OICA

Heavy-duty industry adaptation of gtr22 on in-vehicle battery durability: key issues

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A monitoring phase is needed verifying MPRs

Global HDV Electrification

The HD BEV is under development. Currently, sales of HD BEVs worldwide are still extremely low (13k units: 2,7% of market share (EU 2022: 1.5 % for trucks > 3.5 ton, and 0,9% for trucks > 16 ton), with very narrow applications, with dedicated customers (mostly with closed working place and customer owned charging infrastructure) for trying out the technology

Challenges with Transformation of HDV sector

- It is worth to point out that the battery capacity/range of HD vehicle is always the customer's choice in firsthand (a comprise of total costs of ownership, application use case and electric range)
- The business mode of BEVs is under development, OEMs need to develop a complete business solution (both technical and financial) for our customers to have a beneficial TCO
- Without knowing the future battery technologies, without a wide scale application of BEVs in HDV sector, without knowing the infrastructure development, we need to keep all doors open for future expansion of HD BEV

Conclusion

A monitoring phase is needed in order to be able to regulate battery durability for HDV, setting correct(ed) MPRs, due to different decarbonization roadmaps and technical solutions in different regions.

A monitoring phase is needed for the following decisions

- Usable battery capacity vs Usable battery energy
- Measurements from charging and discharging
- Statistical pass/fail criteria
- Energy throughput
- MPR

Proposals

- During the monitoring phase, all the key points above will be measured/monitored. OEMs will provide more data than required by the draft to help making the final decision.
- A monitoring phase of minimum 5 years is needed to collect enough customer data from the field.

A monitoring phase is needed verifying MPRs

MPR for GTR22b

If CP wants to introduce the MPR (regulatory value) within the HDV GTR22b, OICA proposes that it should be used as a provisional value until the monitoring is completed and that there will be an opportunity to reconsider grouping (based on HDV types and use-cases) after the monitoring is completed.

Table 1
Battery Energy based (SOCE) MPR for N2, N3<16t

Vehicle age/km/MWh for **N2,N3<16t**	*HD-OVC-HEV*	*HD-PEV*
From start of life to [x] years or [xxx]km or [xxx]kWh, whichever comes first	[xx] per cent	[xx] per cent

Table 2
Battery Energy based (SOCE) MPR for N3>16t

Vehicle age/km/MWh for **N3>16t_Grp 3**	*HD-OVC-HEV*	*HD-PEV*
From start of life to [x] years or [xxx]km or [xxx] MWh, whichever comes first	[xx] per cent	[xx] per cent

Table 3
Battery Energy based (SOCE) MPR for M2

Vehicle age/km/MWh for ***M2***	*HD-OVC-HEV*	*HD-PEV*
From start of life to [x] years or [xxx]km or [xxx]kWh, whichever comes first	[xx] per cent	[xx] per cent

Table 4
Battery Energy based (SOCE) MPR for M3<7.5t

Vehicle age/km/MWh for **M3<7.5t**	*HD-*	
From start of life to [x] years or [xxx]km or [xxx]kWh, whichever comes first	[xx] per cent	[xx] per cent

Table 5
Battery Energy based (SOCE) MPR for M3>7.5t

Vehicle age/km/MWh for **M3>7.5t**	*HD-OVC-HEV*	*HD-PEV*
From start of life to [x] years or [xxx]km or [xxx]kWh, whichever comes first	[xx] per cent	[xx] per cent

Conclusion

For HDV industry, use-case and vehicle type dependent MPR are key for fair treatment and to meet feasible customer needs. Oversized MPRs may lead to oversized batteries just to fulfill the law, to the drawback of customers due to increased vehicle weights, less payload etc. (we will not comment prizing due to competitional law)

Draft placeholders for MPR decisions

➢ Example; Years or Mileage or Energy throughput, whichever comes first

EU 2019/1242 CO2 standards (incl. review), vehicle groups >16t. :

Vehicle group	Annual mileage (km)	Long Haul	Regional delivery	Urban delivery	Municipal utility	Construction	Typical annual energy throughput (MWh)
4-UD	60 000			X			55
4-RD	78 000		X				78
4-LH	98 000	X					140
4v	60 000				X	X	150
5-RD	78 000		X				85
5-LH	116 000	X					150
5v	60 000				X	X	150
9-RD	73 000		X				90
9-LH	108 000	X					210
9v	60 000				X	X	160
10-RD	68 000		X				80
10-LH	107 000	X					150
10v	60 000						170

Vehicles specified for the purpose of urban delivery and regional delivery typically has an annual energy throughput < 100 MWh

Vehicles specified for the purpose of long-haul transport, municipal utility and construction typically has an annual energy throughput > 140 MWh

⚠ Basic VECTO output from « standard » BEV configuration as a first approach (no sensitivity analysis on vehicle components / simulations conditions to analyze spread)

Groups	Description	Capacity / Energy Throughput	Years	MPR (SOCC)
1	53,54, 1s, 1, 1v, 2, 2v (N2)	X_1	Y_1	Z_1
2	3, 3v (12t.<R4x2 <16t.)	X_2	Y_2	Z_2
3	4-UD, 4-RD, 5-RD, 9-RD, 10-RD, 11, 12 (urban & regional delivery)	X_3	Y_3	Z_3
4	4-LH, 4v, 5-LH, 5v, 9-LH, 9v, 10-LH, 10v, 11v, 12v, 16, 16v (long-haul, municipal utility & construction delivery)	X_4	Y_4	Z_4

Table 2

Battery Energy based (SOCE) MPR for N3>16t

Battery energy based MPR for N3>16t	*HD-OVC-HEV*	*HD-PEV*
From start of life to [XX] years or [XX] km, or [XX] MWh whichever comes first and	[YY] per cent	[ZZ] per cent
Main Lifetime	[YY] per cent	[ZZ] per cent
From start of life to [XX] years or [XX] km, or [XX] MWh whichever comes first and		
Additional Lifetime	[YY] per cent	[ZZ] per cent
From start of life to [XX] years or [XX] km, or [XX] MWh whichever comes first and		

- Other tables; N2, N3<16t, M2, M3

Proposals

- The metrics; mileage/ET/CT/FCE and [SB] are going to be determined in minimum 5 years for monitoring phase.

RESULTING FCE FROM ENERGY THROUGHPUT VS. MILEAGE AND YEARS FOR DIFFERENT CASES

lbs	kg	USA vehicle Class	tonnes	EU vehicle group	vehicle category	UN categories		tonnes	JPN Truck group	JPN Tractor group	JPN Route Bus group	JPN Bus group	Energy Throughput MPR Differentiation
6000	2,722	1		N.A.	N1,M1 and M2<3.5t	categories 1-1, 1-2 and category 2	UN GTR22						20%
8500	3,856	2		N.A.	3.5t<M2<5t								30%
10000	4,536	3	3.5	N.A.	N2<12t 5t < M3 <7.5t M3>7.5t	Category 2 vehicles not exceeding 16 tonnes	UN GTR HDV	3.5-7.5	T1/T2/ T3/T4	TT1		B1	40%
14000	6,350	4	7	N.A.									50%
16000	7,257	5	7.4	1s							BR1	B2	50%
			7.5	1				8	T5				50%
19500	8,845	6	10	2				10	T6		BR2	B3	52%
26000	11,793	7	12	3	12t<N3<16t M3>7.5t			12	T7		BR3	B4	52%
33000	14,969	8						14	T8		BR4	B5	
60000	27,216	8	>16	4,5,9,10,11,12,16	N3>16t M3>7.5t	Category 2 vehicles exceeding 16 tonnes		16	T9		BR5	B6	100%
								20	T10			B7	
								20<	T11	TT2			

Observation

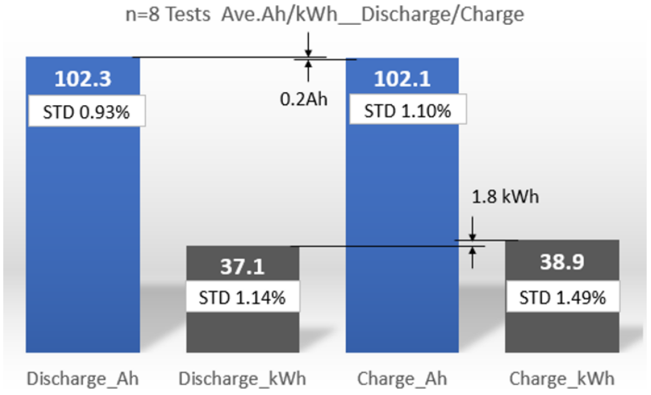
- Different use-cases resulting in different energy throughput, whilst years stay same
- Mileage and FCE do not correlate linearly
- For smaller trucks with small batteries c-rate increases. Thus, smaller trucks with lower installed battery energy cycled more often

UBC vs. UBE. OICA compromise proposal: keep both in parallel – monitoring

Results(2) Comparison UBE vs. UBC

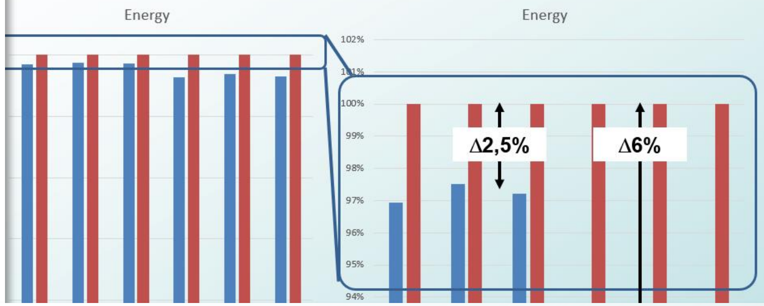
> RTE test results of discharging up to On-Board discharge and charging with DC/AC for each method.
> Compare average UBE(kWh) and UBC(Ah)

Draft



<Result>
> UBE(kWh) ; Due to internal resistance, discharge is Δ1.8kWh compared to charging.
The variation is 1.14-1.49% which is much larger than UBC due to voltage multiplication.
> UBC(Ah) ; Measured using DC charging and AC charging, The values are almost same, the difference is Δ0.2Ah. Variation are 0.93 - 1.10 %.

Results energy



Tolerances:
Discharge: ~6%
Charge: ~3%

test Nr.	route	charge
1	flat 10,5t	fast
2	flat 10,5t	fast
3	flat 10,5t	mobile
4	hilly 39t	fast
5	hilly 39t	mobile
6*	hilly 39t	fast
7**	hilly 39t	mobile

* Driving mode „Range"
** charging aborted

RESULTS

- Results from closed test track & for discharge part of test procedure
- Measured variation in energy max 1.04% among tests

Test Case	Test 1	Test 2	Test 3
Preconditioning	Slow Charge from 32% SOC	Slow Charge from 37% SOC	Slow charge from 40% SOC
Measured Variation UBE (UBE: $\int (U * I)\,dt$)	1,04%	0%*	0,71%
Measured Variation UBC (UBC: $\int (I)\,dt$)	1,34%	0%*	0,84%

* reference to calculate variation among tests

- Average Cell Temperature is ~25 °C

Discharge Cycle – Avg cell temperature over 6 BP		
Avg Max Cell Temperature	Avg Min Cell Temperature	Avg Cell Temperature
25,82	24,65	25,39

Conclusion

- Capacity is the same in the charging and discharging phase (e.g. Coulomb efficiency approximately 100%)
- Capacity is more reproducibly measurable, since only the current sensor with very high accuracy (e.g. error << 1%) is used.
- Capacity can be measured easily and reproducibly as well as technology neutral during the charging process at the charging station. Easy to replicate by third-party organizations or even by customers. Which leads to given transparency and possible validation at all time.

Keep charging results from type approval and in-service

<u>Procedure for non-BiDi vehicles</u>

Unlike WLTP which has a defined reference drive cycle, the current proposal for HD to drive on the road with an average speed has a lot of uncertainties during test, eg. driver behaviors, road conditions, brake etc.

$Energy_{discharged} = Energy_{charged} + Energy_{regenerated}$

<u>Metrics:</u>

Charging process is more static and controllable which eliminates the uncertainties from road test

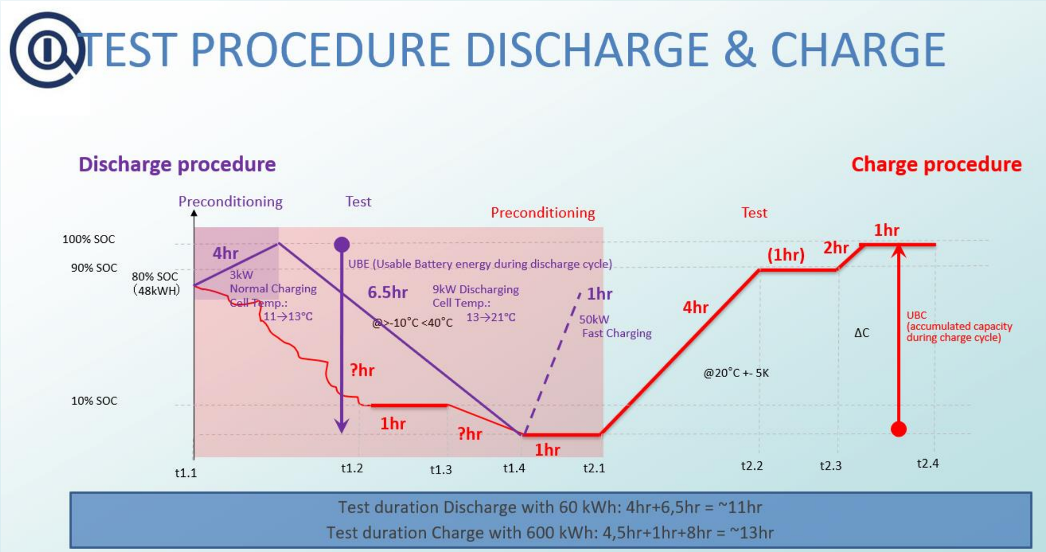
The customers care charging as much as discharging as operation cost is the key

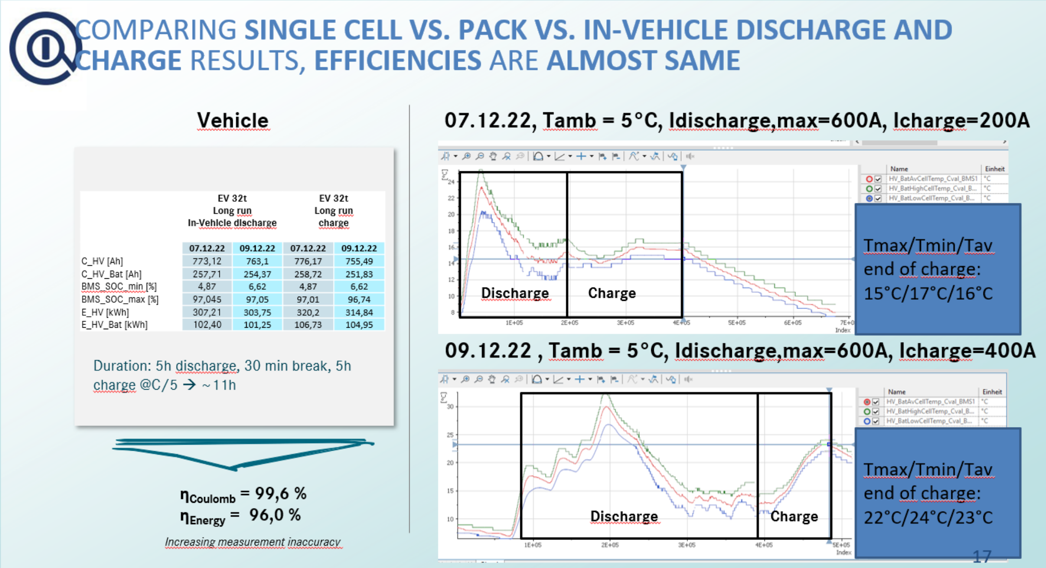
<u>Proposal:</u>

Report and monitor measurements from charging(following the discharge procedure) as a complement to discharge measurements $SOCE_{measured}$ shall be calculated by UBE/UBC from both charge and discharge measurements for the monitor verification.

<u>Bottom line:</u>

Results from charging cycle shall be reviewed and compared to results from discharging cycle and to be discussed within phase II of HDV GTR22b whether to this should be reflected within the procedure itself





	EV 32t Long run In-Vehicle discharge		EV 32t Long run charge	
	07.12.22	09.12.22	07.12.22	09.12.22
C_HV [Ah]	773,12	763,1	776,17	755,49
C_HV_Bat [Ah]	257,71	254,37	258,72	251,83
BMS_SOC_min [%]	4,87	6,62	4,87	6,62
BMS_SOC_max [%]	97,045	97,05	97,01	96,74
E_HV [kWh]	307,21	303,75	320,2	314,84
E_HV_Bat [kWh]	102,40	101,25	106,73	104,95

Keep charging results from type approval and in-service

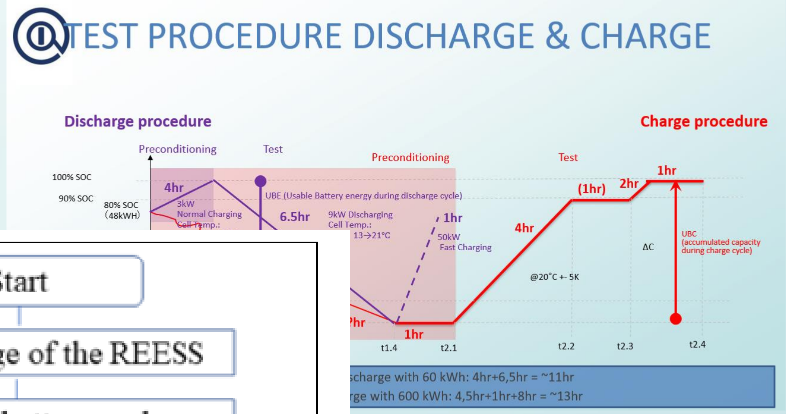
For BiDi vehicles

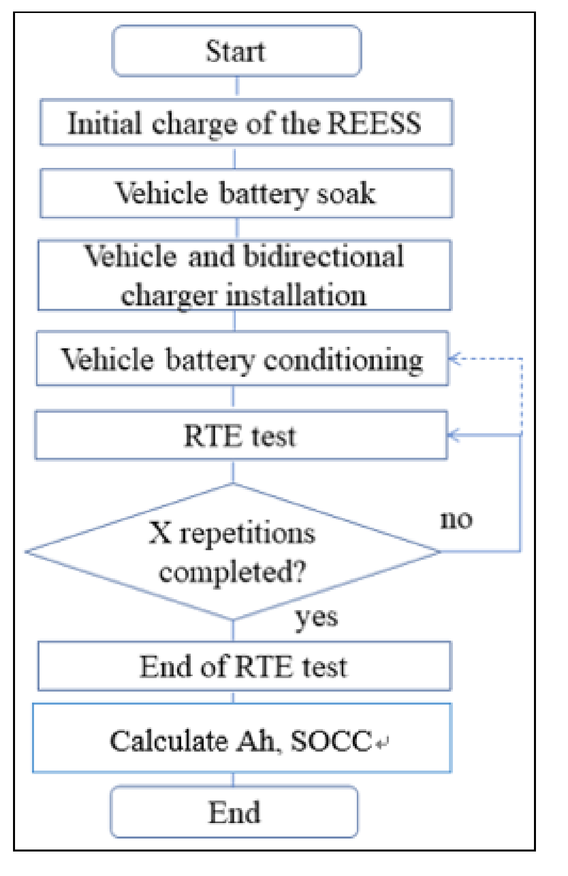
Bidi vehicles also require charging results. Especially during the monitoring phase.

It is necessary to confirm the validity of the Bidi test (again, especially during monitoring phase) due to a lack of experience with it in HDV industry.

Proposal:

Different procedure and by this test flow chart to 1a/b: confirming the accuracy of the test at RTE (Round Trip Efficiency).





Energy/Capacity throughput

POSITION ON VIRTUAL MILEAGE

Based on real-world data, we request EVE IWG to rethink the virtual mileage proposal and to consider energy throughput as additional lifetime requirement.

$$\textbf{Virtual distance}\ (km) = \text{Odometer km} \times \left(\frac{\text{total discharge energy during V2X} + PTO + \cdots [Wh]}{total\ discharge\ energy\ while\ driving\ [Wh]}\right)$$

Or

$$Total\ km = odometer\ km + virtual\ distance\ (km) = $$
$$= Odometer\ km \times \left(\frac{total\ discharge\ energy [Wh]}{total\ discharge\ energy\ while\ driving\ [Wh]}\right)$$

~~Where:~~

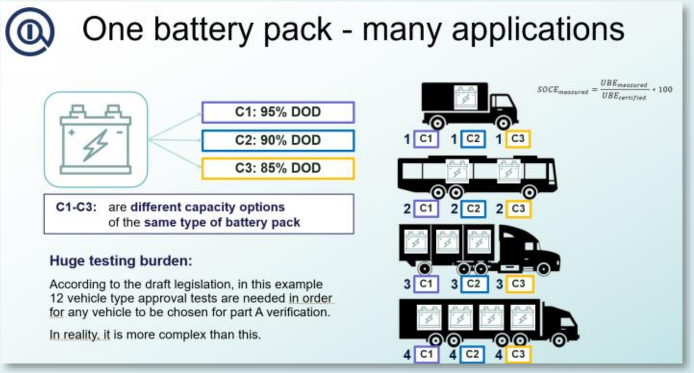
~~"worst case certified energy consumption of Part B family" means the worst case certified energy consumption of a Part B family which needs to be provided according to Annex 2.~~

At the option of the manufacturer, instead of using the worst case certified energy consumption value of the Part B family, the manufacturer may be allowed to use any higher energy consumption value.

The total distance used for confirming the compliance with the minimum performance requirements will consist of the sum of the distance driven and the virtual distance. The total virtual distance shall be recorded and monitored.

Considering the unique configurations and/or functionalities of HD vehicles:

1) **Based on expert discussions and real-world data, it is not feasible to differentiate all the seperate electric vehicle-internal energy flows**
2) **OICA prefers to apply the whole battery energy/capacity throughput instead of mileage for MPR criteria.**



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8	The manufacturer shall prevent the possibility of exploiting vulnerabilities referred to in paragraph 7 to the fullest extent possible based on the best available knowledge at the time of type approval. When such a vulnerability is found, the manufacturer shall take all the possible measures taking into account the state of technology to remove the vulnerability, by software update or any other appropriate means.

Conclusion

- Virtual mileage and with this Part C odometer needs to be deleted.
- To the customer it adds no value and is not feasible for HDV OEMs to distinguish all the different energy flows from battery to the systems as PTO and so on…

External on-board verification for Method 1a/b

- Repetition of tests can only check the precision, accuracy of tests can only be checked via reference
- Measurement accuracy **can not** be verified by repetition of tests
- **Unlike WLTP which has a defined reference drive cycle and stable environmental conditions for the use of external measurement equipment (not on-road)**, the current proposal for HD to drive on the road with an average speed has a lot of uncertainties, thus the tests can not be checked for either precision or accuracy

Conclusion

- The accuracy of on-board sensors and energy counter could be verified during type approval through a test-rig based component test combined with a parent vehicle test verification. Declared values can be verified.
- Accuracy verification: value from charging station vs. accuracy of external measurement equipment vs. …

Monitor field data before setting statistical pass/fail criteria

- The pass/fail criteria for light-duty GTR22 has been established on a large amount of field data and has based on the assumption of homogeneity in the customer usage
- Assuming the same statistical model can equally be applied for LD and HD vehicles need to be verified but most likely adaptions need to be made

Proposal

- Pass/fail criteria shall be set after the monitoring phase

Additional Items for Annex 2

Annex2 Values to be read from vehicles:

<u>Proposal:</u>

OICA proposes to add the following non-exhaustive item-list to **Annex 2 from the Method1a/b & 2 studies** and the statistical analysis of MPR metrics during this period in order to to be able to adapt the procedures accordingly after monitoring phase.

- Total soak and driving time (sum of the time driven as reported by the odometer and the other (i.e., PTO/V2X) time) (hours)
- Total charging time (sum of the hour driven as reported by the odometer and the other (i.e., PTO/V2X/charging) time) (hours)
- Total discharging time that C-rate was more than or equal to C/2 (hours)
- Total time for test preparation

Conclusion

- It is important for OICA-HD to present factors that are expected to be relevant to be collected by monitors in order to consider MPR metrics for HD battery degradation.

SUPPORTING DRAFTING ACTIVITIES AND SUMMARY: 4-COLUMNS DOCUMENT

OICA worked out 110 pages of comments!

1) **Expressed within a „4-column document", commenting on the draft text**
2) **Taking into consideration state of the art technology and outlook**
3) **Focussing on metrics, test methods, definitions, feasibility and regional differences for electric HDV vehicles**

Basic principles:

1) **Non-invasive measurement procedures:** customer vehicles in service must be operated safely and without damaging the customers' property
2) **External equipment while driving very problematic (robust measurement, non-invasive, vehicle hardware only for regulation):** Homologation of internal current sensor (high accuracy anyways basis for good battery performance) and checkup via repeated in-service measurements
3) **Measurement procedure options charging and discharging:** to recognize different infrastructures and vehicle types
4) **Flexibilities on metrics capacity vs. energy:** taking different accuracies and allowed tolerances into account
5) **Additional lifetime requirement:** Energy Throughput more meaningful than mileage in heavy duty business.
6) **Modularity:** family concept must consider number of same packs. MPRs must consider vehicle configuration.