Presentation to support UBE as durability metric (rev.2)

37th IWG EVE (web-audio)

September 8th/9th 2020

Presentation prepared and supported by:

ACEA European Automobile Manufacturers Association

ALLIANCE FOR AUTOMOTIVE INNOVATION

Transforming Personal Mobility

Both members of OICA

EVE In Vehicle Battery Durability (Input for 37th IWG EVE)

OVC-HEV and PEV: Justification and conclusions on UBE as durability metric

ACEA and Alliance support UBE as appropriate metric for in-vehicle battery durability

Justification:

- UBE is not much influenced by external factors not related to the battery (purest value)
- Range is more influenced by external (not to the battery related) factors than UBE

Example for external factors (not coming from the battery) influencing range:

- Test-to-test variation coming from the different test benches
- Test-to-test variation coming from different customer driving behavior ("driving EC")
- Increasing driving energy consumption by a faulty component (but not the battery)

Conclusion:

- UBE is less influenced by external parameters and therefore more robust parameter than range
- Robust basis required for the durability indicator → UBE shall be selected as the metric
- Range based indicator requires normalization regarding external factors (not coming from the battery), e.g. driver behavior (economic driving vs. aggressive driving), UBE does not
  → Benefit of UBE based indicator (less complexity, more robust, covering the scope)

EVE In Vehicle Battery Durability (Input for 37th IWG EVE)

OVC-HEV and PEV: Concerns on a range based indicator, benefits of UBE based indicator

Main concern is coming the driving behavior of the driver which has an influence on the driving EC

- No issue for Part A → In Part A, only check between range and range based indicator, no MPR
- Big issue for Part B → Only read out of indicator and comparison with MPR

➔ Indicator without normalization to eliminate driver influence: not fair for Part B

<u>Background of the necessity of a normalized range based indicator:</u>

→ Range based indicator without normalization would punish battery when comparing that to the MPR if less range is not a function of the reduced available energy (compensation of at least external factors like driving energy consumption parameters influenced by the driver)

→ Only a normalized range based indicator ensures a fair comparison of the indicator with MPR

→ Only a normalized range based indicator ensures a reliable customer information as without normalization, the indicator would jump up and down depending on the driver

<u>Challenges coming along with the normalization:</u>

→ Normalization is not impossible but the more challenging the more dynamic parameters

→ Therefore, normalization is adding additional complexity and uncertainty (higher tolerance?)

<u>Benefit of the UBE based indicator:</u>

- UBE based indicator would be almost independent from driving behavior
- Therefore, UBE based indicator would require no or almost no normalization
- Furthermore, UBE (and the UBE based indicator) would be easier to harmonize than range

EVE In Vehicle Battery Durability (Input for 37th IWG EVE)

OVC-HEV and PEV: influence of driving EC on range

	UBE (or ∑Delta E)	Range
Part A	OK	OK (but higher tolerance required)
Part B	OK	Challenging, normalization required → Adding not necessary complexity

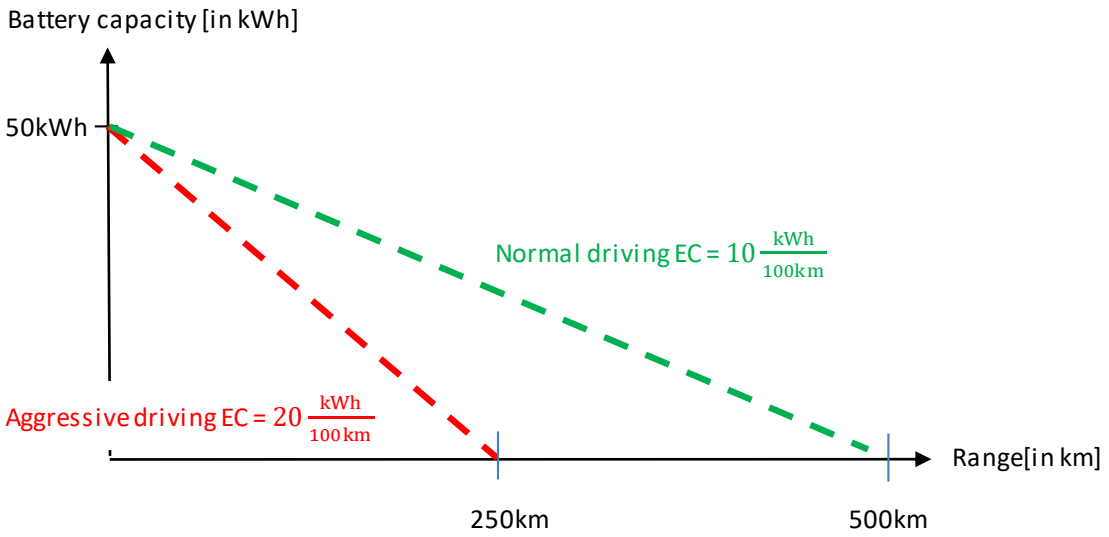
Range highly dependent from individual customer driving behavior ("driving EC")

- While having same UBE, different customer driving behavior is resulting in different range values.
- UBE therefore more neutral and balanced metric to evaluate in-vehicle-battery durability.

<u>Example showing influence of individual consumption:</u>

Driving electric consumption on range value while UBE (50 kWh) is identical

- Aggressive driving EC: 20 kWh/100km
- Normal driving EC: 10 kWh/100km



➔ **Next slides show why a different EC (without normalization) is no issue for Part A, but for Part B**

EVE In Vehicle Battery Durability (Input for 37th IWG EVE)

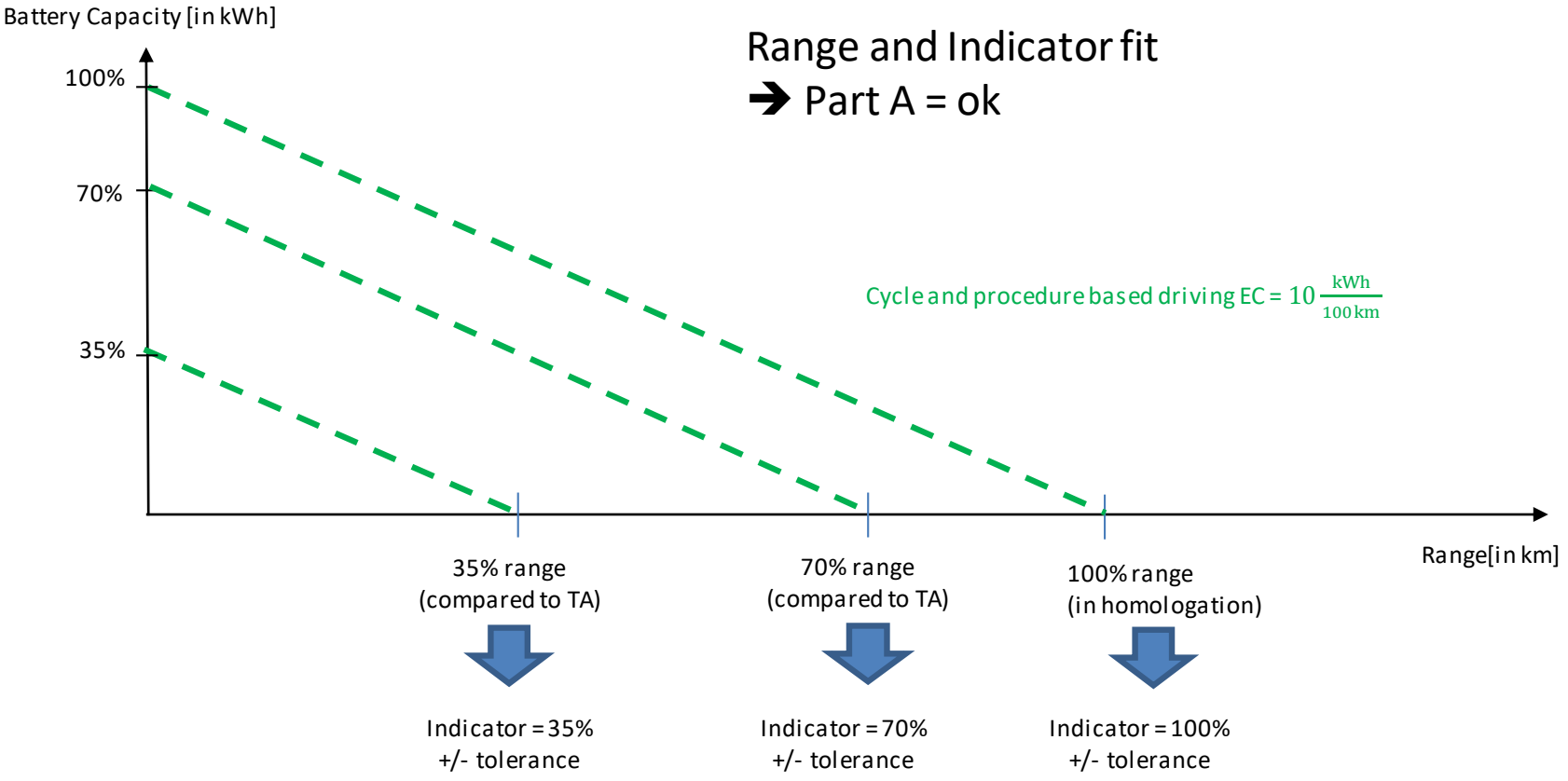
OVC-HEV and PEV: Range based indicator → Part A: no concern

	UBE (or ∑Delta E)	Range
Part A	OK	OK (but higher tolerance required)
Part B	OK	Challenging, normalization required → Adding not necessary complexity

Reason why no concern regarding range based indicator for Part A

→ Purpose of Part A: Verification of indicator ➔ Do range and indicator fit together?

→ Minimum performance requirement is not relevant for Part A



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EVE In Vehicle Battery Durability (Input for 37th IWG EVE)

OVC-HEV and PEV: Range based indicator → Part B: Big concern

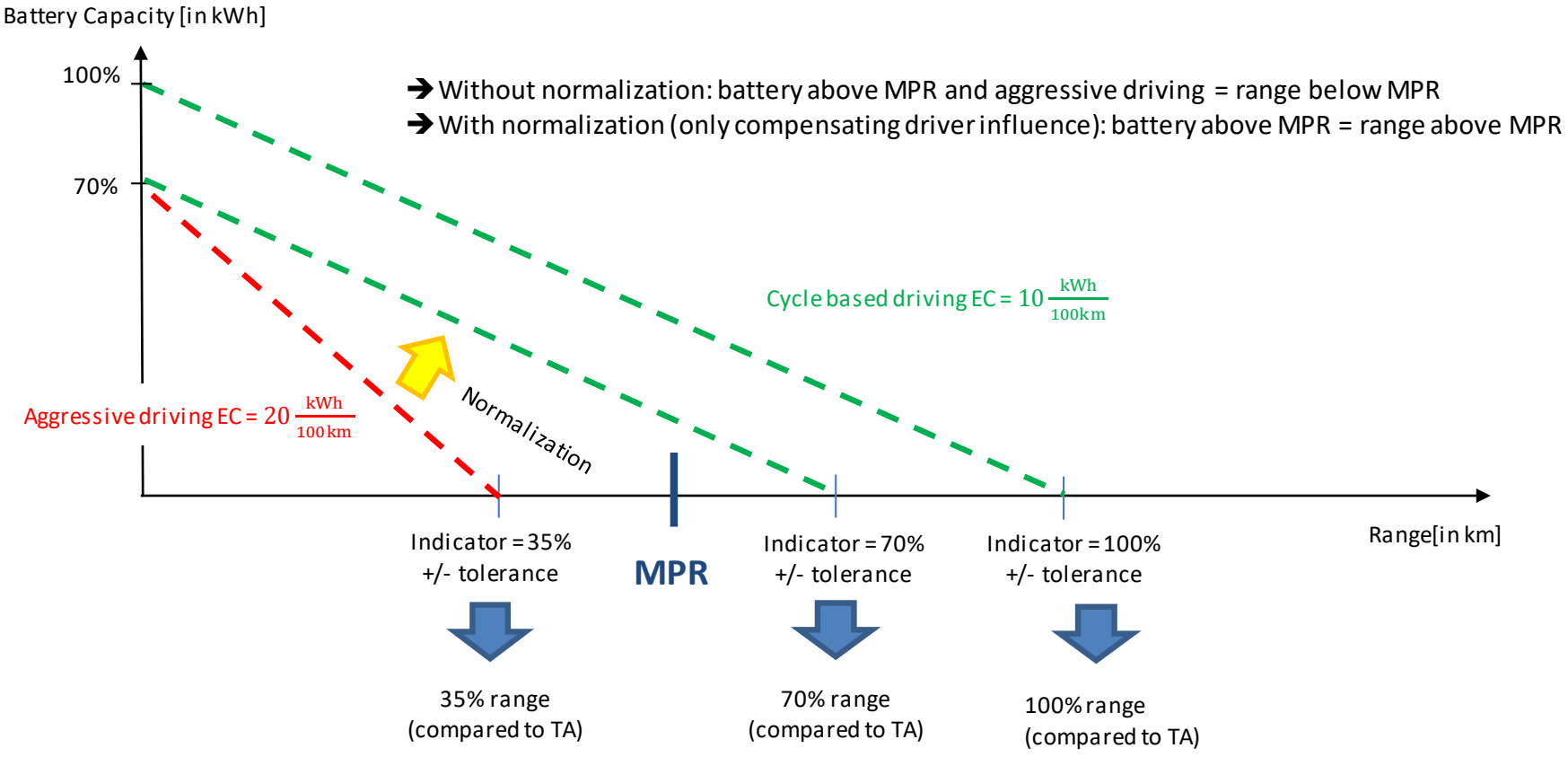
	UBE (or ∑Delta E)	Range
Part A	OK	OK (but higher tolerance required)
Part B	OK	Challenging, normalization required → Adding not necessary complexity

Reason why big concern regarding range based indicator for Part B

→ Minimum performance requirement is relevant for Part B → being below MPR could cause a recall

→ Driving energy consumption of incoming vehicles highly depending on customer and therefore range

→ For comparison with MPR, a normalization of range indicator is required (to compensate driver)



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EVE In Vehicle Battery Durability (Input for 37th IWG EVE)

OVC-HEV and PEV: Range based indicator normalization

	UBE (or ∑Delta E)	Range
Part A	OK	OK (but higher tolerance required)
Part B	OK	Challenging, normalization required → Adding not necessary complexity

Normalization required for Part B → to make a fair comparison with MPR
Normalization not impossible but adding complexity → what is the additional value to add this?

Challenges coming along with adding normalization:

- Indicator algorithm need to be extended to the online parameter of the actual driving consumption → adding complexity which could influence the robustness
- Normalization of the range indicator would also need to consider other parameters, e.g. higher consumption of any other component in the vehicle which is influencing the range: → if deterioration is not battery related: how to deal with it in Part B? → would need to be discussed

UBE based indicator
→ No normalization required

Required input parameters:
- **from battery**

Indicator calculation for UBE based indicator

Works for Part A and Part B

Not normalized range based indicator

Required input parameters:
- **from battery**
- **from vehicle**

Indicator calculation for not normalized range based indicator

Works for Part A
Works not for Part B

Normalized range based indicator

Required input parameters:
- **from battery**
- **from vehicle**
- **from parameter outside the vehicle (not under control of OEM)**

Indicator calculation for normalized range based indicator

Works for Part A and B but adds unnecessary complexity

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EVE In Vehicle Battery Durability (Input for 37th IWG EVE)

OVC-HEV and PEV: Concern → driving EC not monitored

	UBE (or ∑Delta E)	Range
Part A	OK	OK (but higher tolerance required)
Part B	OK	Challenging, normalization required → Adding not necessary complexity

Concern raised during the IWG EVE call on July 7th from EU-Com and US EPA:
By using UBE as durability metric, the driving EC of the vehicle is not being monitored

→ Possible loop whole

→ In-Vehicle-Durability also need to cover aspects outside the battery

<u>ACEA and Alliance reflections on this concern:</u>

- The scope of the GTR is in-vehicle-battery-durability and therefore the focus should be on the battery and not on parameters which are not related to the battery

- An increasing consumption of any component (except the battery) has nothing to do with in-vehicle-battery durability and therefore should not be in the focus of this GTR

- Main driver for the decreasing range of a vehicle over lifetime is the deteriorated battery and not the increasing driving electric energy consumption → ACEA and Alliance will provide data

EVE In Vehicle Battery Durability (Input for 37th IWG EVE)

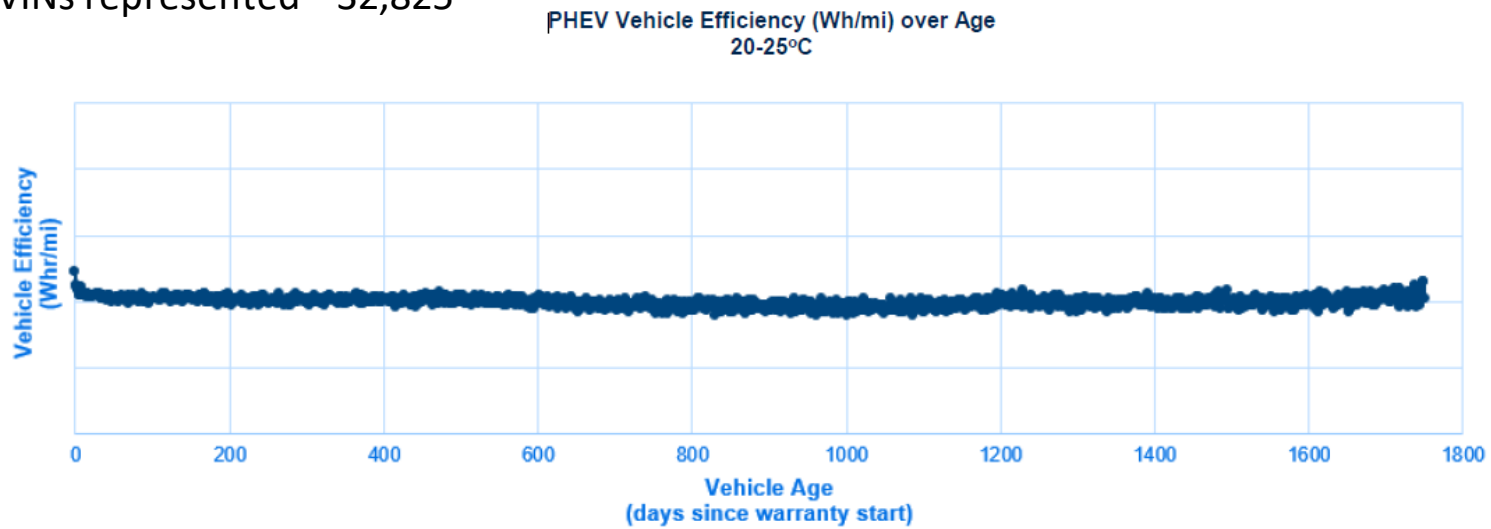
OVC-HEV and PEV: Arguments for UBE as robust and pure value

	UBE (or ∑ Delta E)	Range
Part A	OK	OK (but higher tolerance required)
Part B	OK	Challenging, normalization required → Adding not necessary complexity

Test Set-Up

- PHEV charging depletion trips (battery only)
- Ambient temps between 20 and 25°C
- Total trips recorded – 7,414,561
- Total VINs represented – 32,825

Please note:
More data to come



Results:

- PHEV efficiency (energy consumption) over vehicle age is constant, therefore **range deterioration is predominantly attributed to battery useable energy** (including efficiency from internal resistance and capacity degradation)

Equations:

- Range = useable energy / vehicle efficiency
- Vehicle efficiency = electric energy used / trip distance (Wh/mi)
- Electric energy used = Sum of electric energy discharged during a trip

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OVC-HEV and PEV: Arguments for UBE as robust and pure value

	UBE (or ∑Delta E)	Range
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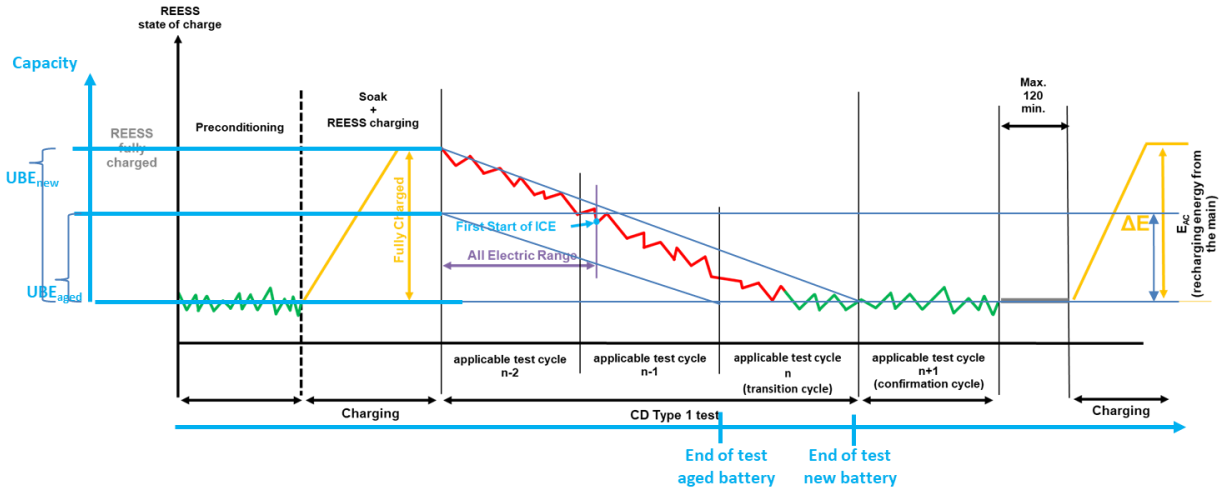
For OVC-HEV, UBE more robust on test-to-test variation than range values



AER range determination:

- The AER is defined as the distance driven from the beginning of the charge-depleting Type 1 test to the point in time where the combustion engine starts consuming fuel
- The start of the combustion engine can have various reasons: Battery; driver driving between the allowed tolerances; other factors
- The not-battery-related factors could lead to a low AER range while the UBE or Sum of Delta E is still ok
- Challenging/impossible to cover all this non-battery related influences in a robust battery durability indicator

Benefit of UBE is the less test-to-test variation (in case of OVC-HEV: ICE start):

→ UBE based indicator would be independent from ICE start

→ Range based indicator based on AER → big risk that indicator is wrong

→ Range based indicator would only make sense on EAER → then: requirement of normalization towards reference driver (complexity)

EVE In Vehicle Battery Durability (Input for 37th IWG EVE)

OVC-HEV and PEV: Arguments for UBE as robust and pure value

	UBE (or ∑Delta E)	Range
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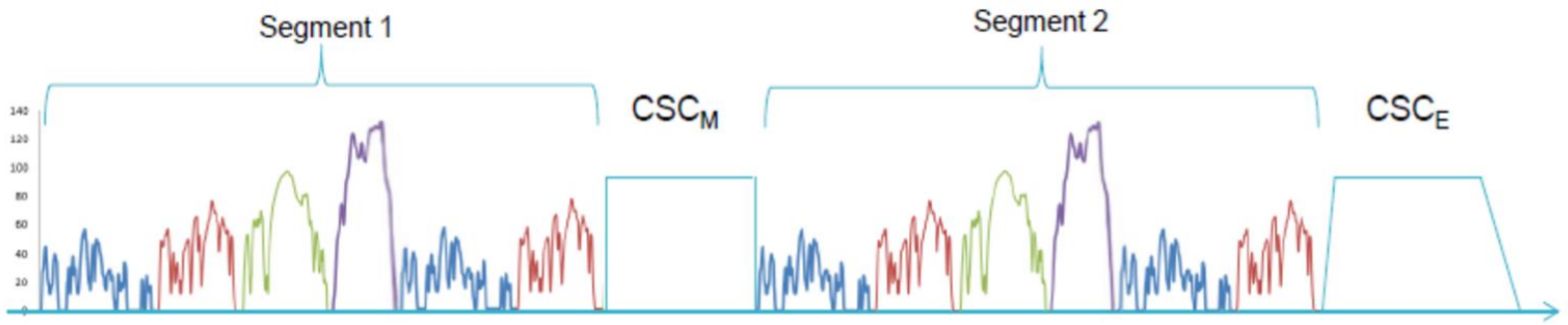
For PEV, UBE more robust on test-to-test variation than range values

Figure: Shortened Test Procedure for PEVs in WLTP (same set up as MCT in US)



- During Segment 1 and Segment 2 → influence on driving EC → higher/lower battery losses
- In CSC_M and CSC_E → driver has no influence, CSCs only there for UBE determination (no dynamic, just constant speed) → no influence on driving EC which is influencing the losses

<u>Findings why UBE is more robust and the better parameter than range:</u>

➔ Influence of driver on UBE gets lower the bigger the REESS is (UBE is sum of ΔE during DS and CSC)

➔ An aggressive driver can lower the range value and therefore the range based indicator with his/her driving behavior due to different driving EC in Segment 1 and 2 (if no normalization)

<u>Consequence:</u>

➔ Range based indicator therefore definitely requires a normalization (not for Part A but for Part B)

EVE In Vehicle Battery Durability (Input for 37th IWG EVE)

OVC-HEV and PEV: Arguments for UBE as robust and pure value

	UBE (or ∑Delta E)	Range
Part A	OK	OK (but higher tolerance required)
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Possible influencing factors on the considered parameters:

	Useable Energy (kWh)	Energy Consumption (Wh/mile)	Label Range (mi)
Road load adjustment		X	X
Non-Battery Vehicle to Vehicle Variation (generic powertrain differences, minor part differences, differences in driveline losses etc		X	X
Battery Vehicle to Vehicle Variation & Performance (fast charging / usage / storage temp /age etc.)	X	X	X
Site to site variations		X	X
Auxiliary Loads – aux load variation on cycle e.g. pump usage, trim level and options in the customer vehicles.		X	X
12V Battery (linked to aux loads) – health and SOC level of 12V		X	X
Driver (longer test cycle for range testing can lead to increased driver deviation)		X	x

→ **More parameters influencing range and EC than influencing UBE**

EVE In Vehicle Battery Durability (Input for 37th IWG EVE)

OVC-HEV and PEV: Arguments for UBE as robust and pure value

	UBE (or ∑Delta E)	Range
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Test data to show the impact of test-to-test variation on UBE and range:

PEV 1 (test according to NEDC range test procedure):

	UBE – percentage deviation	Range – percentage deviation
Test 1 (reference)	0%	0%
Test 2	- 0,26%	+ 6,6%
Test 3	- 0,44%	+ 6,5%

PEV 2 (tested according WLTP Shortened Test Procedure):

	UBE – percentage deviation	Range – percentage deviation
Test 1 (reference)	0%	0 %
Test 2	+0,01%	+ 2,13 %

PEV 3 (tested according WLTP Shortened Test Procedure):

	UBE – percentage deviation	Range – percentage deviation
Test 1 (reference)	0%	0 %
Test 2	+0,12%	+ 3,7 %

Results:

- **Range variation is considerably impacted by the test-to-test variation**
- **UBE is relatively consistent** in the different tests

Please note: More data to come

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OVC-HEV and PEV: Arguments for UBE as robust and pure value

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Test Set-Up

- Simulations to evaluate electric consumption (EC), battery capacity (UBE) and pure electric range (PER)
- Vehicle weight, tire pressure, and ambient temperatures were all non-standard test conditions, but are all possible in real-world operation
- Example shown below: New battery with a 100% capacity

Simulation data

New battery (100% UBE)							
delta vs WLTC homologation	**WLTP (with new battery)**	**Load at Gross vehicle weight**	**Non-standard ambient temperature**				**Flat tire**
Inertia [kg]	ref	+14%	ref	ref	ref	ref	ref
Temperature [°C]	25	25	-20	-10	0	40	25
Tire Pressure [bar]	Ref	Ref	Ref	Ref	Ref	Ref	-20% (Low tire pressure)
Rolling Resistance [kg/ton]	Ref	Ref	Ref	Ref	Ref	Ref	+9%
EC-AC [Wh/km]	**Ref**	+6%	+115%	+75%	+48%	+29%	+6%
UBE [kWh]	**Ref**	0%	-5%	-2%	-1%	0%	0%
WLTC Range [km]	**Ref**	-5%	-55%	-44%	-33%	-21%	-5%

Results:

- **Range variation is considerably impacted by the variation analyzed**, especially by ambient conditions at cold temperatures
- **UBE is relatively consistent** in different simulations
- Largest variation of UBE is connected to the SOH capacity fade

Please note: More data to come

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OVC-HEV and PEV: Arguments for UBE as robust and pure value

	UBE (or ∑Delta E)	Range
Part A	OK	OK (but higher tolerance required)
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Test Set-Up

- Simulations to evaluate electric consumption (EC), battery capacity (UBE) and pure electric range (PER)
- Vehicle weight, tire pressure, and ambient temperatures were all non-standard test conditions, but are all possible in real-world operation
- Example shown below: Aged battery with a considered 20% capacity reduction (compared to new battery)

Assumed aged battery (UBE -20%)							
delta vs WLTC homologation	**WLTP (with assumed aged battery)**	**Load at Gross vehicle weight**	**Non-standard ambient temperature**				**Flat tire**
Inertia [kg]	ref	+14%	ref	ref	ref	ref	ref
Temperature [°C]	25	25	-20	-10	0	40	25
Tire Pressure [bar]	Ref	Ref	Ref	Ref	Ref	Ref	-20% (Low tire pressure)
RR [kg/ton]	Ref	Ref	Ref	Ref	Ref	Ref	+9%
EC-AC [Wh/km]	**+1.5%**	+7%	+116%	+77%	+49%	+30%	+7%
UBE [kWh]	**-20%**	-20%	-24%	-22%	-21%	-20%	-20%
WLTC Range [km]	**-21%**	-25%	-65%	-55%	-47%	-38%	-25%

Simulation data

Results:

- **Range variation is considerably impacted by the variation analyzed**, especially by ambient conditions at cold temperatures
- **UBE is relatively consistent** in different simulations
- Largest variation of UBE is connected to the SOH capacity fade

Please note: More data to come

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EVE In Vehicle Battery Durability (Input for 37th IWG EVE)

OVC-HEV and PEV: Summary slide

	UBE (or ∑Delta E)	Range
Part A	OK	OK (but higher tolerance required)
Part B	OK	Challenging, normalization required → Adding not necessary complexity

Scope:

- UBE is the closest value to the purpose of this regulation → in-vehicle **battery durability**
- Range is not the right parameter as an indicator need to take into account parameters which are not inside the vehicle as e.g. the driving behavior of the driver and therefore the higher/lower EC

Conclusion range and range based indicator:

- Range can be a lot more influenced by external parameters which are not related to the battery
- Therefore, a range based indicator need to be normalized to at least exclude the influence of the driving style of any individual driver → Important for Part B
- Therefore, a range based indicator need to consider all lot more parameters than a UBE based indicator
- Programming a normalized range based indicator is is not impossible but brings a lot of not required complexity into this regulation → Question: is this really necessary?

Conclusion UBE and UBE based indicator:

- UBE is almost independent from external parameters which are not related to the battery
- Therefore, an UBE based indicator does not need to be normalized
- UBE based indicator would reflect the remaining battery energy compared to homologation