Giorgos Mellios | 13 May 2020 | TFEIP meeting (web)

Guidebook updates

Chapters 1.A.3.b.i-iv / Road Transport

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

New elements in 2020

- Introduction of plug-in hybrid (PHEV) passenger cars

- Introduction of hybrid buses

- Revision of Tier 1 emission factors for shipping (1.A.3.d)

Energy consumption and emission factors for PHEV passenger cars

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

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

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)

EEA database (2012-2017)

Vehicle specs.

Combined database with plug-in hybrid vehicles specifications

PHEV small

PHEV medium

PHEV large

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
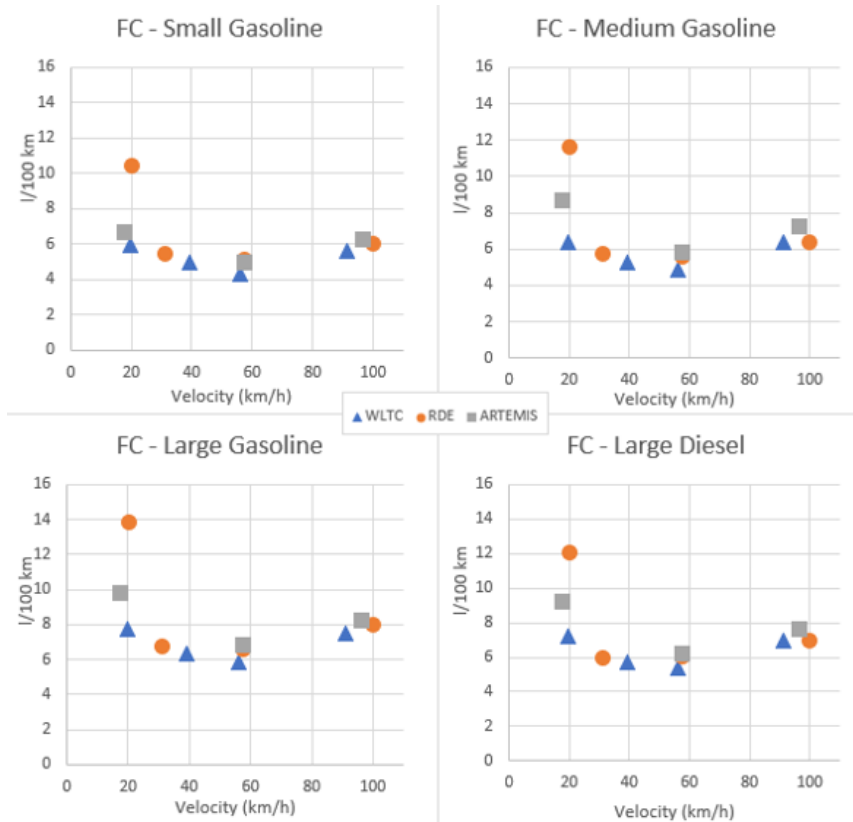
Simulation approach

- 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

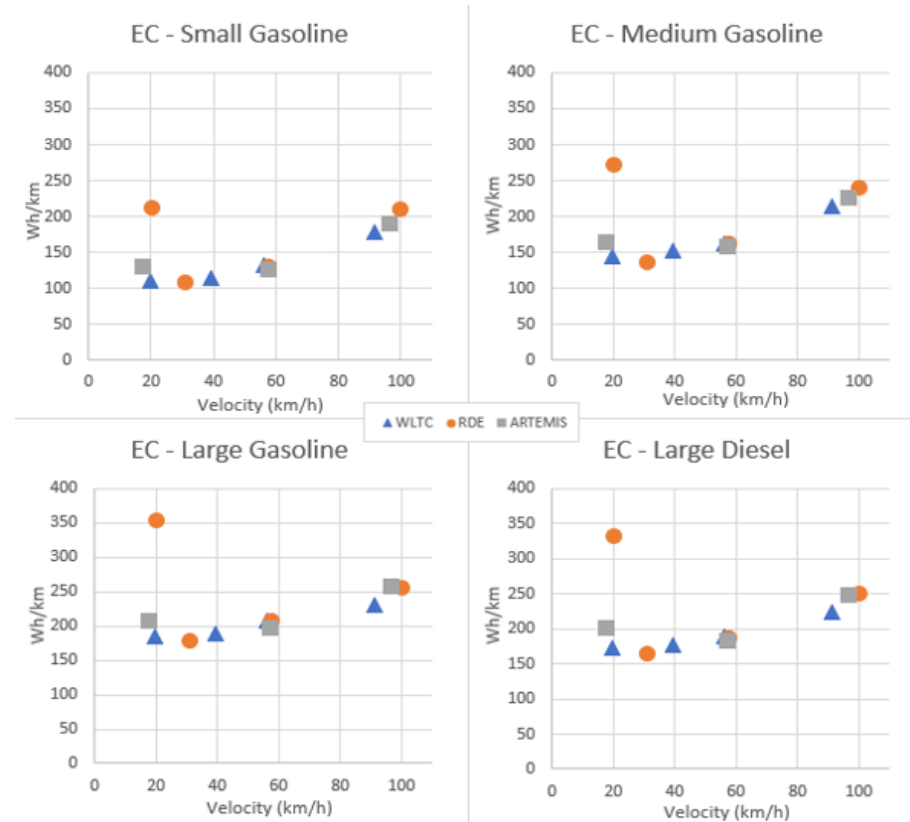- Scaled electric motor full load characteristic

Simulation results in CS and CD mode

Fuel consumption (only CS mode)

FC - Small Gasoline
FC - Medium Gasoline
FC - Large Gasoline
FC - Large Diesel

▲ WLTC   ● RDE   ■ ARTEMIS

Model's FC in CS mode is consistent with the typical behavior of conventional powertrain vehicles
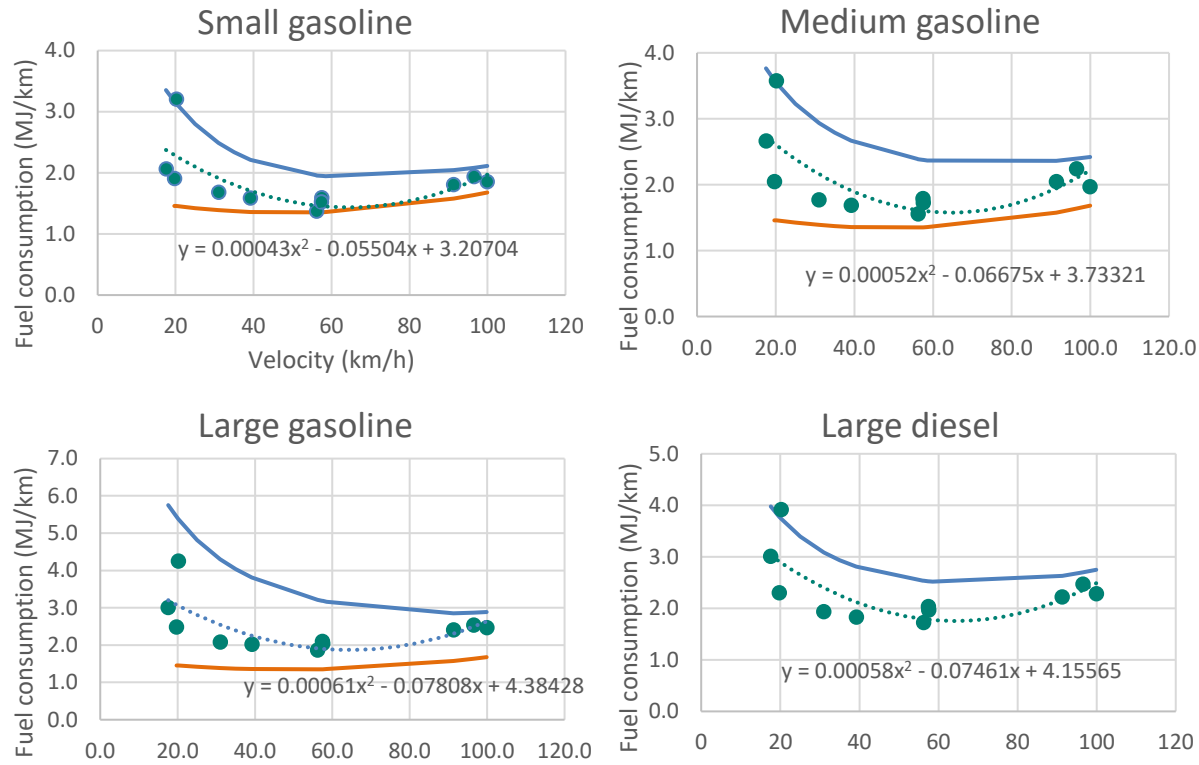
Electric energy consumption (only CD mode)

EC - Small Gasoline
EC - Medium Gasoline
EC - Large Gasoline
EC - Large Diesel

▲ WLTC   ● RDE   ■ ARTEMIS

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,
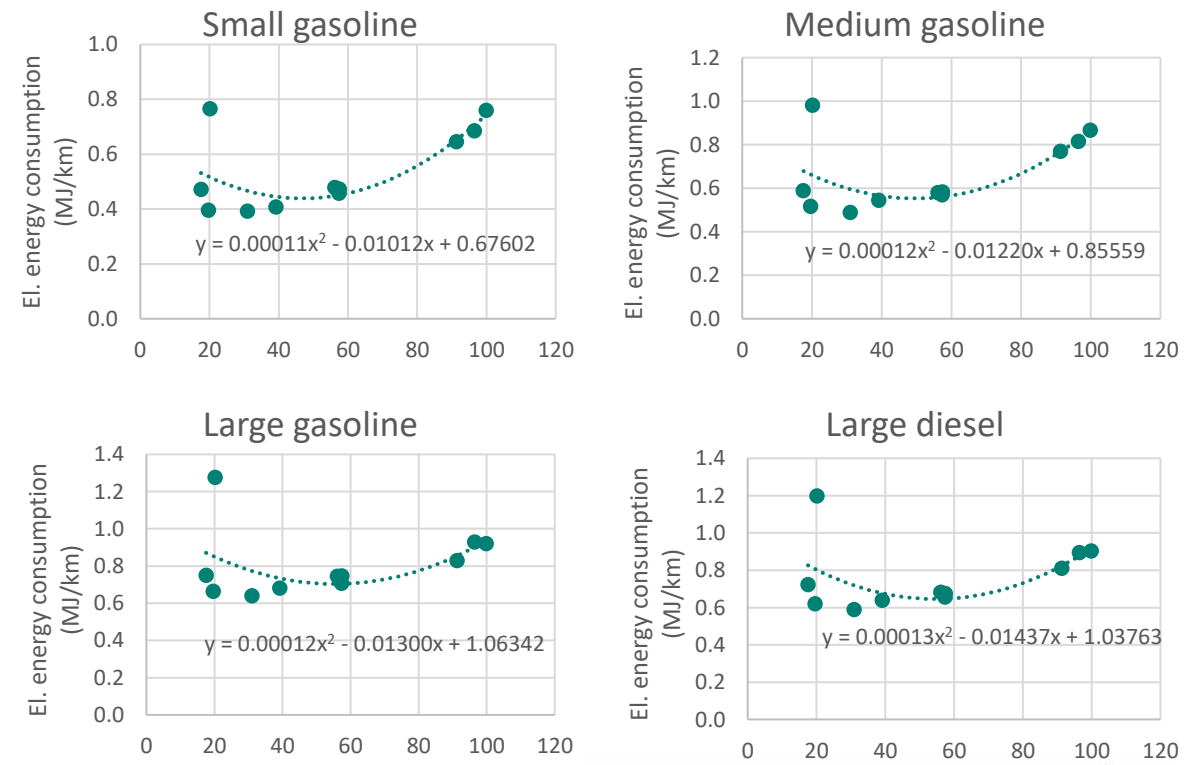**transport, noise and industrial pollution**

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

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)

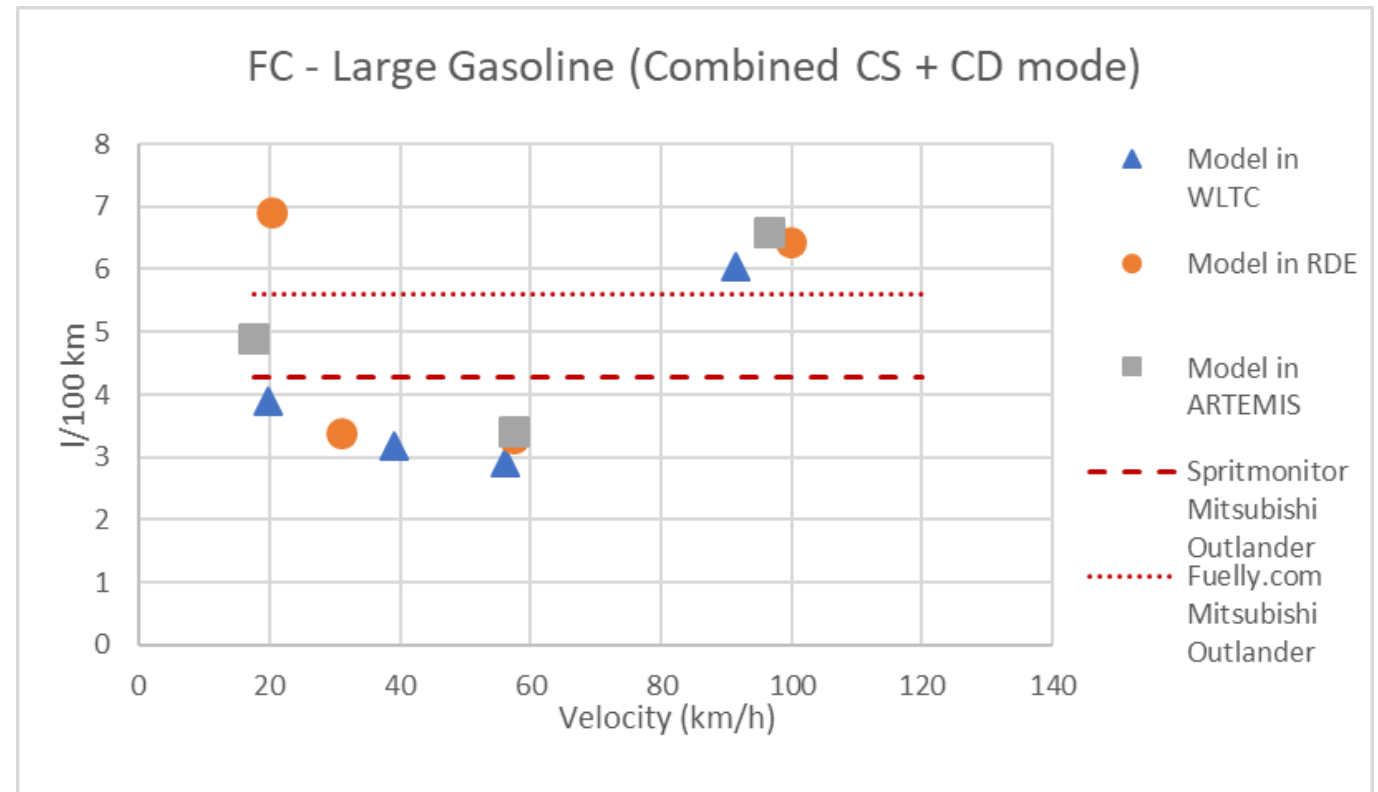- The average fuel consumption and electric energy consumption of PHEVs can be calculated as follows:

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

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

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

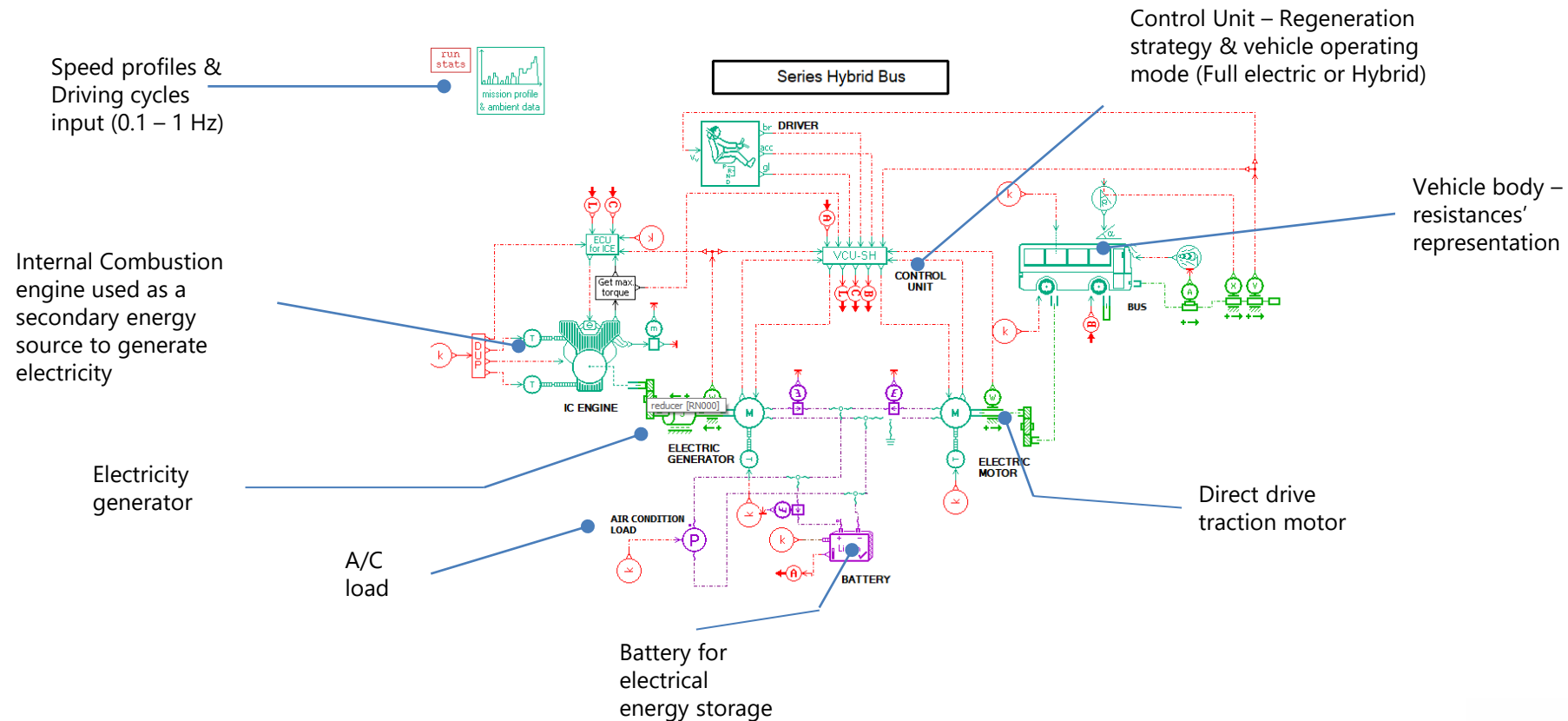- UF of 0.5/0.5/0.2 (U/R/H) assumed, based on data collected by TNO

FC - Large Gasoline (Combined CS + CD mode)

Legend:
- ▲ Model in WLTC
- ● Model in RDE
- ■ Model in ARTEMIS
- – – Spritmonitor Mitsubishi Outlander
- ···· Fuelly.com Mitsubishi Outlander

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

Series Hybrid bus model: Energy performance assessment

Model set-up in LMS AMESIM

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

Speed profiles & Driving cycles input (0.1 – 1 Hz)

Control Unit – Regeneration strategy & vehicle operating mode (Full electric or Hybrid)

Series Hybrid Bus

Vehicle body – resistances' representation

Internal Combustion engine used as a secondary energy source to generate electricity

Electricity generator

Direct drive traction motor

A/C load

Battery for electrical energy storage

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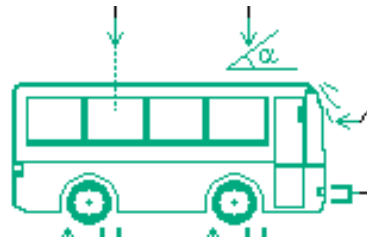
Characteristic	Value
Mass	16 tn
Wheel dimeter	22.5 in
Vehicle active area	6.9 m^2
Final gear ratio	9
Air drag coefficient	0.536

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
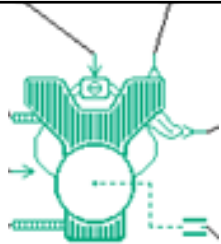
Characteristic	Value
Fuel	Diesel

A/C
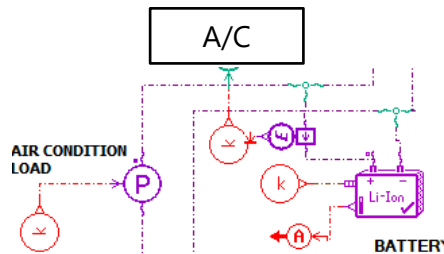
Characteristic	Value
Electricity consumer	
Constant Power demand	15 kW

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)
Braunschweig	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

Fuel consumption - CS mode

$y = 0.016x^2 - 1.802x + 77.401$

Electric energy consumption - CD mode

$y = 0.718x^2 - 79.777x + 2{,}987.917$

European Environment Agency
European Topic Centre on Air pollution, transport, noise and industrial pollution
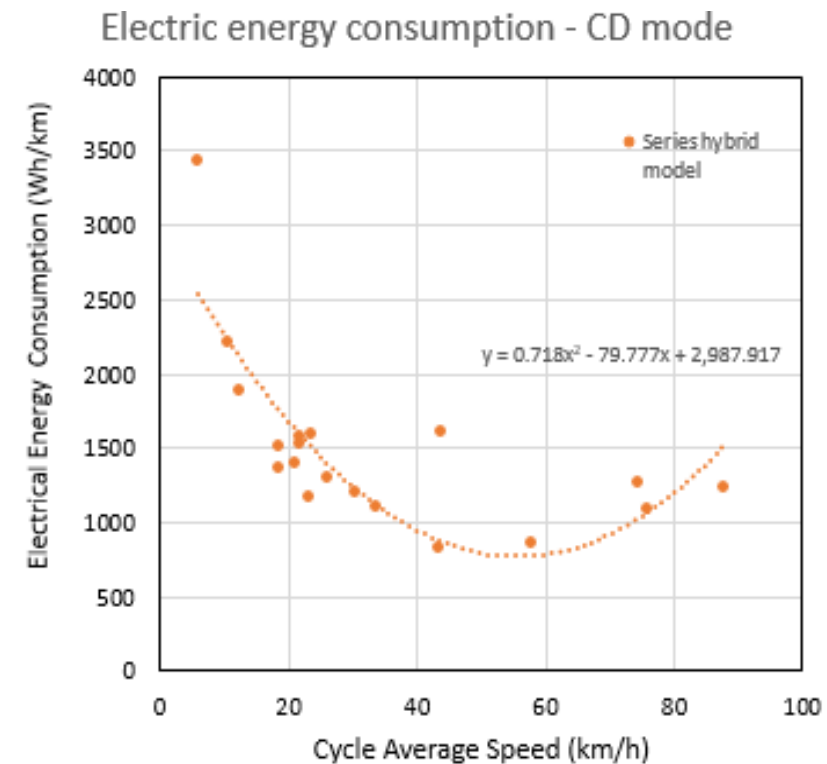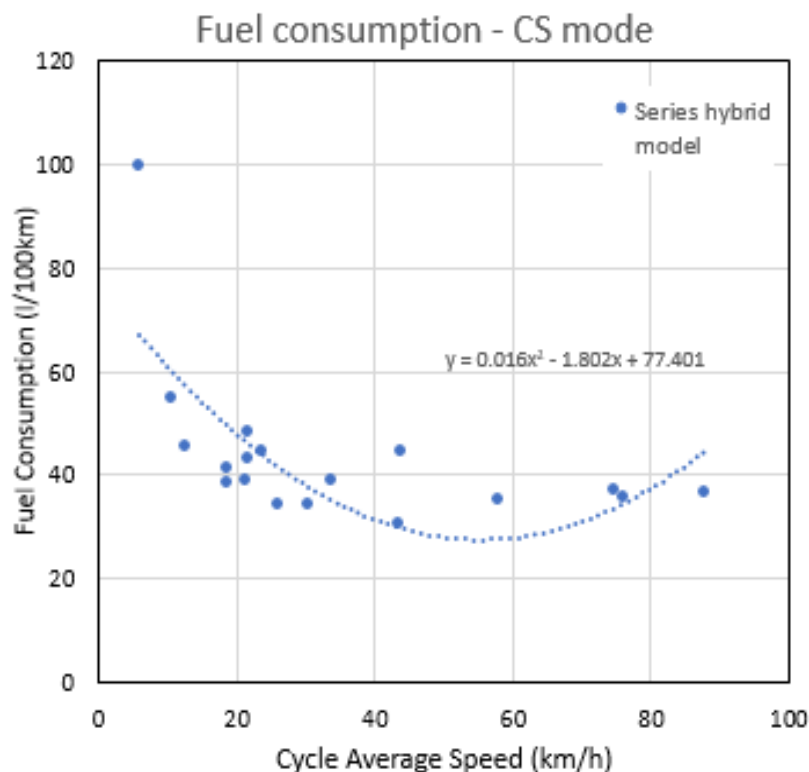
Revision of Tier 1 non-regulated pollutants emission factors for shipping (1.A.3.d)

Approach

- Source:
  Aakko-Saksa, P. (2019). Nordic programme on developing air pollutant emission inventories, especially POP and heavy metal emission inventories "NMR": Marine. VTT Technical Research Centre of Finland.

- Updated emission factors for:
  - Benzo(a)pyrene
  - Benzo(b)fluoranthene
  - Benzo(k)fluoranthene
  - Indeno(1,2,3-cd)pyrene

  for ships using bunker fuel oil or marine diesel oil

Pollutant	bunker fuel oil	marine diesel oil	Unit
BaP	0.005	0.002	g/tonne fuel
BbF	0.03	0.01	g/tonne fuel
BkF	0.02	0.01	g/tonne fuel
IP	0.009	0.001	g/tonne fuel

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

Planned updates for next year

- Review of emission degradation functions

- Revision of PM characteristics (particle number and surface area) as a result of H2020 projects

- Review of Euro 6d emission factors in light of new RDE measurements

- Revision of non-exhaust emissions from tyre wear (partly done in 2019)

- Revision of Tier 3 emission factors for shipping (1.A.3.d)

Thank you for your attention!