COPERT Training

What's new in version 5.4

European Environment Agency
European Topic Centre on Air pollution,
transport, noise and industrial pollution

Summary of new elements in v5.4

- Introduction of plug-in hybrid (PHEV) passenger cars
- Introduction of hybrid buses
- Revision of Euro 5 emission factors for PCs & LCVs
- Revision of Euro 6 emission factors for PCs & LCVs
- Parameter updates – error fixes

Energy consumption and emission factors for PHEV passenger cars

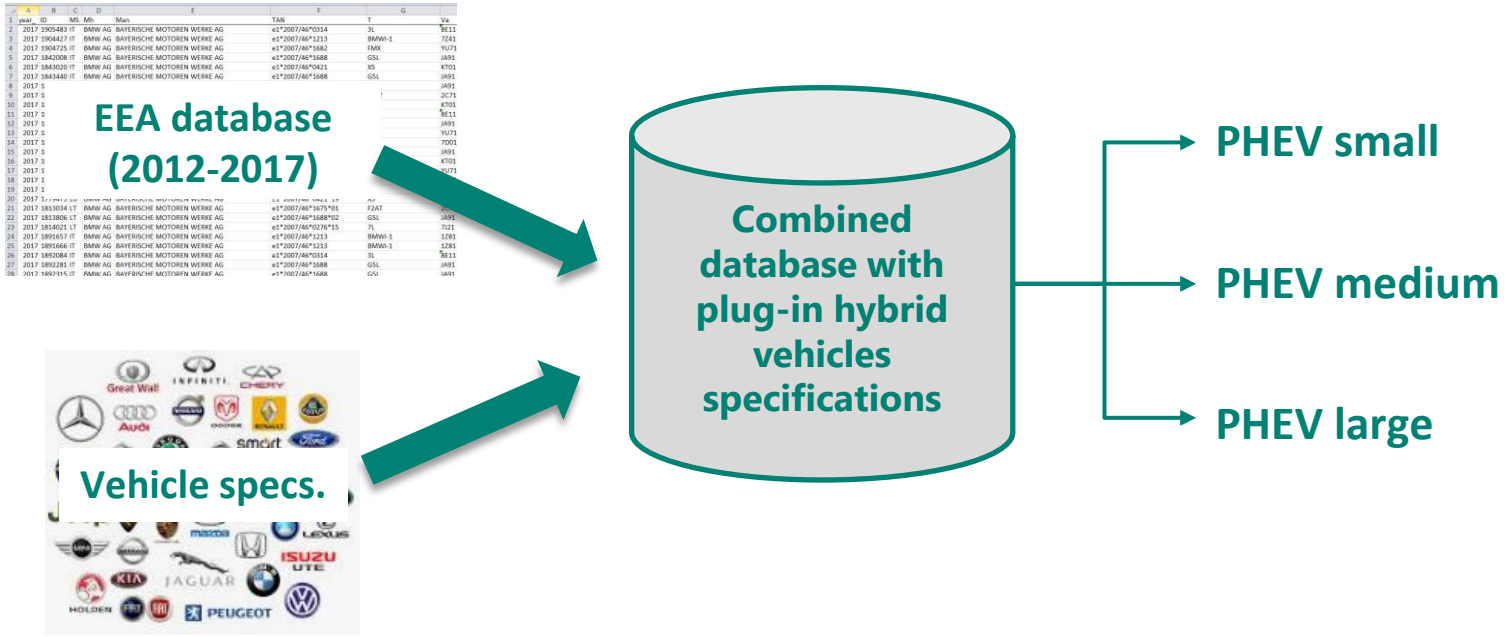
European Environment Agency
European Topic Centre on Air pollution, transport, noise and industrial pollution

Methodology

- Computational simulation of PHEV's operation
- Two operating modes simulated: charge depleting (CD) and charge sustaining (CS)
- Different simulation models for each segment (small / medium / large) of PHEV cars.
  - Average specifications for each segment are used to create simulation models of the average vehicle per segment
- Models run over various driving cycles (WLTC / CADC / RDE) with high and low initial SOC
  - High initial SOC → CD mode → Electric energy consumption
  - Low initial SOC → CS mode → Fuel consumption

Data collection

- Plug-in hybrid vehicles extracted from the EEA CO_2 monitoring database (2012-2017)
- Technical specifications regarding the vehicle models collected from publicly available sources (e.g. OEM official websites)
- Vehicle models classified into three size categories (small, medium, large)



European Environment Agency
European Topic Centre on Air pollution, transport, noise and industrial pollution

Definition of average vehicle

Vehicle category	Fuel type	Topology	Weight (kg)*	Drag coefficient	Battery capacity (kWh)	Engine power (kW)*	Electric motor power (kW)	Models
Small	Gasoline	Parallel	1412 (1390-1480)	0.29	27.2	28	125	BMW i3
Medium	Gasoline	Power split	1560 (1500-1625)	0.25 (0.23-0.32)	3.9 (3.2-10.9)	72.8 (63-115)	97.1 (44.5-111)	Toyota Prius
Large	Gasoline	Power split	1982 (1560-2635)	0.307 (0.25-0.36)	10.8 (5-12)	148.3 (99-410)	97 (60-130)	Simulation
Medium	Gasoline	Parallel	1672 (1500-1880)	0.292 (0.23-0.32)	9.1	102.1	102.1	VW Golf GTE
Large	Gasoline	Parallel	1982 (1560-2635)	0.307 (0.25-0.36)	10.8 (5-12)	148.3 (99-410)	97 (60-130)	Mitsubishi Outlander
Large	Diesel	Parallel	2093 (1949-2785)	0.3 (0.29-0.34)	12.5 (8-15)	164.8 (158-190)	59.3 (50-94)	Volvo V60 Twin Engine

*Data obtained from the EEA CO_2 monitoring database (ranges in parentheses)

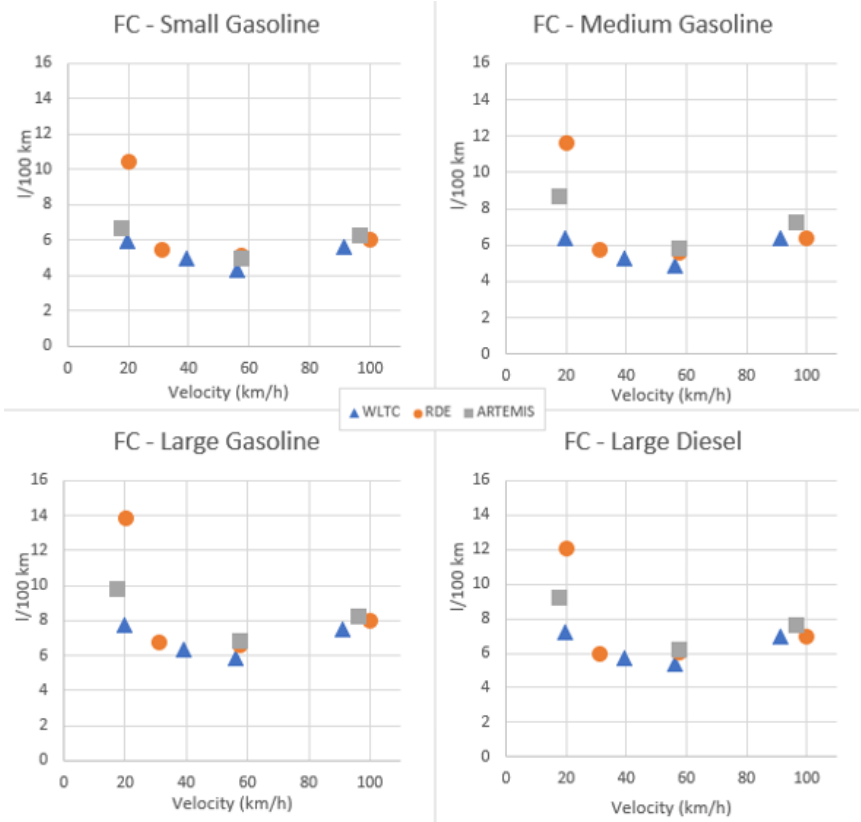
European Environment Agency
European Topic Centre on Air pollution, transport, noise and industrial pollution

Simulation approach

- Body's characteristics are used to estimate vehicle's road load used for simulation
- A generic engine fuel consumption map has been used to match the engine displacement of the simulated average vehicle → internal database
- Scaled full load curve
- Scaled battery characteristic curves
- Scaled electric motor full load characteristic

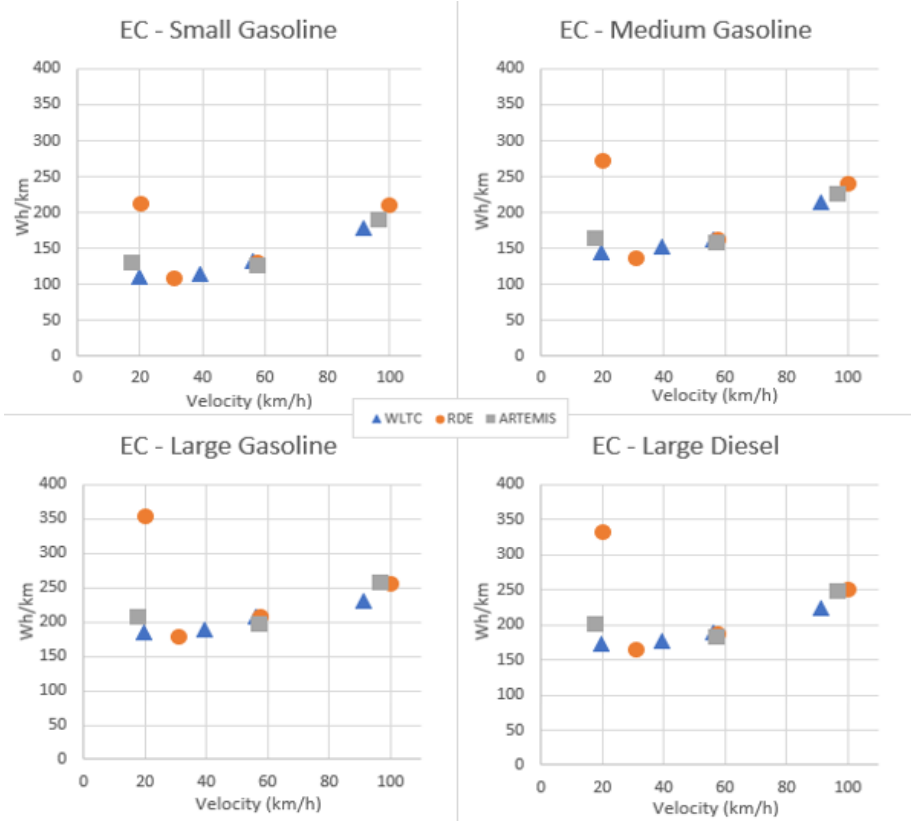
Simulation results in CS and CD mode

Fuel consumption (only CS mode)



Model's FC in CS mode is consistent with the typical behavior of conventional powertrain vehicles

Electric energy consumption (only CD mode)



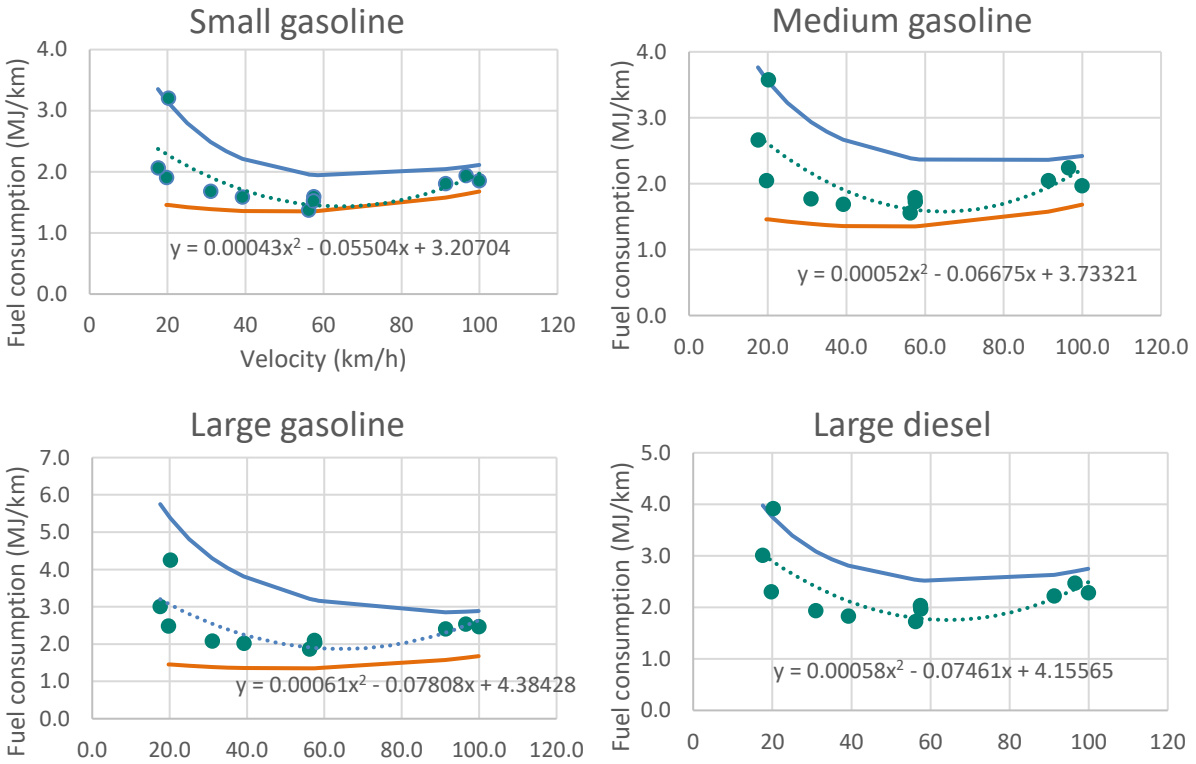
Model's electric EC in CD mode mainly affected by the driving speed and the associated driving resistance as electric motors have high efficiency values (over 90%) in almost all operating conditions

European Environment Agency
European Topic Centre on Air pollution, transport, noise and industrial pollution

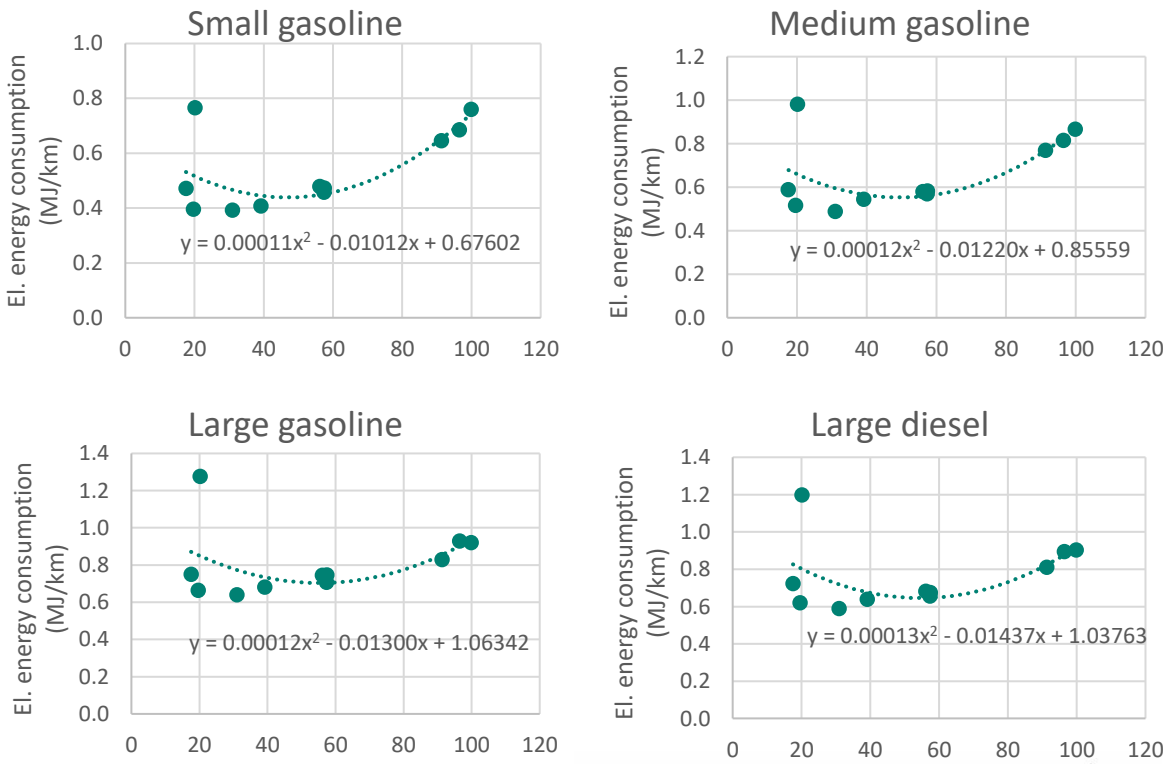
Derived emission functions

Speed-dependent fuel and electricity consumption functions derived from simulation results (best fit curves)

Fuel consumption - CS mode



Electric energy consumption - CD mode



Simulations — COPERT conventional powertrain — COPERT Petrol Hybrid

European Environment Agency
European Topic Centre on Air pollution, transport, noise and industrial pollution

Regulated pollutants

- For regulated pollutants (NOx, CO, HC, PM) no simulation was carried out
- Until more experimental data become available, the following approach is proposed:
  - Petrol PHEV (in CS mode): use equation for petrol hybrid
  - Diesel PHEV (in CS mode): use equation for diesel conventional
  - In CD mode, there are no emissions
- The results of this approach generally agree with LAT data on tested PHEV models

CS mode		Urban 29 (km/h)	Rural 56 (km/h)	Highway 110 (km/h)
NO_X (g/km)	Small gasoline	0.0058	0.0148	0.0164
	Medium gasoline	0.0058	0.0148	0.0164
	Large gasoline	0.0058	0.0148	0.0164
	Large diesel	0.4301	0.3225	0.3859
CO (g/km)	Small gasoline	0.0651	0.0303	0.0138
	Medium gasoline	0.0651	0.0303	0.0138
	Large gasoline	0.0651	0.0303	0.0138
	Large diesel	0.0617	0.0463	0.0534
HC (g/km)	Small gasoline	0.0012	0.0007	0.0010
	Medium gasoline	0.0012	0.0007	0.0010
	Large gasoline	0.0012	0.0007	0.0010
	Large diesel	0.0012	0.0009	0.0007
PM Exhaust (g/km)	Small gasoline	0.0019	0.0015	0.0018
	Medium gasoline	0.0019	0.0015	0.0018
	Large gasoline	0.0019	0.0015	0.0018
	Large diesel	0.0021	0.0014	0.0009

Development of emissions factors

- Statistics on Utility Factor (UF) used for the calculation of emissions factors (EF) from PHEVs
- The UF is the ratio between the distance driven in ‘charge depleting’ (CD) mode divided by the total driven distance, and can therefore range from 0 (e.g. for an HEV) to 1 (for a BEV or PHEV that is driven in CD mode only)
- The average fuel consumption and electric energy consumption of PHEVs can be calculated as follows:

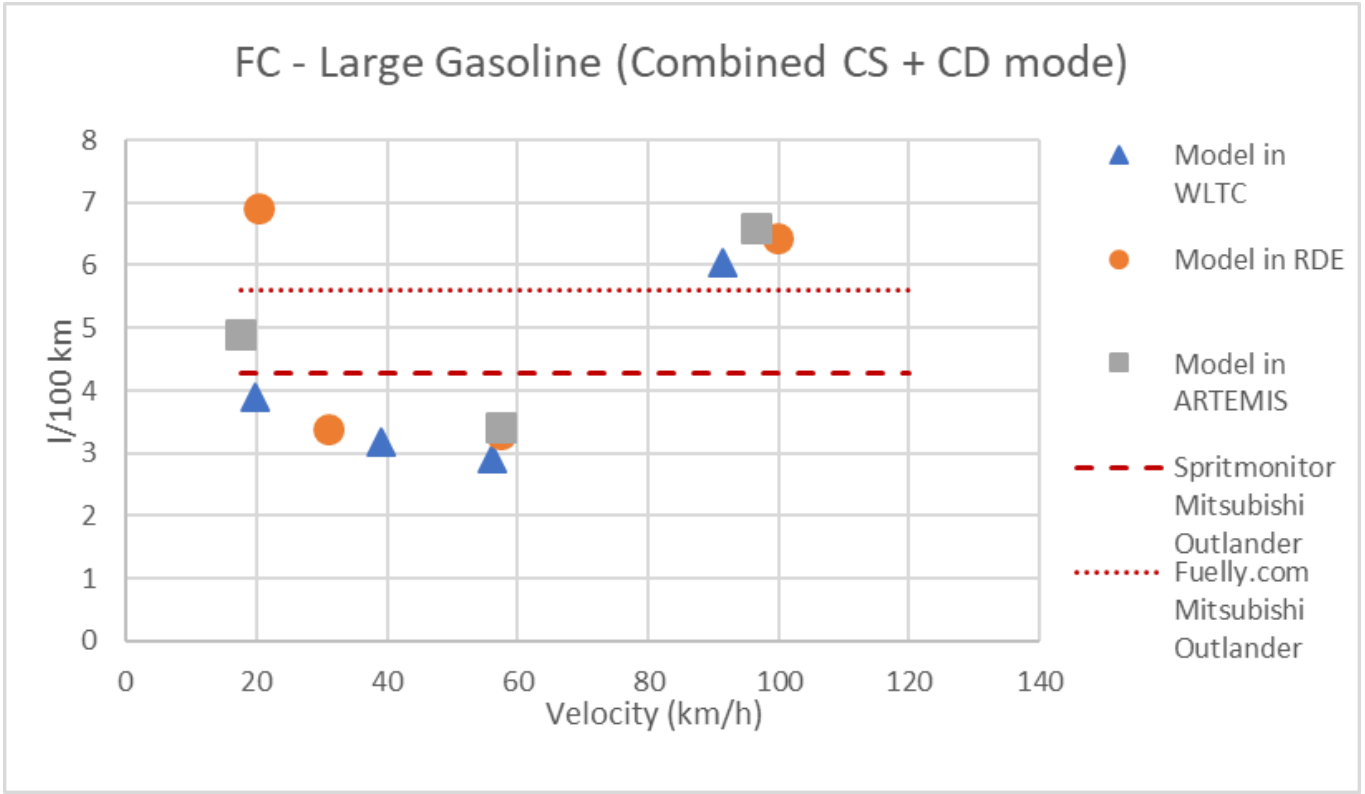
$$FC_{average\ U/R/H} = (1\text{-}UF_{U/R/H}) * FC_{CS}$$

$$EC_{average\ U/R/H} = UF_{U/R/H} * EC_{CD}$$

European Environment Agency
European Topic Centre on Air pollution, transport, noise and industrial pollution

Comparison with users reported data

- Web-based platforms such as Spritmonitor.de and Fuelly.com allow car owners to report fuel and/or electricity consumption of their own vehicles
- Mitsubishi Outlander PHEV selected for comparison; it is the most popular PHEV in terms of sales in Europe
- Simulation results are consistent with vehicle owners' reported fuel consumption values
- UF of 0.5/0.5/0.2 (U/R/H) assumed, based on data collected by TNO



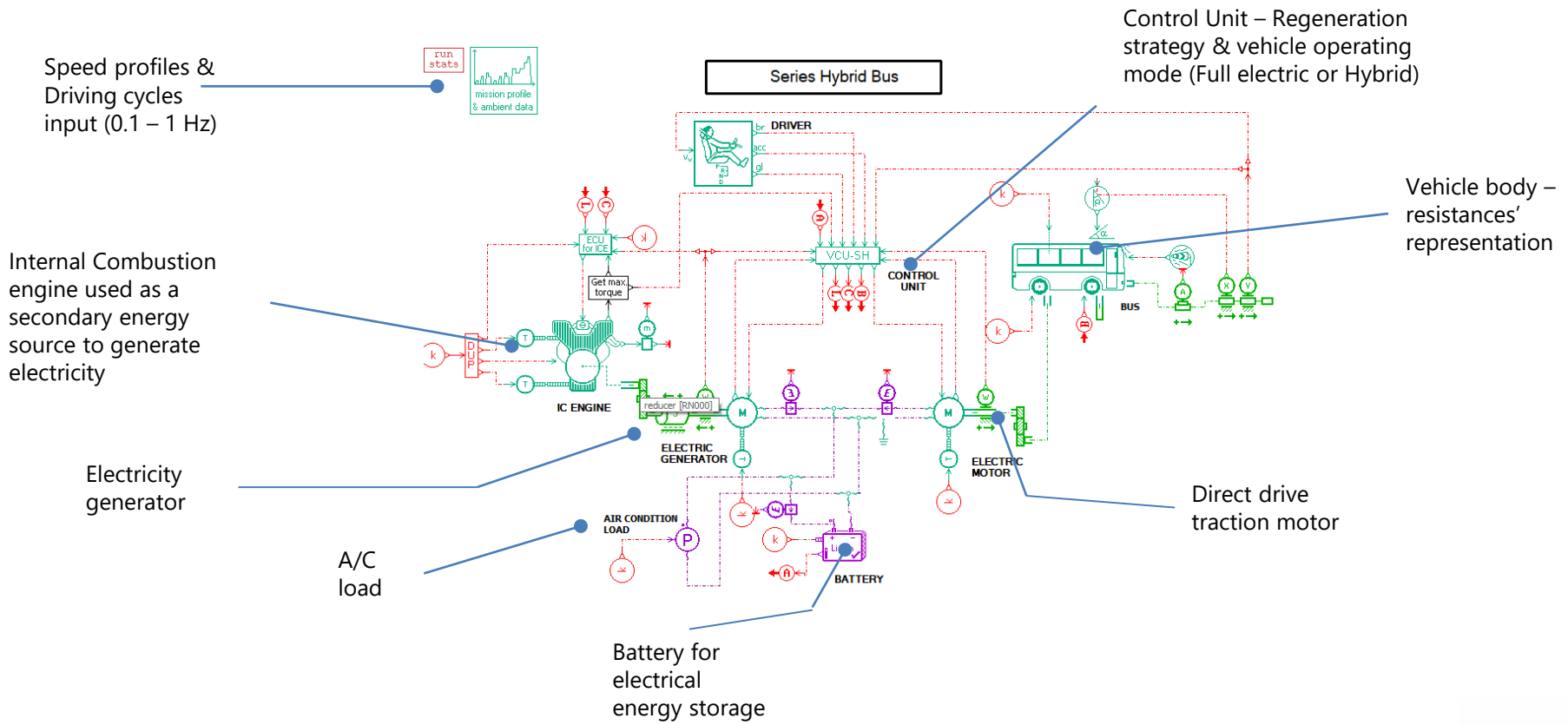
European Environment Agency
European Topic Centre on Air pollution, transport, noise and industrial pollution

Series Hybrid bus model: Energy performance assessment

European Environment Agency
European Topic Centre on Air pollution, transport, noise and industrial pollution

Model set-up in LMS AMESIM

Various types of powertrains including electric vehicles and hybrids can be simulated



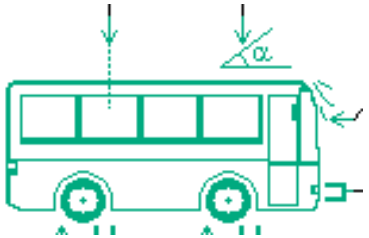
European Environment Agency
European Topic Centre on Air pollution, transport, noise and industrial pollution

Approach

- Tractive force is explicitly provided by the electric motor
- Motor acts also as generator to charge battery during braking
- ICE is used supplementary to drive the electric motor and/or charge the battery once needed though a generator
- The efficiency of the motor and the generator are considered constant
- The air conditioning system is a constant-power consumer and is directly connected to the battery
- The model was run for various driving cycles suitable for HDVs

Model specifications

Bus Body



Characteristic	Value
Mass	16 tn
Wheel dimeter	22.5 in
Vehicle active area	6.9 m^2
Final gear ratio	9
Air drag coefficient	0.536

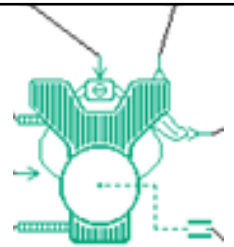
Battery – BAE type

Characteristic	Value
Type	Li – NMC
Nominal Capacity	31.8 KWh
Nominal Voltage	660 V

Motor & Generator – BAE type

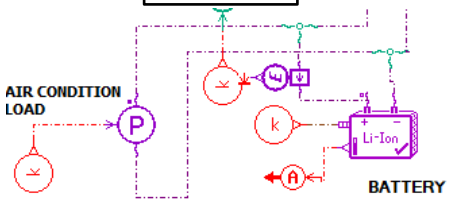
Characteristic	Value
Motor	
Max Power	195 kW
Max Torque	2100 Nm
Max Rotary velocity	4500 rpm
Mean efficiency	85%
Generator	
Max Power	140 kW
Max Torque	660 Nm
Max Rotary velocity	2700 rpm
Mean efficiency	85%

Internal Combustion engine



Characteristic	Value
Fuel	Diesel

A/C



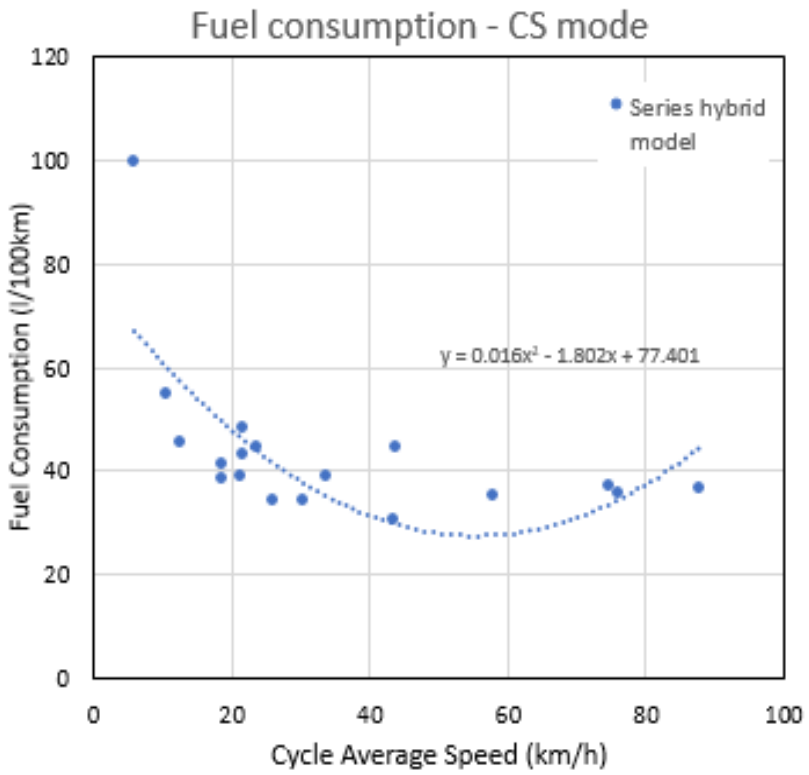
Characteristic	Value
Electricity consumer	
Constant Power demand	15 kW

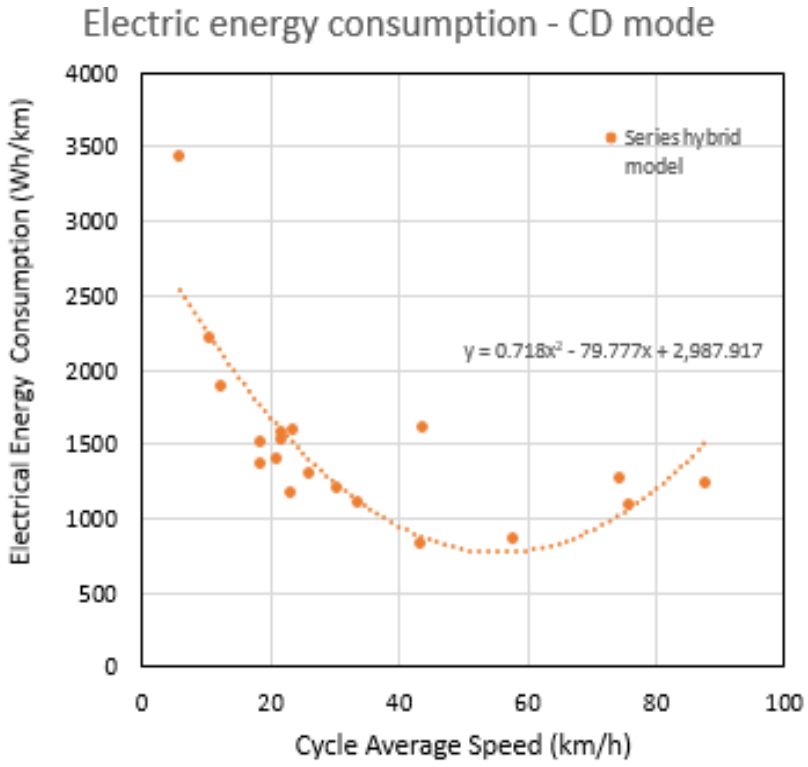
Battery and motor data source: baesystems.com

European Environment Agency
European Topic Centre on Air pollution, transport, noise and industrial pollution

Simulation results

Cycle	Avg speed (km/h)	CS mode (l/100km)	CD mode (Wh/km)
Braunchsweig	21.8	42.8	1524
VECTO Delivery rural	58.1	35.0	853
VECTO Delivery urban	33.9	38.7	1090
Manhattan	10.7	54.7	2196
NYC	6.0	99.4	3421
OCC	23.8	44.6	1583
VTP VECTO	30.5	34.2	1193
CBD	21.8	48.3	1569
Arterial	43.9	44.5	1608
Commute	74.7	37.0	1256
ETC (urban)	23.5		1161
ETC (extra urban)	76.1	35.4	1081
WHVC urban	21.3	38.7	1391
WHVC rural	43.6	30.2	820
WHVC motorway	87.8	36.5	1221
SORT 1	12.6	45.4	1871
SORT 2	18.6	38.2	1499
SORT 3	26.3	34.1	1289
UDDS HDV	18.9	41.1	1363





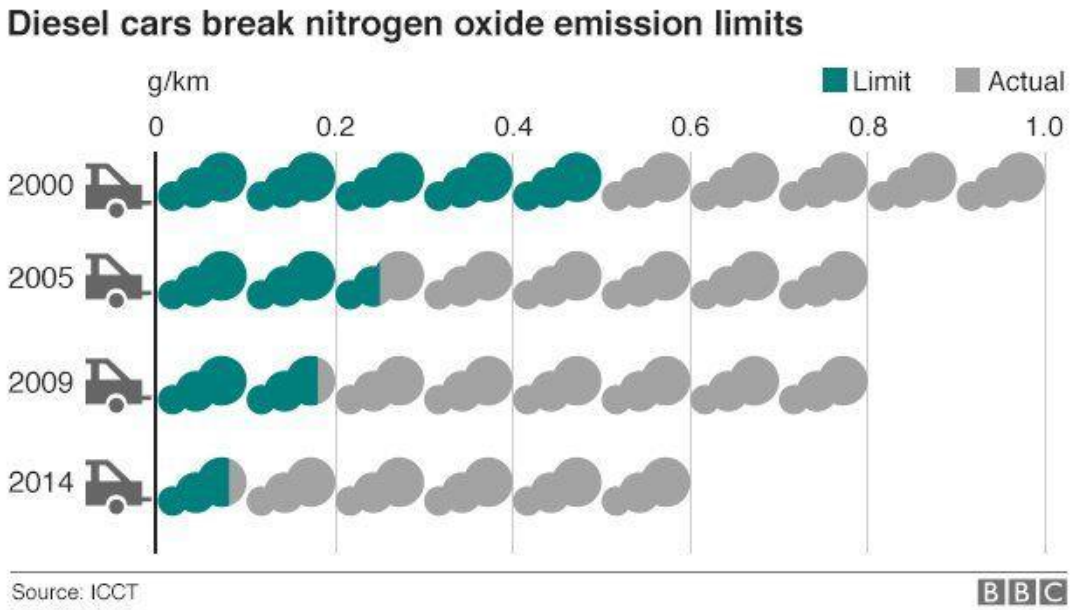
European Environment Agency
European Topic Centre on Air pollution, transport, noise and industrial pollution

Revision of Euro 5 emission factors for PCs & LCVs

European Environment Agency
European Topic Centre on Air pollution,
transport, noise and industrial pollution

Why this update?

- The Volkswagen NOx emissions scandal broke out in September 2015
- ‘Defeat device’ installed in 10.5 million diesel vehicles worldwide
- NOx emission levels of Euro 5 diesel cars in real-world conditions several times above the limit
- Several cars recalled for software upgrade and hardware fix



European Environment Agency
European Topic Centre on Air pollution, transport, noise and industrial pollution

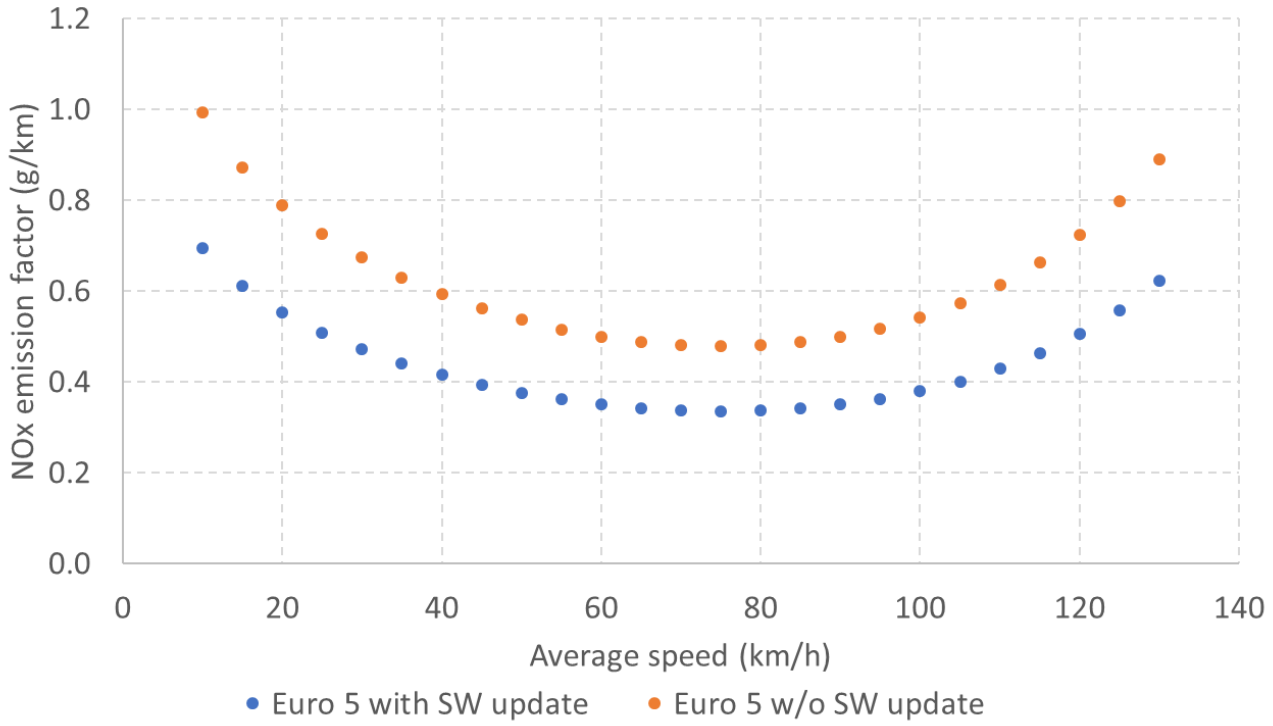
Approach

- Reduction factors for Euro 5 diesel vehicles ‘with software update’ developed in line with HBEFA 4.1, considering the mix of urban-rural traffic situations in HBEFA
- Applied to NOx, CO and VOC emissions for PCs and to CO and VOC for LCVs N1-I
- Share of affected vehicles ‘with software update’ included as variable in COPERT
- A default value of 30% has been set, reflecting the share of the affected Volkswagen vehicles in the entire Euro 5 diesel car fleet in Germany, as reported in HBEFA v4.1

Affected emission factors

- Emission factors of Euro 5 diesel cars with software update reduced by about 25%
- Other regulated pollutants also reduced

		Petrol	Diesel
CO	PC	–	↘
	LCV N1-I	↘	↓
NOx	PC	–	↘
	LCV N1-I	↓	–
VOC	PC	–	↔
	LCV N1-I	↓	↓



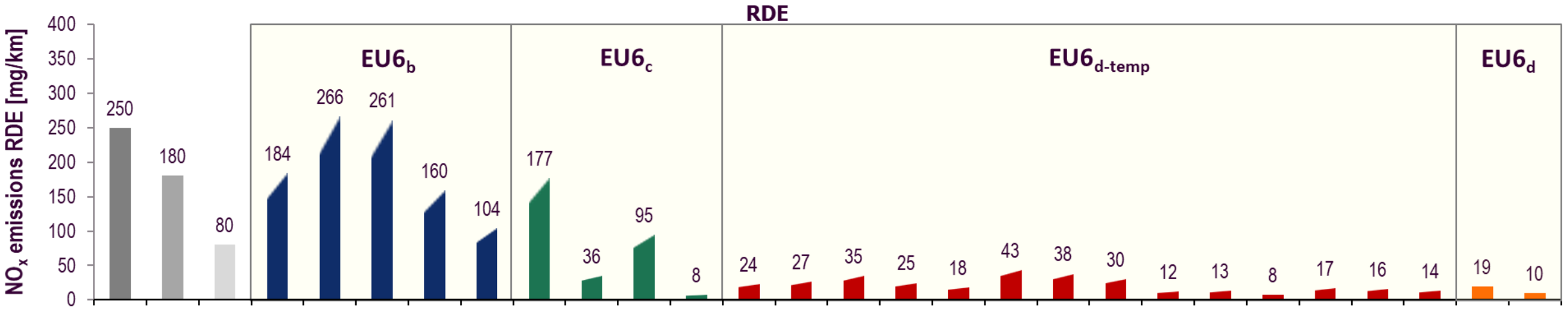
European Environment Agency
European Topic Centre on Air pollution, transport, noise and industrial pollution

Revision of Euro 6 emission factors for PCs & LCVs

European Environment Agency
European Topic Centre on Air pollution,
transport, noise and industrial pollution

Why this update?

- NOx emission levels of Euro 6 diesel RDE ($6_{d\text{-}temp}$ and 6_d) cars in real-world conditions are lower than initially anticipated
- Euro 6 diesel before RDE continued to emit much higher than limit
- Latest Euro $6_{d\text{-}temp}$ already by far fulfil Euro 6_d



European Environment Agency
European Topic Centre on Air pollution, transport, noise and industrial pollution

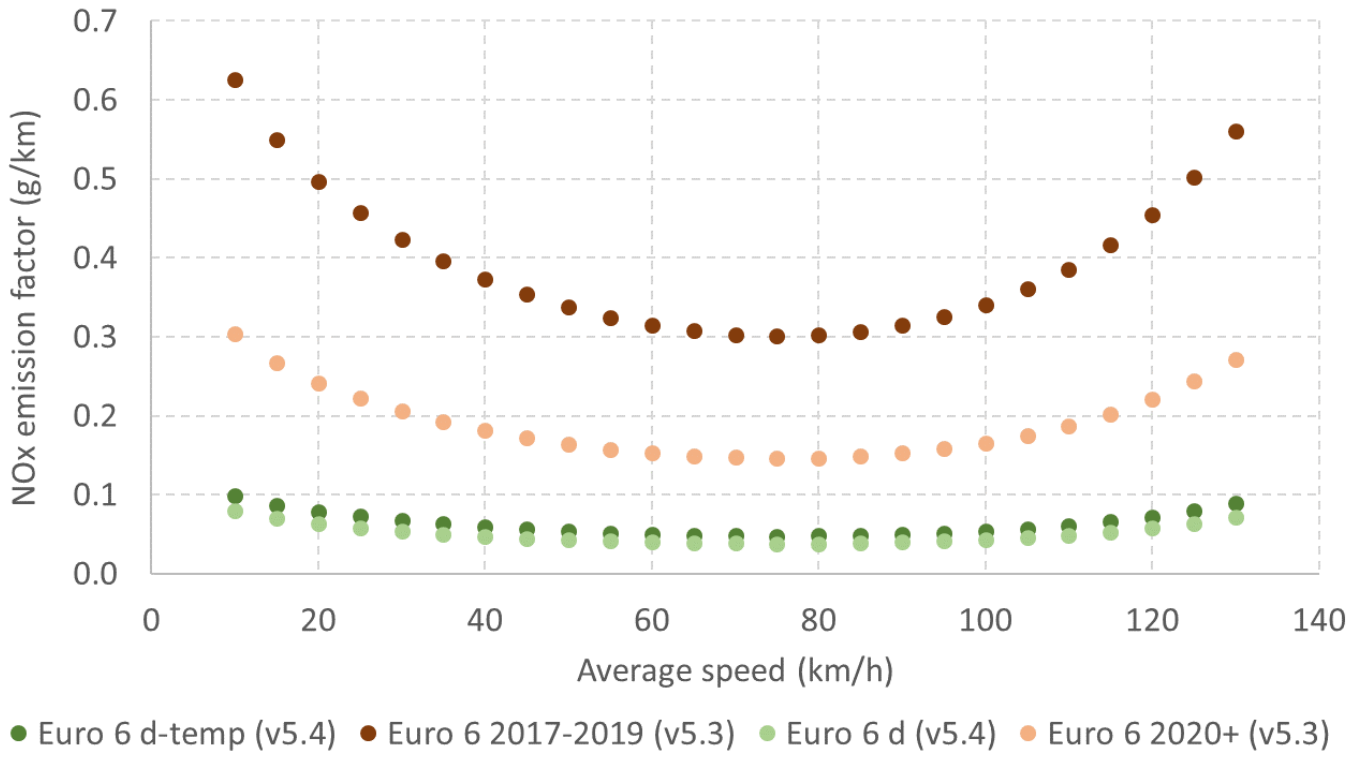
Approach

- Reduction factors for Euro 6 RDE (6d-temp and 6d) vehicles developed in line with HBEFA 4.1
- Applied to NOx (diesel PCs), CO (diesel N1-I LCVs) and PM (in petrol LDVs) emissions
- Emission factors of other pollutants also corrected in case they were higher than previous Euro standards

Affected emission factors

- Emission factors of Euro $6_{d\text{-}temp}$ and Euro 6_d diesel cars reduced by about 85% and 75% respectively

		Petrol	Diesel
CO	PC	↔	↓
	LCV N1-I	↘	↓
NOx	PC	↘	↓
	LCV N1-I	↓	–
VOC	PC	↔	–
	LCV N1-I	↓	↓



European Environment Agency
European Topic Centre on Air pollution, transport, noise and industrial pollution

Parameter updates – error fixes

European Environment Agency
European Topic Centre on Air pollution,
transport, noise and industrial pollution

Parameter updates – error fixes

Software

- Option to export results per mode and emission type
- Efficiency improvement feature added
- Split of Non exhaust PM to their components (Tyre- break wear, road abrasion)
- Non-exhaust BC calculated
- Updated NFR export, option added to export multiple years
- FAME and ETBE forms updated
- CRF reporting updated
- Implied emission factor form updated
- CLI feature updated

Bugs

- Energy Balance
- Implied Emission factor form
- Bi fuel vehicles export
- CH4 emission factors for Quads and ATVs
- Export factors
- PM exhaust for petrol hybrid passenger cars
- SO2 calculation for high Sulphur content
- Minor bugs fixed

Thank you for your attention!

European Environment Agency
European Topic Centre on Air pollution,
transport, noise and industrial pollution