European Automobile Manufacturers Association

Combined approach and family definition for EV (OIL#56 & OIL#2)

ACEA EV Group

17.06.2014

ACEA WLTP E-Lab group
Story and current state of play.

Directly linked to each other because the criteria define if the calculation method and the logic works or not.

Combined approach for EV's.

►Combined approach for **conventional vehicles** was agreed in 09/2013.

►BMW started with simulations, shared the results with the ACEA members and created an proposal for the GTR of WLTP phase 1a (attached to the Email).

►ACEA decided to postpone the combined approach to WLTP phase 1b.

►JAP presented a starting note at the beginning of WLTP phase 1b that shows the Japanese position.

Family definition for EV's.

►ACEA as well as JAP made a proposal for a starting note.

►ACEA declared that the finalization has to be postpones because the family definition has to be discussed in parallel with the combined approach.
→Agreement from Subgroup EV available.
Comparison and recommendation.

►No further action required at the moment. In advance we have to decide which values will be needed for OVC-HEV and PEV.

ACEA WLTP E-Lab group
Next steps.

Directly linked to each other because the criteria define if the calculation method and the logic works or not.

Combined approach for EV's.

►The starting note from Japan is not consistent with the current BMW proposal.

►ACEA needs common position.

►The ACEA position will be shared with Japan.

►Open Issues:
Japan declared that there is a need for phase specific values. Hence there is a need for the validation of the combined approach for phase specific values. ACEA is waiting for a reply which values are really needed.

►Remark:
No phase specific values needed in EU.

Family definition for EV's.

► No further action required at the moment. Shall be discussed during the development of the combined approach.

ACEA WLTP E-Lab group
Combined approach family definition

Agreed.

Current GTR for conventional vehicles only.

5.6. CO_2 vehicle family

5.6.1. Unless vehicles are identical with respect to the following vehicle/powertrain/transmission characteristics, they shall not be considered to be part of the same CO_2 vehicle family:

(a) Type of internal combustion engine: fuel type, combustion type, engine displacement, full-load characteristics, engine technology, and charging system shall be identical, but also other engine subsystems or characteristics that have a non-negligible influence on CO_2 under WLTP conditions;

(b) Operation strategy of all CO_2-influencing components within the powertrain;

(c) Transmission type (e.g. manual, automatic, CVT);

(d) n/v ratios (engine rotational speed divided by vehicle speed). This requirement shall be considered fulfilled if, for all transmission ratios concerned, the difference with respect to the transmission ratios of the most commonly installed transmission type is within 8 per cent;

(e) Number of powered axles;

(f) [RESERVED: family criteria for EVs].

►The main idea is to categorize vehicles within a family to reduce the test burden.

►The consumption of vehicles within a CO_2 family can be interpolated between “low” and “high” vehicle (small extrapolation also possible).

►The approach is based on the cycle energy and regards all impacts caused by different driving resistances.

►The family definition ensures that other CO_2 influencing impacts outside of typical measurement tolerance can not be within a family.

ACEA

ACEA WLTP E-Lab group
Combined approach family definition

Agreed.

Current Japanese proposal for an addition for N-/OVC-HEVs.	Current proposal from ACEA for an addition for N-/OVC-HEVs.
In addition above, the following specification/characteristics shall be identical for NOVC-HEV and OVC-HEV. (f) Hybrid system configuration (series/parallel/split) (g) Battery specification (type, voltage, output) (h) Motor specification (type, voltage, output) (i) Inverter specification (j) R_{CDC} value	(f) Architecture of the hybrid power train (serial, parallel, power split, ...) (g) Type of traction battery including the type of battery cells and the assembly, kind of cooling as well as the battery positioning within the vehicle; (h) Type and amount of electric machines: full-load characteristic, type of used current (AC/DC), construction type (asynchronous/ synchronous / ...), kind of cooling (air, coolant, oil,...); (i) Type of converter between electric machine and traction battery; (j) Type of converter between traction battery and low voltage power supply; (k) Non- negligible deviation concerning the hybrid operation strategy of all CO_2-influencing components (l) ...?

►ACEA position:

The finalization for the “combined approach for EV’s” is planned for April/May 2015. As long as the details of the application are discussed, ACEA recommends against the finalization of the criteria for combined approach family for EVs because it might be useful to add more criteria during the following discussions.

ACEA WLTP E-Lab group
Combined approach family definition

Agreed.

Current Japanese proposal for PEVs.

The basic concept for the PEV family definition is same with that of OVC-HEV & NOVC-HEV family definitions in regard to electric systems.

Unless vehicles are identical with respect to the following motor/transmission characteristics, they shall not be considered to be part of the same vehicle family for PEVs:

(a) motor type (e.g. UN R85)

Other software or characteristics that have a non-negligible influence on energy consumption and electric range under WLTP conditions shall be identical.

(b) battery type (e.g. Energy density for battery pack [Wh/kg])

Other software or characteristics that have a non-negligible influence on energy consumption and electric range under WLTP conditions shall be identical.

(c) transmission type (e.g. manual, automatic, CVT);

(d) n/v ratios (motor rotational speed divided by vehicle speed). This requirement shall be considered fulfilled if, for all transmission ratios concerned, the difference with respect to the transmission ratios of the most commonly installed transmission type is within 8 per cent;

(e) number of powered axles;

►ACEA position:

The recommendation is equal to the statement for N-/OVC-HEVs.

We should start the discussion with respect to the formulated criteria, but we should not finalize them now, because it might be helpful the add criteria if we recognize that we have to consider more aspects.

ACEA WLTP E-Lab group
Combined approach family definition

Agreed.

►The shown criteria are a suitable start for the discussions of the combined approach for EVs.

►To be able to use the opportunity to add more criteria to ensure the application of the combined approach we should keep this topic open until the finalization of the combined approach.

►Integration into the GTR:

1.option:

Change the subtitle 5.6 “CO_2 vehicle family” in “Combined approach vehicle family”.

If we consider to add the criteria to that paragraph, we have to change the subtitle because its not longer only a topic of CO_2 but a topic of electric range and consumption too.

2.option:

Add 2 paragraphs; a first for N-/OVC-HEV and a second for PEV.

N. Schütze, 15.07.13

SIMULATIVE VALIDATION OF COMBINED APPROACH FOR OVC-HEV.

BMW GROUP

WLTP – COMBINED APPROACH FOR OVC-HEV.

VALIDATION PROCESS FOR COMBINED APPROACH.

1. • Simulation of four OVC-HEVs each with five different road loads and test masses.
2. • Calculation of defined values according to GTR annex 8.
3. • Application of interpolation method that is proposed as combined approach.

1st vehicle
No engine start until SOC_{min} is reached because the performance of the electric power train is higher than the necessary power for the WC-vehicle.

2nd vehicle
A limited power of the electric power train causes no engine start of the BC-vehicle and one power triggered engine start of the WC-vehicle before SOC_{min} is reached.

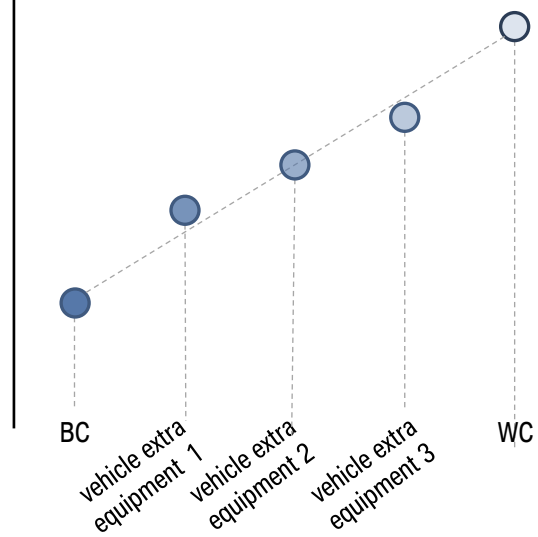
3rd vehicle
A limited power of the electric power train causes no engine start of the BC-vehicle and more than one power triggered engine start of the WC-vehicle before SOC_{min} is reached.

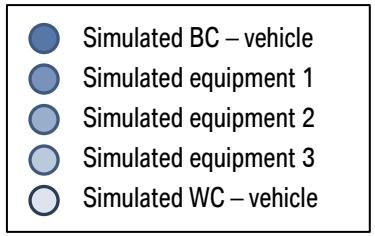
4th vehicle
A limited speed for electric driving causes an engine start for each vehicle before SOC_{min} is reached.

WLTP – COMBINED APPROACH FOR OVC-HEV.

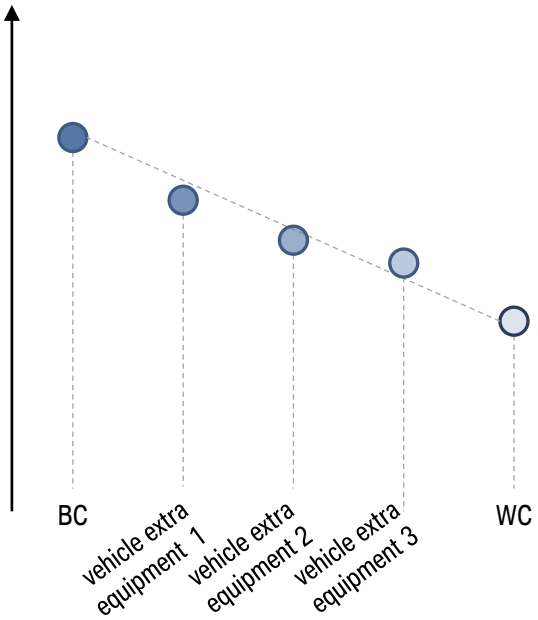
CONSIDERED VALUES FOR COMBINED APPROACH.

schematic figure for fuel and electric consumption





schematic figure for electric range

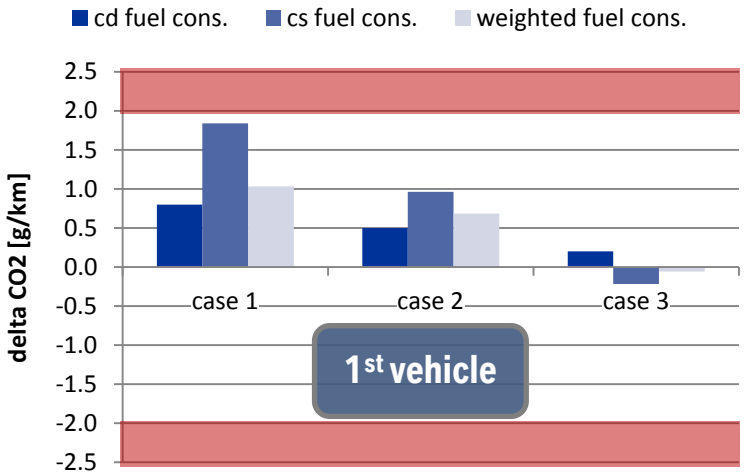


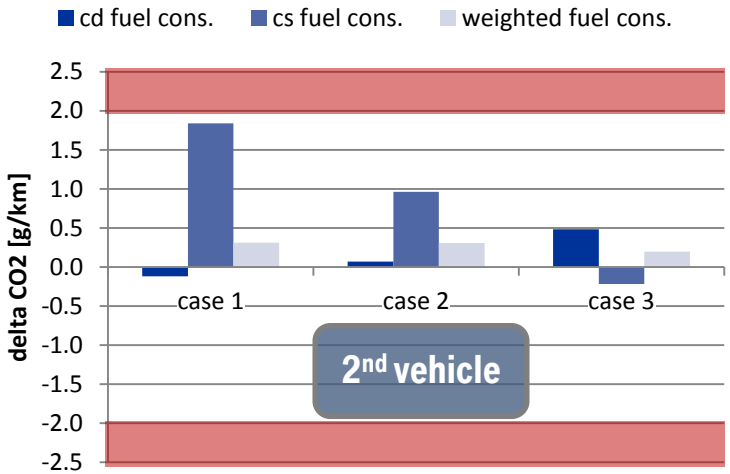
consumptions	abbreviation
charge depleting electric cons.	C_{CD}
weighted electric cons.	$C_{weighted}$
electric cons.	C
charge depleting fuel cons.	FC_{CD}
charge sustaining fuel cons.	FC_{CS}
weighted fuel cons.	$FC_{weighted}$

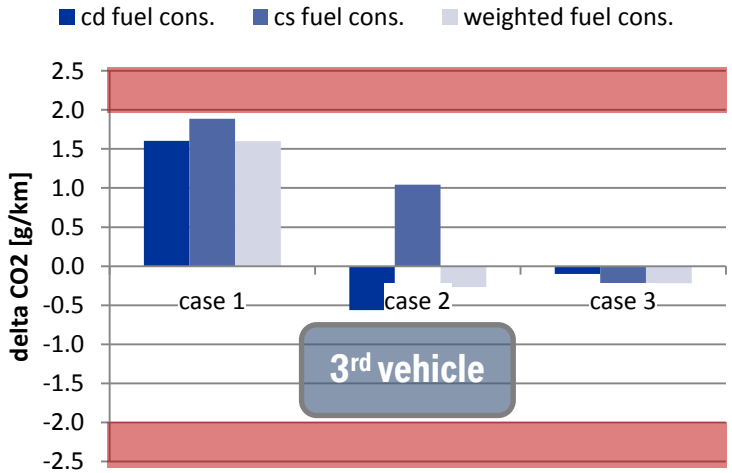
ranges	abbreviation
all electric range	AER
equivalent all electric range	EAER
charge depleting actual range	R_{CDA}

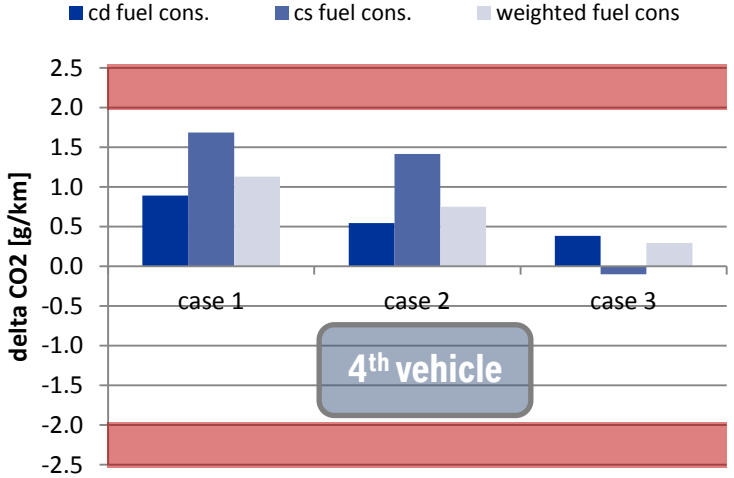
WLTP – COMBINED APPROACH FOR OVC-HEV.

SIMULATION RESULTS - FUEL CONSUMPTION.





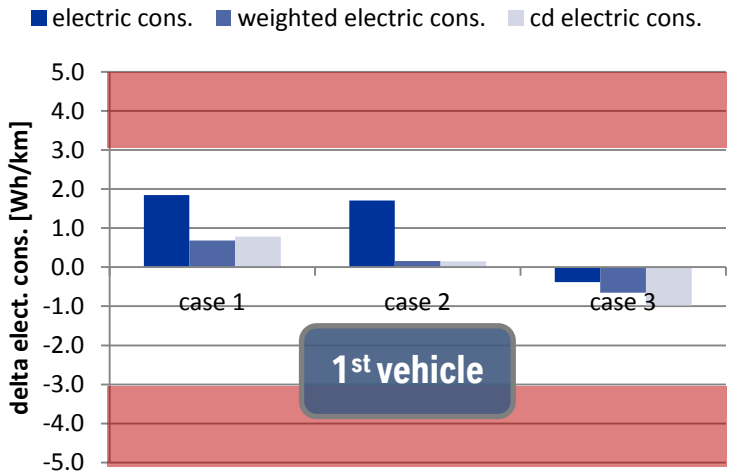


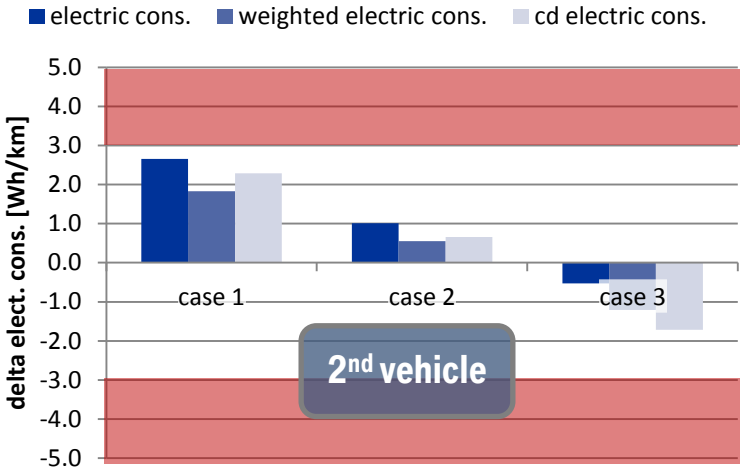


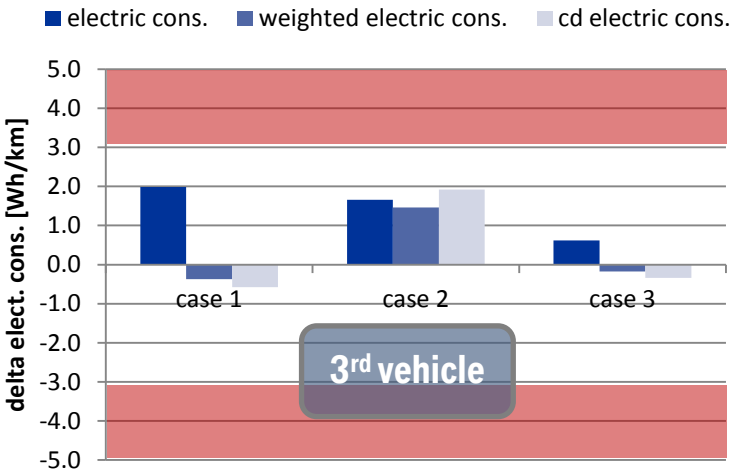
► Each deviation within the tolerance of +/-2 g CO_2 /km.

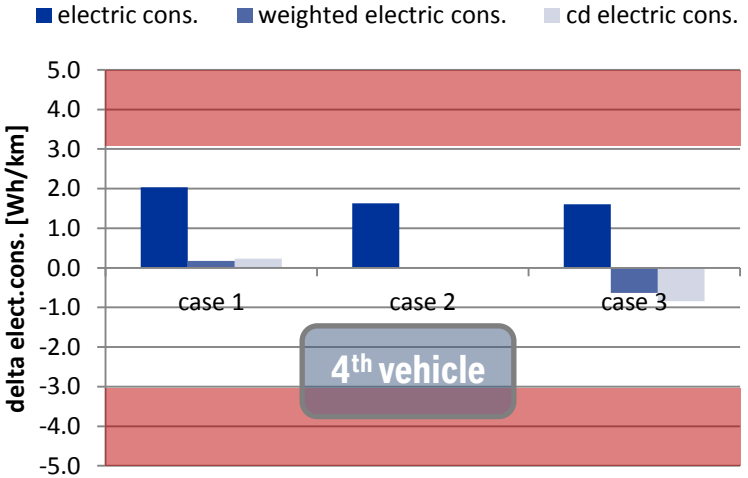
WLTP – COMBINED APPROACH FOR OVC-HEV.

SIMULATION RESULTS - ELECTRIC CONSUMPTION.





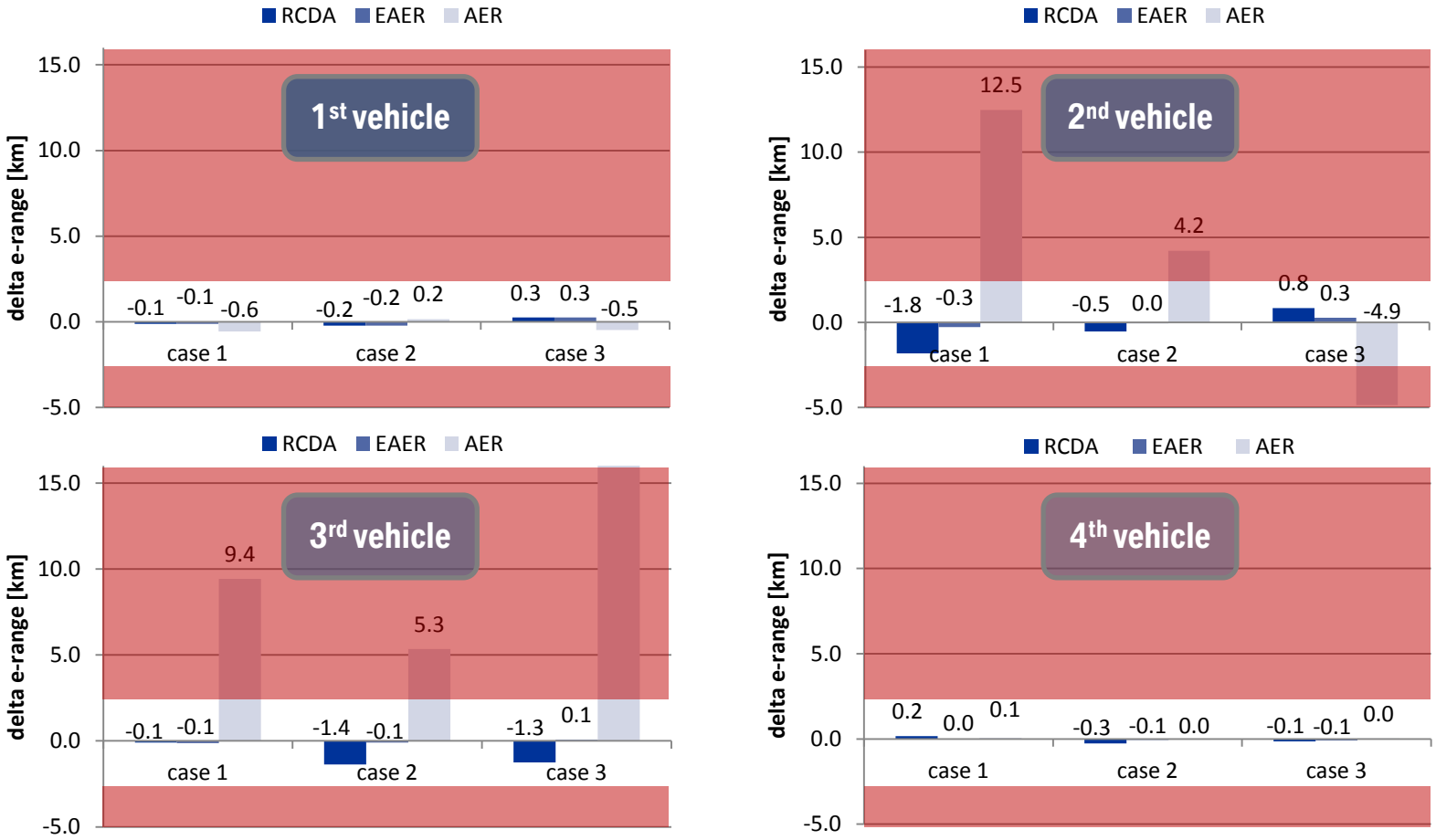




► In each case the relative deviation is bigger than -1 % and less than +2 %. All electric consumptions are within a tolerance of +/-3 Wh/km.

WLTP – COMBINED APPROACH FOR OVC-HEV.

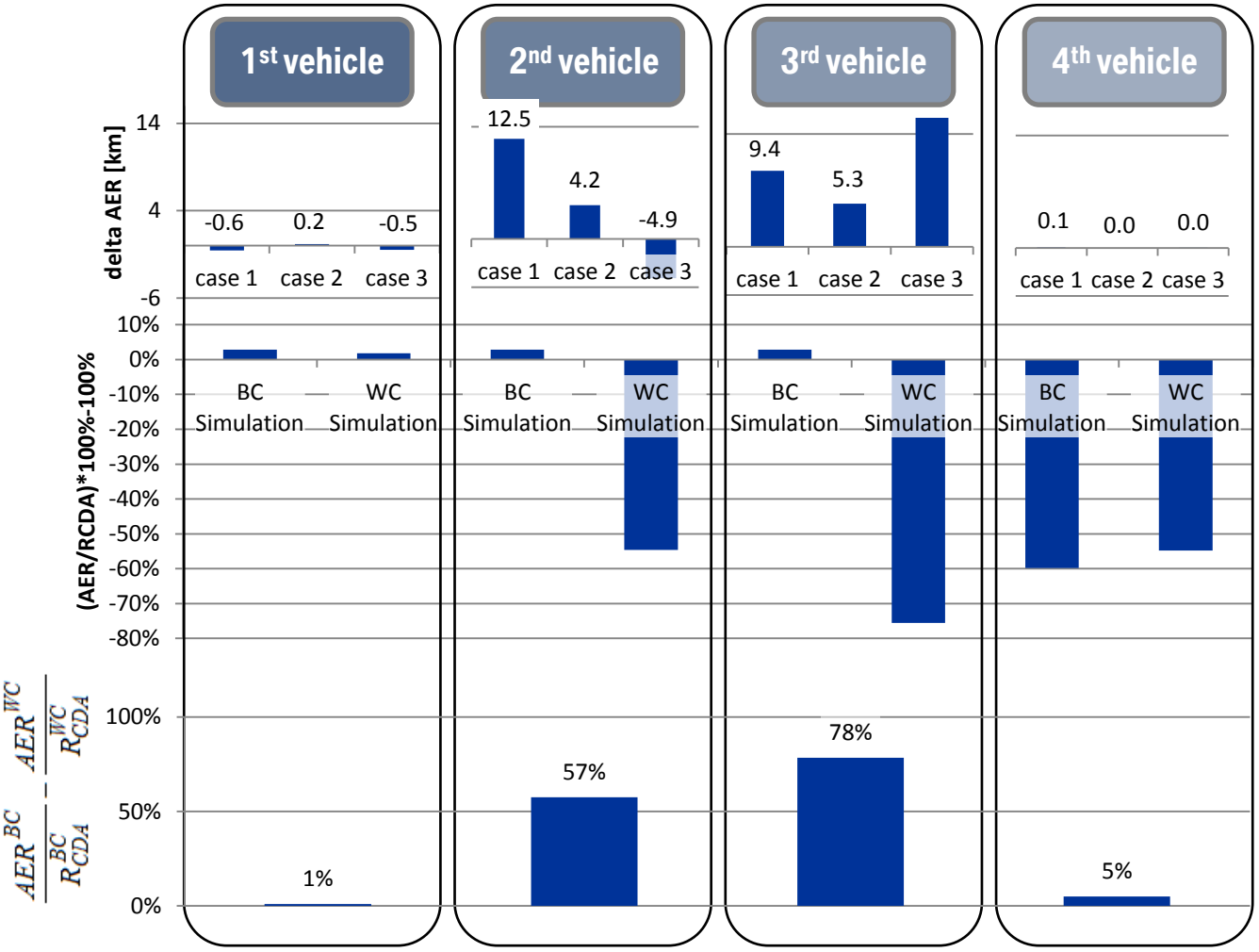
SIMULATION RESULTS - ELECTRIC RANGE.



- The interpolation works for RCDA and EAER.
- A huge AER deviation is caused by an power triggered engine start.

WLTP – COMBINED APPROACH FOR OVC-HEV.

PROPOSAL FOR THE AER DEVIATION PROBLEM.



The combined approach does not work if the number of engine starts between BC and WC are different.

An indicator for the valid apply of the interpolation is the difference between the deviation of AER and RCDA of the BC and WC vehicle.

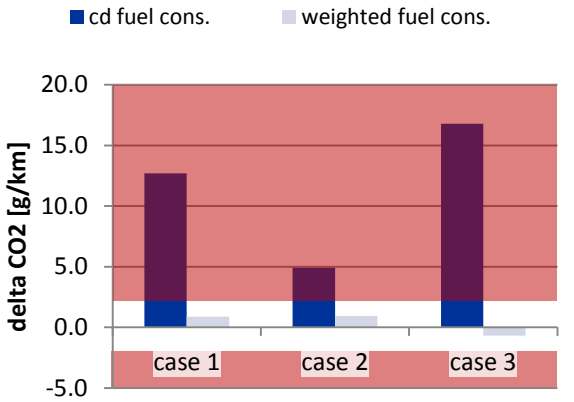
The consideration of the used criteria can be used to separate the different cases of engine starts.

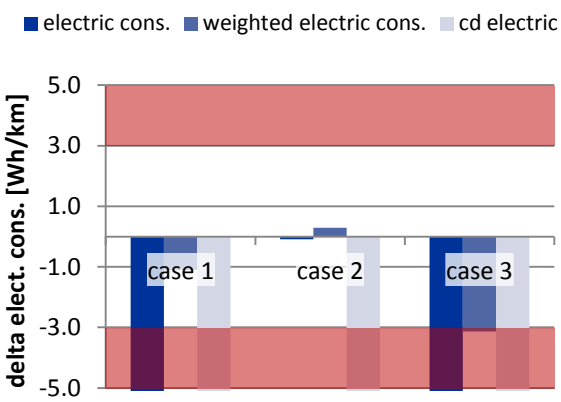
► Proposal: If the absolute deviation is less than 10%, interpolation of AER can be used, else AER of the WC-vehicle has to be applied.

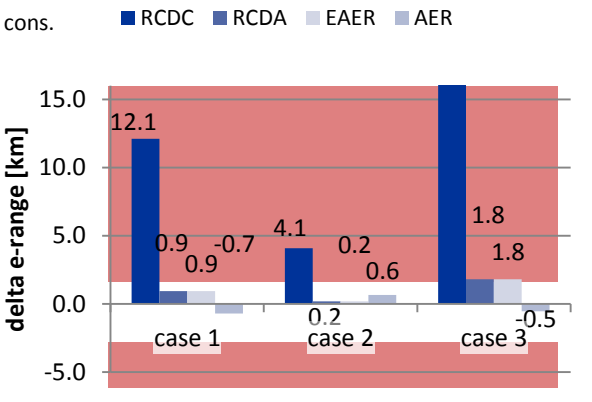
WLTP – COMBINED APPROACH FOR OVC-HEV.

SWITCH OF R_{CDC} BETWEEN BC- AND WC-VEHICLE.

1st vehicle







FC_{CD} shows a very high deviation

consumptions	deviation
charge depleting fuel cons.	✗
charge sustaining fuel cons.	✓
weighted fuel cons.	✓

Very high deviation of C and C_{CD}.

consumptions	deviation
charge depleting electric cons.	✗
weighted electric cons.	✓
electric cons.	✗

The switch from one to two CD cycles causes high R_{CDC} -deviation.

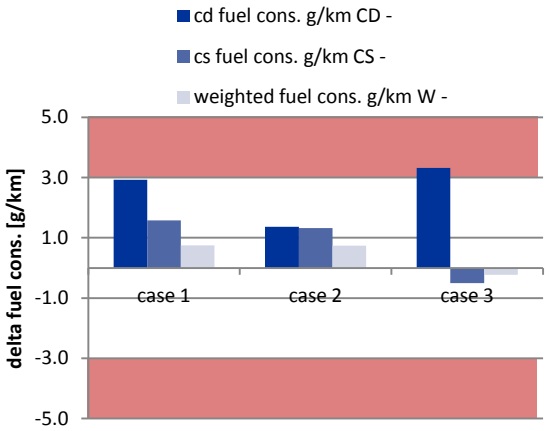
range	deviation
charge depleting cycle range	✗
all electric range	✓
equivalent all electric range	✓
charge depleting actual range	✓

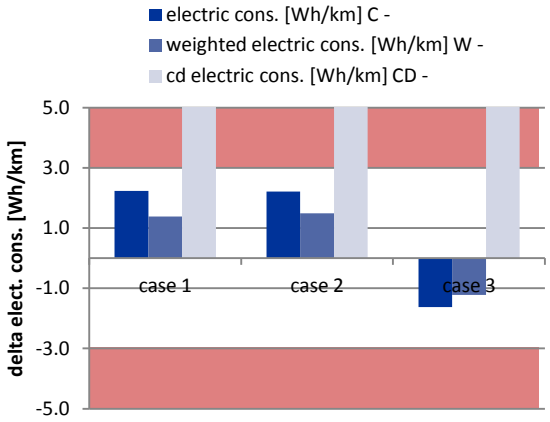
► There is no need to calculate an individual charge depleting cycle range because this range has no additional value. It is only needed to calculate the equivalent all electric range and for the EAER the combined approach works well.

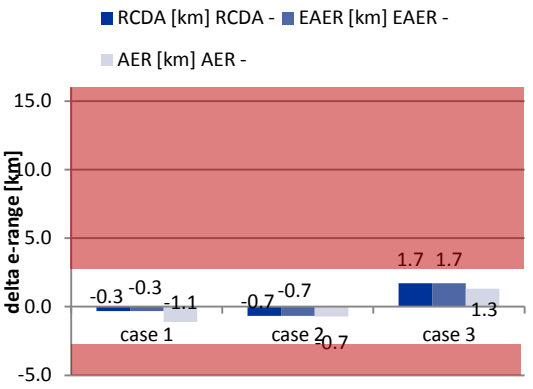
WLTP – COMBINED APPROACH FOR OVC-HEV.

SWITCH OF R_{CDC} BETWEEN BC- AND WC-VEHICLE.

range extender concept (serial hybrid)







FC_{CD} shows a very high deviation

consumptions	deviation
charge depleting fuel cons.	✗
charge sustaining fuel cons.	✓
weighted fuel cons.	✓

Very high deviation of C and C_{CD}.

consumptions	deviation
charge depleting electric cons.	✗
electric cons.	✓
weighted electric cons.	✓

The switch from one to two CD cycles causes high R_{CDC} -deviation.

range	deviation
charge depleting cycle range	✗
all electric range	✓
equivalent all electric range	✓
charge depleting actual range	✓

► There is no need to calculate an individual charge depleting cycle range because this range has no additional value. It is only needed to calculate the equivalent all electric range and for the EAER the combined approach works well.

WLTP – COMBINED APPROACH FOR OVC-HEV.

SUMMARY FOR COMBINED APPROACH.

fuel consumption	application
charge depleting fuel cons.	✗
charge sustaining fuel cons.	✓
weighted fuel cons.	✓

electric consumption	application
charge depleting electric cons.	✗
electric cons.	✗
weighted electric cons.	✓

range	application
charge depleting cycle range	✗
all electric range	(✓)
equivalent all electric range	✓
charge depleting actual range	✓

► The application of the combined approach works well for:

- weighted and charge sustaining fuel consumption ($FC_{weighted}$, FC_{CS})
- weighted electric consumption ($C_{weighted}$)
- equivalent all electric and charge depleting actual range (EAER, R_{CDA})

► In case of no power triggered engine start for the BC-, but power triggered engine starts for the WC-vehicle:

$$\frac{AER^{BC}}{R_{CDA}^{BC}} - \frac{AER^{WC}}{R_{CDA}^{WC}} \leq 10\%$$

comb. appr. valid

$$\frac{AER^{BC}}{R_{CDA}^{BC}} - \frac{AER^{WC}}{R_{CDA}^{WC}} > 10\%$$

use AER of WC vehicle

► In case of R_{CDC} switch the following WC-vehicle values shall be used:

- charge depleting fuel consumption
- charge depleting electric and electric consumption
- charge depleting cycle range

Combined Approach for electrified vehicles

< Background >

Due to its technical difficulty and time shortage, it was agreed to take care of applicability of “combined approach” to electrified vehicle during Phase1b.

Current gtr allows to apply “combined approach” only to ICE vehicles (see below).

		Each phase					L+M (regional option)					L+M+H(+Ex-H)				
		EM	CO2	FC	EC	Range	EM	CO2	FC	EC	Range	EM	CO2	FC	EC	Range
ICE		○*	○	○	NA	NA	NA	NA	NA	NA	NA	●	○	○	NA	NA
NOVC-HEV		○*	○	○	NA	NA	NA	NA	NA	NA	NA	●	○	○	NA	NA
OVC-HEV	CS	○*	○	○	NA	NA	NA	NA	NA	NA	NA	●	○	○	NA	NA
	CD	○*	○	○	○	AER EAER Rcda Rcdc	NA	NA	NA	NA	AER EAER Rcda Rcdc	●	○	○	○	AER EAER Rcda Rcdc
	Combined	NA	○	○	NA	NA	NA	NA	NA	NA	NA	NA	○	Independent or combined		NA
PEV		NA	NA	NA	○	NA	NA	NA	NA	NA	○	NA	NA	NA	○	○

● : emission compliance, ○ : user information / incentive, *) no PM data is available

□ : apply combined approach

Proposal

apply for both NOVC and OVC-HEVs with the following conditions.

conditions : (1) same specification of battery/inverter/motor

(2) SOC correction factor need to be developed for both points

(3) Rcdc shall be same for OVC-HEV

Applicability to OVC-HEV and NOVC-HEV (1)

		Each phase					L+M (regional option)					L+M+H(+Ex-H)				
		EM	CO2	FC	EC	Range	EM	CO2	FC	EC	Range	EM	CO2	FC	EC	Range
ICE		○*	○	○	NA	NA	NA	NA	NA	NA	NA	●	○	○	NA	NA
NOVC-HEV		○*	○	○	NA	NA	NA	NA	NA	NA	NA	●	○	○	NA	NA
OVC-HEV	CS	○*	○	○	NA	NA	NA	NA	NA	NA	NA	●	○	○	NA	NA
	CD	○*	○	○	○	AER EAER Rcda Rcdc	NA	NA	NA	NA	AER EAER Rcda Rcdc	●	○	○	○	AER EAER Rcda Rcdc
	Combined	NA	○	○	NA	NA	NA	NA	NA	NA	NA	NA	○	Independent or combined		NA
PEV		NA	NA	NA	○	NA	NA	NA	NA	NA	○	NA	NA	NA	○	○

NOVC-HEV and CS test for OVC-HEV

→ It's straight-forward to apply same concept as ICE with additional family concept (*1).
→ However, SOC correction factor shall be developed for both conditions.

Applicability to OVC-HEV and NOVC-HEV (2)

		Each phase					L+M (regional option)					L+M+H(+Ex-H)				
		EM	CO2	FC	EC	Range	EM	CO2	FC	EC	Range	EM	CO2	FC	EC	Range
ICE		○*	○	○	NA	NA	NA	NA	NA	NA	NA	●	○	○	NA	NA
NOVC-HEV		○*	○	○	NA	NA	NA	NA	NA	NA	NA	●	○	○	NA	NA
OVC-HEV	CS	○*	○	○	NA	NA	NA	NA	NA	NA	NA	●	○	○	NA	NA
	CD	○*	○	○	○	AER EAER Rcda Rcdc	NA	NA	NA	NA	AER EAER Rcda Rcdc	●	○	○	○	AER EAER Rcda Rcdc
	Combined	NA	○	○	NA	NA	NA	NA	NA	NA	NA	NA	○	Independent or combined		NA
PEV		NA	NA	NA	○	NA	NA	NA	NA	NA	○	NA	NA	NA	○	○

CD test for OVC-HEV

→Rcdc: same value is one of conditions to apply “combined approach”.

→CO_2/FC/EC/EAER/Rcda: Both conditions (TM_H and TM_L) shall be tested to check Rcdc value anyway, then apply “combined approach” concept.

Applicability to OVC-HEV and NOVC-HEV (3)

		Each phase					L+M (regional option)					L+M+H(+Ex-H)				
		EM	CO2	FC	EC	Range	EM	CO2	FC	EC	Range	EM	CO2	FC	EC	Range
ICE		○*	○	○	NA	NA	NA	NA	NA	NA	NA	●	○	○	NA	NA
NOVC-HEV		○*	○	○	NA	NA	NA	NA	NA	NA	NA	●	○	○	NA	NA
OVC-HEV	CS	○*	○	○	NA	NA	NA	NA	NA	NA	NA	●	○	○	NA	NA
	CD	○*	○	○	○	AER EAER Rcda Rcdc	NA	NA	NA	NA	AER EAER Rcda Rcdc	●	○	○	○	AER EAER Rcda Rcdc
	Combined	NA	○	○	NA	NA	NA	NA	NA	NA	NA	NA	○	Independent or combined		NA
PEV		NA	NA	NA	○	NA	NA	NA	NA	NA	○	NA	NA	NA	○	○

Combined data for OVC-HEV

→CO_2/FC: Apply “combined approach” only when Rcdc are same under TM_H and TM_L conditions.

→EC: current GTR doesn’t define combined EC.

*1) additional family concept for NOVC-HEV and OVC-HEV

(a) Type of internal combustion engine: fuel type, combustion type, engine displacement, full-load characteristics, engine technology, and charging system shall be identical, but also other engine subsystems or characteristics that have a non-negligible influence on CO2 under WLTP conditions;
(b) Operation strategy of all CO2-influencing components within the powertrain;
(c) Transmission type (e.g. manual, automatic, CVT);
(d) n/v ratios (engine rotational speed divided by vehicle speed). This requirement shall be considered fulfilled if, for all transmission ratios concerned, the difference with respect to the transmission ratios of the most commonly installed transmission type is within 8 per cent;
(e) Number of powered axles;
In addition above, the following specifications/characteristics shall be identical for NOVC-HEV and OVC-HEV.
(f) Hybrid system configuration (series/parallel/split)
(g) Battery specifications (type, voltage, output)
(h) Rcdc value
(i) Motor specification (type, voltage, output)
(j) Inverter specifications