CoP for PEVs and OVC-HEVs
WLTP: under discussion

ACEA WLTP EV proposal for PEVs on slides 6 - 8

ACEA WLTP EV proposal for OVC-HEVs on slides 12/13

COP for PEVs and OVC-HEVs: Changes from NEDC test procedure to WLTP

Distance driven by CoP vehicle is higher due to the…

…test procedure:

- In NEDC, the range test is separate from EC and CO2 measurement test
- Under WLTP conditions, the determination of range, EC and CO_2 test are combined in one procedure
- Calculation scheme of the values changed from NEDC to WLTP

…cycle:

- WLTC (23km) is longer than the NEDC (11km)
- Longer cycle would also increase the complete distance within the NEDC procedure

Based on the WLTP test procedure and calculation schemes: Distance driven in CoP is a function of the REESS capacity and in consequence not limited

➔ **There is a need to provide values out of homologation which can be verified in CoP by driving less mileage**

ACEA WLTP EV proposal for PEVs on slides 6 - 8

CoP for PEVs

WLTP: under discussion

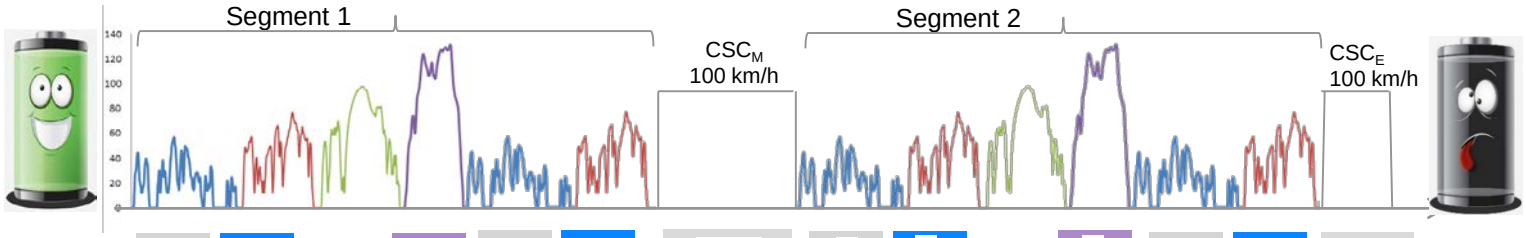
→ verification of electric energy consumption

ACEA WLTP EV – COP requirements for PEVs

Reminder: PEV test procedure (shortened test procedure)

Homologation (*Energy consumption and range determination test*)

Shorten range test procedure
- **WLTC Range and Energy consumption determination (Reminder)**
- **Possible solution for CoP**



1. Measurement of distance driven
2. Measurement of DC current
3. Measurement of DC voltage
4. Calculation of Usable Battery Energy
5. Measurement of total AC energy
6. *Calculation of DC energy each WLTC*
7. Calculation of Weighting factor
8. Estimation of DC energy (WLTC)
9. Estimation of Pure Electric Range
10. Estimation of AC energy consumption

d_j | $I(t)_{j,i}$ | $U(t)$; d_{CSSM} | $I(t)_{j,i}$ | $U(t)$; d_{CSSE} | $I(t)_{j,i}$ | $U(t)$

$$UBE_{STP} = \Delta E_{REESS,DS_1} + \Delta E_{REESS,DS_2} + \Delta E_{REESS,CSS_M} + \Delta E_{REESS,CCS_E}$$

UBE_{STP}

E_{AC}

$$EC_{DC,j} = \frac{\Delta E_{REESS,j}}{d_j}$$

$$K_{WLTC,1} = \frac{\Delta E_{REESS,WLTC,1}}{UBE_{STP}}$$

$$EC_{DC,j} = \frac{\Delta E_{REESS,j}}{d_j}$$

$$K_{WLTC,2} = 1 - K_{WLTC,1}$$

$$EC_{DC,WLTC} = \sum_{j=1}^{2} EC_{DC,WLTC,j} \times K_{WLTC,j}$$

$$PER_{WLTC} = \frac{UBE_{STP}}{EC_{DC,WLTC}}$$

$$EC_{WLTC} = \frac{E_{AC}}{PER_{WLTC}}$$

$$AF = \frac{EC_{WLTC,declared}}{EC_{WLTC}}$$

AF: To compensate for the difference between the declared value and the test results.

ACEA WLTP EV – COP requirements for PEVs

Reminder: Mileage resulting out of complete shortened test procedure

Values required:
- Electric Energy Consumption

Test procedure required:
- Test procedure for PEVs – **shortened test procedure (range of PEV > 3 WLTC)**

Warm up	Road Load Adjustment	Preconditioning	Shorten Test Procedure
1 x WLTC	2 – 4 coast downs à 4km	REESS depletion (according to manufacturer's recommendation) and charging until SOC_{max}	- Shorten Test Procedure - Charging until SOC_{max} ➔ Recharged energy from the grid: E_{AC} - Calculation of results: $EC_{WLTC} = \frac{E_{AC}}{PER_{WLTC}}$ [Wh/km]

$$PER_{WLTC} = \frac{UBE_{STP}}{EC_{DC,WLTC}}$$

with:

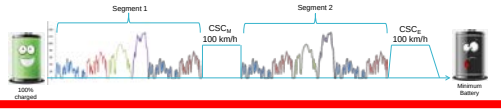
$$UBE_{STP} = \Delta E_{REESS,DS_1} + \Delta E_{REESS,DS_2} + \Delta E_{REESS,CSS_M} + \Delta E_{REESS,CCS_E}$$

and

$$EC_{DC,WLTC} = \sum_{j=1}^{2} EC_{DC,WLTC,j} \times K_{WLTC,j}$$

with

$$K_{WLTC,1} = \frac{\Delta E_{REESS,WLTC,1}}{UBE_{STP}} \text{ and } K_{WLTC,2} = 1 - K_{WLTC,1}$$



Range driven by a CoP tested vehicle: Warm up + road load adjustment + Segment 1 + CSS_M + Segment 2 + CSS_E

➔ **<u>Driven distance by CoP vehicle (*examples*)</u>**
PEV (vehicle with low REESS capacity): 23km + 8-16km + 62km + 80km = approx. 180km
PEV (vehicle with higher REESS capacity): 23km + 8-16km + 62km + 160km = approx. 260km

➔ **To reproduce the determination of the electric energy consumption as defined in the GTR, the full procedure would have to be performed**

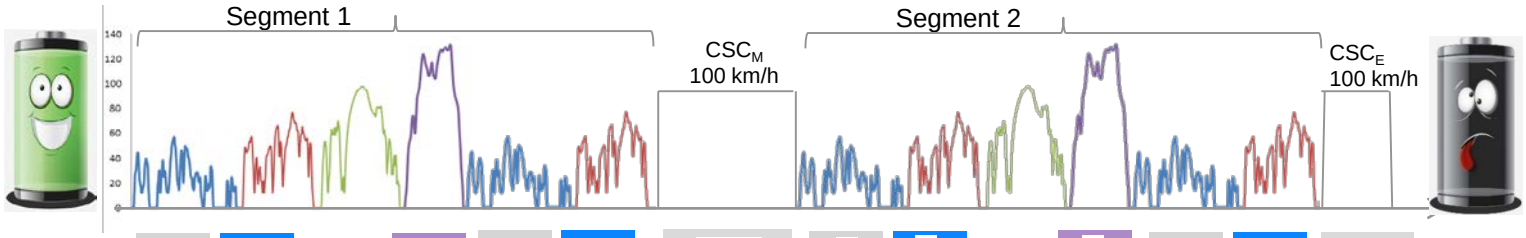
Electric Range: ↑ ➔ CoP-distance: ↑

ACEA WLTP EV – COP requirements for PEVs

Proposal ACEA WLTP EV: CoP value provided by homologation

Homologation (*Energy consumption and range determination test*)

Shorten range test procedure
- **WLTC Range and Energy consumption determination (Reminder)**
- **Possible solution for CoP**



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d_j $I(t)_{j,i}$ $U(t)$ ... d_{CSSM} $I(t)_{j,i}$ $U(t)$ ... d_{CSSE} $I(t)_{j,i}$ $U(t)$

$$UBE_{STP} = \Delta E_{REESS,DS_1} + \Delta E_{REESS,DS_2} + \Delta E_{REESS,CSS_M} + \Delta E_{REESS,CCS_E}$$

UBE_{STP}

E_{AC}

$$EC_{DC,WLTC1} = \frac{\Delta E_{REESS,WLTC1}}{d_{WLTC1}} \times AF = EC_{COP,declared}$$

Can be used for COP
-Worst case scenario
-Measured value

$$EC_{DC,j} = \frac{\Delta E_{REESS,j}}{d_j}$$

$$K_{WLTC,1} = \frac{\Delta E_{REESS,WLTC,1}}{UBE_{STP}}$$

$$K_{WLTC,2} = 1 - K_{WLTC,1}$$

$$EC_{DC,WLTC} = \sum_{j=1}^{2} EC_{DC,WLTC,j} \times K_{WLTC,j}$$

$$PER_{WLTC} = \frac{UBE_{STP}}{EC_{DC,WLTC}}$$

$$EC_{WLTC} = \frac{E_{AC}}{PER_{WLTC}}$$

$$AF = \frac{EC_{WLTC,declared}}{EC_{WLTC}}$$

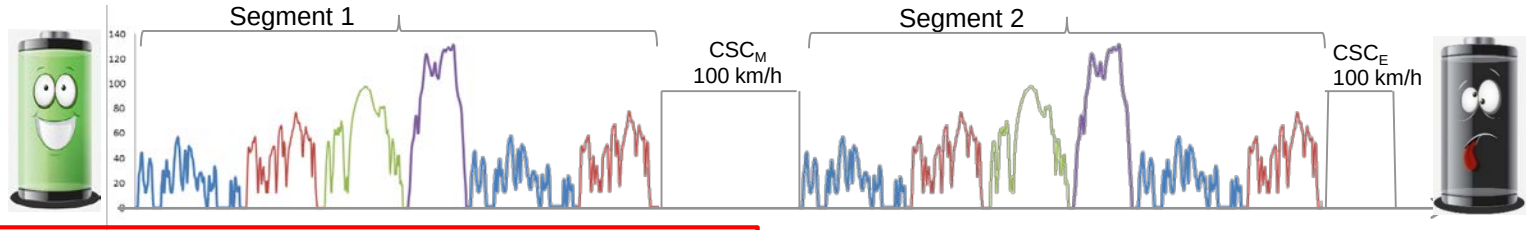
AF: To compensate for the difference between the declared value and the test results.

ACEA WLTP EV – COP requirements for PEVs

Proposal ACEA WLTP EV: verification of EC_{COP} in COP

Homologation (*Energy consumption and range determination test*)

Shorten range test procedure
- **WLTC Range and Energy consumption determination (Reminder)**
- **Possible solution for CoP**



6. Calculation of DC energy each WLTC

$$EC_{DC,WLTC1} = \frac{\Delta E_{REESS,WLTC1}}{d_{WLTC1}} \times AF = EC_{COP,declared}$$

Can be used for COP
-Worst case scenario
-Measured value

AF: To compensate for the difference between the declared value and the test results.

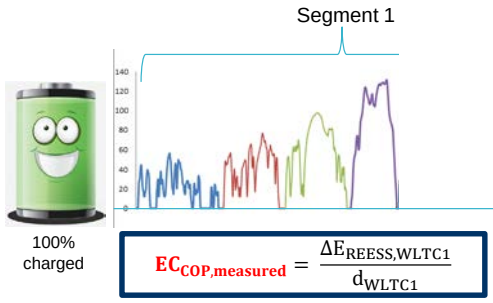
COP (*Energy consumption test*)

ACEA WLTP EV – COP requirements for PEVs

Proposal ACEA WLTP EV: Mileage resulting by verifying EC_{COP}

Warm up	Road Load Adjustment	Preconditioning	CoP-Test (energy consumption)
1 x WLTC	2 – 4 coast downs à 4km	REESS depletion (according to manufacturer's recommendation) and charging until SOC_{max}	1x WLTC

COP-Test (*Energy consumption*)



➔ **Driven distance by CoP vehicle:**
Warm-Up + road load adjustment + REESS depleting + CoP-Test

23km	8-16km	? (could be "Zero" if vehicle is immediately charged)	23km	= 62km + x

ACEA WLTP EV proposal for OVC-HEVs on slides 12/13

CoP for OVC-HEVs

WLTP: under discussion

→ verification of electric energy consumption and CO_2 emission

ACEA WLTP EV – OVC-HEV CoP requirements

Reminder: OVC-HEV test procedure

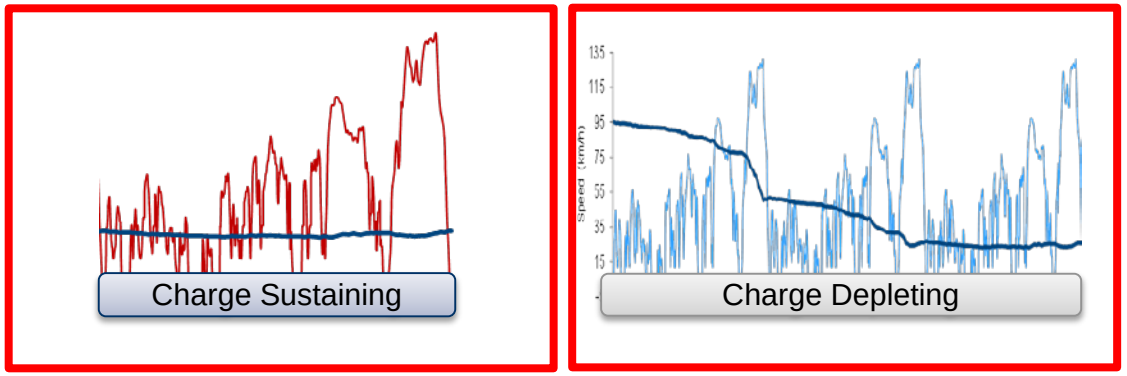
Values required:
- CO_2 mass emission
- Electric energy consumption

Test procedures required:
- Charge-Sustaining-test and charge-depleting-test

Soaking

Soaking and charging until SOC_{max}

Warm up	Road Load Adjustment	Preconditioning	CS-Test	CD-Test
1 x WLTC	2 – 4 coast downs à 4km	1 x WLTC [at least one, break-off-criterion has to be reached at the end of the preconditioning]	1 x WLTC	WLTCs (until break-off-criterion is reached)



➔ **Driven distance by CoP vehicle:**
Warm-Up + road load adjustment + Preconditioning + CS-Test + CD-Test (includes confirmation cycle)

OVC-HEV (vehicle with a low REESS capacity):
23km + 8-16km + 23km + 23km + 92km = approx. 170km
OVC-HEV (vehicle with higher REESS capacity):
23km + 8-16km + 23km + 23km + 184km = approx. 260km

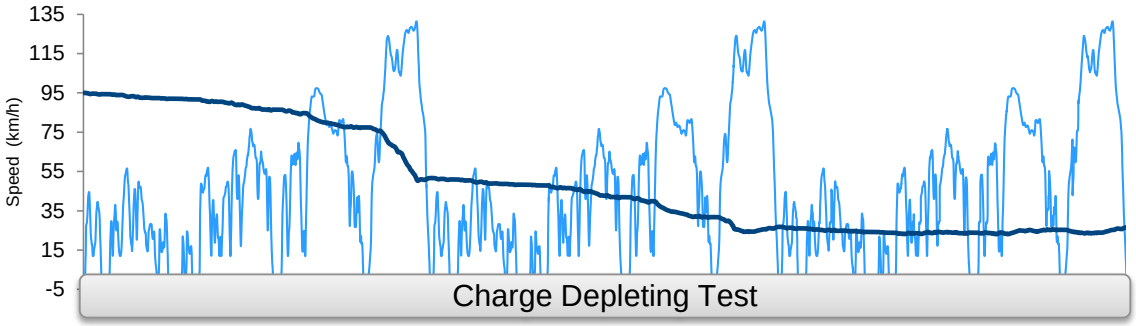
➔ **To reproduce the determination of the electric energy consumption as defined in the GTR, the full procedure would have to be performed**

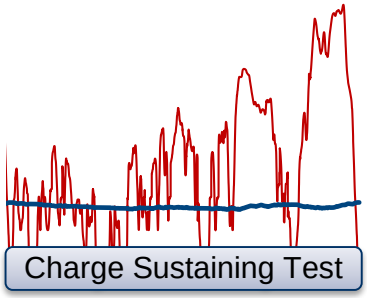
Electric Range: ↑ ➔ **CoP-distance:** ↑

ACEA WLTP EV – OVC-HEV CoP requirements

Reminder: calculation schemes CO_2 and EC [both requiring complete test procedure]

Homologation





Values [required for CoP]:

- CO_2 mass emission
- Electric energy consumption

Homologation

$$M_{CO2,CD} = \frac{\sum_{j=1}^{k}(UF_j \times M_{CO2,CD,j})}{\sum_{j=1}^{k} UF_j}$$

➔ **CD –test is required**

$$M_{CO2,weighted} = \sum_{j=1}^{k}(UF_j \times M_{CO2,CD,j}) + (1 - \sum_{j=1}^{k} UF_j) \times M_{CO2,CS}$$

➔ **both CD-test and CS-test are required**

$$M_{CO2,CS} = \frac{\sum_{p}(M_{CO2,CS,p} \times d_p)}{\sum_{p} d_p}$$

➔ **CS-test is required**

$$EC_{AC,weighted} = \sum_{j=1}^{k}(UF_j \times \frac{\Delta E_{REESS,j}}{d_j} \times \frac{E_{AC}}{\sum_{j=1}^{k} \Delta E_{REESS,j}})$$

➔ **Complete CD –test is required**

$$EC_{AC,CD} = \frac{EC_{AC,weighted}}{\sum_{j=1}^{k} UF_j}$$

➔ **Complete CD –test is required**

$$EC = \frac{E_{AC}}{EAER}$$

➔ **Complete CD –test is required**

$$AF_{CO2,CS} = \frac{M_{CO2,CS,declared}}{M_{CO2,CS}}$$

AF: To compensate for the difference between the declared value and the test results.

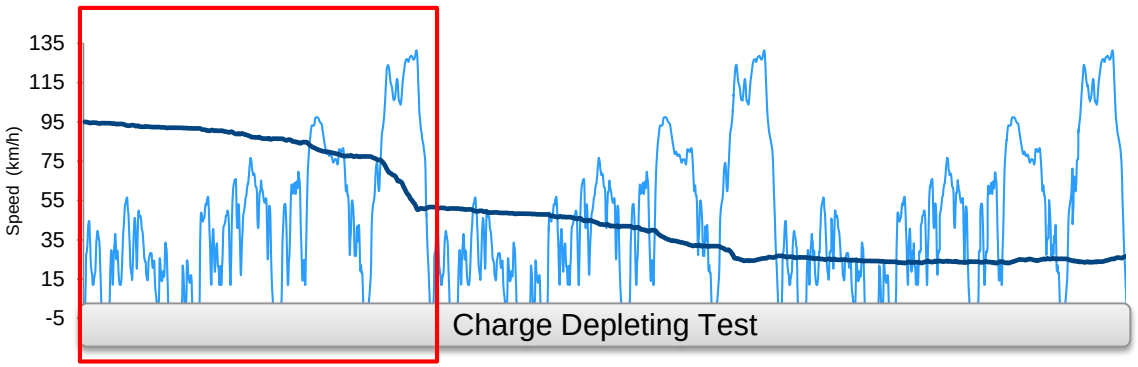
$$AF_{EC,AC\_CD} = \frac{EC_{AC,CD,declared}}{EC_{AC,CD}}$$

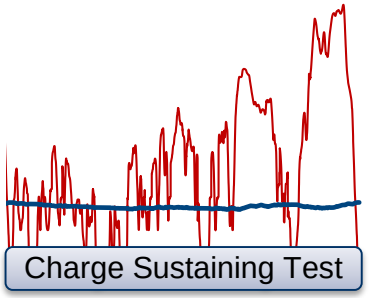
AF: To compensate for the difference between the declared value and the test results.

ACEA WLTP EV – OVC-HEV CoP requirements

Proposal ACEA WLTP EV: Adjusted CoP value provided by homologation

Homologation





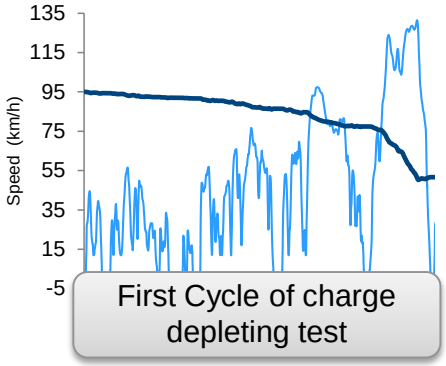
$$EC_{COP,declared} = \frac{\Delta E_{REESS,WLTC1}}{d_{WLTC1}} \times AF_{EC,AC\_CD}$$

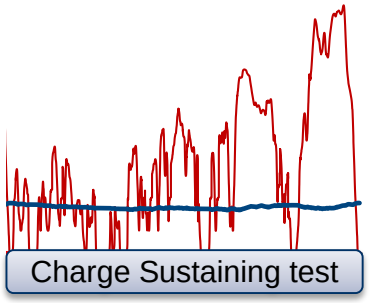
$$M_{CO2,CS,COP\_declared} = \frac{\sum_p (M_{CO2,CS,p} \times d_p)}{\sum_p d_p} \times AF_{CO2,CS}$$

AF: To compensate for the difference between the declared value and the test results.

AF: To compensate for the difference between the declared value and the test results.

COP





$$EC_{COP,measured} = \frac{\Delta E_{REESS,WLTC1}}{d_{WLTC1}}$$

$$M_{CO2,CS,COP\_measured} = \frac{\sum_p (M_{CO2,CS,p} \times d_p)}{\sum_p d_p}$$

ACEA WLTP EV – OVC-HEV CoP requirements

Proposal ACEA WLTP EV: Mileage resulting by verifying $M_{CO2,CS,COP}$ and EC_{COP}

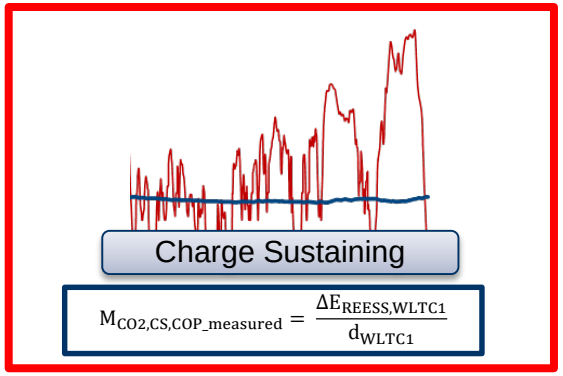
Values required:
- CO_2 mass emission
- Electric energy consumption

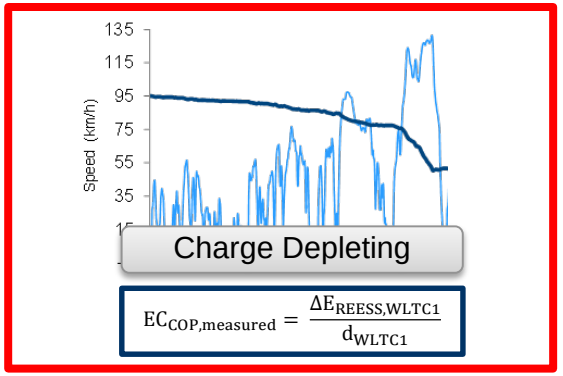
Test procedures required:
- Charge-Sustaining-test and first cycle of charge-depleting-test

Soaking

Soaking and charging until SOC_{max}

Warm up	Road Load Adjustment	Preconditioning	CS-Test (CO_2 determination)	First cycle of CD-Test (energy consumption)
1 x WLTC	2 – 4 coast downs à 4km	1 x WLTC [at least one, break-off-criterion has to be reached at the end of the preconditioning]	1 x WLTC	1 x WLTC





Option 1: CoP with one vehicle

➔ **Driven distance by CoP vehicle:**

Warm-Up + road load adjustment + Preconditioning + CS-Test + CD-Test

23km 8-16km 23km + x 23km 23km = 108km

Option 2: CoP with two vehicle (one vehicle driving CS-test, one vehicle driving CD-test)

➔ **Mileage of first vehicle (driving CS-test)**

Warm-Up + road load adjustment + Preconditioning + CS-Test

23km 8-16km 23km + x 23km = 85km

➔ **Mileage of second vehicle (driving CD-test)**

Warm-Up + road load adjustment + Preconditioning + CD-Test

23km 8-16km 23km + x 23km = 85km

COP for PEVs and OVC-HEVs: Conclusion

- The values provided by the ACEA WLTP EV proposal can be verified during CoP by driving less mileage
  - These values can be determined out of the already existing type approval procedure
  - But: the calculation schemes for the COP values have to added to the calculation schemes of the type 1 test procedure to enable a shorten COP test procedure

- Adjustment factor for homologation values necessary which have to be verified during CoP
  - Reminder: For phase specific values, manufacturer is required to apply an adjustment factor as there can be a difference between a declared value and measured value during type approval (as already defined in GTR)
  - Value out of homologation which has to be verified during CoP is in any case the declared value (same procedure than for conventional vehicles)
  - Determination of the AF for CO_2 and EC is described on the corresponding slides of this presentation

- Concerning evolution factor for HEVs and PEVs:
  - First step: Overtake evolution factor [fixed value or determination] for CO_2 and EC from conventional vehicle CO_2
  - Second step: review evolution factor after WLTP phase 2 outcome (CoP will be discussed in WLTP phase 2)

- UBE verification
  - To check the UBE in CoP, we would have to perform exactly the same test as in homologation (UBE is depending on the way the REESS is discharged)
  - CoP of the REESS at the REESS manufacturer, not part of CoP at the vehicle manufacturer
  - Full REESS capacity first available after two to three charging events (charging/discharging procedure may lead to a high mileage and is very time consuming)

- Statistical evaluation for HEVs and PEVs
  - First step: Apply statistical approach from conventional vehicles
  - Second step: Review statistical evaluation for HEVs and PEVs

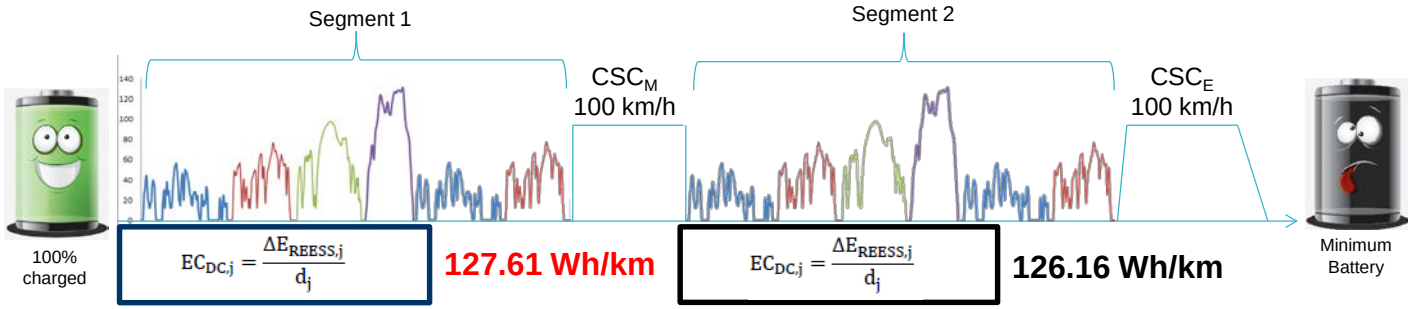
BACKUP

ACEA WLTP EV – COP requirements for PEVs

Proposal ACEA WLTP EV: Example for verification of EC_{COP} in COP

Homologation

1 ***Energy consumption and range determination test***



$$EC_{DC,j} = \frac{\Delta E_{REESS,j}}{d_j}$$ **127.61 Wh/km**

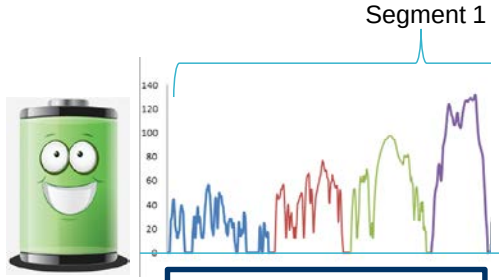
$$EC_{DC,j} = \frac{\Delta E_{REESS,j}}{d_j}$$ **126.16 Wh/km**

$$PER_{WLTC} = \frac{UBE_{STP}}{EC_{DC,WLTC}}$$ **174 km**

$$EC_{WLTC} = \frac{E_{AC}}{PER_{WLTC}}$$ **139 Wh/km (declared value: 140 Wh/km)**

COP

1 ***Energy consumption test***



$$EC_{DC,j} = \frac{\Delta E_{REESS,j}}{d_j}$$ **127 Wh/km**

What we need to check in COP ?

AC Energy consumption homologation
- Measured value: 139 Wh/km
- Declared value: **140** Wh/km

Adjustment Factor for COP DC energy

$AF = \frac{Declared\ value}{Measured\ value} = \frac{140\ wh/km}{139\ wh/km}$ = **1.007**

Target value for COP DC energy

$EC_{DC.COP} = AF * EC_{DC.1}$

= 1.007*127.61 = **128.53** Wh/km