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Estimated real-world energy consumption and driving range

Test Procedure

September 2025

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1. PREFACE

The purpose of this procedure is to define a methodology to determine reliable estimated actual fuel/energy consumption values of each vehicle assessed. These values should be realistic for consumers and closer to the driving scenarios, ambient conditions and HVAC usage that might be faced in real-world. During the experimental vehicle assessment, only one real-world test is performed in one specific route and ambient conditions, which leads to measured energy demand unique for that trip. A single test cannot be seen as sufficient for providing a representative real-world consumption value of one vehicle rated, as real-world testing is characterized by limited repeatability and reproducibility. At the same time, comparability between vehicles is of paramount importance for a fair provision of information to consumers.

Energy consumption is strongly dependent on the real-world running resistance[1], the ambient conditions that lead to specific HVAC use and on the driving dynamics. Figure 1 summarizes the main variabilities, which impact the real-world consumption value on a specific vehicle.

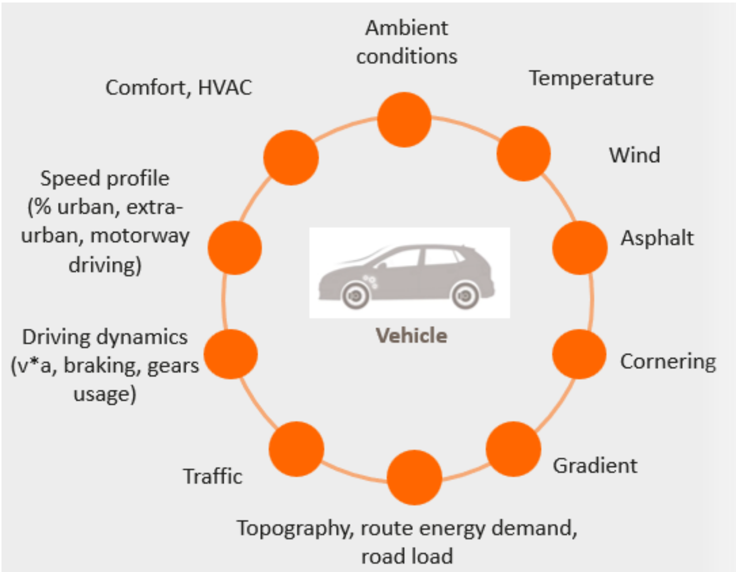

Figure 1 Variabilities in real-world testing

The real-world energy consumption paradigm can be described as: one vehicle, one day, one user. This leaves one option in the quest for providing specific use-case scenarios − applying a statistical probability concept, aiming to cover as many representative consumption scenarios as possible for a specific vehicle.

The concept is based on the gap between real-world and laboratory testing, following the same principle as DG CLIMA OBFCM reports developed in CO_2 expert group, but applied to Green NCAP testing data available in the Green NCAP database, hereinafter called “the database”.

The gap between real-world and type-approval CO_2 and/or energy consumption values is based on the total consumption of each vehicle and averaged by the European fleet. The novelty applied considering Green NCAP fleet with the use of the database, is the calculation of the gap for different driving conditions and segmented by vehicle speed since it is based on time-resolved data with vehicle speed and consumption for each of the events driven on the road.

The principle encompasses main variabilities of real-world consumption with different laboratories / topography, energy demand, drivers / driving dynamics, ambient conditions, wind, road, running resistance; therefore, it is a good indicator of real-world possible operation.

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[1] X. Urgell, A. Garbí, A. Martí, J. Bertomeu, P. Maroto, A. Gascón, The Transition to the Real-World Running Resistance [TECHNICAL PAPER] IDIADA Publications

2. APPLICABILITY

This procedure applies to all vehicles tested with Green NCAP procedures: Petrol, Diesel, HEV and PEV. The calculation of estimated actual consumption and driving range scenarios will be part of the "Driving Experience" package of 2025 Assessment.

Provisions for GFV, PHEV and FCEV will be included in a later next procedure version.

3. DEFINITIONS AND ABBREVIATIONS

- EC: fuel/energy consumption
- EEA database: Data set made available by the European Environment Agency, which contains OBFCM data as reported by Member States for individual vehicles, as well as some properties of those vehicles.
  https://climate-energy.eea.europa.eu/topics/transport/real-world-emissions/data
- GNCAP: Abbreviation for "Green NCAP" used in tables and figures
- Green NCAP database: SQL database containing raw data and aggregated data of official Green NCAP results
- KPI: Key Performance Indicator
- OBFCM: On-board Fuel Consumption Monitoring.
- PEMS+**:** An enhanced regulatory RDE test procedure used by Green NCAP to test real-world environmental performance. For more details, see *Past Test Procedures* in **Test Procedures**.
- Ratio Green NCAP: the % difference between the real-world consumption figures and the in-laboratory consumption values measured by Green NCAP in the tested vehicles fleet.
- Ratio OBFCM: the percentage difference between real-world consumption figures and official WLTP consumption values for Diesel, Petrol and Petrol HEV in European fleet and provided by DG CLIMA within OBFCM reports.
- RPA: Relative positive acceleration
- v*a,pos: mathematical product of vehicle speed and positive acceleration

WLTC+: The regulatory WLTC test custom-tailored for Green NCAP assessment. For more details, see Test Procedures.

4. GREEN NCAP DATABASE

4.1. Content and representativeness

The database contains a full set of the results of vehicles tested in the program in the period 2021 to 2024. Regarding WLTC+ data included in Green NCAP database, all data contained is described below in Table 1 to Table 5.

Table 1 includes the total number of tests, vehicles and total distance covered by each powertrain technology.

Table 1 Number of tests, vehicles, and the total distance covered by all Gren NCAP real-world tests

Powertrain	Nº tests	Nº vehicles	Distance covered (km)
Petrol	207	55	4,903.7
Petrol HEV	46	12	1,089.2
Diesel	123	29	2,909.0
GFV	10	2	235.6
PEV	173	40	4,096.3
PHEV	44	8	1,735.2
E85	4	1	94.8
Fuel Cell	5	1	118.1
Total	**612**	**148**	**15,181.9**

Table 2 lists the total number of laboratory tests, vehicles and total distance covered by each test laboratory in Green NCAP Consortium.

Table 2 Number of tests, vehicles, and the total distance covered throughout WLTC+ measurements for each test laboratory

LAB	Nº tests	Nº tehicles	Total distance (km)
Lab 1	58	12	1,369.8
Lab 2	78	17	2,005.9
Lab 3	49	12	1,208.0
Lab 4	79	18	1,961.3
Lab 5	105	26	2,649.1
Lab 6	172	48	4,076.5
Lab 7	67	14	1,816.6
Lab 8	4	1	94.6
Total	**612**	**148**	**15,181.9**

Table 3 summarizes the boundary conditions for each WLTC+ and BAB130 tests, as well as for the PEMS+ Cold.

Table 3 Tests boundary conditions and test requirements for chassis dyno measurements and PEMS+ Cold on-road test

Test name	WLTC+ Cold	WLTC+ CAT	BAB130	WLTC+ Warm	PEMS+ Cold
Type	Chassis dynamometer				On road
Ambient conditions	23°C	-7°C	23°C	23°C	RDE boundaries
Start	Cold	Cold	Warm	Warm	Cold
Auxiliaries	Air-conditioning set at 23°C, daytime running lights on, radio on				
Gear shifting	GSI	GSI	4th: 80-13 6th: 110-130 Or: kick-down	GSI	GSI
Measurements	HV Battery Current and Voltage, LV Battery Currant and Voltage, cabin temperature, pedal position, OBD signals				
	Test bench signals: speed, dyno forces, ambient conditions				Amb Temp, GPS signals: speed, position, altitude

Table 4 shows the same information as in Table 2, but categorized by the test type in this case.

Table 4 Number of tests, vehicles, and the total distance covered by each typology of WLTC+ measurements and BAB130 test

Test	Nº tests	Nº vehicles	Distance covered (km)
WLTC warm	148	148	3,443.2
WLTC cold	148	148	3,442.8
BAB warm	148	148	3,689.1
WLTC warm_rep	50	50	1,163.3
WLTC cold CAT	110	110	2,559.1
WLTC CD Sequence	8	8	884.4
Total	612	148	15,181.9

Table 5 displays the total distance covered per operation mode in WLTC+ measurements including all the variants, except the WLTC+ Charge Depleting (CD) sequence driven with PHEVs.

Table 5 Distance covered for each operation mode by all WLTC+ measurements, except WLTC+ CD Sequence

Operation mode	Distance covered (km)
Urban	3,578.2
Rural	3,267.0
Highway	3,763.2
Total	10,608.4

Regarding real-world data included in Green NCAP database, all data contained is described below in Table 6 to Table 9.

Table 6 introduces the total number of real-world tests, vehicles and total distance covered by each powertrain technology.

Table 6 Number of tests, vehicles, and the total distance covered by all real-world tests

Powertrain	Nº tests	Nº vehicles	Distance covered (km)
Petrol	111	55	9,670.1
Petrol HEV	28	12	2,443.4
Diesel	73	29	6,328.7
GFV	6	2	517.2
PEV	54	40	4,707.8
PHEV	34	8	3,010.4
E85	3	1	306.7
Fuel Cell	3	1	264.4
Total	312	148	27248.8

Table 7 visualizes the total number of tests, vehicles and total distance covered by each test laboratory in the Green NCAP Consortium. Regarding the first test laboratory, tests have been performed on two different routes (route 1a and route 1b).

Table 7 Data of number of tests, vehicles, and the total distance covered throughout real-world measurements for each test laboratory. Route 1a and 1b correspond to different routes from the same laboratory

Route	Nº tests	Nº vehicles	Total distance (km)
Route 1a	18	6	1,601.9
Route 1b	6	6	506.8
Route 2	80	48	6,783.6
Route 3	58	26	5,105.9
Route 4	42	18	3,598.4
Route 5	37	17	3,070.7
Route 6	34	12	3,366.2
Route 7	36	14	3,123.8
Route 8	1	1	91.5
Total	**312**	**148**	**27,248.8**

Table 8 provides the same information as Table 6, but categorized by the respective test type.

Table 8 Number of tests, vehicles, and the total distance covered by each type of real-world measurements

Test	Nº tests	Nº vehicles	Distance covered (km)
PEMS cold	148	148	12,856.3
PEMS eco warm	74	74	6,483.3
PEMS heavy warm	74	74	6,499.3
PEMS eco cold CD	2	2	174.2
PEMS eco warm CD	6	6	531.0
PEMS heavy cold CD	2	2	174.0
PEMS heavy warm CD	6	6	530.8
Total	**312**	**148**	**27,248.8**

Figure 2 pictures the boundary conditions for each real-world test.

On-road tests	PEMS+ Eco	PEMS+ Cold	PEMS+ Heavy
Vehicle start	Warm	Cold	Warm
Weight	Minimum	70% payload	90% payload
Air-conditioning	OFF	ON 23°C	ON
Driving style	Economy	Regular	Sportive
Braking	Moderate	Regular	Aggressive
Start-stop	ON	ON	OFF
Motorway speed	100 km/h	110-120 km/h	120-130 km/h
Full pedal acc	No	No	Yes

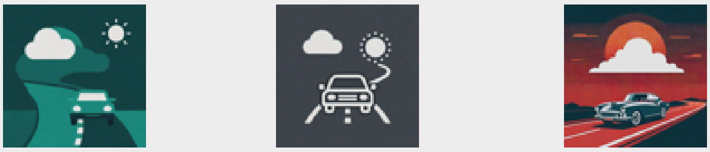

Figure 2 Tests requirements of the different real-world measurements.

Table 9 presents the total distance covered per operation mode on all real-world measurements.

Table 9 Distance covered for each operation mode by all real-world measurements

Operation mode	Distance covered (km)
Urban	9,981.2
Rural	9,110.3
Highway	8,157.2
Total	**27,248.8**

4.2. Phase discretisation of WLTC and real-world measurements

The energy consumption scenario from WLTC representing urban driving is considered as the sum of the two phases Low (Ph1) and Medium (Ph2). Therefore, Ph3 and Ph4 correspond with rural and highway phases respectively, as represented in Figure 3 and Figure 4, where the time and distance-based representation of WLTP speed trace are shown.

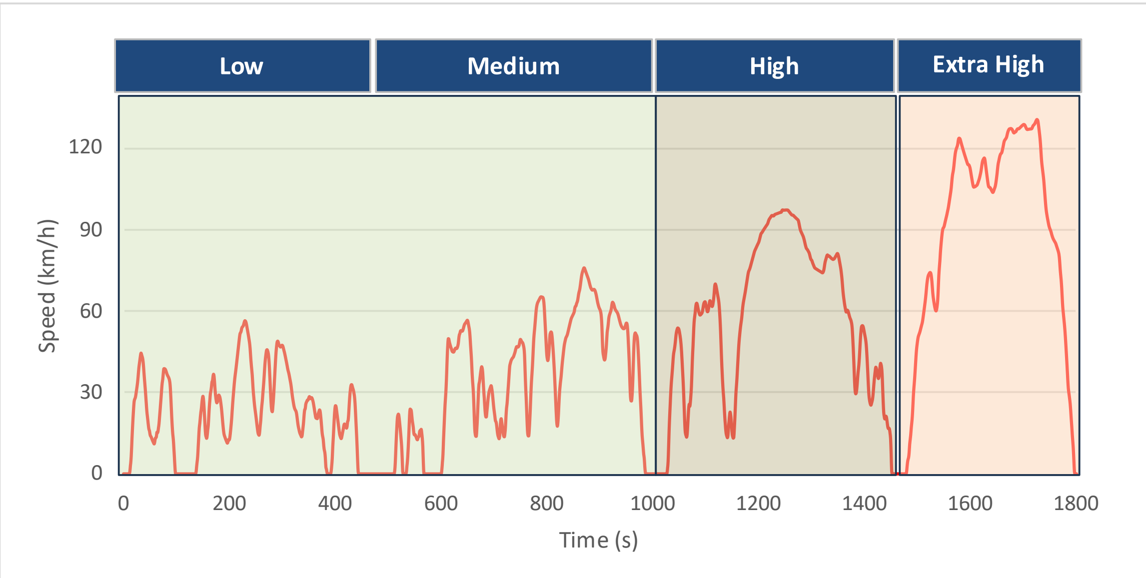

Figure 3 Speed (km/h) vs time (s) of WLTC speed profile, including phases discretization

Table 10 shows the total distance and time elapsed for each of the phases considered, as well as the average speed and distance share in percentage.

Table 10 Distance covered (m), time (s), average speed (km/h) and percentage of distance share for the different phases of WLTC.

Phase	Distance (m)	Time (s)	Avg speed (km/h)	% Distance Share
Ph1+Ph2	7851	1022	27.7	33.74%
Ph3	7162	455	56.7	30.78%
Ph4	8254	323	92.0	35.48%
Total	**23266**	**1800**	**46.5**	**100%**

Phase	Distance (m)	Time (s)	Avg speed (km/h)	% Distance Share
Ph1+Ph2	7,851	1,022	27.7	33.74%
Ph3	7,162	455	56.7	30.78%
Ph4	8,254	323	92.0	35.48%
Total	**23,266**	**1,800**	**46.5**	**100%**

Figure 4 includes the same information as Figure 3, but the x-axis represents the distance in kilometres. The additional plot clearly shows the distance share of the three operation modes resulted from the original WLTC phases.

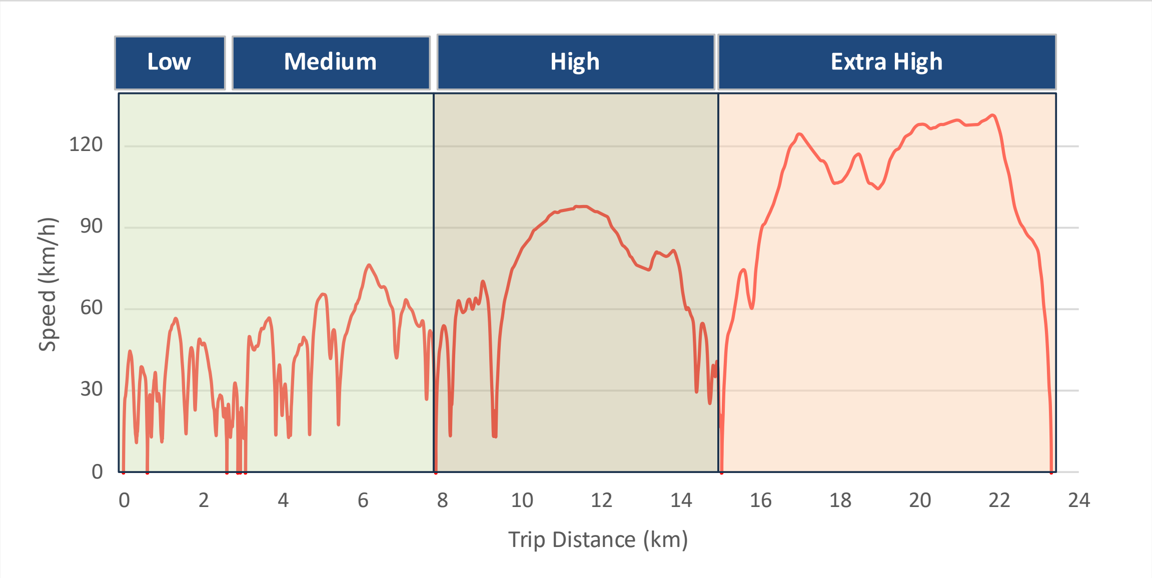

Figure 4 Speed (km/h) vs distance (km) of WLTC speed profile, including phases discretization

The real-world urban, rural and highway phases are discretized based on the vehicle speed according to (EU) 2017/1151 as follows:

- Urban: speed ≤ 60 km/h
- Rural: 60 < speed < 90 km/h
- Highway: speed ≥ 90 km/h

The speed trace of one of the real-world measurements is displayed in Figure 5 (time based) and Figure 6 (distance based). The speed-based distinction of urban, rural and highway driving is shown as three colored horizontal bars.

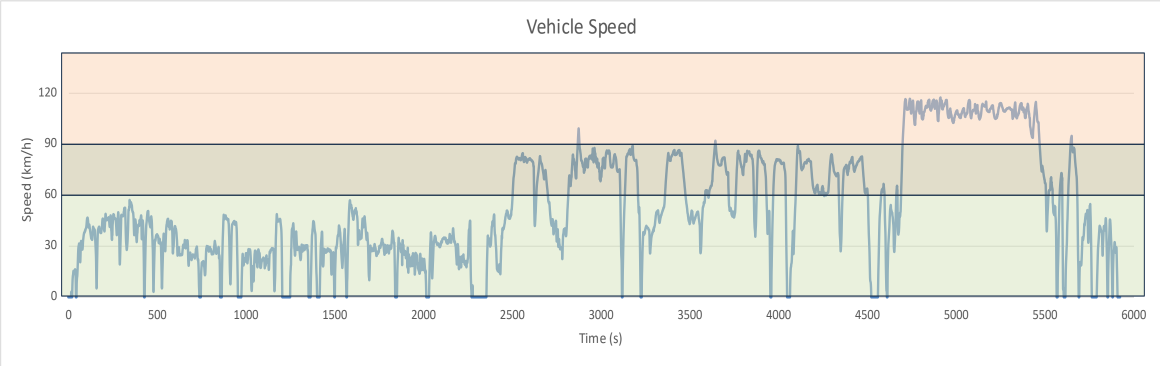

Figure 5 Time based (in seconds) plot of vehicle speed (km/h) for a determined route, including accounted phases discretization

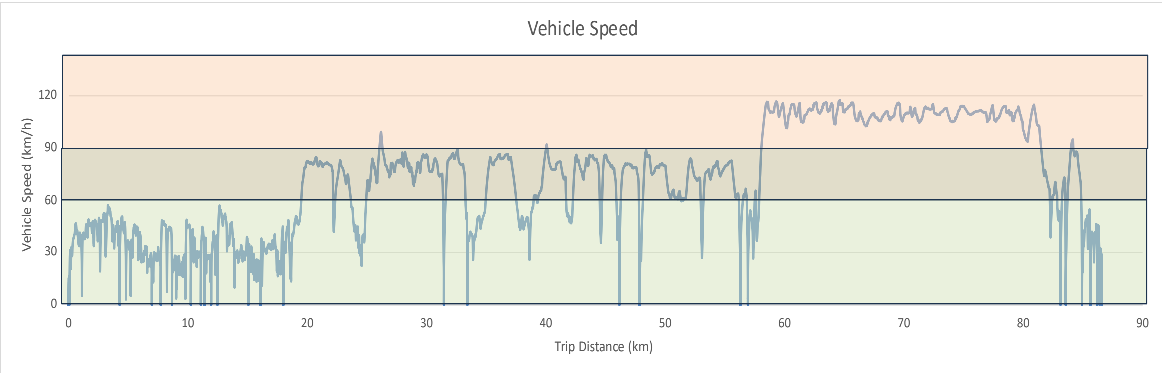

Figure 6 Distance based (in kilometres) plot of vehicle speed (km/h) for a determined route, including accounted phases discretization

Table 11 includes the average distance and the overall distance share of each operation mode, for each of the routes contained in Green NCAP database. Average distance share of all this data results in almost an equally proportioned share between all phases, which matches with the established WLTC phases discretization criteria.

Table 11 Average distance (km) and distance share (%) for each phase of each route of real-world measurements

Route	Nº Tests	Urban		Rural		Highway		Mixed
		Avg Distance (km)	% Distance share	Avg Distance (km)	% Distance share	Avg Distance (km)	% Distance share	Avg Distance (km)
Route 1a	18	34.3	38.5%	29.1	32.6%	25.7	28.9%	89.0
Route 1b	6	33.3	39.4%	24.1	28.5%	27.1	32.1%	84.5
Route 2	80	31.8	37.5%	29.6	35.0%	23.4	27.6%	84.8
Route 3	58	33.0	37.5%	29.7	33.8%	25.3	28.8%	88.0
Route 4	42	32.4	37.8%	27.6	32.2%	25.6	29.9%	85.7
Route 5	37	31.1	37.5%	28.3	34.1%	23.5	28.4%	83.0
Route 6	34	31.8	32.1%	31.7	32.0%	35.5	35.9%	99.0
Route 7	36	30.0	34.6%	28.8	33.2%	28.0	32.2%	86.8
Route 8	1	33.7	36.8%	28.8	31.4%	29.1	31.8%	91.5
Total	**312**	**32.0**	**36.6%**	**29.2**	**33.4%**	**26.1**	**29.9%**	**87.3**

Table 12 presents the average speed of each operation mode, for each of the routes contained in Green NCAP database. Additionally, deviation from mixed results average has been also calculated.

Table 12 Average speed (km/h) for each phase of each route of real-world measurements, and deviation from total average.

Route	Urban		Rural		Highway		Mixed	
	Avg Speed (km/h)	Dev (%)	Avg Speed (km/h)	Dev (%)	Avg Speed (km/h)	Dev (%)	Avg Speed (km/h)	Dev (%)
Route 1a	34.2	18.5%	73.7	-3.7%	103.5	-3.3%	54.0	7.5%
Route 1b	33.3	15.5%	73.1	-4.5%	105.4	-1.6%	53.2	6.0%
Route 2	28.2	-2.3%	76.9	0.5%	107.2	0.1%	48.9	-2.6%
Route 3	29.1	0.9%	78.8	3.0%	105.6	-1.3%	50.2	0.0%
Route 4	28.9	0.1%	75.0	-2.0%	106.9	-0.1%	49.4	-1.6%
Route 5	28.3	-1.9%	74.7	-2.5%	106.7	-0.3%	48.8	-2.8%
Route 6	28.3	-2.0%	80.1	4.7%	108.7	1.6%	53.5	6.5%
Route 7	27.5	-4.7%	74.4	-2.8%	110.1	2.8%	50.1	-0.3%
Route 8	31.1	7.8%	71.6	-6.4%	105.7	-1.2%	52.0	3.6%
Total	**28.8**		**76.5**		**107.0**		**50.2**	

In Figure 7, all routes already introduced are represented throughout the vehicle speed and altitude.

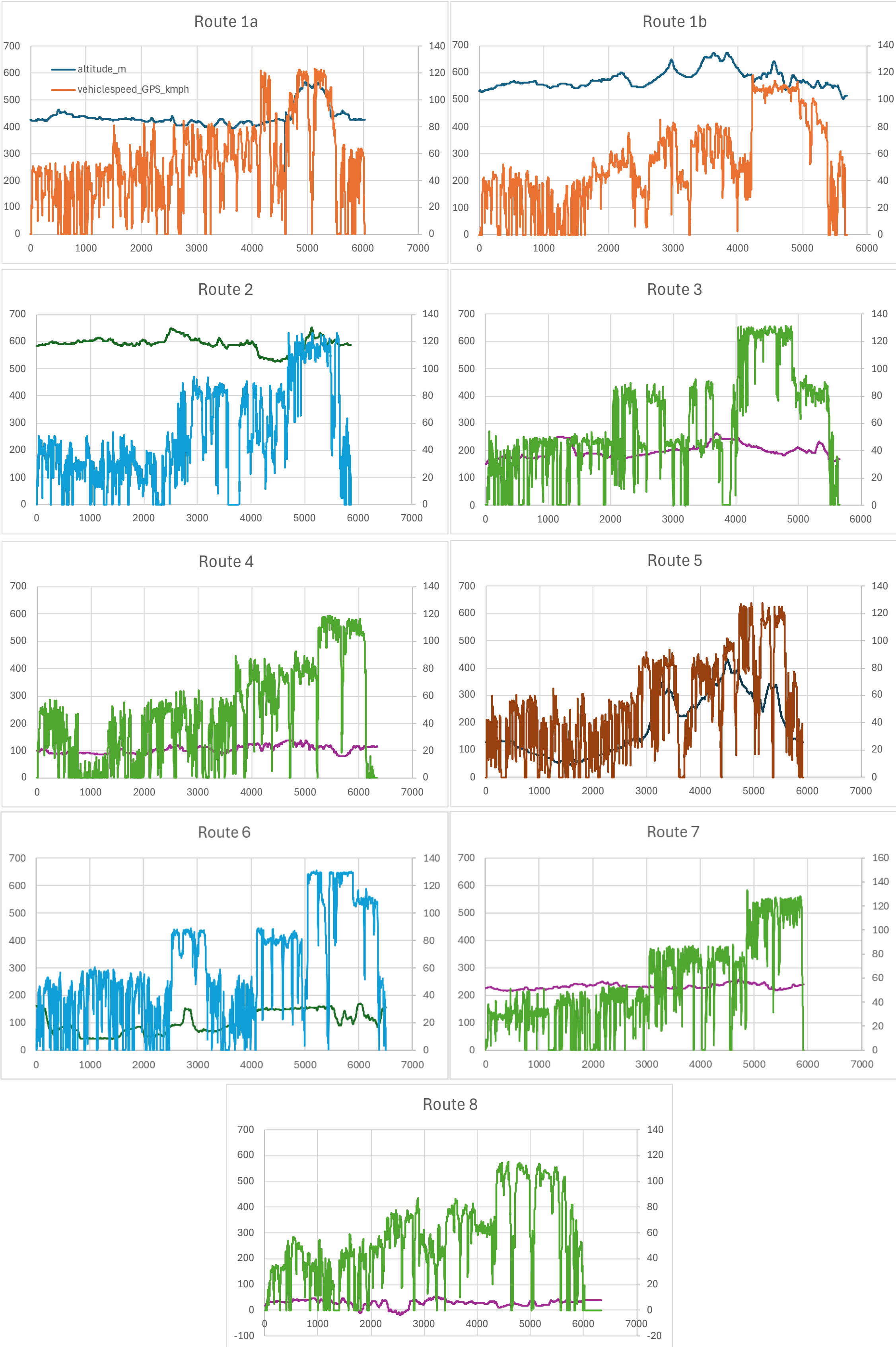

Figure 7 Speed profile (km/h) and altitude (m) from the different routes of real-world measurements

In the 2022-2024 Green NCAP test programme period, tests were done in two stages; *Stage 2* was carried out dependent on the results of *Stage 1*. WLTC+ Cold Ambient Temperature (CAT) at -7ºC, PEMS+ Eco, Congestion and PEMS+ Heavy tests were included for ICE, HEV and PHEV CS and CD. Regarding PEV, only WLTC+ CAT and Congestion measurements were conducted in *Stage 2*. According to the past procedures, only some vehicles were subjected to *Stage 2*. Consequently, not all vehicles have performed PEMS+ Heavy, PEMS+ Eco and/or WLTC+ CAT as represented in Table 13.

Table 13 Percentage (%) of vehicles that have been subjected to the different measurement types in the 2022-2024 programme period

Test Type	% Vehicles
WLTC warm	100
WLTC cold	100
BAB warm	100
PEMS cold	100
PEMS heavy warm	51.8
PEMS eco warm	51.8
WLTC cold CAT	73.0

4.2.1. Ambient temperature of real-world tests

In Figure 8, average ambient temperature (ºC) distribution of all real-world measurements is introduced, discretized per test laboratory.

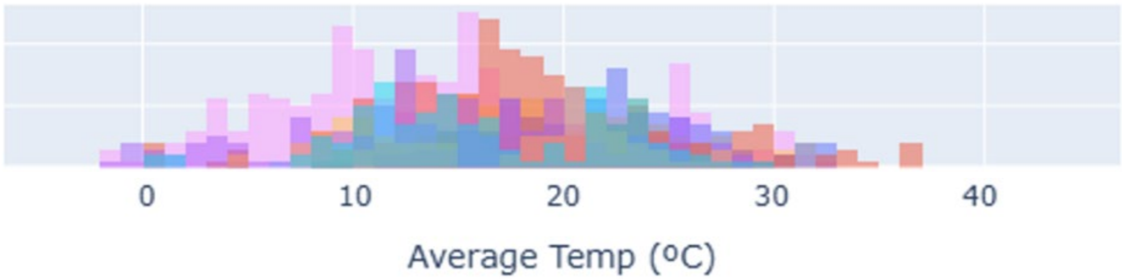

Figure 8 Real-world test average ambient temperature (ºC). Different colors means different test laboratory

Table 14 presents the minimum, maximum and average temperature (in ºC), for each phase and route.

Table 14 Number of tests, minimum, maximum and average temperature (ºC), and number of tests under and above 23ºC for each operation mode and each route of the real-world measurements

Route	Nº tests	Min temp (ºC)	Max temp (ºC)	Avg temp (ºC)	Nº test <5ºC	Nº test 5<x <23ºC	Nº tests >23ºC
Route 1a	18	4.35	27.08	17.48	2	14	2
Route 1b	6	7.97	21.51	11.56	0	6	0
Route 2	80	-1.31	30.86	14.35	8	56	16
Route 3	58	0.28	36.42	18.15	2	45	11
Route 4	42	-0.55	27.93	14.41	6	30	6
Route 5	37	6.44	32.65	21.57	0	24	13
Route 6	34	1.00	28.16	16.09	1	27	6
Route 7	36	9.33	31.35	18.87	0	25	11
Route 8	1	9.37	9.37	9.37	0	1	0
Total	**312**	**3.61**	**27.98**	**16.74**	**19**	**228**	**65**

4.2.2. Altitude of real-world tests

In Figure 9, the accumulated altitude distribution of all real-world measurements is discretized per test laboratory.

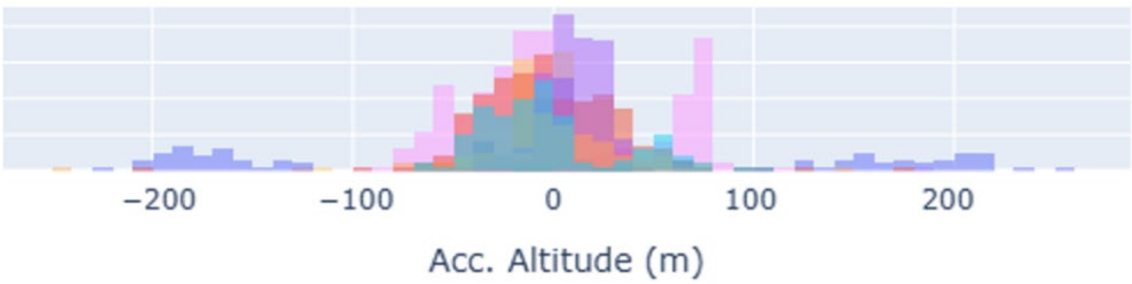

Figure 9 Real-world test average accumulated altitude (in meters) per phase. Different colour means different test laboratory.

Table 15 lists the average altitude (in meters) for each phase and route.

Table 15 Average altitude (m) for each operation mode and each route of the real-world measurements

Route	Nº Tests	Average altitude (m)			
		Urban	Rural	Highway	Mixed
Route 1a	18	433.3	428.1	494.6	441.2
Route 1b	6	566.2	601.8	584.8	576.6
Route 2	80	587.9	558.2	570.0	579.0
Route 3	58	198.6	204.2	208.8	201.2
Route 4	42	100.4	122.6	101.1	105.2
Route 5	37	137.2	290.4	326.0	196.0
Route 6	34	83.3	126.3	132.7	101.2

Route 7	36	234.8	240.0	237.1	236.3
Route 8	1	31.5	24.9	22.4	28.6
Total	**312**	**288.7**	**309.1**	**317.8**	**297.3**

4.2.3. Driving Dynamics of real-world tests

In Table 16, average values of v*a,pos (perc 95) (m^2/s^3) for each mode of operation and each route are shown, besides average vehicle speed (km/h).

Table 16 v*a,pos (perc 95) (m^2/s^3) and average speed (km/h) for each operation mode and each route of the real-world measurements

Route	Nº tests	Urban		Rural		Highway		
		Speed (km/h)	v*a pos (m^2/s^3)	Speed (km/h)	v*a pos (m^2/s^3)	Speed (km/h)	v*a pos (m^2/s^3)	Max speed (km/h)
Route 1a	18	36.36	13.31	73.58	18.31	104.67	19.98	114.04
Route 1b	6	33.31	11.97	73.10	19.78	105.38	19.56	114.63
Route 2	80	29.13	12.53	76.93	18.59	109.21	16.48	119.26
Route 3	58	31.33	12.28	78.60	17.52	107.61	16.17	120.37
Route 4	42	30.14	12.63	74.79	16.55	110.87	17.02	120.18
Route 5	37	29.65	10.81	74.78	14.17	108.70	15.65	120.57
Route 6	34	29.94	10.45	80.88	18.01	111.09	17.22	120.85
Route 7	36	28.20	11.49	74.09	16.70	111.51	17.99	119.98
Route 8	1	31.10	12.52	71.64	17.05	105.72	10.55	115.41
Total	**312**	**30.15**	**12.04**	**76.44**	**17.45**	**109.08**	**16.82**	**119.49**

Figure 10 and Figure 11 below, represent PEMS+ Cold, Heavy and WLTC dynamic parameter *v*a,pos* against the average vehicle speed for each phase to analyse the differences in driving dynamics between all measurements. As a conclusion, PEMS+ Cold and WLTC dynamics show similarities in terms of *v*a,pos* and average speed, when considering the same criteria for phases discretization (see

Figure 10). When considering proposed WLTC phase discretization criteria from Table 10, the average speed for each WLTC phase differs from the real-world test values, because of the difference in the criteria definition itself, see Figure 11.

Finally, Figure 12 shows the difference in terms of driving dynamics KPIs on WLTC measurements when applying the decided phase discretization based on the original WLTC phases by combining Ph1 and Ph2 for urban driving; and following same criteria as in real-world measurements.

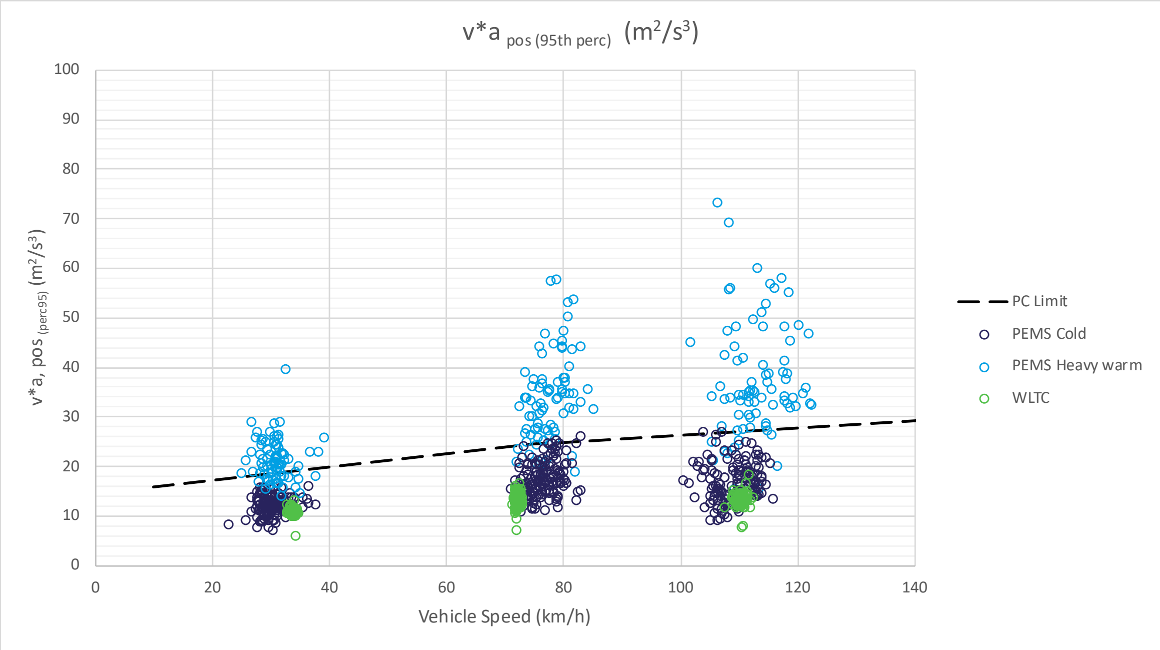

Figure 10 **v*a,pos (perc 95) (m^2/s^3) vs mean vehicle speed (km/h) per phase. WLTC phase discretization following real-world criteria according to (EU) 2017/1151.**

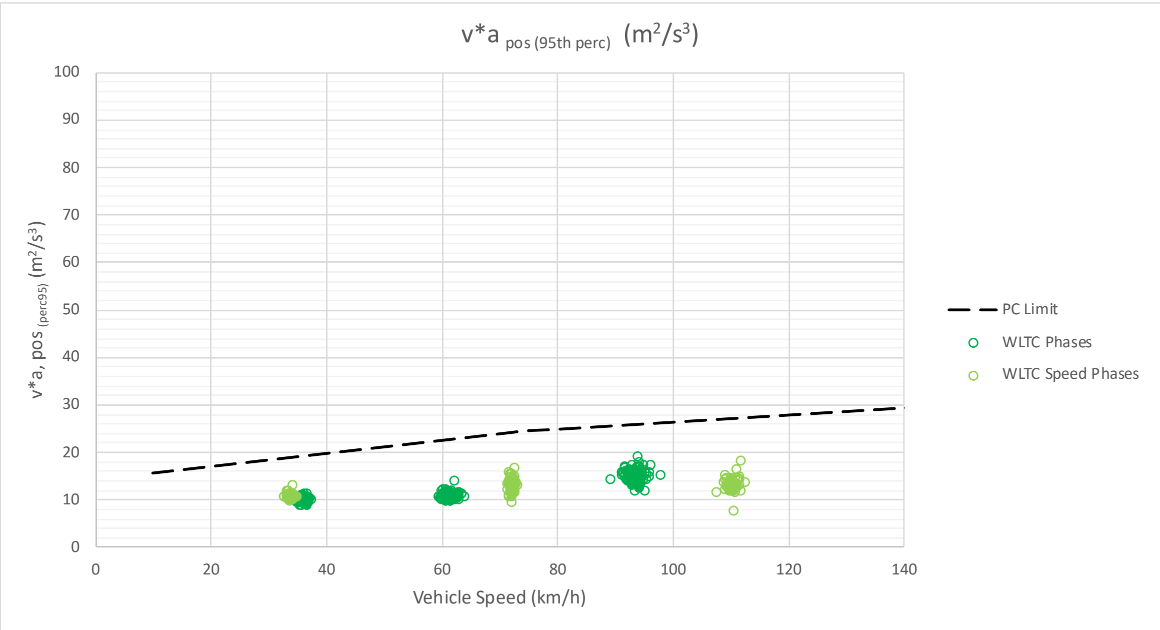

Figure 11 **v*a,pos (perc 95) (m2/s3) vs mean vehicle speed (km/h) per phases. WLTC phases discretization comparison.**

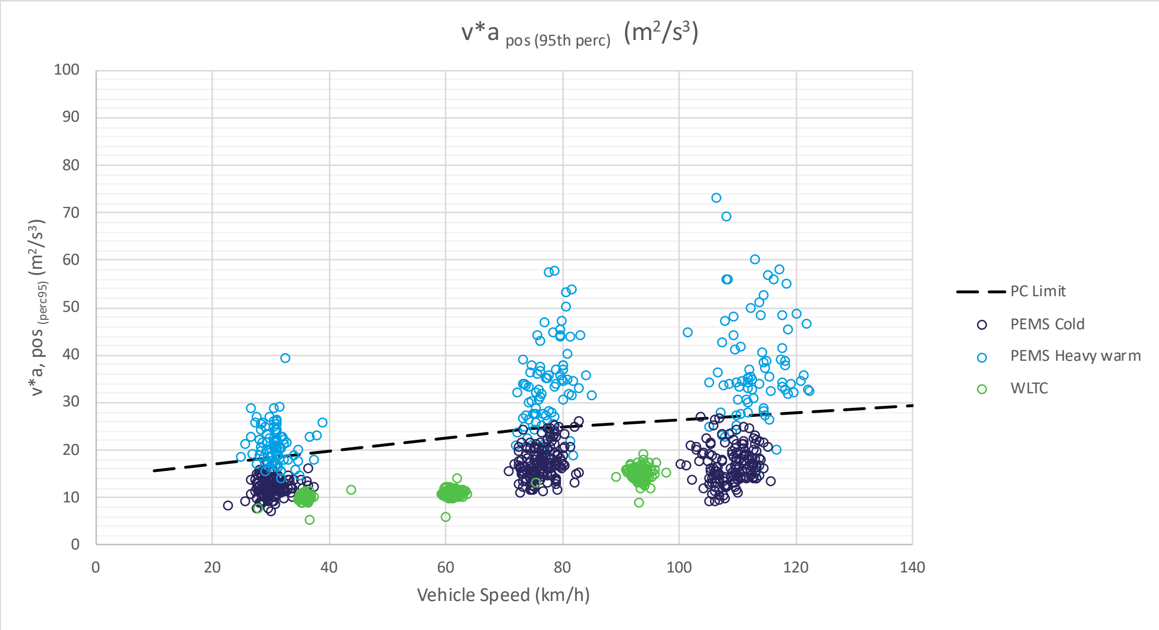

Figure 12 **v*a,pos (perc 95) (m2/s3) vs mean vehicle speed (km/h) per phases. WLTC phases discretization considering PH1+Ph2 as urban phase, Ph3 as rural, and Ph4 as highway phase.**

5. ESTIMATED ACTUAL CONSUMPTION AND DRIVING RANGE

To provide an estimation of a real-world fuel or electricity consumption, a WLTC-to-real world ratio was calculated. The ratio, used as a multiplication factor on the Green NCAP test results, is determined separately for each phase (urban, rural, motorway) and for the mix of the three (total WLTC cycle). This is done for both WLTC+ Warm (23°C) and WLTC+ Cold Ambient Test (-7°C).

These ratios are then applied to the laboratory test consumption results to provide to consumers a more realistic value of representative real-world consumption.

The ratio for the mix (total WLTC cycle) is not based on Green NCAP test data, but on monitoring data collected by the European Commission from the On-Board Fuel Consumption Monitoring (OBFCM) implemented on new vehicles. The OBFCM dataset contains real world fuel consumption as well as the type approval WLTP value of each vehicle; the ratio is calculated by dividing these two numbers for a selection of vehicles. Note that OBFCM based factors are applied only for vehicles with a combustion engine, because (as the abbreviation suggests) only fuel is monitored, not electricity consumption. More information on the OBFCM based ratios can be found in chapter 1.1 below.

For the calculation, PEMS+ Eco measurements have been disregarded. The reason is that PEMS+ Eco requirements are not representative when comparing with real-world driving conditions, in terms of energy demand. In this test, the highway maximum speed is 100 km/h, and the HVAC is deactivated. These conditions are rarely representative for today's real world driving scenarios. In Figure 13 and Figure 14, this evidence is presented with the driving dynamics KPIs obtained from the different types of measurements, with both *v*a,pos* and *RPA*. The average speed of PEMS+ Eco measurements is much lower, as well as *v*a,pos* final values for each operation mode.

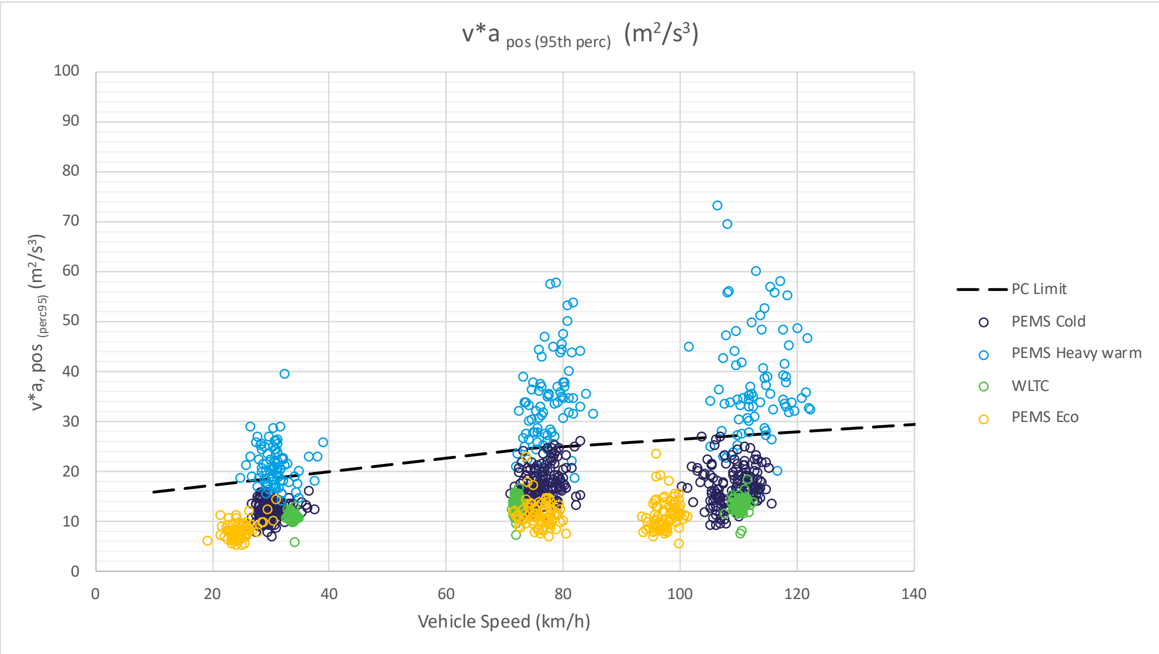

Figure 13 **v*a,pos (perc 95) (m^2/s^3) vs mean vehicle speed (km/h) per phase. WLTC phase discretization following real-world criteria according to (EU) 2017/1151.**

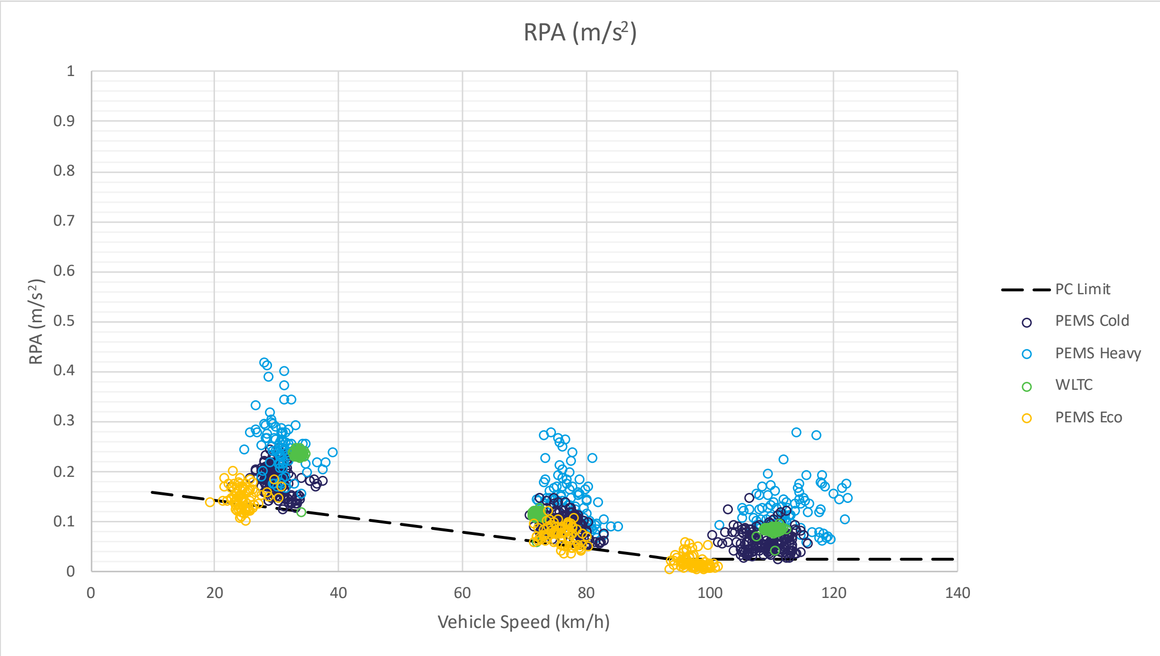

Figure 14 RPA (m/s^2) vs mean vehicle speed (km/h) per phase. WLTC phase discretization following real-world criteria according to (EU) 2017/1151.

Estimated actual consumption and driving range calculations are described in Table 17 and Table 18 shown below, one for ICE and HEV vehicles, and a separate one for PEV. Regarding MHEV, they are included with ICEs when computing the ratios as per HEV definitions in Green NCAP's **Definitions, Acronyms & Symbols**.

Table 17 lists the estimated actual consumption scenarios for ICE and HEV powertrain technologies. Figure 15 and Figure 16, picture the laboratory tests WLTC+ Warm and the Cold Winter Cold Ambient Test sequence (WLTC+ CAT 1, Intermediate WLTC+, and WLTC+ CAT 2) as introduced in 2025. The Cold Winter measurements are described in **WLTC+ CAT (Cold Ambient Temperature) Test Procedure**.

Table 17 Estimated Actual Consumption scenarios for ICE and HEV powertrain technologies

Estimated actual consumption	Urban	Rural	Highway	Mixed
Warm	(WLTC Warm, ph1+ph2) * Ratio, urban GNCAP db	WLTC Warm, ph3 * Ratio, rural GNCAP db	WLTC Warm, ph4 * Ratio, Highway, GNCAP db	WLTC Warm Mixed * Ratio, Mixed OBFCM db
Cold Winter	½ * (CAT 1(ph1+ph2) + CAT 2 (ph1+ph2)) * Ratio, urban GNCAP db	½ * (CAT 1(ph3) + CAT 2 (ph3)) * Ratio, rural GNCAP db	½ * (CAT 1(ph4) + CAT 2 (ph4)) * Ratio, Highway, GNCAP db	½ * (CAT 1(Mixed) + CAT 2 (Mixed)) * Ratio, Mixed OBFCM db

Table 18 features the estimated actual consumption scenarios for PEV powertrain technology. Energy Consumption (kWh/100km) values of each of the phases are understood as energy from the electrical grid, measured at the charging plug. This considers the losses from the plug to the output terminals of the high voltage battery.

Table 18 Estimated Actual Consumption scenarios for PEV powertrain technology

Estimated actual consumption	Urban	Rural	Highway	Mixed
Warm Weather	(WLTC Warm, ph1+ph2)* Ratio, urban GNCAP db	WLTC Warm, ph3 * Ratio, rural GNCAP db	WLTC Warm, ph4 * Ratio, Highway, GNCAP db	WLTC Warm Mixed * Ratio, Mixed Green NCAP db
Cold Winter	½ * (CAT 1(ph1+ph2) + CAT 2 (ph1+ph2))	½ * (CAT 1(ph3) + CAT 2 (ph3))	½ * (CAT 1(ph4) + CAT 2 (ph4))	½ * (CAT 1(Mixed) + CAT 2 (Mixed))

The baseline laboratory test for the estimated actual consumption in warm weather conditions is the WLTC+ Warm test. The tests for the definition of the estimated actual consumption scenarios in cold winter conditions are WLTC+ CAT 1 (cold start) and WLTC+ CAT 2 (warm start).

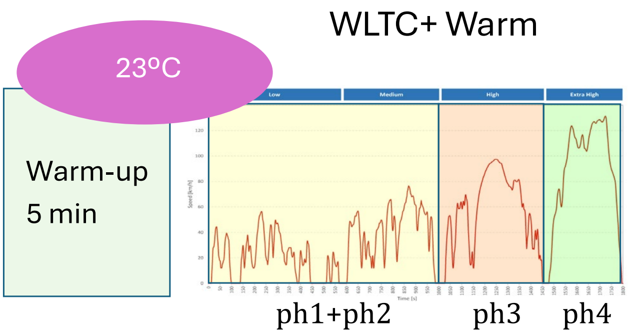

Figure 15 WLTC+ Warm test sequence

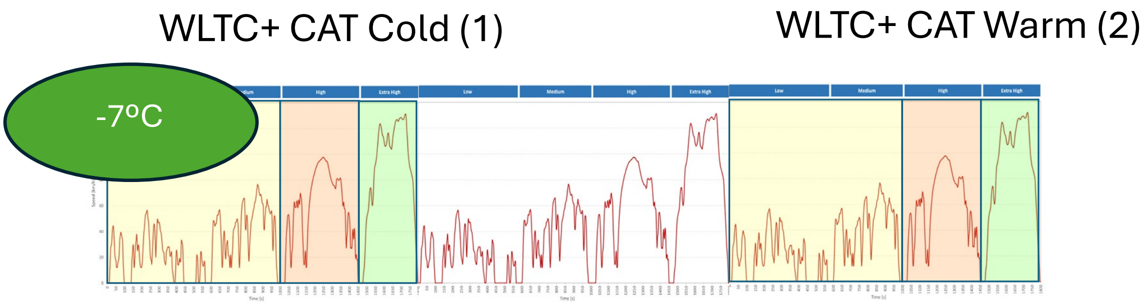

Figure 16 WLTC+ CAT 1 and CAT 2 test sequence

The driving range matrix for PEV, included in Table 19**,** is calculated considering the Total Energy delivered from the grid (kWh) and measured at the charging plug, divided by the final consumption results from Table 18.

Table 19 Real-world driving range matrix for Warm Weather and Cold Winter conditions.

Driving Range (km)	Urban	Rural	Highway	Mixed
Warm Weather	**Total Energy from mains /** RW Energy Consumption, urban Warm Weather conditions	**Total Energy from mains /** RW Energy Consumption, rural Warm Weather conditions	**Total Energy from mains /** RW Energy Consumption, Highway Warm Weather conditions	**Total Energy from mains /** RW Energy Consumption, Mixed Warm Weather conditions
Cold Winter	**Total Energy from mains /** RW Energy Consumption, urban Cold Winter conditions	**Total Energy from mains /** RW Energy Consumption, rural Cold Winter conditions	**Total Energy from mains /** RW Energy Consumption, Highway Cold Winter conditions	**Total Energy from mains /** RW Energy Consumption, Mixed Cold Winter conditions

The ratios are introduced in chapters 5.1 and 1.1. OBFCM ratio and Green NCAP database ratio encompass all variabilities in real-world: short trips, speed and load scenarios, driving style, weight, ambient temperature, altitude, etc.

The Green NCAP ratio encompasses driving style and cold/warm start conditions, which affect much the fuel consumption values of ICE. The ratios are also applied to the average of CAT 1 + CAT 2. It has been observed that CAT 2 fuel consumption values do not differ significantly from those obtained from WLTC+ Warm for this powertrain type, both diesel and petrol, and for HEV, meaning that these powertrain types are less affected by ambient temperature when performing a warm start drive.

Regarding pure electric vehicles (PEV), if ratios are applied to the CAT 1 + CAT 2, the final estimated actual consumption in Cold Winter conditions gets too high, this is because cold weather consumption of PEVs is mainly affected by ambient temperature, which is directly related to HVAC usage. Therefore, real-world ratios are not applied in cold weather consumption.

Figure 17 to Figure 19 describe the estimated actual consumption average for Petrol and Diesel ICE, and PEV and driving range. Consumption values have been computed as the average of all vehicles of each powertrain technology from Green NCAP's database. Moreover, average, minimum and maximum test mass in tonnes (Tn) from the vehicles considered from each powertrain type is represented, as well as the ratio distribution per phase.

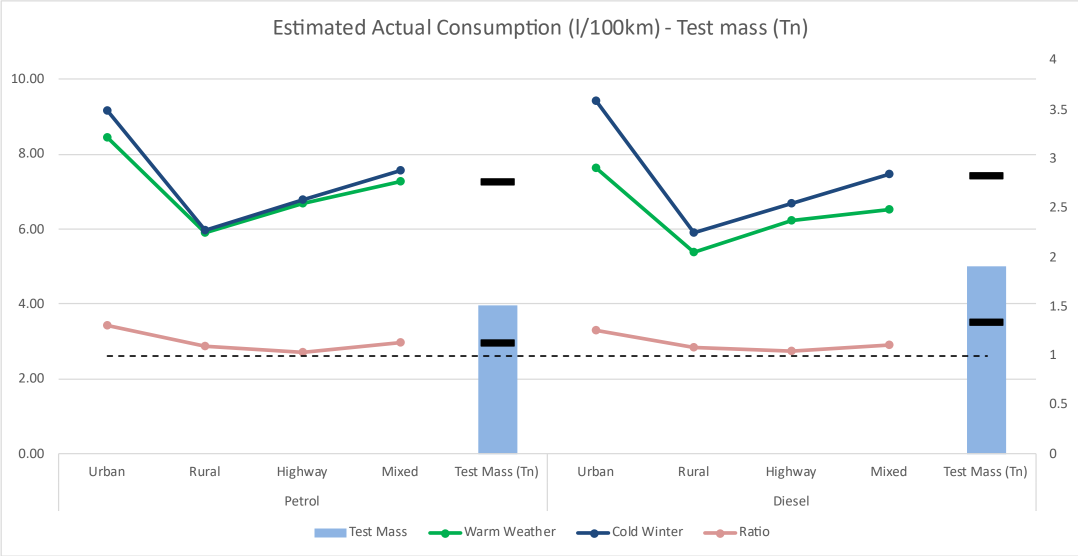

Figure 17 Average estimated actual consumption (l/100km) of all Petrol and Diesel ICE measurements from both Warm Weather (WLTC+ Warm) and Cold Winter (WLTC+ CAT) conditions

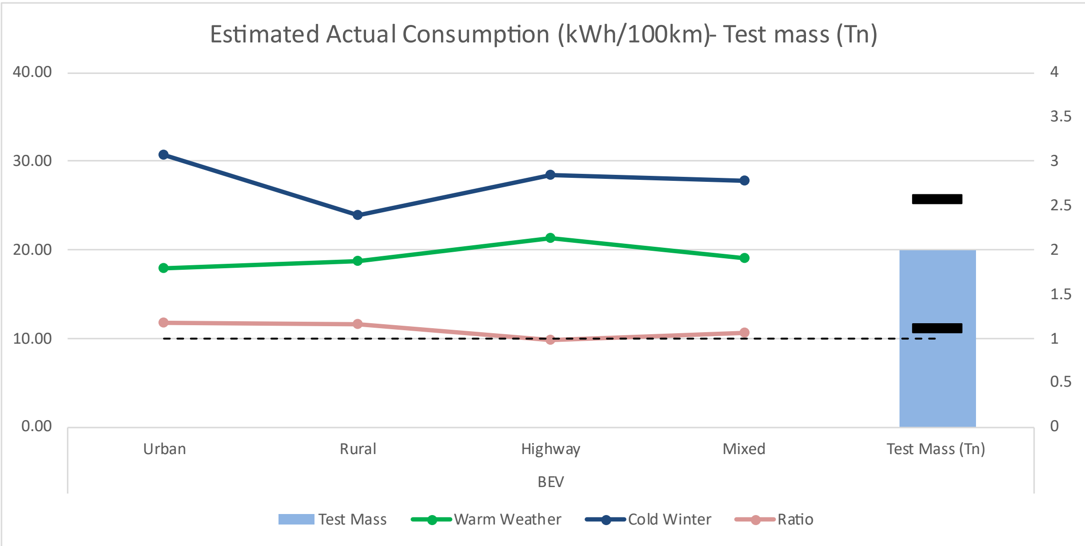

Figure 18 Average estimated actual consumption (kWh/100km) of all PEV measurements from both Warm Weather (WLTC+ Warm) and Cold Winter (WLTC+ CAT) conditions

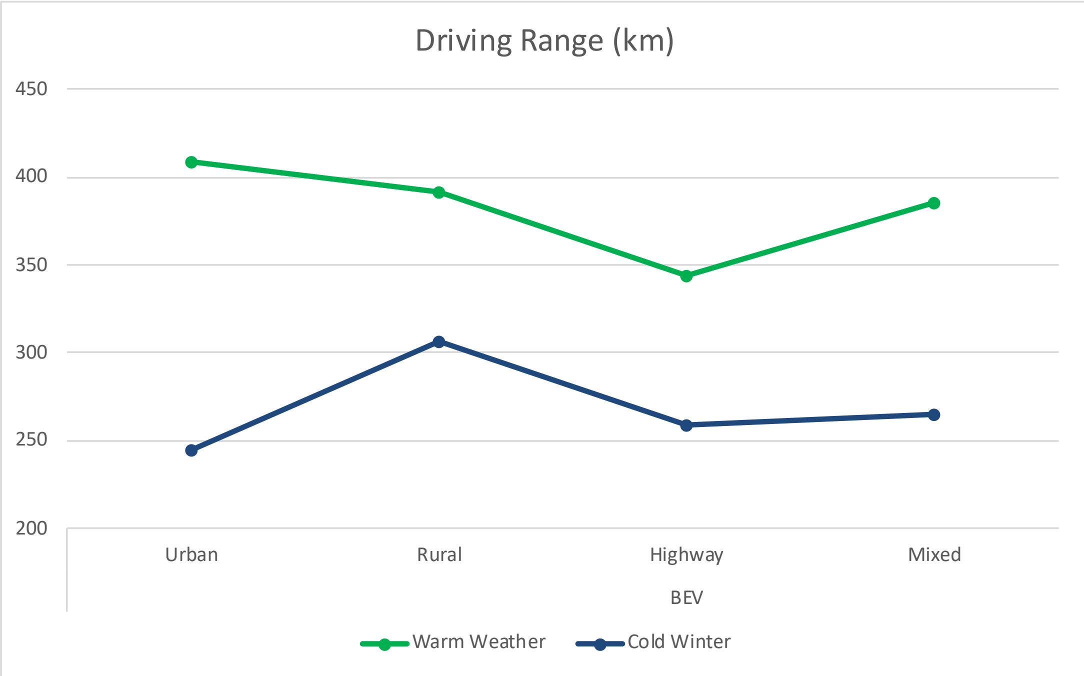

Figure 19 Driving range (km) values calculated as an average of all PEV estimated actual consumption results from both Warm Weather (WLTC+ Warm) and Cold Winter (WLTC+ CAT) conditions

5.1. Green NCAP data based real-world consumption ratio applicable to the cycle phase consumptions

5.1.1. Calculation method

At the beginning of the procedure development, two different possibilities were considered for the ratio calculation. The first one was to calculate the overall average of all individual ratios, where each ratio is the real-world test consumption over the WLTC+ Warm consumption of a vehicle; and the second one was to calculate an overall ratio as the sum of all the real-world consumption values divided by the sum of all the WLTC+ Warm consumption figures. Both methodologies have been evaluated: the overall average of individual ratios gives an equal weight to each of the samples, whereas the ratio of the overall sum of all results gives greater weight to those samples with higher consumption values. Consequently, the overall average of individual ratios has been selected due to the equal ponderation of all samples, which better describes the deviation between different driving behaviours.

The ratios are then calculated as follows:

$$Ratio_{Phase} = \frac{\sum_{i=0}^{n} Ratio_{Phase,i}}{n}$$

$$where\ Ratio_{Phase,i} = \frac{OnRoad\ \ EC_{Phase,i}\ or\ CO2_{Phase,i}}{WLTC\ Warm\ EC_{Phase,i}\ or\ CO2_{Phase,i}}$$

$$where\ \text{"Phase"}\ can\ be{:}\ urban, \text{rural}, highway, \text{mixed}$$

5.1.2. Powertrain type segmentation

A powertrain segmentation has to be chosen to calculate the ratios. Table 20 summarizes the possible ratio value, calculated with different considerations of granularity. Green NCAP refers to mild hybrid vehicles (MHEV) as to ICE. In OBFCM data, however, MHEVs are commonly categorized in the same way as Petrol HEV vehicles.

Table 20 Green NCAP EC (energy consumption) ratios for the different powertrain technology segmentations

Powertrain	Nº vehicles	Real-world tests	Urban	Rural	Highway	Mixed
All	152	227	1.28	1.14	1.02	1.13
Petrol+Diesel+GFV+ Petrol HEV	103	166	1.27	1.10	1.03	1.13
Diesel	30	52	1.26	1.09	1.05	1.13
Petrol	58	88	1.31	1.10	1.03	1.15
Petrol HEV	13	22	1.31	1.26	1.06	1.16
PEV	40	47	1.19	1.17	0.98	1.07
PHEV (Charge Sust.)	9	14	1.41	1.34	1.07	1.25

5.1.3. Real-world data granularity

The summary of the Green NCAP based data in Table 21 is compared with the OBFCM data from Table 22, which conveys all the variability of real-world driving in Europe.

Table 21 Green NCAP ratios for all powertrain types and different real-world test types considered individually and overall

Powertrain		URBAN	RURAL	HIGHWAY	MIXED
Petrol	PEMS Cold	1.12	0.97	0.96	1.02
Petrol	PEMS Heavy Warm	1.67	1.34	1.17	1.40
Petrol	**PEMS Cold+PEMS Heavy Warm**	**1.31**	**1.10**	**1.03**	**1.15**
Diesel	PEMS Cold	1.12	0.97	0.97	1.02
Diesel	PEMS Heavy Warm	1.44	1.25	1.16	1.27
Diesel	**PEMS Cold+PEMS Heavy Warm**	**1.26**	**1.09**	**1.05**	**1.13**
Petrol HEV	PEMS Cold	1.15	1.12	0.98	1.05
Petrol HEV	PEMS Heavy Warm	1.53	1.46	1.18	1.33
Petrol HEV	**PEMS Cold+PEMS Heavy Warm**	**1.31**	**1.26**	**1.06**	**1.16**
PEV	PEMS Cold	1.15	1.16	0.94	1.05
PEV	PEMS Heavy Warm	1.38	1.21	1.18	1.19
PEV	**PEMS Cold+PEMS Heavy Warm**	**1.19**	**1.17**	**0.98**	**1.07**
PHEV CS	PEMS Cold	1.10	1.25	0.98	1.08
PHEV CS	PEMS Heavy Warm	2.19	1.54	1.19	1.58
PHEV CS	**PEMS Cold+PEMS Heavy Warm**	**1.49**	**1.35**	**1.06**	**1.26**

Table 22 Average real-world and WLTP fuel consumption, CO_2 emissions, and gap between real-world and WLTP values (cars) from 2021 data.[2]

	Average fuel consumption (l/100 km)		Average CO_2 emissions (g/km)		Gap (%)	
Powertrain/fuel type	**Real-world**	**WLTP**	**Real-world**	**WLTP**	**Average**	**Km-weighted average**
Petrol	7.89	6.38	179.8	145.3	23.7	20.4
Diesel	6.88	5.82	181.0	153.2	18.1	16.7
Petrol + Diesel	7.44	6.13	180.3	148.8	21.2	18.1
Plug-in hybrid (petrol)	5.97	1.76	135.9	40.2	238	251
Plug-in hybrid (diesel)	5.83	1.41	153.3	37.2	312	318
Plug-in hybrid (all)	5.94	1.69	139.4	39.6	252	267

Data from Table 22 is based on the type-approval WLTP. The trips of the vehicles in Europe statistically are shorter and the share of driving is different than the WLTP or Green NCAP real-world considered routes.

5.1.4. Final ratios

The final ratios to be applied to consider the estimated actual consumption scenarios at warm weather conditions and/or cold winter conditions for each vehicle are presented in Table 23 (except for mixed ratio on ICEs and HEV technologies, where OBFCM ratio is to be applied). Additionally, as presented in the corresponding calculation Table 17, these ratios are also applied to cold winter conditions for ICEs and HEVs. For the mixed consumption values, the ratios from OBFCM should be considered. Figure 20 and Figure 21 show energy consumption results from both real-world and laboratory measurements and together with the calculated values.

Table 23 Green NCAP final ratios for each operation mode (phase) and powertrain type.

Green NCAP Phase Energy Consumption Ratios						
Powertrain	**Nº vehicles**	**Real-world tests**	**Urban**	**Rural**	**Highway**	**Mixed**
Diesel	30	52	1.26	1.09	1.05	1.13
Petrol	58	88	1.31	1.10	1.03	1.15
Petrol HEV	13	22	1.31	1.26	1.06	1.16
PEV	40	47	1.19	1.17	0.98	1.07

[2] European Commission, Directorate-General for Climate Action. (2024, March 18). Report from the Commission: Commission report under Article 12(3) of Regulation (EU) 2019/631 on the evolution of the real-world CO_2 emissions gap for passenger cars and light commercial vehicles and containing the anonymised and aggregated real-world datasets referred to in Article 12 of Commission Implementing Regulation (EU) 2021/392 (COM(2024) 122 final) [Report]. European Union. **https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52024DC0122**

Figure 20 Real-world Energy Consumption (EC) against WLTC+ Warm EC per powertrain type

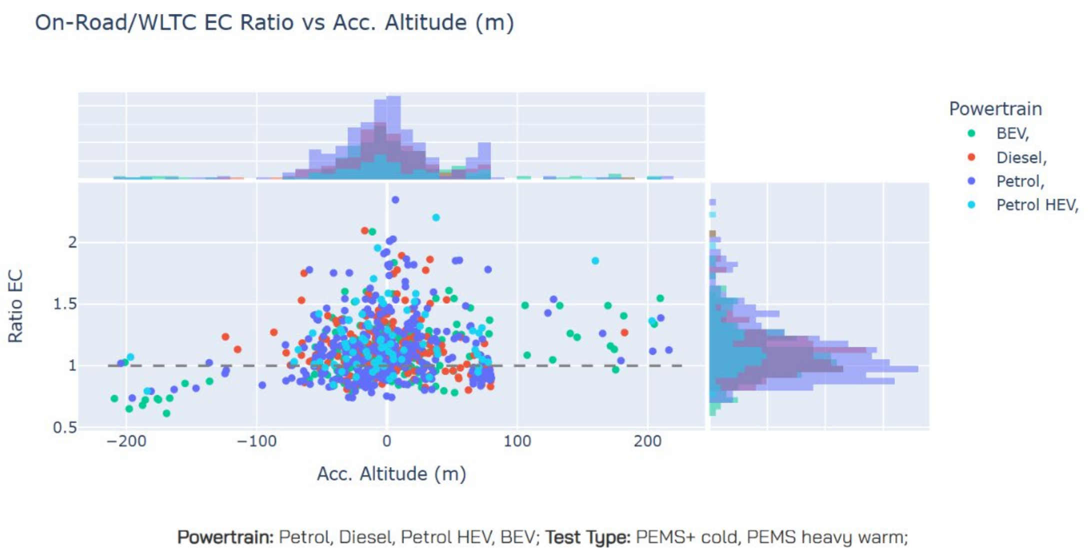

Figure 21 Energy Consumption (EC) ratio distribution against accumulated altitude (m) per powertrain type.

5.2. Vehicle specific, OBFCM based real-world consumption ratio applicable to the mixed consumption

The mixed real-world consumption is based on actual On-Board Fuel Consumption Monitoring (OBFCM) data[3] from newer vehicles, collected by the European Commission through workshops during periodical technical inspection and made available by the EEA[4]. The data used for this analysis is up to and including the year 2023 (2021, 2022 and 2023 reporting periods), published on EEA website per August 2025. OBFCM was first implemented on new vehicle models in January 2020, so the data set covers only relatively young vehicles. Data includes lifetime mileage and lifetime fuel consumption for internal combustion engine vehicles, and additionally, lifetime electricity consumption for plug-in hybrids. Metadata is described in "*Guidelines for reporting countries on the monitoring and reporting of CO_2 emissions from new passenger cars and light commercial vehicles, Version 17, 29th November 2024, European Commission*)

After filtering for validity and a minimum of 1000 kilometers on the odometer, 6.44 million vehicles remain in the OBFCM database. The average ratio between real-world and type approval CO_2 values for petrol and diesel vehicles (including hybrids without a plug) is 1.192.

The ratio is obtained following the same methodology as for calculating the Green NCAP ratio. This means that individual ratios are obtained, and then the average of all ratios for each aggregation level (described later) is calculated. CO_2 Type-approval values are converted into fuel volume units (l) applying the energy content conversion factor from Table 24. Figure 22 shows the ratio distribution and final ratio value obtained for the different powertrain technologies included in the OBFCM database.

$$Fuel\ Consumption_{\ OBFCM} = \frac{Total\ fuel}{Total\ distance\ travelled}$$

$$Fuel\ Consumption_{\ CoC} = CO2_{CoC} \times EF_{\ E10\ or\ B7}$$

Table 24 emission conversion factors from gCO_2 to liters of fuel, for each fuel type

Fuel	Emission Conversion Factors ($gC0_2$/l fuel)
Petrol E10	22.78
Diesel B7	26.31

$$\boldsymbol{Ratio}_{\ \boldsymbol{OBFCM,i}} = \frac{Fuel\ Consumptiom_{OBFCM,i}}{Fuel\ Consumptiom_{CoC,i}}$$

$$\boldsymbol{Ratio}_{\ \boldsymbol{OBFCM}} = \frac{\sum_{i=0}^{n} Ratio_{\ OBFCM,i}}{n}$$

3 https://www.eea.europa.eu/en/datahub/datahubitem-view/1c1ffad2-34c3-471b-bd69-dd013cdd7b80

4 https://climate-energy.eea.europa.eu/topics/transport/real-world-emissions/data

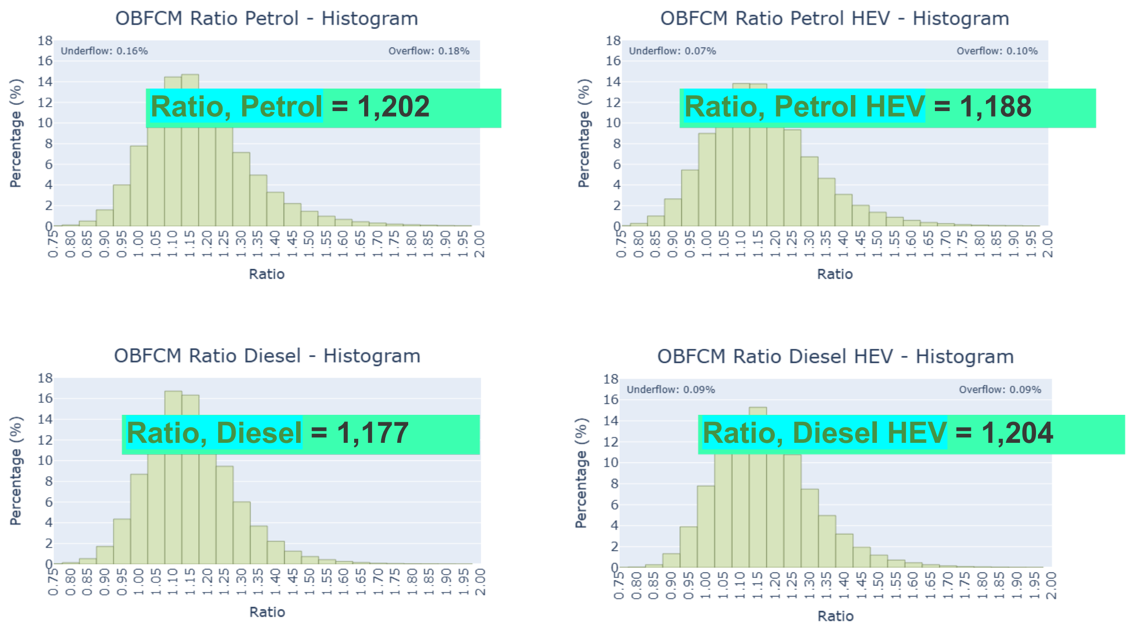

Figure 22 OBFCM ratio distribution per powertrain technology

The ratio can be further refined. A specific ratio was calculated for each combination of manufacturer, model, powertrain type and power-to-mass ratio (PMR) class. Vehicles with a power-to-mass ratio outside certain boundaries have a fuel consumption penalty[5]. The following power-to-mass ratio classes are defined, see Table 25.

Table 25 Classes of power-to-mass ratio

Class	P/M ratio (kW/t)	Percentage of vehicles in OBFCM database in this class
1	<55	18%
2	>=55 and <90	73%
3	>=90	9%

To apply an OBFCM-based ratio to each Green NCAP-tested vehicle, the make, model, drivetrain type and power-to-mass ratio class has to be matched, which is done semi-automatically. Some vehicles do not occur in the OBFCM dataset, because they are too new, too old, or not reported on. To work around this and still have a ratio that is as specific as possible, a four-level aggregation setup is introduced, see Table 26. Whenever a vehicle cannot be found, a ratio is taken from the next table, raising to a higher aggregation level. The minimum required vehicle mileage for considering OBFCM samples is set to 1000 km. The criteria besides minimum individual mileage, and matching make, model, drivetrain type and power-to-mass, per aggregation level, are:

- **Level 1 and level 2**
  - Minimum number of samples: 10
  - Minimum number of countries: 4

[5] Ruiter, J.M. de, Gijlswijk, R.N. van, Ligterink, N.E., 2019: More Information, Less Emissions. Estimating the real-world CO2 emissions of passenger cars based on vehicle properties. TNO report 2019 R10872, LIFE+ MILE21 project.

- **Level 3 and level 4**
  - No criteria needed. Minimum number of samples and countries are already covered when discretizing only per PMR class and powertrain technology

Powertrain technologies are described with the fields "*Fm*" and "*Ft*" in the OBFCM database. These two fields refer to:

- **"*Ft*" = Fuel type**
  - Petrol
  - Diesel
  - Petrol/Electric
  - …
- **"*Fm*" = Fuel mode**
  - H = Hybrid
  - M = Monofuel
  - P = Plug-in hybrid

Table 26 Four-level aggregation of OBFCM data-based CO_2 ratio values

Level	Classification variables	Number of lines
1	Model, Manufacturer, PMR class, Powertrain type	5776
2	Manufacturer, PMR class, Powertrain type	375
3	PMR class, Powertrain type	17
4	Powertrain type	6

Table 27 summarizes the total number of samples and distance covered for each powertrain technology, considering only ICEV's and HEVs.

Table 27 OBFCM data total number of vehicles and distance covered per powertrain technology, considering only ICEV's and HEVs

	Powertrain	Nº vehicles	Nº km (billion)
OBFCM database content	Petrol	≈ 2.19M	≈ 45
	Petrol HEV	≈ 1.51M	≈29
	Diesel	≈ 1.45M	≈ 58
	Diesel HEV	≈ 434k	≈ 17

Regarding mild-hybrid vehicles (MHEV), they are commonly categorized as Petrol/Diesel HEV in OBFCM database, instead of pure ICE. Green NCAP treats them as ICE and uses the same ratios, see summary Table 28. The procedure requires identifying the specific vehicle and how it has been labelled in the OBFCM database. Afterwards, when referring to the aggregation level 1, the OBFCM ratio with the correct vehicle model data has to be calculated, regardless whether label "*H*" or "*M"* (see Table 28). If there are no matches, aggregation level 2 with the field "*Fm=M*" (ICE's) data should be taken (i.e. a non-model-specific OBFCM factor).

Table 28 MHEV powertrain grouping in Green NCAP and OBFCM databases

	Classification	Fm	Powertrain
Green NCAP	Petrol	-	ICE + MHEV
	Petrol HEV	-	HEV
OBFCM	Petrol	M	ICE
	Petrol	H	HEV + MHEV

Aggregation levels 3 and 4 results are presented in Table 29 and Table 30 respectively.

Table 29 Aggregation level 3. CO_2 ratio for the different powertrain technologies including Power-to-Mass ratio categorization. Data until the 2023 reporting period, included.

PMR Class	Ft	Fm	CO_2 ratio	No. of vehicles
1	DIESEL	H	1.162	9,712
1	DIESEL	M	1.158	143,124
1	DIESEL/ELECTRIC	P	7.265	32,995
1	PETROL	H	1.184	601,159
1	PETROL	M	1.198	255,062
1	PETROL/ELECTRIC	P	3.155	129,116
2	DIESEL	H	1.192	323,598
2	DIESEL	M	1.179	1,235,721
2	DIESEL/ELECTRIC	P	4.005	51,816
2	PETROL	H	1.187	828,544
2	PETROL	M	1.201	1,688,422
2	PETROL/ELECTRIC	P	4.294	526,577
3	DIESEL	H	1.247	100,978
3	DIESEL	M	1.188	71,313
3	PETROL	H	1.236	77,885
3	PETROL	M	1.215	244,697
3	PETROL/ELECTRIC	P	4.939	96,637

Table 30 Aggregation level 4. CO_2 ratio for the different powertrain technologies without Power-to-Mass discretization. Data until the 2023 reporting period, included.

Ft	Fm	CO_2 ratio	No. of vehicles
DIESEL	H	1.204	434,288
DIESEL	M	1.177	1,450,158
DIESEL/ELECTRIC	P	5.273	84,811
PETROL	H	1.188	1,507,588
PETROL	M	1.202	2,188,181
PETROL/ELECTRIC	P	4.181	752,330

5.3. Example of calculations of estimated actual consumption and driving range

5.3.1. ICE and HEV

5.3.1.1. Warm weather conditions

Starting with the results of WLTC+ Green NCAP tests at 23ºC, fuel consumption data is available for each vehicle in three different phases: urban (Ph1 + Ph2), rural, and highway, as well as for mixed operation fuel consumption, see Table 31.

Table 31 Example values of fuel consumption (l/100km) on WLTC+ Warm for the different phases of a Petrol HEV

FC_{WLTC} (l/100km)	Urban	Rural	Highway	Mixed
	6.975	5.895	7.370	6.783

For each of these three phases, a ratio is applied based on the tests performed in Green NCAP real-world tests for each powertrain technology, see Table 32.

Table 32 Green NCAP ratios of Petrol HEV powertrain

$Ratio_{GNCAP}$	Urban	Rural	Highway
	1.31	1.26	1.06

Additionally, a ratio based on OBFCM data is used for the mixed result. Depending on the available data for the assessed vehicle, the appropriate table must be selected. In this case, the reference is to aggregation level 1 of the database, which considers the model, manufacturer, power-to-mass ratio, and drivetrain type. The vehicle meets the criterion of having more than 10 units assessed but does not meet the minimum number of countries required. Therefore, it must be referred to aggregation level 2, which considers manufacturer, PMR, and drivetrain type. Since the selected vehicle in this table meets the required minimum number of samples, the ratio in Table 33 should be taken for mixed condition fuel consumption.

Table 33 OBFCM ratios of a determined Petrol HEV vehicle

$Ratio_{OBFCM}$	Mixed
	1.18

Finally, the estimated actual consumption for each phase is obtained by multiplying the initial consumption by the corresponding ratio. Final values are shown in Table 34.

$$FC_{RW\ Phase} = Ratio_{Phase\ i} \times FC_{WLTP\ Phase}$$

Table 34 Estimated Actual Consumption (l/100km) for Real-world Warm Weather Conditions

FC (l/100km)	Urban	Rural	Highway	Mixed
	9.137	7.428	7.812	8.004

5.3.1.2. Cold winter conditions

For cold winter conditions driving scenarios, there are two different tests in the Green NCAP database, CAT 1 (cold start) and CAT 2 (warm start), the sequence of which is presented in Figure 16. Obtained values for the selected vehicles are shown in Table 35.

Table 35 Example values of fuel consumption (l/100km) on WLTC for the different phases of a Petrol HEV determined vehicle under Cold Winter conditions

FC_{WLTC} (l/100km)	Urban		Rural		Highway		Mixed	
	CAT 1	CAT 2	CAT 1	CAT 2	CAT 1	CAT 2	CAT 1	CAT 2
	7.69	4.05	5.83	5.70	6.88	6.83	6.83	5.26

Both are equally weighted at 50% each, and the same ratios as in Warm Weather conditions (phase ratio as in Table 32 and mixed ratio as in Table 33) are applied to better represent real-world operation mode, see Table 36, where estimated actual consumption values are shown.

$$FC_{RW\ Phase\ i} = \frac{1}{2}\left(FC_{WLTC\ Phase\ i,CAT\ 1} + FC_{WLTC\ Phase\ i,CAT\ 2}\right) \times Ratio_{Phase\ i}$$

Table 36 Estimated Actual Consumption (l/100km) for Real-world Cold Winter Conditions

FC (l/100km)	Urban	Rural	Highway	Mixed
	7.690	7.264	7.266	7.133

5.3.2. PEV

5.3.2.1. Warm weather conditions

As well as for the ICE and HEV example, WLTC+ Warm energy consumption data is available for all the three phases considered. Table 37 shows example values of energy consumption from a selected determined PEV.

Table 37 Example values of energy consumption (kWh/100km) on WLTC for the different phases of a PEV determined vehicle

EC_{WLTC} (kWh/100km)	Urban	Rural	Highway	Mixed
	14.24	16.32	24.35	18.46

The same methodology used for ICE vehicles is applied, except for the mixed phase, where Green NCAP ratio is considered, since there is no available data from electric vehicles in the OBFCM database, see Table 38, where applicable ratios are shown.

Table 38 Green NCAP ratios of PEV powertrain

$Ratio_{GNCAP}$	Urban	Rural	Highway	Mixed
	1.19	1.17	0.98	1.07

Finally, the estimated actual consumption for each phase is obtained by multiplying the initial consumption by the corresponding ratio. Final values are shown in Table 39.

Table 39 Estimated Actual Consumption (kWh/100km) for Real-world Warm Weather Conditions

EC (kWh/100km)	Urban	Rural	Highway	Mixed
	16.94	19.05	23.80	19.72

The real-world driving range can also be calculated using the total energy from the mains obtained in the Battery capacity Green NCAP test. Table 40 shows the results from this specific vehicle.

$$Driving\ Range_i\ (km) = \frac{Total\ Energy\ From\ Mains_i\ (kWh)}{EC_i\ \left(\frac{kWh}{100km}\right)}$$

Table 40 Driving range (km) calculation on Warm Weather conditions for each mode of operation of a determined PEV vehicle

Total energy from mains (kWh)	Driving Range (km)			
	Urban	Rural	Highway	Mixed
66.44	392.21	348.84	279.14	336.96

5.3.2.2. Cold winter conditions

Table 41 shows the energy consumption values from each operation mode and for both CAT 1 and CAT 2 measurements.

Table 41 Example values of energy consumption (kWh/100km) on WLTC for the different phases of a PEV determined vehicle under Cold Winter conditions

EC_{WLTC} (kWh/100km)	Urban		Rural		Highway		Mixed	
	CAT 1	CAT 2	CAT 1	CAT 2	CAT 1	CAT 2	CAT 1	CAT 2
	43.33	27.44	26.75	22.46	33.52	31.19	34.77	27.32

$$EC_{RW\ Phase,i} = \frac{1}{2}\left(EC_{WLTC\ Phase\ i,CAT1} + EC_{WLTC\ Phase\ i,CAT2}\right)$$

For cold ambient temperature tests, the same weighting as for ICE and HEV vehicles is applied, but no ratio is used, as described in the beginning of chapter 5 (after Table 19) and as it is shown in the corresponding equation above. Table 42 shows the estimated actual consumption values obtained for Cold Winter conditions.

Table 42 Estimated Actual Consumption (kWh/100km) for Real-world Cold Winter Conditions

EC (kWh/100km)	Urban	Rural	Highway	Mixed
	35.38	24.61	32.36	31.04

Following the same procedure as for Warm Weather conditions, real-world driving range is calculated based on the results of real-world energy consumption, considering now Cold Winter conditions results, see **Table** 43.

Table 43 Driving range (km) calculation on Cold Winter conditions for each mode of operation of a determined PEV vehicle.

Total energy from mains (kWh)	Driving Range (km)			
	Urban	Rural	Highway	Mixed
66.44	187.79	270.03	205.35	214.04

5.4. Results consistency check

Data consistency revisions have been executed in order to identify a possible situation, where all different phases energy consumption result in lower (or higher) values than overall mixed energy consumption figure, which would mean an illogical result for the mixed value. This scenario is more likely to happen with non-pure electric vehicles because the source of the mixed consumption ratio is not obtained though Green NCAP ratios, but from OBFCM. However, this phenomenon is also observable in electric vehicles when the difference between urban and highway energy consumption is relatively low.

When this situation arises a multiplier factor should be applied in order to mathematically align OBFCM / Green NCAP mixed consumption figures. Mixed real-world consumption after applying the mixed ratio is prioritized, as it is reflected as the real behavior of a specific vehicle, therefore, the different phase consumption values are the ones that will be corrected by a multiplier in concordance with the mixed conditions consumption value. The method to be considered is expressed by the following equation:

$$RW\ EC_{mixed} = \ x * \frac{\left(RW\ EC_{urban} * d_{urban} + RW\ EC_{rural} * d_{rural} + RW\ EC_{highway} * d_{highway}\right)}{d_{total}}$$

$$where\ \text{"d"}\ means\ distance,$$

$$and\ \text{"x"}\ refers\ to\ the\ multiplier\ factor$$

6. THRESHOLDS USED FOR PERFORMANCE EVALUATION

6.1. Energy consumption thresholds

This section details the procedure used to calculate the thresholds for estimated actual consumption, which helps in grading a vehicle as good, average, or poor based on its energy consumption values. As an input, the data of all the vehicles tested within the test program are collected in the database, after the application of corresponding *Green NCAP / OBFCM* ratios as described in the previous sections. The distribution of the energy consumption data across all vehicles for a particular test type (warm weather/cold winter), per phase (urban, rural, highway, mixed) is plotted, and the data is split into 3 bins based on 20% and 80% markers. An example for the data distribution and the data split into thresholds is shown below in the figures below. Figure 23 and Figure 24 represent the energy consumption distribution for all fuel vehicles (petrol/diesel/hybrids) with the WLTC+ Warm test, for the urban phase only. Mathematically, this translates to performing a quantile cut of the data into 20th and 80th percentiles. This in-turn implies that the energy consumption values which fall:

- Less than the 20% mark, are categorized as good.
- Between the 20% and 80% mark, are categorized as average.
- Greater than 80% mark, are categorized as poor.

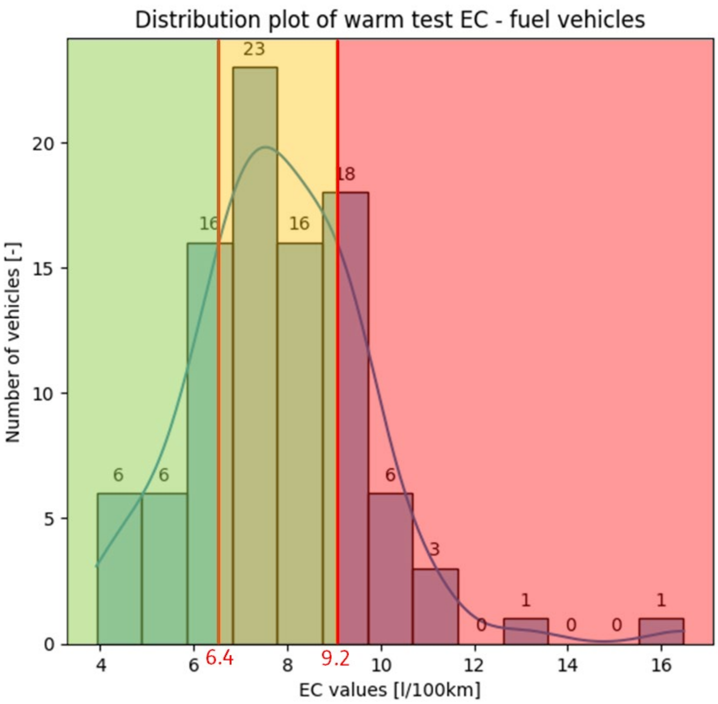

Figure 23 Distribution plot for vehicles with warm test in urban zone

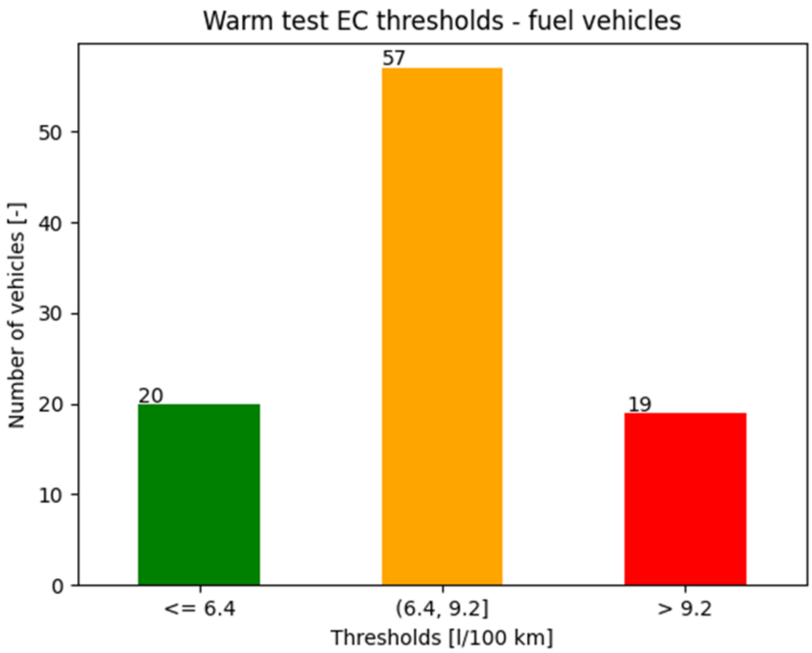

Figure 24 The number of vehicles in each bin, as per the data distribution in previous figure. Note that this is only for warm test and urban phase.

Note: Within the program, not all combustion engine vehicles have both the warm weather and cold winter test performed. Only the stage-2 vehicles have both the tests performed. To compensate for this gap, all non-stage-2 vehicles get an absolute extra fuel consumption added for the cold test, based on the average increase of energy consumption per phase for all the stage-2 vehicles.

With this procedure, the thresholds for the estimated actual consumption are as follows:

- Petrol/Diesel/Hybrids, Table 44

Table 44 Energy Consumption thresholds for combustion engine vehicles

Test type	Number of vehicles	Test phase	Thresholds l/100km Good > Poor	
			Lower	**Upper**
Warm Weather test	**96**	Urban	6.4	9.2
		Rural	4.9	6.4
		Highway	5.7	7.3
		Mixed	5.8	7.7
Cold Winter test	**96***	Urban	7.9	10.7
		Rural	5.3	6.8
		Highway	6.0	7.7
		Mixed	6.5	8.5

*Vehicles adjusted according to the note mentioned above

- PEV, Table 45

Table 45 Energy Consumption thresholds for pure electric vehicles

Test type	Number of vehicles	Test phase	Thresholds kWh/100km Good > Poor	
			Lower	Upper
Warm Weather test	**40**	Urban	15.8	19.7
		Rural	17.2	20.2
		Highway	19.4	23
		Mixed	17.4	20.4
Cold Winter test	**40**	Urban	25.3	35.5
		Rural	20.7	26.2
		Highway	25.8	30.7
		Mixed	24.1	31.2

6.2. Thresholds for PEV driving range

The approach followed for the thresholds for estimated actual consumption, is replicated for the driving range for PEVs. This leads to the following values for the thresholds, Table 46:

Table 46 Driving range thresholds for pure electric vehicles

Test type	Number of vehicles	Test phase	Thresholds Km Poor -> Good	
			Lower	Upper
Warm Weather test	**40**	Urban	342.9	499.1
		Rural	321.8	480.4
		Highway	278.8	424.2
		Mixed	317.5	482.8
Cold Winter test	**40**	Urban	188.9	315.4
		Rural	237.6	365.2
		Highway	199.5	314.4
		Mixed	208.5	329.4