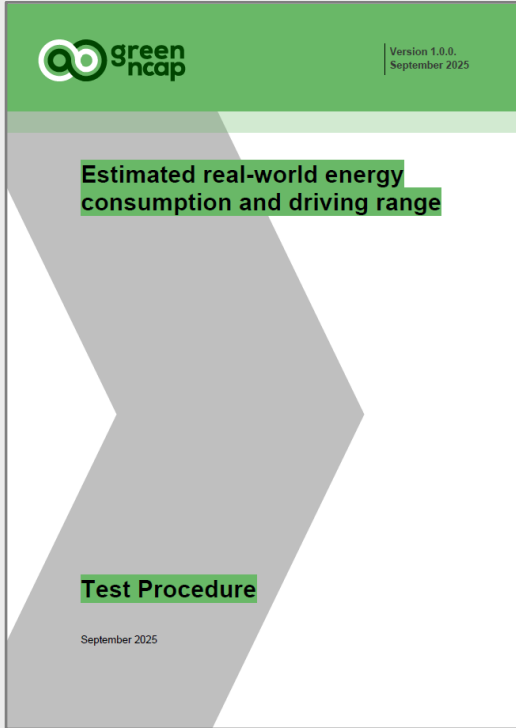




GNT- Real World Energy consumption and Driving range

Alba Garbi (Applus IDIADA)
Adrian Belda (Applus IDIADA)

GNT- Real-world energy consumption



Driving Experience (informative only)

Though not part of the sustainability rating, Green NCAP provides useful information about real-world performance—especially for EVs. These insights help consumers understand the practical trade-offs involved in owning a low-emissions vehicle.

Consumption & Range

Estimated actual consumption

Based on measured data (which are only partly representative of real-world use) and adjusted with real-world correction factors.

Driving range

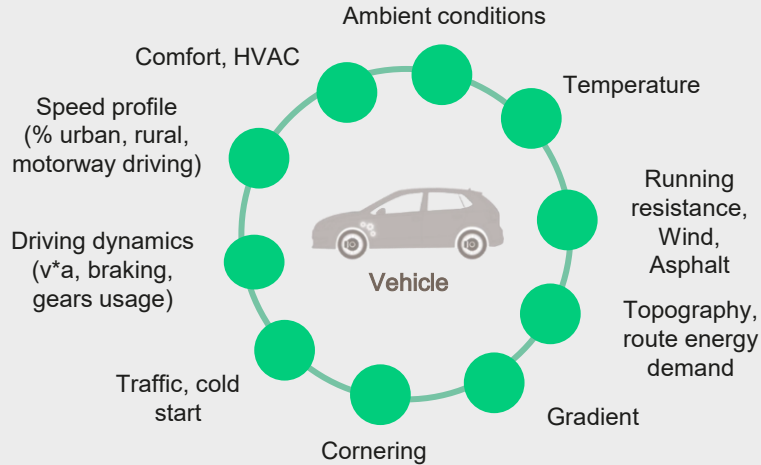
For EVs only: Of special importance to consumers is the real-world driving range. Green NCAP estimates it based on measured data, modified by correction factors.

Accuracy of display

Rating the discrepancy -if any- between the measured energy consumption and what is shown on the vehicle's onboard display.

Real-World Energy Consumption and Range

Real world energy consumption paradigm: one user, one vehicle, one day



Real world correction factors come from:

Green NCAP database – High quality data (time-resolved data)

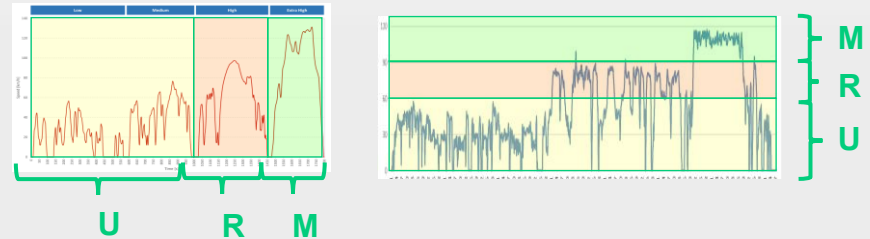
OBFCM database – High quantity data (accumulated data)

1st Commission report comparing real-world CO₂ emissions and fuel consumption using data from on-board fuel consumption monitoring devices



- DG CLIMA.B.3 - Mobility (I): Road
- **OBFCM data**
- ≈ 600k vehicles (7.2% of 2021 M1 registrations)
- Gap (%) real-world vs WLTP for diesel, petrol and (P)HEV

WLTP(*) vs RDE vs “real-world”



(*) Controlled conditions, 23°C, no slope, HVAC OFF

Approximately 765,000 km of data were collected for its development

GNT- Real-world energy consumption

Real world correction factors:



Green NCAP database – High quality data (time-resolved data)

| Powertrain | N° vehicles | N° RW Tests | Urban ratio | Rural ratio | HW ratio | Mixed ratio |
|------------|-------------|-------------|-------------|-------------|----------|-------------|
| 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 |



OBFCM database – High quantity data (accumulated data)

| OBFCM db content | Powertrain | N° vehicles | N° km (billion) |
|------------------|------------|-------------|-----------------|
| | Diesel | ≈ 2.19M | ≈ 45 |
| | Diesel HEV | ≈ 1.51M | ≈ 29 |
| | Petrol | ≈ 1.45M | ≈ 58 |
| | Petrol HEV | ≈ 434k | ≈ 17 |

| Ft | Fm | OBFCM Ratio |
|--------|----|-------------|
| DIESEL | M | 1.177 |
| DIESEL | H | 1.191 |
| PETROL | M | 1.202 |
| PETROL | H | 1.188 |

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

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

$n = No. vehicles$

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

$$Ratio_{OBFCM,i} = \frac{Fuel\ Consumption_{OBFCM,i}}{Fuel\ Consumption_{CoC,i}}$$

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

$n = No. vehicles$

GNT- Real-world energy consumption

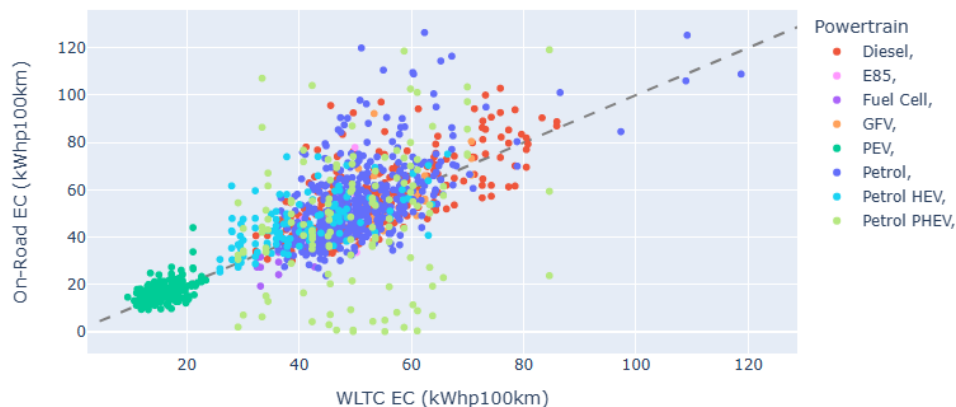
Real world correction factors :



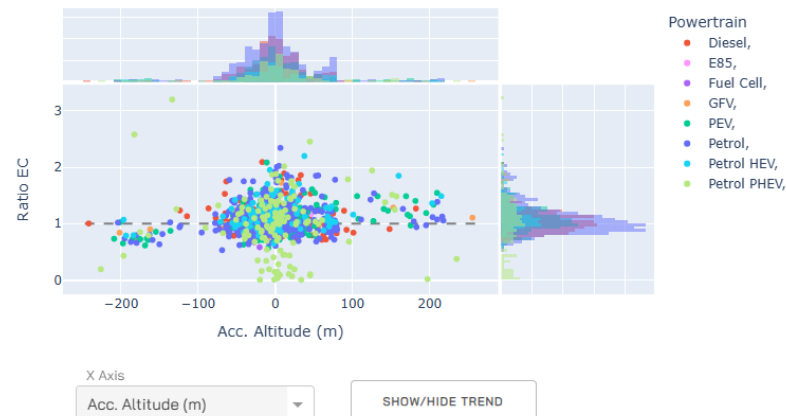
Green NCAP database – High quality data (time-resolved data)

| Green NCAP db content | N° vehicles | N° tests | N° km |
|-----------------------|-------------|----------|--------|
| | 148 | 312 | 27,250 |
| PEMS+ Cold | | 148 | 12,858 |
| PEMS+ Heavy | | 82 | 7204 |
| PEMS+ Eco | | 82 | 7188 |

On-Road vs WLTC EC



On-Road/WLTC EC Ratio vs Acc. Altitude (m)



GNT- Real-world energy consumption



OBFCM database – High quantity data (accumulated data)

Four-level aggregation for OBFCM ratios determination

| Level | Classification variables |
|-------|---|
| 1 | Model, Manufacturer, PMR class, Powertrain type |
| 2 | Manufacturer, PMR class, Powertrain type |
| 3 | PMR class, Powertrain type |
| 4 | Powertrain type |

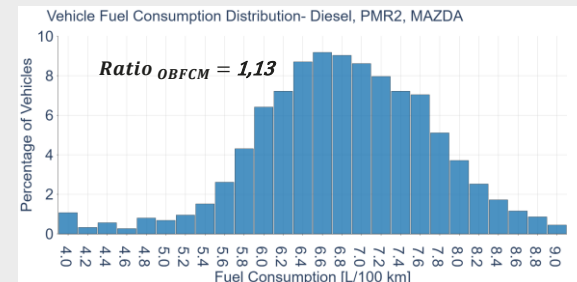
Power-to-mass ratio (PMR):

- Class 1 (<55 kW/t)
- Class 2 (55-90 kW/t)
- Class 3 (>90 kW/t)

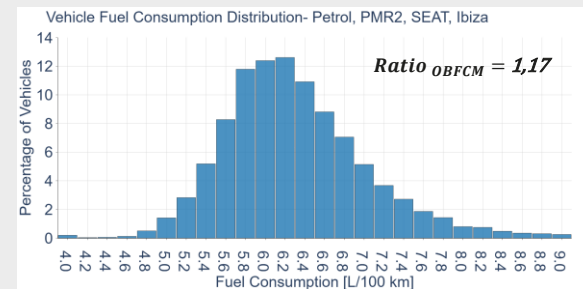
Data completeness: Minimum N° vehicles according to defined criteria and thresholds: km range, country of use

| PMR bin | Ft | Fm | OBFCM Ratio | No. of vehicles |
|---------|--------|----|-------------|-----------------|
| 1 | DIESEL | H | 1.162 | 9712 |
| 1 | DIESEL | M | 1.158 | 143124 |
| 1 | PETROL | H | 1.184 | 601159 |
| 1 | PETROL | M | 1.198 | 255062 |
| 2 | DIESEL | H | 1.192 | 323598 |
| 2 | DIESEL | M | 1.179 | 1235721 |
| 2 | PETROL | H | 1.187 | 828544 |
| 2 | PETROL | M | 1.201 | 1688422 |
| 3 | DIESEL | H | 1.247 | 100978 |
| 3 | DIESEL | M | 1.188 | 71313 |
| 3 | PETROL | H | 1.236 | 77885 |
| 3 | PETROL | M | 1.215 | 244697 |

Aggregation Level 3



Aggregation Level 2

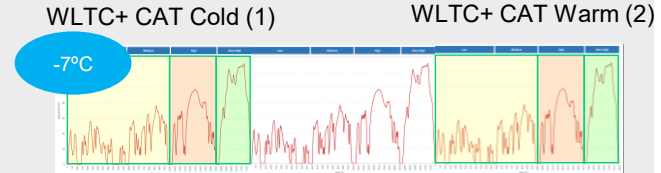
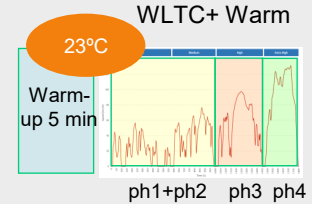


Aggregation Level 1

GNT- Real-world energy consumption

- Estimated actual consumption and driving range as part of the Driving Experience Assessment

| | Actual Consumption (l/100km) | Urban | Rural | Highway | Mixed |
|----------|--------------------------------|---|---|--|--|
| ICE, HEV | Warm Weather | WLTC Warm, (ph1+ph2) *Ratio, urban GNCAP db | WLTC Warm, ph3 *Ratio, rural GNCAP db | WLTC Warm, ph4 *Ratio, motorway GNCAP db | WLTC Warm, Total *Ratio, OBFCM db |
| | Cold Winter | (CAT1, (ph1+ph2)*1/2 + CAT2, (ph1+ph2)*1/2) *Ratio, urban GNCAP db | (CAT1, ph3*1/2 + CAT2, ph3*1/2) *Ratio, rural GNCAP db | (CAT1, ph4*1/2 + CAT2, ph4*1/2) *Ratio, motorway GNCAP db | (CAT1, Total*1/2 + CAT2, Total*1/2) *Ratio, OBFCM db |
| | Actual Consumption (kWh/100km) | Urban | Rural | Highway | Mixed |
| PEV | Warm Weather | WLTC Warm, (ph1+ph2) *Ratio, urban GNCAP db | WLTC Warm, ph3 *Ratio, rural GNCAP db | WLTC Warm, ph4 *Ratio, motorway GNCAP db | WLTC Warm, Total *Ratio, total GNCAP db |
| | Cold Winter | (CAT1, (ph1+ph2)*1/2 + CAT2, (ph1+ph2)*1/2) | (CAT1, ph3*1/2 + CAT2, ph3*1/2) | (CAT1, ph4*1/2 + CAT2, ph4*1/2) | (CAT1, Total*1/2 + CAT2, Total*1/2) |



Driving range matrix is calculated considering the Total Energy Output (kWh) from the Battery Capacity test

GNT- Real-world energy consumption

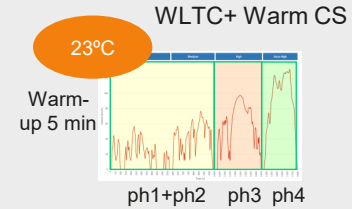
PHEV Charge Sustaining

| Actual Consumption (l/100km) | Urban | Rural | Highway | Mixed |
|------------------------------|---|---|--|---|
| Warm Weather | WLTC Warm, (ph1+ph2) <i>*Ratio, urban</i> GNCAP db | WLTC Warm, ph3 <i>*Ratio, rural</i> GNCAP db | WLTC Warm, ph4 <i>*Ratio, motorway</i> GNCAP db | WLTC GNCAP, Weighted, Combined <i>*Ratio, OBFM db</i> |
| Cold Winter | (CAT1, (ph1+ph2)*1/2 + CAT2, (ph1+ph2)*1/2) <i>*Ratio, urban</i> GNCAP db | (CAT1, ph3*1/2 + CAT2, ph3*1/2) <i>*Ratio, rural</i> GNCAP db | (CAT1, ph4*1/2 + CAT2, ph4*1/2) <i>*Ratio, motorway</i> GNCAP db | (CAT1, Total*1/2 + CAT2, Total*1/2) <i>*Artificial Ratio</i> |

PHEV Charge Depleting

| Actual Consumption (kWh/100km) | Urban | Rural | Motorway | Mixed | Driving range EAER | Driving range PER |
|--------------------------------|-------------------------------|-------------------------|-------------------------|---------------------------|--------------------|--|
| Warm Weather | WLTC CD n=1 (23°C), (ph1+ph2) | WLTC CD n=1 (23°C), ph3 | WLTC CD n=1 (23°C), ph4 | WLTC CD n=1 (23°C), Total | WLTC CD EAER | WLTC CD PER |
| Cold Winter | WLTC Cold CAT CD, (ph1+ph2) | WLTC Cold CAT CD, ph3 | WLTC Cold CAT CD, ph4 | WLTC Cold CAT CD, Total | | WLTC Cold CAT CD PER State >23km |

If the engine is ON (look Special requirements HEV) during the first cycle in CD or in the WLTC Cold CAT, we do not provide the consumption and add a disclaimer about vehicle behaviour not being able to work in Pure electric mode!



WLTC+ CAT Cold (1)

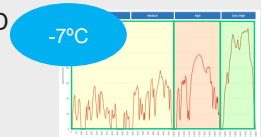


WLTC+ CAT Warm (2)

WLTC CD sequence



WLTC Cold CAT CD



GNT- Real-world energy consumption

Real-World Fuel Consumption CS – OBFCM Ratio

OBFCM fuel and distance data for plug-in hybrids vehicles are split into the following operation modes:

- Total lifetime.
- Charge depleting operation with engine off.
- Charge depleting operation with engine running.
- Drive-selectable charge increasing operation.

Assumption:

- Charge sustaining distance and fuel are estimated as the remainder after subtracting reported operation modes from the total:

$$\text{Fuel consumed}_{CS} = \text{Fuel consumed}_{Tot} - \text{Fuel consumed}_{CD,on} - \text{Fuel consumed}_{CI}$$

$$\text{Distance travelled}_{CS} = \text{Distance travelled}_{Tot} - \text{Distance travelled}_{CD,on} - \text{Distance travelled}_{CI} - \text{Distance travelled}_{CD,off}$$

$$\text{Fuel consumption}_{CS} = \frac{\text{Fuel consumed}_{CS}}{\text{Distance travelled}_{CS}}$$

Data filtering

- Total fuel in CS >10 l.
- Total distance in CS >1000 km.

| Total fuel consumed (lifetime) (l) | Total distance travelled (lifetime) (km) | Total distance travelled in charge depleting operation with engine off (lifetime) (km) | Total distance travelled in charge depleting operation with engine running (lifetime) (km) | Total distance travelled in driver-selectable charge increasing operation (lifetime) (km) | Total fuel consumed in charge depleting operation (lifetime) (l) | Total fuel consumed in driver-selectable charge increasing operation (lifetime) (l) | Total grid energy into the battery (lifetime) (kWh) | Total fuel consumed in CS (lifetime) (l) | Total distance travelled in CS (lifetime) (km) | FC CS (l/100km) |
|------------------------------------|--|--|--|---|--|---|---|--|--|-----------------|
| 1515.08 | 25781.1 | 5041.4 | 936.6 | 32.7 | 64.86 | 6.41 | 1220.1 | 1443.81 | 19770.4 | 7.30 |
| 1101.63 | 21851.5 | 6795.7 | 1596.9 | 1921.6 | 123.18 | 166.52 | 166.52 | 811.99 | 11535.3 | 7.04 |
| 141.88 | 2526.3 | 753.9 | 385.4 | 0 | 37.85 | 0.09 | 237.5 | 103.94 | 1387 | 7.49 |
| 807.98 | 20183.5 | 8266.1 | 1285.4 | 6404.8 | 66.98 | 506.48 | 1189.1 | 234.52 | 4227.2 | 5.55 |
| 316.98 | 8653.4 | 4138 | 1779 | 1.9 | 120.03 | 0.52 | 1232.2 | 196.43 | 2734.5 | 7.18 |
| 999.1 | 14999.7 | 3464.2 | 692.5 | 3233.5 | 66.64 | 371.91 | 632.3 | 560.55 | 7609.5 | 7.37 |
| 967.09 | 18684.4 | 6276.7 | 2553 | 7014.3 | 155.23 | 632.04 | 1008 | 179.82 | 2840.4 | 6.33 |
| 2908.23 | 65156.6 | 18776.3 | 2943.3 | 2196.9 | 183.7 | 178.08 | 3683.6 | 2546.45 | 41240.1 | 6.17 |
| 797.95 | 12710 | 2028.5 | 680.2 | 185.2 | 51.93 | 18.52 | 581.9 | 727.5 | 9816.1 | 7.41 |
| 1172.41 | 22040.6 | 3009.1 | 565.2 | 171.2 | 36.81 | 15.99 | 666.3 | 1119.67 | 18295.1 | 6.12 |
| 539.56 | 17855.5 | 9872.7 | 1842.3 | 439.3 | 138.06 | 46.21 | 2657.5 | 355.29 | 5701.2 | 6.23 |
| 275.88 | 13376 | 9284.8 | 620.6 | 0 | 50.22 | 0.02 | 2129.2 | 225.64 | 3470.6 | 6.50 |
| 597.24 | 11907.5 | 2827.3 | 433.1 | 0.1 | 35.39 | 0.05 | 706.7 | 561.8 | 8647 | 6.50 |
| 653.87 | 15376.7 | 5501.1 | 1561.7 | 0 | 107.53 | 1.6 | 1346.6 | 544.74 | 8313.9 | 6.55 |
| 718.93 | 18244.3 | 7925.1 | 462.2 | 1366 | 38.62 | 120.4 | 1600.2 | 559.91 | 8491 | 6.59 |

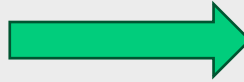
GNT- Real-world energy consumption


Real-World Fuel Consumption CS – OBFCM Ratio

 Step 1: Filter database for the vehicle selected:

Vehicle data filter

- Ft: Fuel type
- Fm: Fuel mode
- PMR Class → PMR= Ep/Mt
 - Ep (kw): Maximum net power (internal combustion engine for OVC-HEV)
 - MT (kg): WLTP Test Mass
- Mk: Make
- Cn: Commercial name



 Step 2: Calculate the OBFCM ratio

$$Ratio_{OBFCM,i} = \frac{Fuel\ consumption_{CS,i}}{Ewtp_i\ (l/100km)}$$

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

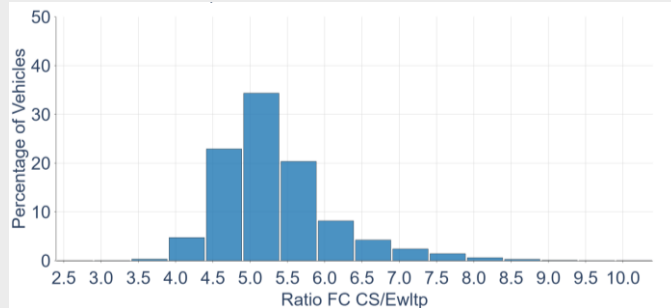
Ewtp: Specific consumption (weighted combined for OVC-HEV)

| | |
|---------------------|-------------|
| Ratio OBFCM: | 5.32 |
|---------------------|-------------|

Samples: 9442

| | |
|----------------------|------|
| FC CS, av (l/100km): | 7.36 |
|----------------------|------|

| | |
|---------------------|------|
| Ewtp, av (l/100km): | 1.38 |
|---------------------|------|



GNT- Real-world energy consumption

Real-World Fuel Consumption CS - WLTC GNCAP, Weighted, Combined Consumption

The WLTC GNCAP, Weighted, Combined Fuel Consumption is calculated from the GNCAP WLTC, CD Sequence as follows:

$$FC_{\text{weighted, Combined}} = \sum_{j=1}^k (UF_j * F_{CD,j}) + (1 - \sum_{j=1}^k UF_j) * F_{CS}$$

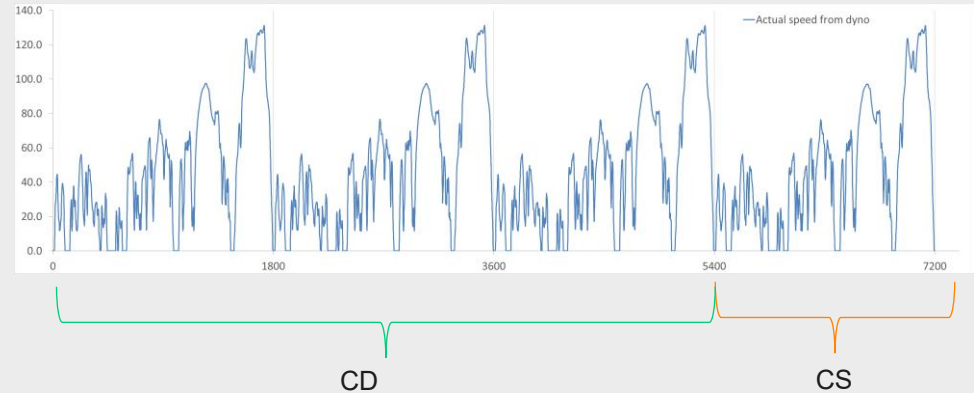
Where:

F_{CS} is obtained from the GNCAP WLTC warm, CS test

F_{CD} and UF are obtained from from the GNCAP WLTC, CD Sequence

| GNCAP, Weighted, Combined Consumption | |
|---------------------------------------|---------------|
| n cycles | 4 |
| Uf | 0.838 |
| FC Weighted Combined | 1.698 l/100km |

| 4. Extern aufladbaren Hybrid-Elektrofahrzeugen | | |
|--|------------------------------|----------------------|
| WLTP Werte: | CO ₂ -Emissionen: | Kraftstoffverbrauch: |
| Niedrig: | 229 g/km | 10.1 l/100km |
| Mittel: | 139 g/km | 6.1 l/100km |
| Hoch: | 139 g/km | 6.1 l/100km |
| Höchstwert: | 172 g/km | 7.6 l/100km |
| Innerorts: | | |
| Kombiniert bei Ladungserhaltung: | 163 g/km | 7.2 l/100km |
| Kombiniert bei Entladung: | 14 g/km | 0.5 l/100km |
| Gewichtet, Kombiniert: | 30 g/km | 1.3 l/100km |



GNT- Real-world energy consumption

Real-World Fuel Consumption CS – Warm weather

$$\text{Real world Fuel Consumption}_{CS, \text{warm weather}} = FC_{\text{weighted, combined GNCAP}} * \text{Ratio}_{OBFCM}$$

Real-World Fuel Consumption CS – Cold Winter

To translate cold ambient fuel consumption into real world conditions, a ratio based on Charge Sustaining operation is applied:

$$\text{Artificial Ratio} = \frac{\text{Real world Fuel Consumption}_{CS, \text{warm weather}}}{FC_{WLTC \text{ warm, CS}}}$$

$$\text{Real world Fuel Consumption}_{CS, \text{cold winter}} = \text{Artificial Ratio} * \frac{WLTC_{CAT,1} + WLTC_{CAT,2}}{2}$$

| | l/100km | Urban | Rural | Highway | Mixed |
|------------|--------------|-------|-------|---------|-------|
| PHEV CS | Warm weather | 10.48 | 8.09 | 8.20 | 8.63 |
| | Cold Winter | 14.08 | 8.34 | 8.35 | 9.78 |

GNT- Real-world energy consumption

Real-World Fuel Consumption CD – Warm weather

WLTC CD n=1

Real-World Fuel Consumption CD – Cold winter

WLTC Cold CAT

PHEV
CD

| kWh/100km | Urban | Rural | Highway | Mixed | Driving range EAER | Driving range PER |
|--------------|-------|-------|---------|-------|--------------------------|-------------------------|
| Warm weather | 27.07 | 23.51 | 28.74 | 26.57 | 50.71 | 50.11 |
| Cold Winter | 44.00 | 32.59 | 35.81 | 37.58 | - | >23 |

GNT- Real-world energy consumption

Estimated Real-world Consumptions

PHEV Charge Sustaining

| l/100km | Urban | Rural | Highway | Mixed |
|--------------|-------|-------|---------|-------|
| Warm weather | 10.48 | 8.09 | 8.20 | 8.63 |
| Cold Winter | 14.08 | 8.34 | 8.35 | 9.78 |

PHEV Charge Depleting

| kWh/100km | Urban | Rural | Highway | Mixed | Driving range EAER | Driving range PER |
|--------------|-------|-------|---------|-------|--------------------|-------------------|
| Warm weather | 27.07 | 23.51 | 28.74 | 26.57 | 50.71 | 50.11 |
| Cold Winter | 44.00 | 32.59 | 35.81 | 37.58 | - | >23 |

