Comparison of UNECE A-LCA SG4 dual energy consumption methodology proposals

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Contents

Summary of key objectives for a dual energy vehicle methodology

- Should maintain reasonable consistency, robustness, accuracy and precision for different models (e.g. with different specifications, electric ranges, etc):
  - Must provide results that provide a reasonable representation of real-world performance
  - Must not create bias between results for models with different specifications (e.g. range)
- Should be calculable using data the OEM has ready access to:
  - Directly from vehicle certification testing and or COC, or regional testing protocols/regulations (e.g. WLTP)
  - Default values to be provided by CPs (e.g. for discrepancy factors) or in the UNECE guidelines directly
- Should provide reasonable alignment with existing regulatory protocols (e.g. utility factors), and be applicable in different regions right away (i.e. pending short period for defining real-world factors)
- Should be reasonably robust to potential changes in regulatory certification requirements, without significant delays (e.g. changes to utility factors and the implications for real-world monitoring data)
- Should be able to feasibly account in a consistent way for all dual fuel powertrain types

Outline of current proposed SG4 methodology

$$FEC_{in-use} = FEC_{in-use\ [CD\ mode]} \times \left(UF_{in-use\ [CD\ mode]}\right) + FEC_{in-use\ [CS\ mode]} \times \left(1 - UF_{in-use\ [CS\ mode]}\right)$$

$$EEC_{in-use} = EEC_{in-use\ [CD\ mode]} \times \left(UF_{in-use\ [CD\ mode]}\right)$$

Where;

FEC_{in-use} → means the weighted in-use fuel consumption of driving in CD and CS mode combined [L/100 km].

EEC_{in-use} → means the weighted in-use electricity consumption of driving in CD and CS mode combined [MJ/km].

$FEC_{in-use[CD\ mode]}$ → means the in-use fuel consumption of driving in CD mode [L/100 km].

$EEC_{in-use[CD\ mode]}$ → means the in-use electricity consumption of driving in CD mode [MJ/km].

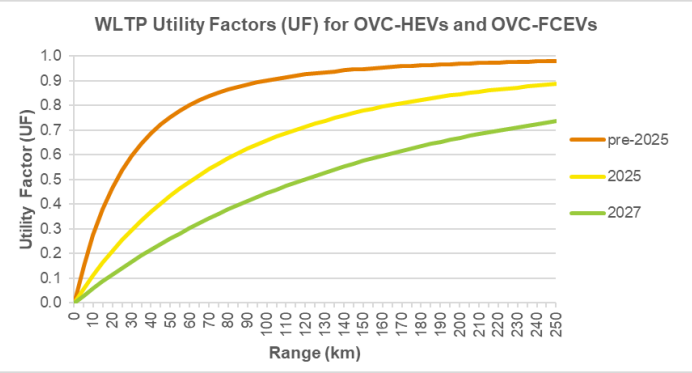
$FEC_{in-use[CS\ mode]}$ → means the in-use fuel consumption of driving in CS mode [L/100 km].

$UF_{in-use\ [CD\ mode]}$ → means the in-use utility factor representing the share of operation in CD mode.

And,

Mode 1 (e.g., CD mode)	$FEC_{in-use\ [CD\ mode]} = FEC_{certification\ [CD\ mode]} \times f_{discrepancy,fuel\ [CD\ mode]} \times f_{deterioration,fuel\ [CD\ mode]}$ $EEC_{in-use\ [CD\ mode]} = EEC_{certification\ [CD\ mode]} \times f_{discrepancy,electricity\ [CD\ mode]} \times f_{deterioration,electricity\ [CD\ mode]}$
Mode 2 (e.g., CS mode)	$FEC_{in-use\ [CS\ mode]} = FEC_{certification\ [CS\ mode]} \times f_{discrepancy,fuel\ [CS\ mode]} \times f_{deterioration,fuel\ [CS\ mode]}$

$$Range_{in-use\ [CD\ mode]} = Range_{certification\ [CD\ mode]} \times \frac{EEC_{certification\ [CD\ mode]}}{EEC_{in-use\ [CDmode]}}$$



- Contracting Parties to provide $f_{(discrepancy)}$ and $f_{(deterioration)}$ factors based on real-world data analysis
- [Additional methodology proposed for calculating $f_{(deterioration,\ range)}$ based on EoL SoCE of battery]

Defining input data and real-world factors for the current SG4 approach

Vehicle data available to OEM | Calculated input/method available to OEM | Inputs defined by CP or in Guidelines | Calculated in method | OEM / CP or Guidelines

Input	Description*	Source/basis*	
CS Fuel	Charge Sustaining mode fuel cons., MJ/km	Total: Included on COC and available to OEM directly from certification testing	
CD Fuel	Charge Depleting mode fuel cons., MJ/km	Total: Available to OEM directly from certification testing	
CD Electricity	Charge Depleting mode elec cons., Wh/km	Total: Available to OEM directly from certification testing	
f(discrepancy, fuel)	RW discrepancy operating on fuel (in CS mode or CD mode)	PHEV-specific OR assume similar to ICEV/nonOVC-hybrid vehicle = CP can define based on real-world OBFCM datasets. Independent of vehicle range or UF variation.	Edit
f(discrepancy, elec)	RW discrepancy for electric operation (100% unweighted operation for CD)	PHEV-specific OR assume similar to BEV = CP can define based on real-world datasets for PHEV or BEV. Independent of vehicle range or UF variation.	Edit
f(deterioration)	Deterioration/change in energy cons.	Unlikely to be significant, but can be defined by CP similarly to f(discrepancy).	
f(deterioration, range)	Deterioration in range due to battery degradation	Part of methodology: calculated based on impact of battery deterioration on electric range(/CD range) => affects calculated UF	
CD range	Charge Depleting Cycle Range (R_{CDC}), km	Available from certification testing, used for calculation of utility factors in WLTP	
Electric range	Equivalent All Electric Range (EAER), km	Included on COC and available to OEM directly from certification testing	
Utility Factor	Used to define the CD/CS operation share	The most recent regional regulatory certification protocol (OR CP alternative)	Edit
Batt. kWh (net)	Starting battery (available) capacity, kWh	Available directly to OEM from their vehicle model specifications	
SoCE [EoL]	Battery State of Certified Energy (SoCE) at end of life (EoL), %	As calculated or defined in CP or OEM methodology/modelling, or standard simplified approach if not available.	

Notes: * Some elements may be converted from different units, e.g. fuel consumption in litres/100 km converted to MJ/km based on the fuel's Net Calorific value (in MJ/kg) and density (in kg/litre), or from gCO_2/km also via the fuel gCO_2/litre

Example of input data (illustrative) and calculated outputs using the current SG4 approach ⓘ

Vehicle data available to OEM | Calculated input/method available to OEM | Inputs defined by CP or in Guidelines | Calculated in method | OEM / CP or Guidelines

Input (certification)	Example	Original unit
CS Fuel	1.854 MJ/km	5.5 l/100km
CD Fuel	0.270 MJ/km	0.8 l/100km
CD Electricity	0.540 MJ/km	150 Wh/km
f(discrepancy, fuel)	1.20	
f(discrepancy, elec)	1.25	
f(deterioration)	1	
f(deterioration, range)	0.925	
CD range	58 km	
Electric range	55 km	
Utility Factor (2025)	0.481	
Batt. kWh (net)	12 kWh	
SoCE [EoL]	85%	
Weighted fuel cons.	1.092 MJ/km	3.24 l/100km
Weighted elec. cons.	0.260 MJ/km	72 Wh/km

Output (in-use)	Example	Original unit
CS Fuel (in-use)	2.224 MJ/km	5.5 l/100km
CD Fuel (in-use)	0.324 MJ/km	0.8 l/100km
CD Elec. (in-use)	0.675 MJ/km	150 Wh/km
CD range (in-use)	42.9 km	
Electric range (in-use)	40.7 km	
Utility Factor (2027) (in-use)	0.229	
Batt. kWh (net) (in-use av.)	11.1 kWh	
Weighted fuel cons. (in-use)	1.789 MJ/km	5.31 l/100km
Weighted elec. cons. (in-use)	0.155 MJ/km	43 Wh/km

ⓘ Results have been calculated using the illustrative calculation Excel file developed by Ricardo, available from SG4 meeting Wiki: SG4 - 34th Meeting - Transport - Vehicle Regulations - UNECE Wiki.

Notes: * Some elements may be converted from different units, e.g. fuel consumption in litres/100 km converted to MJ/km based on the fuel's Net Calorific value (in MJ/kg) and density (in kg/litre), or from gCO_2/km also via the fuel gCO_2/litre

Pros and Cons of the current proposed SG4 method – Ricardo's assessment

	Current proposed SG4 method
Pros	✓ All inputs available to OEMs from certification ✓ Overall approach is ~consistent with regulatory methodology (simplifies to consider the whole cycle for Utility Factor application) ✓ Captures majority of real-world effects well ✓ Is robust to different vehicle electric ranges, FC-REEV, and to current/future changes in the UF ✓ Is applicable/usable in all regions; can be applied right away based on data available
Cons	✗ Not all input parameters are publicly available on the CoC ✗ Methodology is slightly more complex to apply (but still considerably less complex than for other lifecycle stages, and with greater impact on the overall footprint)

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Outline of the OICA proposed simple approach

$$EC_{in-use} = EC_{in-use\ [energy\ 1]} + EC_{in-use\ [energy\ 2]}$$

For energy 1

$$EC_{in-use\ [energy\ 1]} = EC_{certification,\text{energy 1}} \times f_{discrepancy,\text{energy 1}} \times f_{deterioration,energy1}$$

For energy 2

$$EC_{in-use\ [energy\ 2]} = EC_{certification,\text{energy 2}} \times f_{discrepancy,\text{energy 2}} \times f_{deterioration,energy2}$$

Where;

$EC_{certification}$ means the energy consumption or fuel consumption [MJ/km or Wh/km];

$f_{discrepancy}$ means the discrepancy factor (if not available for a region, then 1 should be used)

$f_{deterioration}$ means the deterioration factor (if not available for a region, then 1 should be used)

- In-use energy consumption calculated only directly from CoC values for weighted fuel and energy consumption

- No accounting for/use of utility factors
- No accounting for loss of range due to battery degradation/reduction in SoCE over the life of the vehicle
- Discrepancy (and deterioration) factors simply ‘to be defined by the Contracting Parties’ – no consideration of how this could work in practice in a robust way

Defining input data and real-world factors for the OICA proposed simple approach

Vehicle data available to OEM | Calculated input/method available to OEM | Inputs defined by CP or in Guidelines | Calculated in method | OEM / CP or Guidelines

Input	Description*	Source/basis*
Weighted Fuel	Weighted fuel cons., MJ/km	Total: Included on COC and available to OEM directly from certification testing
Weighted Elec.	Weighted electricity cons., Wh/km	Total: Included on COC and available to OEM directly from certification testing
f(discrepancy, fuel)	RW discrepancy operating on fuel (weighted across all modes of operation)	CP can define only if OBFCM datasets available, BUT values also completely dependant on average monitored vehicle range and specific UF applied.
f(discrepancy, elec)	RW discrepancy for electric operation (weighted)	CP *might* calc. from real-world OBFCM datasets (e.g. from total grid energy into the battery and total distance travelled over lifetime), BUT values completely dependant on average monitored vehicle range and specific UF applied.
f(deterioration)	Deterioration/change in energy cons.	Unlikely to be significant, but can be defined by CP similarly to f(discrepancy).
~~f(deterioration, range)~~	~~Deterioration in range due to battery degradation~~	~~Not used, but an approximation for average range PHEVs might be calculable~~
~~CD range~~	~~Charge Depleting Cycle Range (R_{CDC}), km~~	~~Not used~~
~~Electric range~~	~~Equivalent All Electric Range (EAER), km~~	~~Not used~~
~~Utility Factor~~	~~Used to define the CD/CS operation share~~	~~Not used~~
~~Batt. kWh (net)~~	~~Starting battery (available) capacity, kWh~~	~~Not used~~
~~SoCE [EoL)~~	~~Battery State of Certified Energy (SoCE) at end of life (EoL), %~~	~~Not used~~

Notes: * Some elements may be converted from different units, e.g. fuel consumption in litres/100 km converted to MJ/km based on the fuel's Net Calorific value (in MJ/kg) and density (in kg/litre), or from gCO_2/km also via the fuel gCO_2/litre

Example of input data (illustrative) and calculated outputs using the OICA proposed simple approach ⓘ

Vehicle data available to OEM | Calculated input/method available to OEM | Inputs defined by CP or in Guidelines | Calculated in method | OEM / CP or Guidelines

Input (certification)	Example	Original
~~CS Fuel~~	~~1.854 MJ/km~~	~~5.5 l/100km~~
~~CD Fuel~~	~~0.270 MJ/km~~	~~0.8 l/100km~~
~~CD Electricity~~	~~0.540 MJ/km~~	~~150 Wh/km~~
f(discrepancy, fuel)	2.94	*pre-2025 data basis/UF 2027*
f(discrepancy, elec.)	0.39	*pre-2025 data basis/UF 2027*
f(deterioration/range, fuel)	*1.04*	*From SG4 current method*
f(deterioration/range, elec.)	*0.95*	*From SG4 current method*

	Range1	Range2	Range3
CD range	60 km	40 km	80 km
Utility Factor (pre-2025)	**0.803**	**0.689**	**0.865**
Utility Factor (2025)	0.492	0.369	0.586
Utility Factor (2027)	0.303	0.215	0.379
Weighted fuel cons.	**0.582**	**0.763**	**0.483**
Weighted elec. cons.	**0.433**	**0.372**	**0.467**

Output (in-use)	Range1	Range2	Range3
OICA simple methodology			
CD range	60 km	40 km	80 km
W'td fuel cons., MJ/km	1.776	2.327	1.475
W'td elec. cons., MJ/km	0.159	0.136	0.171
Expected result using UF 2027	60 km	40 km	80 km
W'td fuel cons., MJ/km	1.776	1.911	1.655
W'td elec. cons., MJ/km	0.159	0.111	0.202

Fixed deterioration factors might be calculated by CP for average range PHEV to account for RW effects, but not robust to range variation without UF.

Values should match with UF 2027 if OICA simple method worked correctly/accurately without bias even for pre-2025 certified vehicles.
=> OVER-estimates negative real-world effects for shorter-range PHEVs.
UNDER-estimates for longer-range PHEVs vs RW data av. range.

ⓘ Results have been calculated using the illustrative calculation Excel file developed by Ricardo, available from SG4 meeting Wiki: SG4 - 34th Meeting - Transport - Vehicle Regulations - UNECE Wiki.

Notes: * Some elements may be converted from different units, e.g. fuel consumption in litres/100 km converted to MJ/km based on the fuel's Net Calorific value (in MJ/kg) and density (in kg/litre), or from gCO_2/km also via the fuel gCO_2/litre

Example of input data (illustrative) and calculated outputs using the OICA proposed simple approach ⓘ

Vehicle data available to OEM | Calculated input/method available to OEM | Inputs defined by CP or in Guidelines | Calculated in method | OEM / CP or Guidelines

Input (certification)	Example	Original
~~CS Fuel~~	~~1.854 MJ/km~~	~~5.5 l/100km~~
~~CD Fuel~~	~~0.270 MJ/km~~	~~0.8 l/100km~~
~~CD Electricity~~	~~0.540 MJ/km~~	~~150 Wh/km~~
f(discrepancy, fuel)	2.94	*pre-2025 data basis/UF 2027*
f(discrepancy, elec.)	0.39	*pre-2025 data basis/UF 2027*
f(deterioration/range, fuel)	*1.04*	*From SG4 current method*
f(deterioration/range, elec.)	*0.95*	*From SG4 current method*

	Range1	Range2	Range3
CD range	60 km	40 km	80 km
Utility Factor (pre-2025)	0.803	0.689	0.865
Utility Factor (2025)	**0.492**	**0.369**	**0.586**
Utility Factor (2027)	0.303	0.215	0.379
Weighted fuel cons.	**1.074**	**1.268**	**0.467**
Weighted elec. cons.	**0.266**	**0.200**	**0.925**

Fixed deterioration factors might be calculated by CP for average range PHEV to account for RW effects, but not robust to range variation without UF.

Values should match with UF 2027 if OICA simple method worked correctly/accurately without bias: using the available real-world discrepancy factors based on pre-2025 certified EU vehicles results in extreme OVER-estimates of negative real-world effects for all PHEVs**.

** current discrepancy factors are actually even higher which would further increase the over-estimation for vehicles certified on a different UF basis vs the real-world dataset.

Output (in-use)	Range1	Range2	Range3
OICA simple methodology	Range1	Range2	Range3
CD range	60 km	40 km	80 km
W'td fuel cons., MJ/km	3.277	3.869	2.823
W'td elec. cons., MJ/km	0.097	0.073	0.116
Expected result using UF 2027	60 km	40 km	80 km
W'td fuel cons., MJ/km	1.776	1.911	1.655
W'td elec. cons., MJ/km	0.159	0.111	0.202

ⓘ Results have been calculated using the illustrative calculation Excel file developed by Ricardo, available from SG4 meeting Wiki: SG4 - 34th Meeting - Transport - Vehicle Regulations - UNECE Wiki.

Notes: * Some elements may be converted from different units, e.g. fuel consumption in litres/100 km converted to MJ/km based on the fuel's Net Calorific value (in MJ/kg) and density (in kg/litre), or from gCO_2/km also via the fuel gCO_2/litre

Pros and Cons of both of the methods – Ricardo's assessment

	Current proposed SG4 method	OICA simple approach
Pros	✓ All inputs available to OEMs from certification ✓ Overall approach is ~consistent with regulatory methodology (simplifies to consider the whole cycle for Utility Factor application) ✓ Captures majority of real-world effects well ✓ Is robust to different vehicle electric ranges, FC-REEV, and to current/future changes in the UF ✓ Is applicable/usable in all regions; can be applied right away based on data available	✓ All vehicle input parameters are available to OEMs from vehicle certification, AND are listed on the CoC ✓ CP could calculate discrepancy factors directly from OBFCM reported data – but only for vehicles with similar average electric range and using the same Utility Factor ✓ Relatively simpler to apply in theory
Cons	✗ Not all input parameters are publicly available on the CoC ✗ Methodology is slightly more complex to apply (but still considerably less complex than for other lifecycle stages, and with greater impact on the overall footprint)	✗ Not aligned with regulatory certification approach of using Utility Factors to define operational shares ✗ Using discrepancy factors calculated from average OBFCM data not robust or accurate for vehicles with different electric ranges OR on a different Utility Factor ✗ Does not (and cannot robustly) account for reduced UF from battery degradation (impact on range)

Conclusions

Current proposed SG4 method	OICA simple approach
• Robust, accurate and applicable to new vehicles and adjustments in the UF in type-approval procedure • Applicable also for regions lacking OBFCM data	• Applicable for old vehicles only, and not accurate for vehicles with electric ranges above/below average • Currently not applicable for electricity consumption (no publicly reported data at fleet level for OBFCM) • Not applicable for regions lacking OBFCM data