuel mix (e.g. calculation of fossil CO2, split by base energy) is still calculated, even though this requires a reference year to be assumed (because the fuel mix varies over time). For this, the default year of the HBEFA version (for 5.1: 2025) is assumed.

Please use the "weighted" query (see Chapter 3.4 and Weighting ("weighted" EF query)) by default; the "unweighted" option should only be used for special cases (when you explicitly want to exclude corrections, or to query EF for subsegments not contained in a fleet composition).

Variation in fleet/traffic composition

The Handbook provides one reference traffic scenario/fleet composition per HBEFA version and country. In the Public Version of the Handbook, fleet data (e.g. higher or lower percentages of diesel vehicles, changing splits of Euro-Classes etc) cannot be changed directly in the Handbook.

However, if necessary, you can achieve this by querying emission factors at a detailed fleet aggregation level, if necessary even without corrections (see Chapter 3.4), and then perform the adapted aggregations and corrections outside HBEFA.

Vehicle category

Please refer to Chapter 2.2.3.

Weighting (“weighted” EF query)

In a “weighted” EF query, a “traffic scenario” and reference years are selected, and based on this information, aggregations and corrections can be carried out.

The percentages of the individual vehicle types or concepts are weighted differently in aggregation, depending on the type of emission and road category:

- A traffic composition based on the km driven is applied to the hot emission factors. The weights differ by the 3 types of fleet compositions (motorway, rural, urban).
- For calculating the cold start emissions and the evaporation emissions (hot/warm soak), the "urban" traffic composition is applied.
- A vehicle composition based on the numbers of vehicles is applied to calculate the diurnal evaporation emissions.

The percentages (weights) used in the various versions of Traffic Composition are given in the results tables (for the "per vehicle concept" or "per vehicle segment" aggregation types). The shares are also given the menus “Info: FleetComposition …”.

WTT emission factors

HBEFA versions 4.x contained CO2e emission factors for energy provision (Well-to-Tank, WTT). This option was discontinued in HBEFA 5.1, since it would have required continuous updates of production type-specific emission factors and shares of production types of energy (energy mixes). This would have required relevant continuous effort and is not within the focus of HBEFA, while there are better, dedicated sources for such information (such as various LCA databases).

www.hbefa.net

The HBEFA website www.hbefa.net contains background information and reports describing the sources of the emission factors of the handbook. The website offers also an Online version of the handbook with aggregate emission factors for the 6 countries (D, A, CH, SE, N, F).

Years

Please see Chapter 2.2.6.

Literature references

EcoTransIT World 2023: Environmental Methodology and Data - Update 2023. https://www.ecotransit.org/wp-content/uploads/20230612_Methodology_Report_Update_2023.pdf [Accessed 6. December 2023].

Favez, J. Y., Weilenmann, M., Stilli, J. 2009: Cold start extra emissions as a function of engine stop time: evolution over the last 10 years. Atmospheric Environment, 43(5), 996-1007. https://doi.org/10.1016/j.atmosenv.2008.03.037 [Accessed 2. September 2024].

Hausberger, S., Rexeis, M. 2018: PHEM. Passenger car and Heavy duty Emission Model. Institute for internal combustion engines and thermodynamics, Technical University of Graz, Graz, Austria. https://www.ivt.tugraz.at/assets/files/download/PHEM_en.pdf [Accessed 17. March 2021].

INFRAS 2007: ARTEMIS: Assessment and reliability of transport emission models and inventory systems. Road Emission Model – Model Description. European Commission, Brussels.

Mellios, G., Ntziachristos, L., Samaras, Z., White, L., Martini, G., Rose, K. 2024: EMEP-EEA emission inventory guidebook 2023. Chapter 1.A.3.b.v. Gasoline evaporation from vehicles. https://www.eea.europa.eu/en/analysis/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-v [Accessed 17. June 2025].

Notter, B., Füssler, J. 2018: Road transport GHG emission factors for Kenya. Pilot study for 2015. Short report. GIZ (Gesellschaft für Internationale Zusammerbeit GmbH). https://www.changing-transport.org/publication/road-transport-ghg-emission-factors-kenya/ [Accessed 29. March 2021].

Opetnik, M., Hausberger, S., Dippold, M., Weller, K. 2025: Cold start extra emissions model for HBEFA 5.1. Presentation at the Transport and Pollution (TaP) Conference, 4-6 November 2025, Rueil-Malmaison, France.

Sun, S., Schmied, M., Bongardt, D., Wüthrich, P., Eichhorst, U. 2014: Modelling Energy Consumption and GHG Emissions of Road Transport in China. Technical Paper on the CRTEM/HBEFA China Model.

Tietge, U., Diaz, S., Mock, P., Allekotte, M., Heidt, C., Knörr, W., Althaus, H.-J., Notter, B., Oberpriller, Q., Läderach, A., Hausberger, S., Matzer, C., Eisenmann, C., Kuhnimhof, T. 2020: Erarbeitung einer Methode zur Ermittlung und Modellierung der CO2-Emissionen des Kfz-Verkehrs. Forschungskennzahl 3716 58 180 0. ICCT, ifeu, INFRAS, TU Graz, DLR im Auftrag des deutschen Umweltbundesamtes (UBA). https://www.umweltbundesamt.de/publikationen/erarbeitung-einer-methode-zur-ermittlung [Accessed 11. December 2020].

Weilenmann, M., Robert Alvarez, J-Y Favez 2009: Cold-start emissions of modern passenger cars at different low ambient temperatures and their evolution over vehicle legislation cate-

gories. Atmospheric Environment, 43, 996–1007.
https://www.dora.lib4ri.ch/empa/islandora/object/empa:2359 [Accessed 2. September 2024].