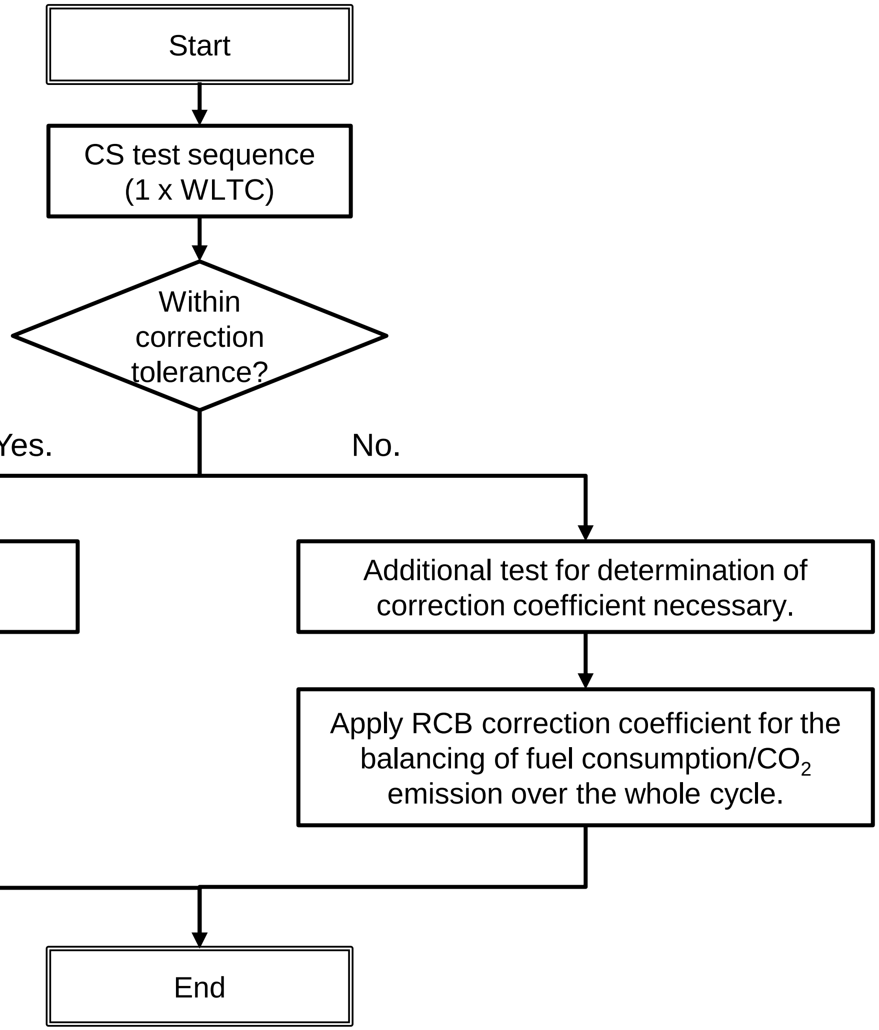
ACEA WLTP EV Group:
RCB correction for (N-)OVC-HEV charge sustaining test.
#OIL 50

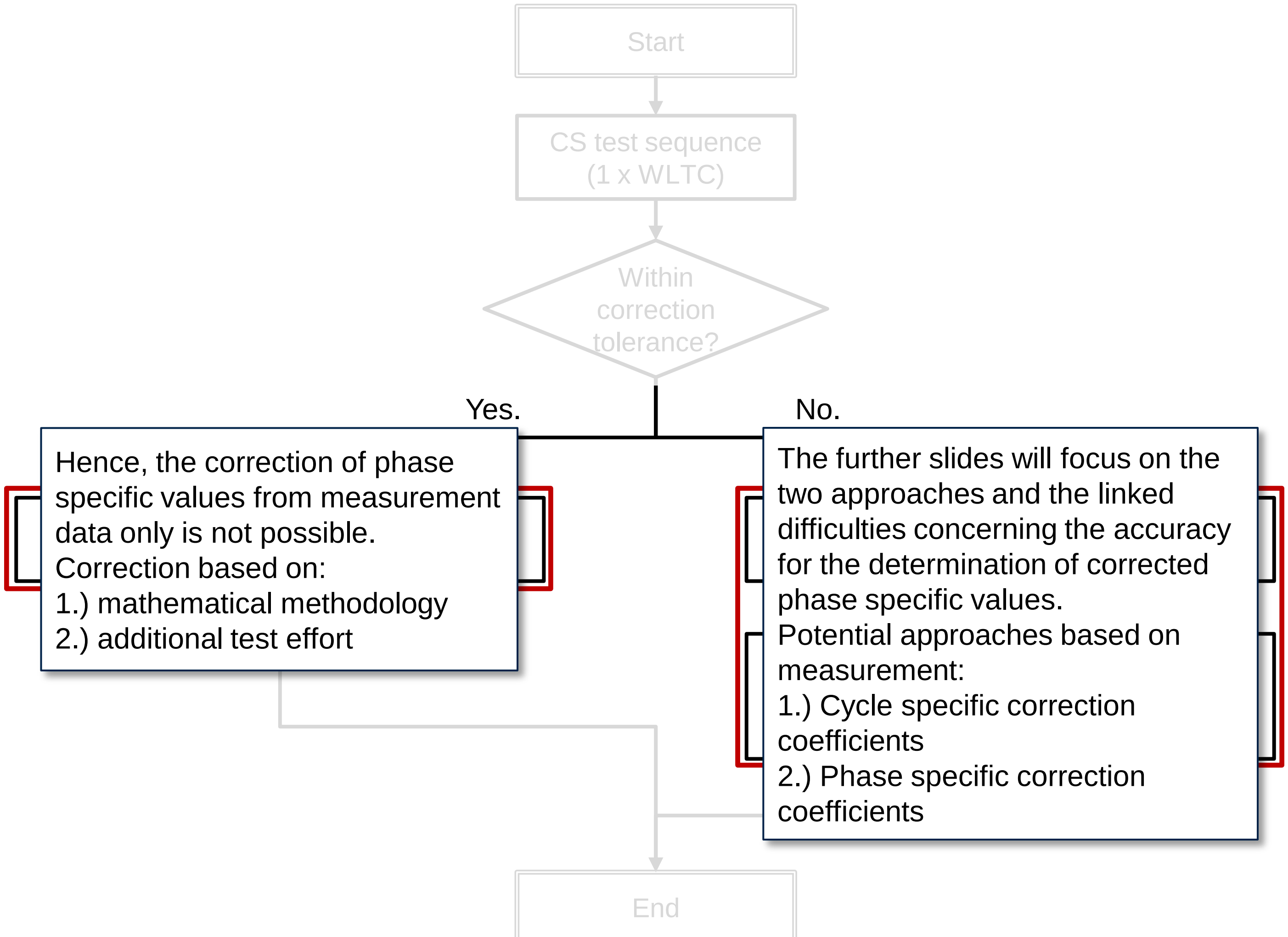
RCB correction
Overview

	RCB correction
Background	– Is a methodology to correct CO_2 emission and fuel consumption to a electric energy change of zero for the charge sustaining test of NOVC- and OVC-HEVs.
History	– In Phase 1a the methodology was adopted from ECE R101. – Caused by little adaptations in Phase 1a, some editorial issues and spaces for interpretations have to be corrected. – Since SubgroupEV meeting in Stockholm there is a need for corrected phase specific values. This is not covered by these methodology as it is described in GTR 1a.
Status quo	– JAMA proposed to use the phase specific correction as option A and the cycle specific correction as option B. – For vehicles driving an SOC balanced CS test, it would mean to drive more CS tests for phase specific value determination only. –To avoid these increasing test burden, JP proposed to allow a third method only in these cases that is based on the ratio of discharged electric energy and cycle energy demand.
Last steps	– Since the last meeting in Stockholm some new approaches had been analysed by simulation and by measurements from validation phase 2.

RCB correction
Current CS test process



RCB correction
CS test process



RCB correction
Phase specific correction based on theoretical approach

Correction based on cycle energy demand

The correction method shall be applied, if the correction criterion is not fulfilled (0.5 % criterion of cycle energy demand).

In this case the correction is done by splitting the fuel consumption/CO_2 emission from the whole cycle according to ratio of phase specific energy demand and cycle energy demand.

The energy demand optional includes deceleration phases (difference to cycle energy demand for conventional vehicles).

Conclusion:
This approach avoids additional test effort but might need an quantitative efficiency of the electric powertrain.

→ Analysis of deviations/tolerances and further development that might be necessary.

Correction based on the ratio of electric energy consumption and cycle energy demand

The correction method shall be applied, if the correction criterion is not fulfilled (0.5 % criterion of cycle energy demand).

In this case the ratio of used electric energy and cycle energy demand of each phase is used to correct each phase fuel consumption and CO_2 emission.

$$CO_{2,0} = \frac{CO_{2,uncorrected}}{1-A} \qquad A = \frac{\text{discharged electric energy}}{\text{cycle energy demand}}$$

Conclusion:
This approach avoids additional test effort.

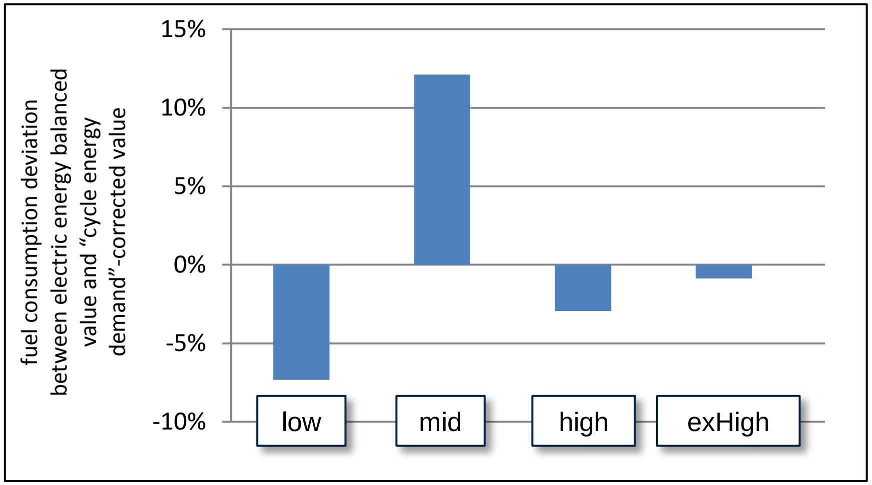
→ Analysis of deviations/tolerances.

RCB correction
Correction based on cycle energy demand

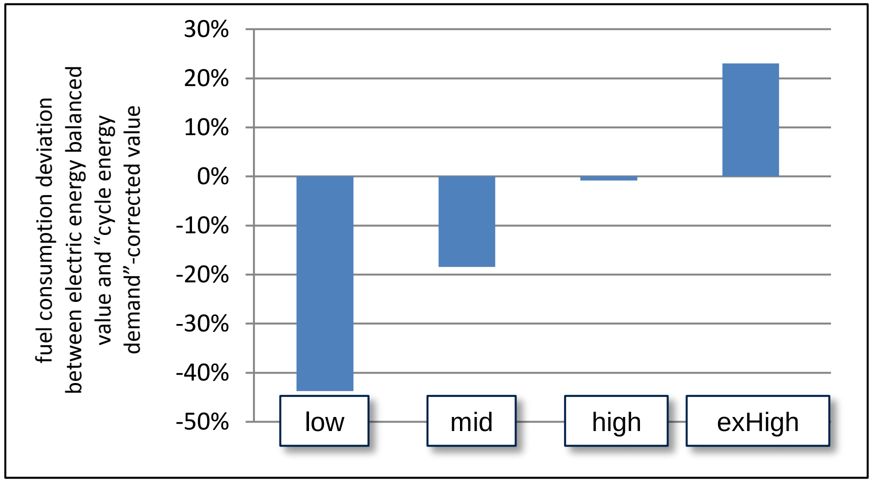
Reminder:
-The correction method shall be applied, if the correction criterion is not fulfilled (0.5 % criterion of cycle energy demand).
-In this case the correction is done by splitting the fuel consumption/CO_2 emission from the whole cycle according to ratio of phase specific energy demand and cycle energy demand.

$$CO_{2,phase} = \frac{\text{phase energy demand}}{\text{cycle energy demand}} \cdot CO_{2,cycle}$$

Results excluding recuperation.



Results including recuperation (η = 80%).



This method leads to an error that is very high for the option excluding recuperation as well as for the option including recuperation.

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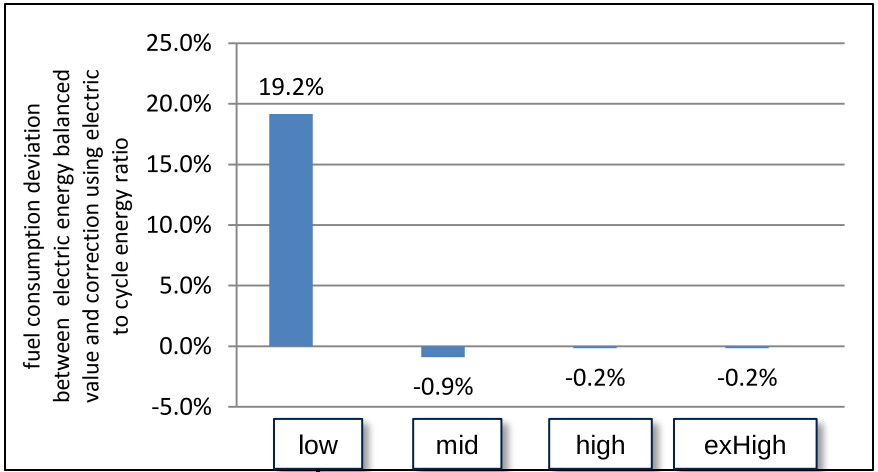
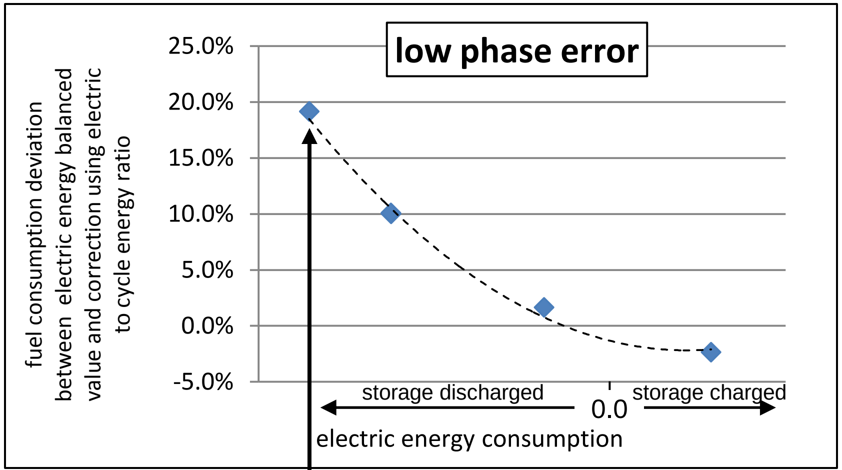
RCB correction
Correction based on the ratio of electric and cycle energy

Reminder:
-The correction method shall be applied, if the correction criterion is not fulfilled (0.5 % criterion of cycle energy demand).
-In this case the ratio of used electric energy and cycle energy demand of each phase is used to correct each phase fuel consumption and CO_2 emission.

$$A_{phase} = \frac{\text{discharged electric energy}_{\text{phase}}}{\text{cycle energy demand}_{\text{phase}}}$$

$$CO_{2,phase} = \frac{CO_{2,uncorrected,phase}}{1 - A_{phase}}$$





- This method seems to work well, if the electric energy consumption does not exceed a phase specific limit. Exceeding the limit leads to a disproportional increasing error (might be a systematic error that can be avoided). More time for evaluation and a potential extension of this approach necessary.
- The sum of all distance-weighted CO_2/fuel consumption values does not meet the value over the whole cycle.

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RCB correction
Phase specific correction based on measurement

Cycle specific approach for correction

Only **one** correction coefficient is used.

The coefficient is determined by driving several CS tests over the whole cycle.

The coefficient is suitable to correct the consumption over the whole cycle.

Conclusion:
The methodology can always be applied but the balancing of each phase consumptions using the cycle specific coefficient needs further analysis to evaluate the applicability.

→ Analysis of deviations/tolerances and further development if possible.

Phase specific approach for correction

The amount of correction coefficients depends on the number of phases (typically more than one coefficient).

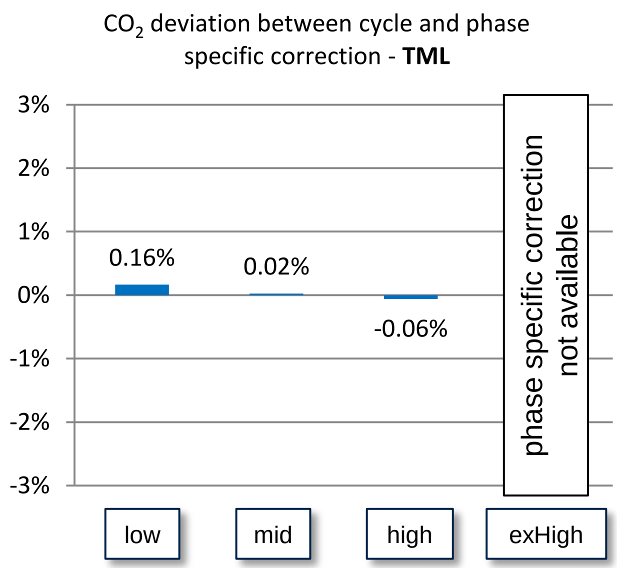
To determine phase specific correction coefficients different electric energy changes for each phase are necessary.

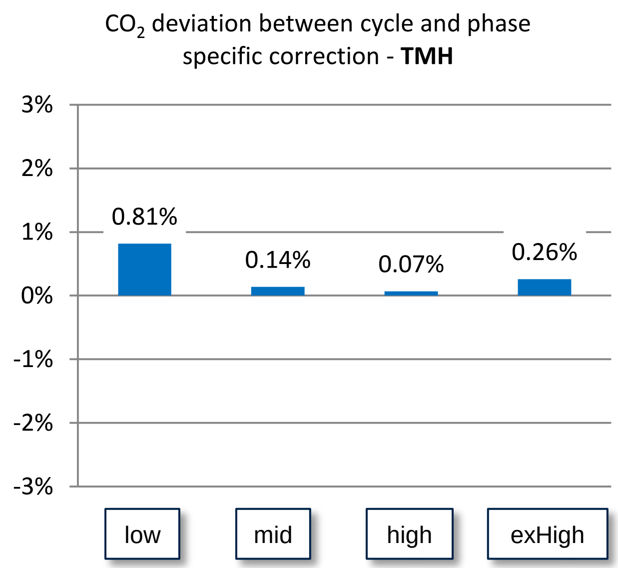
Using the phase specific correction coefficients enables the balancing of each phase consumption.

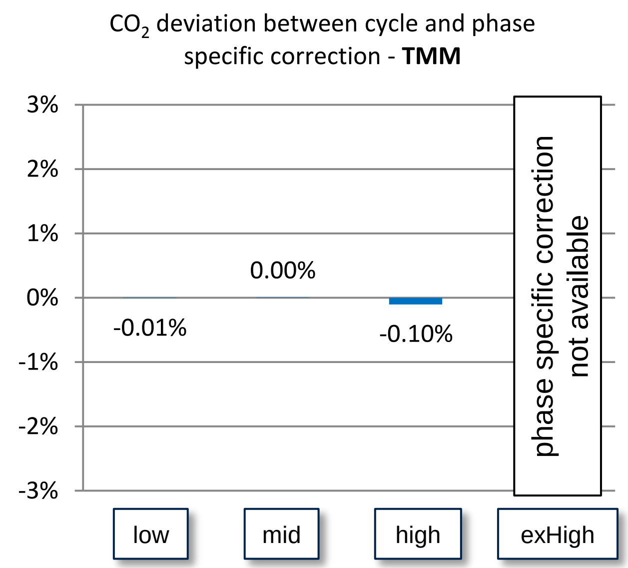
Conclusion:
Depending on the vehicle concept and operation strategy it is not always possible to determine different electric energy changes within a specific phase. **Hence, the methodology is not always applicable.**

RCB correction
Cycle vs. phase specific correction coefficient

Reminder:
-The coefficient is determined by driving several CS tests over the whole cycle.
-The coefficient is suitable to correct the consumption over the whole cycle. The methodology can always be applied but the balancing of each phase consumptions using the cycle specific coefficient needs further analysis to evaluate the applicability.







▶ Using the cycle specific correction coefficient in stead of the phase specific coefficients (if available) for each phase illustrates a low error.

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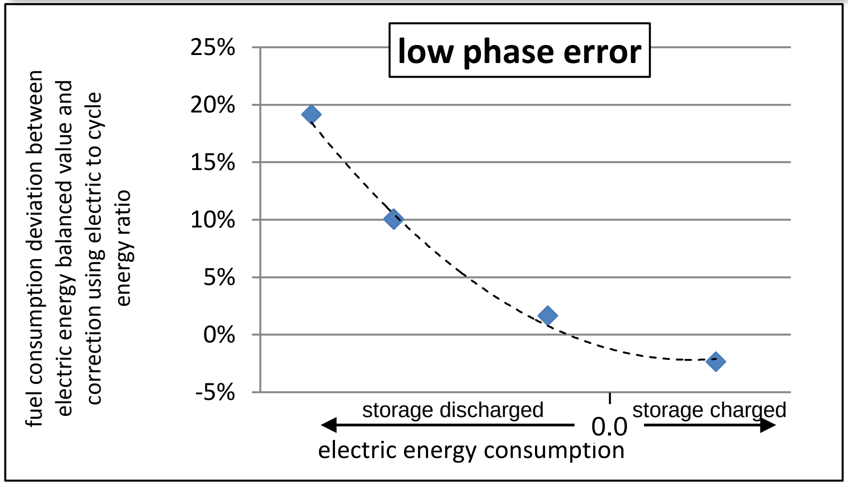
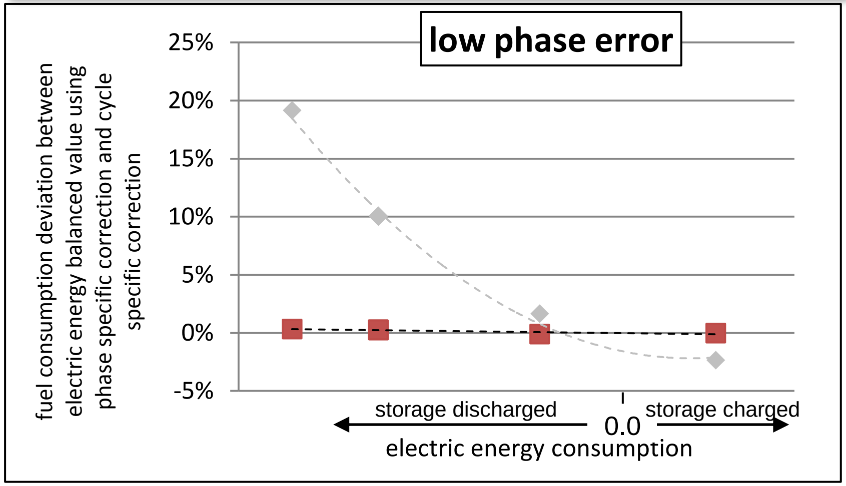
RCB correction
Cycle vs. phase specific correction coefficient

Reminder:
- The correction method based on the ratio of discharged electric energy and cycle energy demand offered a disproportional increasing error for arising electric energy consumption (figure on the left side).

Correction based on the ratio of electric energy consumption (link).



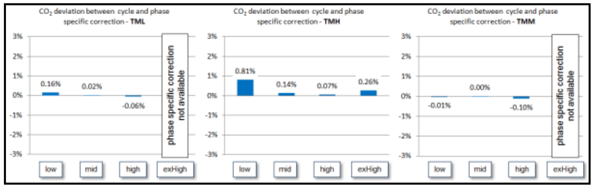
Correction based on the cycle specific coefficient.

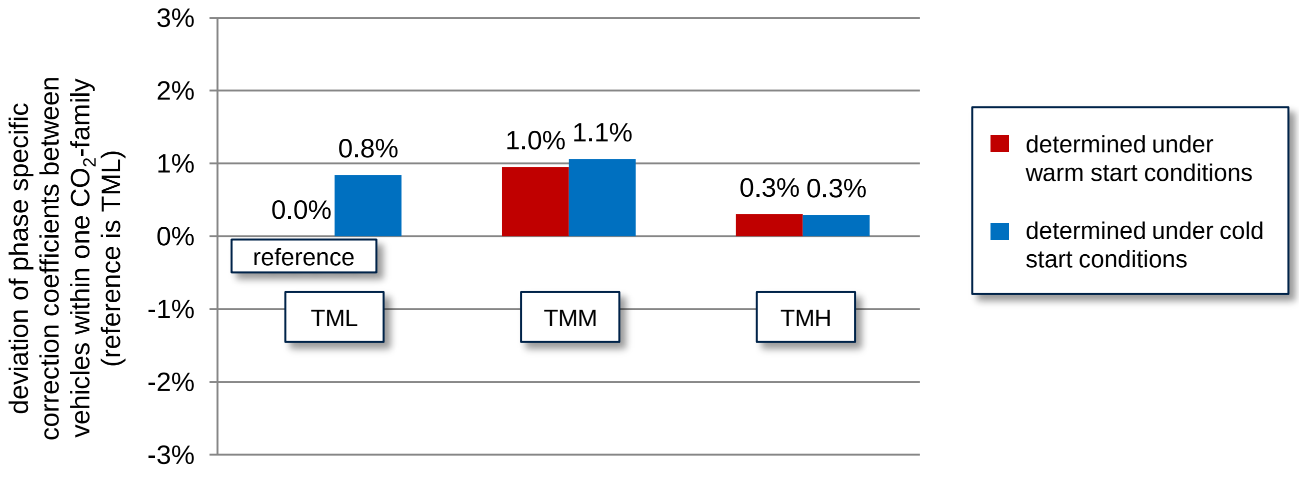


Applying the cycle specific correction coefficient in stead of the phase specific leads to a negligible error that is nearly independent from the deep of charge or discharge within one phase.

RCB correction
Cycle specific correction coefficient within one CO_2-family

Reminder:
- The application of cycle- in stead of phase specific coefficient leads to a negligible error.

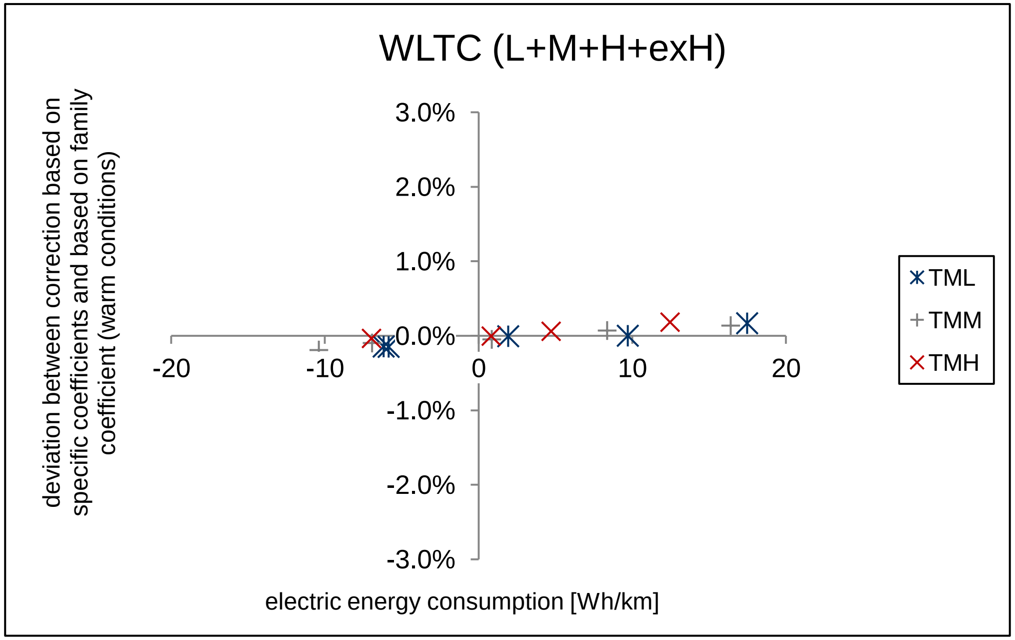




The cycle specific correction coefficient within one CO_2-family is very similar, even under warm and cold start conditions. Caused by some process advantages, the next slides show the deviation of using the cycle specific correction factor determined under warm conditions with TML (reference) instead of using the vehicle specific coefficient under determined under cold start conditions.

RCB correction
Cycle specific correction coefficient within one CO_2-family

Reminder:
- Caused by similar correction coefficients under warm and cold start conditions within one CO_2-family, the idea is to evaluate the deviation due to the application of a CO_2-family correction coefficient to the values over the whole cycle as well as to each phase.



The deviation over the whole cycle using a family correction coefficient in stead of a vehicle specific correction coefficient seems to be negligible.

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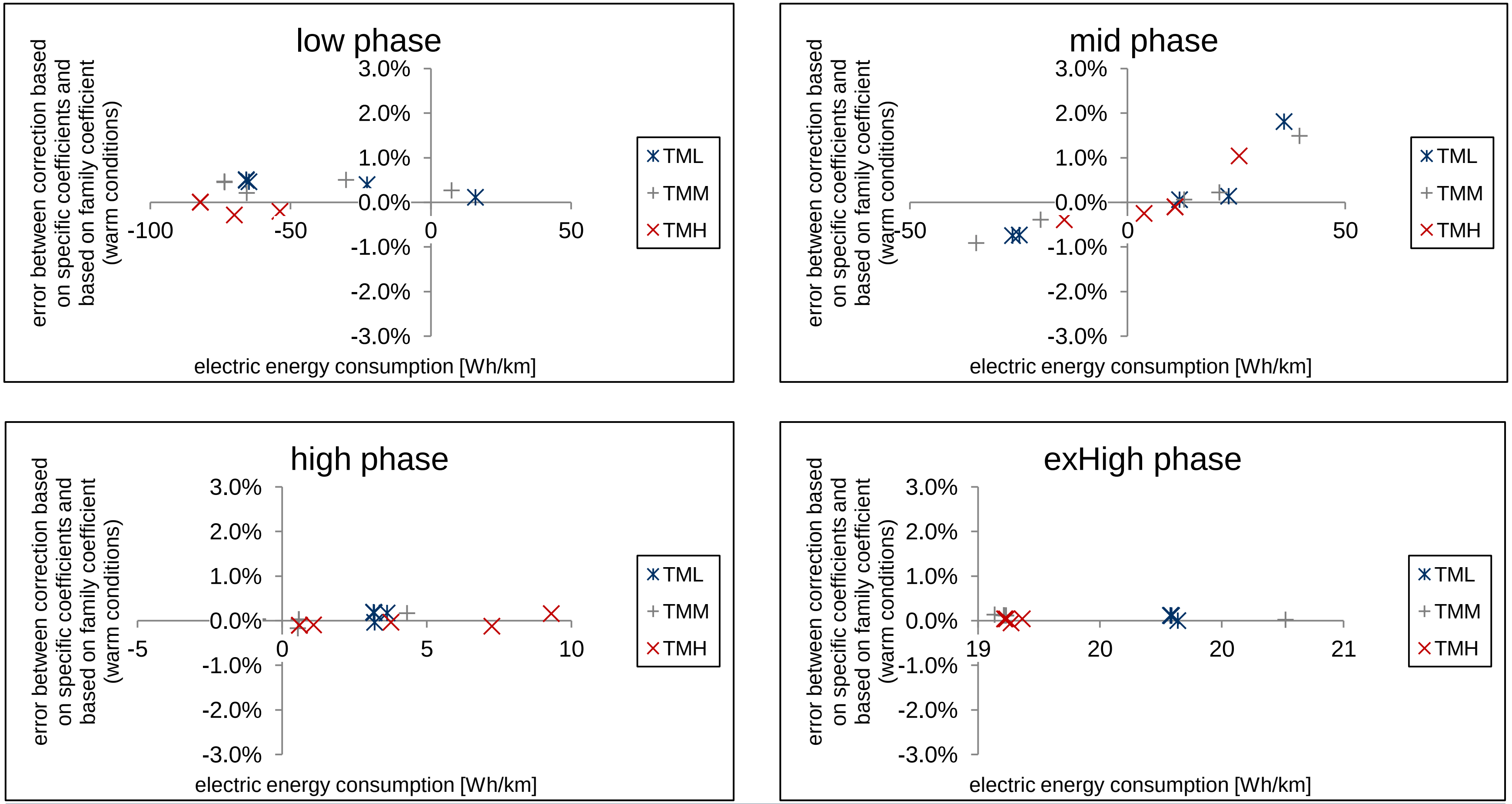
RCB correction
Cycle specific correction coefficient within one CO_2-family



▶ Even the deviation for each phase values seems to be acceptable using the cycle- and family specific correction coefficient determined from CS test with warm starting conditions.

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RCB correction
Cycle specific correction coefficient within one CO_2-family

Proposal for GTR modification

Determine

- a cycle specific correction coefficient
- from CS test under warm conditions with different electric energy balances over the whole cycle
- for the correction of phase specific values (under cold start conditions) and
- for the correction of cycle values (under cold start conditions)
- for all vehicles within a CO_2-family.

Justification & Advantages

- Acceptable error using the cycle- and family specific correction coefficient (CFSCC) compared to vehicle- and phase-specific coefficients.
- Using the CFSCC leads to the most accurate results compared to the energy based calculation methods (for cases where the electric energy balance is inside the limits [0.5 %/1 % - regulation]).
- Applying the CFSCC to the CS test under cold start conditions ensures the consideration of cold start impact.
- Some CS tests under warm conditions for the CFSCC-determination are reasonable because of:
    - the elimination of the city cycle (ACEA requirement for PSV)
    - the avoidance of additional tests in “Low+Mid+High” for certification in Japan because this part can be corrected as well from the “Low+Mid+High+exHigh”-test
    - the high probability that the manufacturer anyway has to perform more CS tests (under cold conditions including cool down) caused by the same operation strategy (family criterion) to achieve a balanced state of charge for the TML as well as for the TMH (resp. TMM if necessary) to avoid the need of correction.
- Reduction of the amount of vehicles that have to be measured for correction factor application.
- Robust and repeatable values for the correction factor caused by testing under warm conditions (starting with cold start conditions with different states of charge leads to different warm up curves caused by different electric operation).
- CFSCC-determination under warm conditions avoids several soak phases for cool down.

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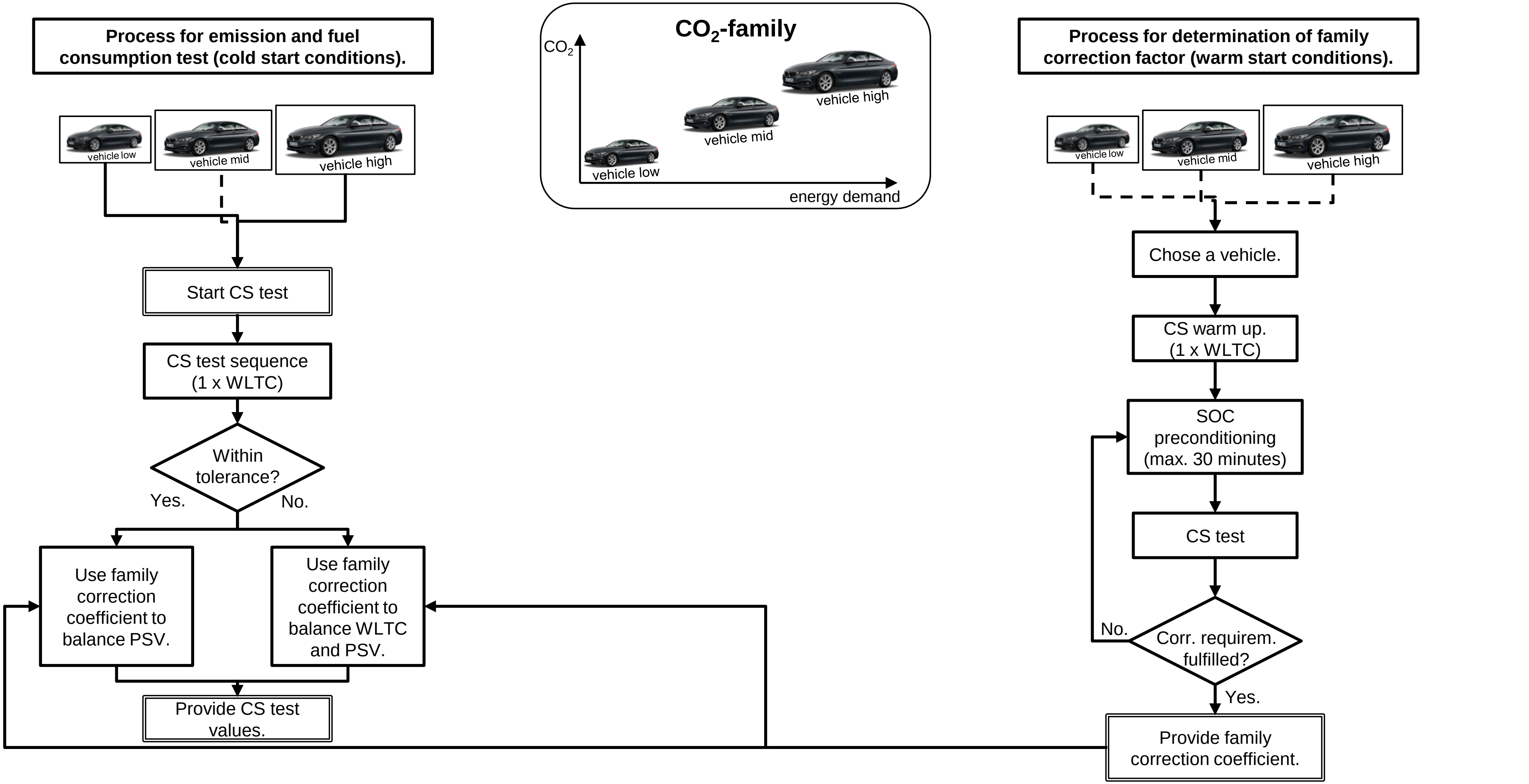
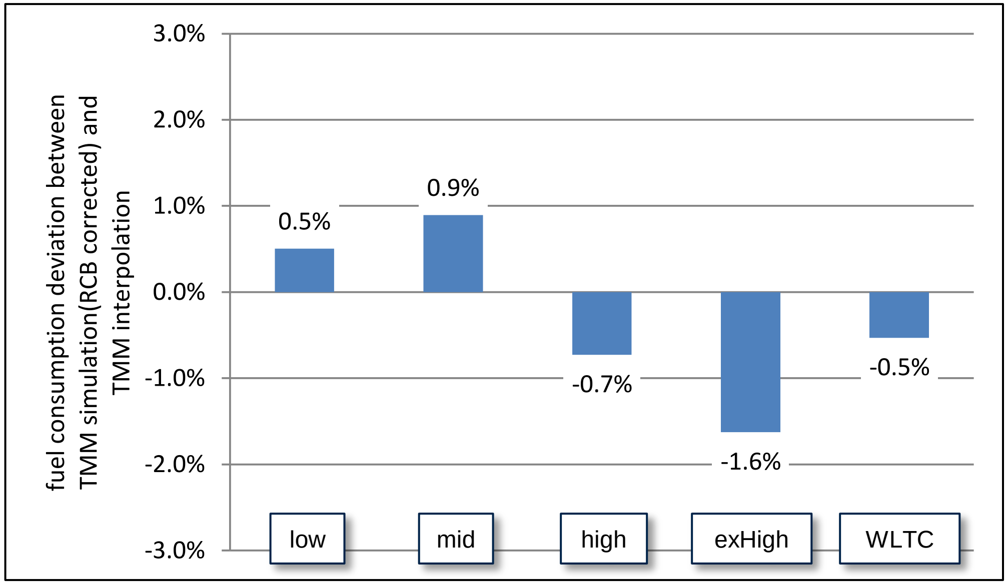
RCB correction
Cycle specific correction coefficient within one CO_2-family



RCB correction
Combined Approach on corrected phase specific values

Reminder:
- To apply phase specific values, the combined approach has to be able to interpolate these values.
- The figure below shows the results of the combined approach for vehicle mid (TMM).

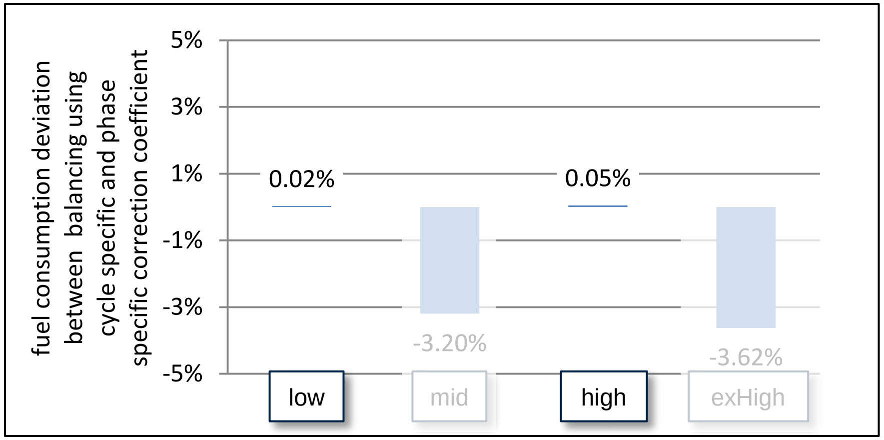
$$M_{CO_2-ind,p} = M_{CO_2-L,p} + \left(\frac{E_{3,p}-E_{1,p}}{E_{2,p}-E_{1,p}}\right) \times \left(M_{CO_2-H,p} - M_{CO_2-L,p}\right)$$



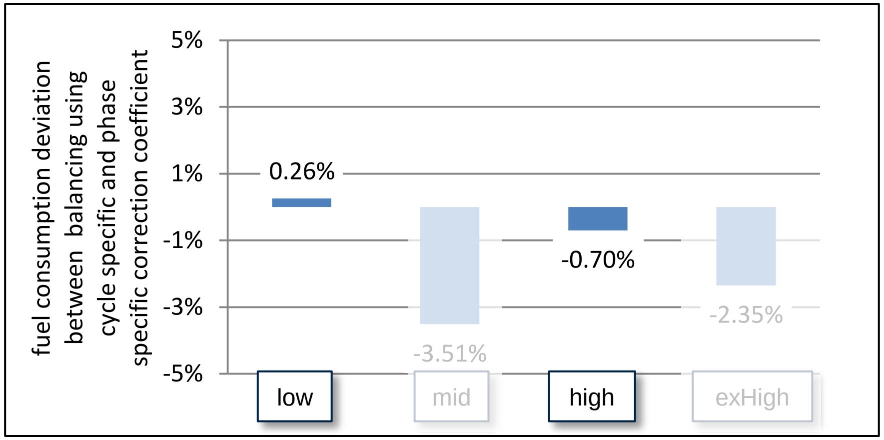
▶ The fuel consumption error between RCB corrected simulation results and the interpolation based on the RCB corrected values from vehicle low and high seems to be acceptable.

RCB correction
Results from validation phase 2 (cycle specific correction)

1st vehicle (upper class sedan hybrid)



2nd vehicle (SUV hybrid)

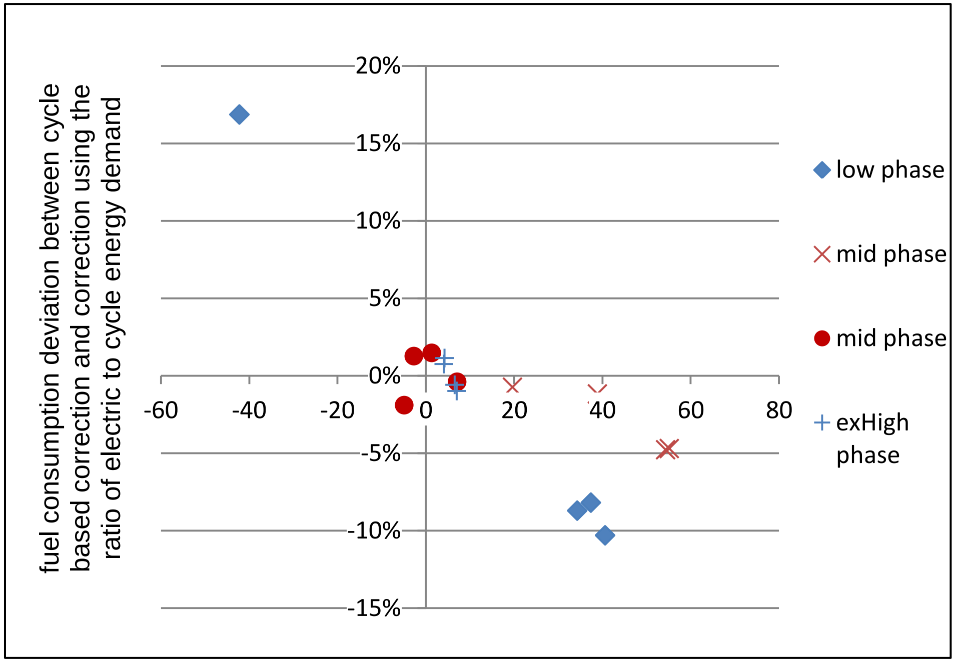


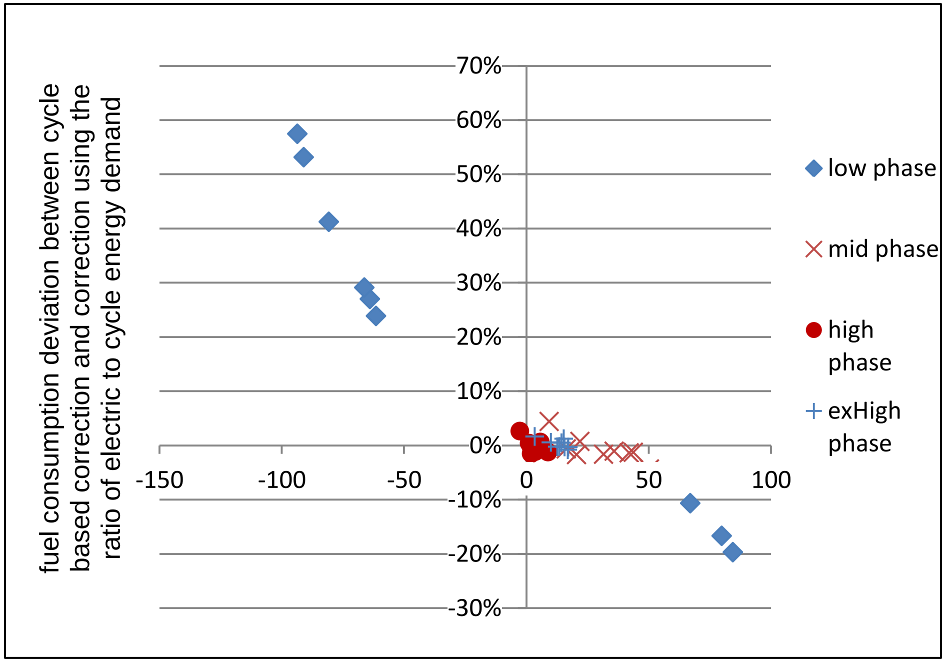
- Due to the fact that the conditions for the determination of phase specific values are not fulfilled, the deviation values of **Mid- and ExHigh-phase are not representative**.
- The **Low- and High-phase** values show a **very high accuracy** if cycle specific correction coefficient is used.

Reminder on conclusion from DEKRA concerning RCB correction:
- " ... in many cases it is difficult to calculate a correct linear equation for each phase. In such a case the phase calculated WLTC result can be incorrect."

RCB correction
Results from validation phase 2 (electric/phase energy ratio)

1st vehicle (upper class sedan hybrid)	2nd vehicle (SUV hybrid)

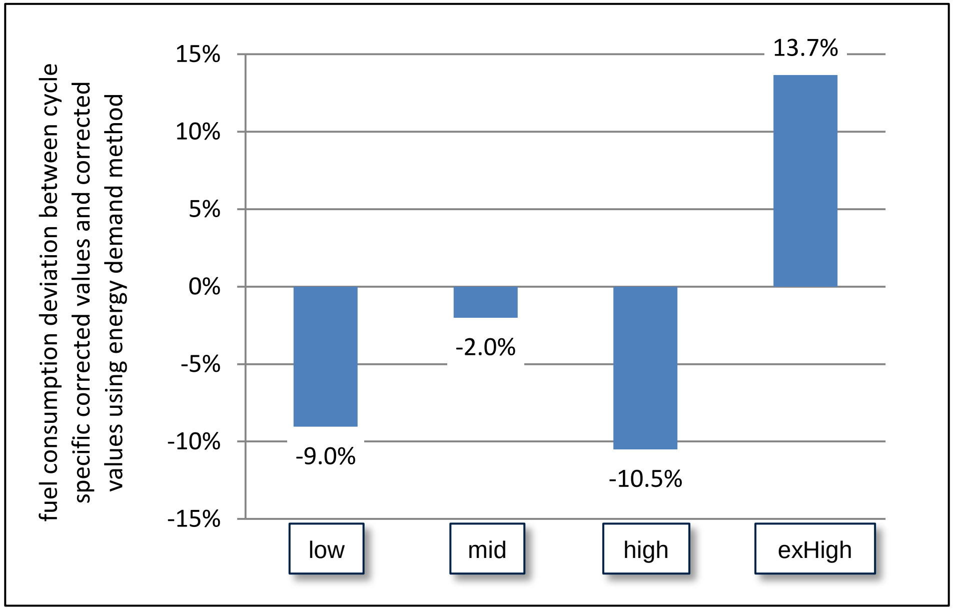


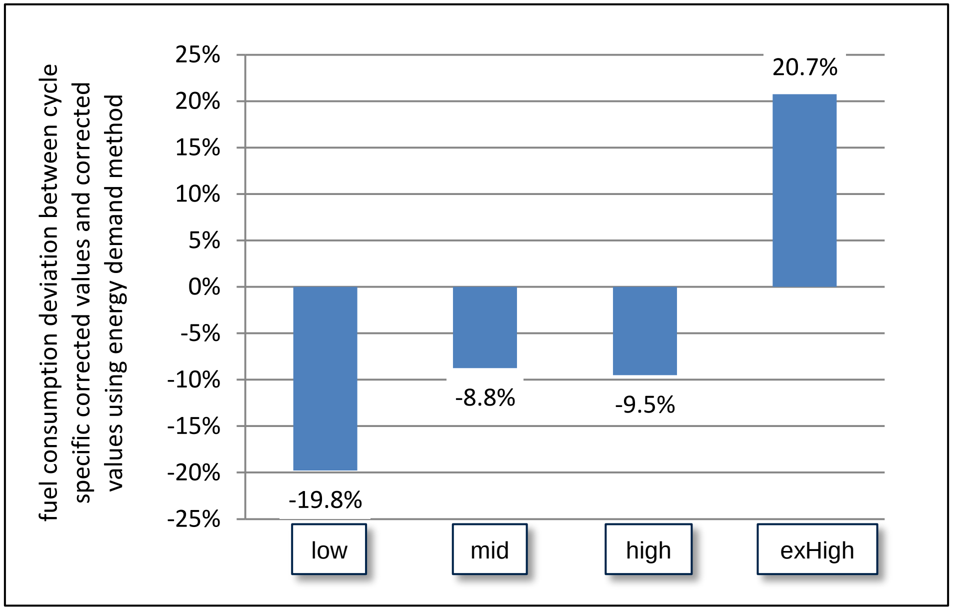


- As the simulation already illustrated is the correction using the ratio of electric energy consumption and cycle energy demand not the most accurate way, especially for high electric energy consumptions.

RCB correction
Results from validation phase 2 (phase/cycle energy ratio)

1st vehicle (upper class sedan hybrid)	**2nd vehicle (SUV hybrid)**





- As the simulation already illustrated is the correction using the percentage of energy demand per phase compared to cycle energy demand no proper way for phase specific correction.

RCB correction
Conclusion and recommendation.

- ACEA proposes to use cycle- and family specific correction coefficient (CFSCC) within a CO_2 family derived from CS tests under warm start conditions.

- The combined approach can also be applied to the corrected phase specific fuel consumption and CO_2 emissions of the charge sustaining test.

- ACEA advise against the usage of phase specific correction factors calculated by using the energy demand due to the high error compared to the usage of a CFSCC.