Regulatory Needs for Electrified HD Vehicles

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GRPE workshop on low- and zero- emissions heavy duty vehicles

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Background

- UN-ECE R49-06 (Euro VI) emission regulation is considered as the most efficient and successful regulation concerning HD engine emission performance, thus is the most adapted regulation worldwide.
- So far, Regulation No. 49 is an engine-based regulation due to that electrification of HD powertrains has not yet been mainstream technology.
- However, the EU 2025 and 2030 HD CO2 limits motivate an expansive development of hybrid technology/BEV in HD sector, from micro hybrid (e.g. brake energy recovery) to full range hybrid (e.g. plug-in, BEV+range extender). Indeed, the CO2 regulation has come relatively far in developing a regulation amendment and update Vecto for hybrid vehicles to meet this progress.
- Furthermore, countries outside EU, such as China, recognize the limitation of Euro VI/R49 regulation, and thus start to modify vehicle test procedures (ISC, PEMS testing) to also cover hybrid technology.
- OICA sees an urgent need to update Regulation No. 49 for powertrain electrification in order to support hybrid technology development
- Some essential modification of the PEMS/ISC test procedure is needed, the modifications could also be used as base for future regulation discussions concerning electrification (outside scope of Regulation No. 49)

HDH vehicles on the market today

- Euro VI/R49 certified engines
- PEMS-demonstration at Type Approval based on conventional ICE only vehicles
- PEMS ISC testing is performed with hybrid system deactivated (only possible for parallel hybrids) due to lack of test procedure and definition

Future HD vehicles

- All tendencies point to full electric vehicles as a long term goal
- As HD charging infrastructure is currently not sufficient, operators may hesitate to choose pure BEV vehicles.
- During a transition period several different powertrain concepts will likely be used i.e. hybrids with varying degree of electrification
  - Short range parallel hybrids (HD ICE)
  - Long range serial hybrids (BEV + LD ICE as REX)

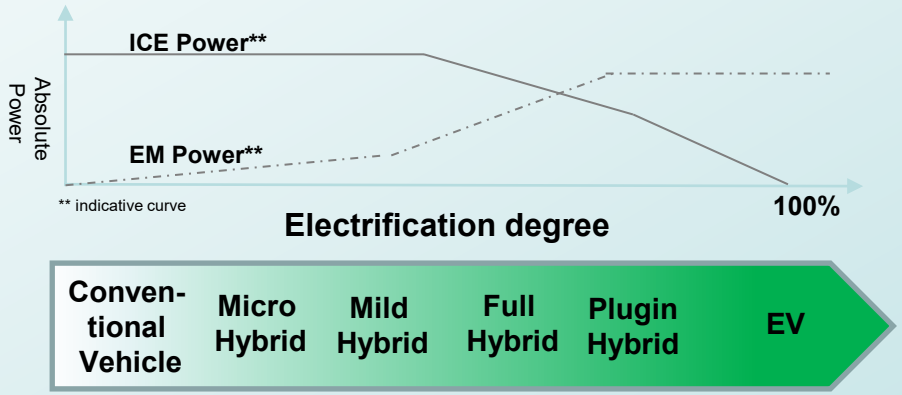
Electrical Hybridization Degree

Many parameters to take into account, e.g.:

- Power ratio between ICE power and EM power
- Stop & Start capability
- Regenerative braking capability
- Power assistance to the ICE
- Full Electric propulsion capability
- External power supply

Electrical Vehicle

Vehicle without ICE. All power is supplied by external electricity (e.g. plugin, pantograph, etc.) and/or internal electricity (e.g. fuel cell, solar power, etc.)



Hybrid powertrain classes:

	Micro Hybrid	Mild Hybrid	Full Hybrid	Plug-in Hybrid
Brake energy recovery	✓	✓	✓	✓
Recovered electrical brake energy used for engine stop-start *and/or* auxiliary power	✓	✓	✓	✓
Electric motor assists ICE by providing part of propulsion power		✓	✓	✓
Capable of vehicle propulsion by using only electric motor*			✓	✓
ICE in generator mode for electrical energy			✓	✓
Traction battery charging from external supply				✓

* Not required in all driving modes

✓ Condition that <u>should</u> be fulfilled

✓ Condition that <u>could</u> be fulfilled

Overview of regulatory gaps

	HD engine capable of WHxC	LD engine (Euro 6), non-road engine (e.g. genset)
Emissions type approval (test bed)	YES	NO
Power type approval (test bed)	YES	YES
OBD type approval (test bed)	YES	NO
PEMS/ISC	NO	NO

What regulations are affected?

- UN-ECE Regulation No. 85 (power)
- UN-ECE Regulation No. 49 (emissions)
- Also, several ISO, SAE etc standards regarding e.g. OBD-requirements and CAN-signals
- General statement: do not invent new things, use and/or modify existing and well functioning regulations & standards

R85 issues

- Current R85 focuses on ICE performance and (pure) electric drivetrains

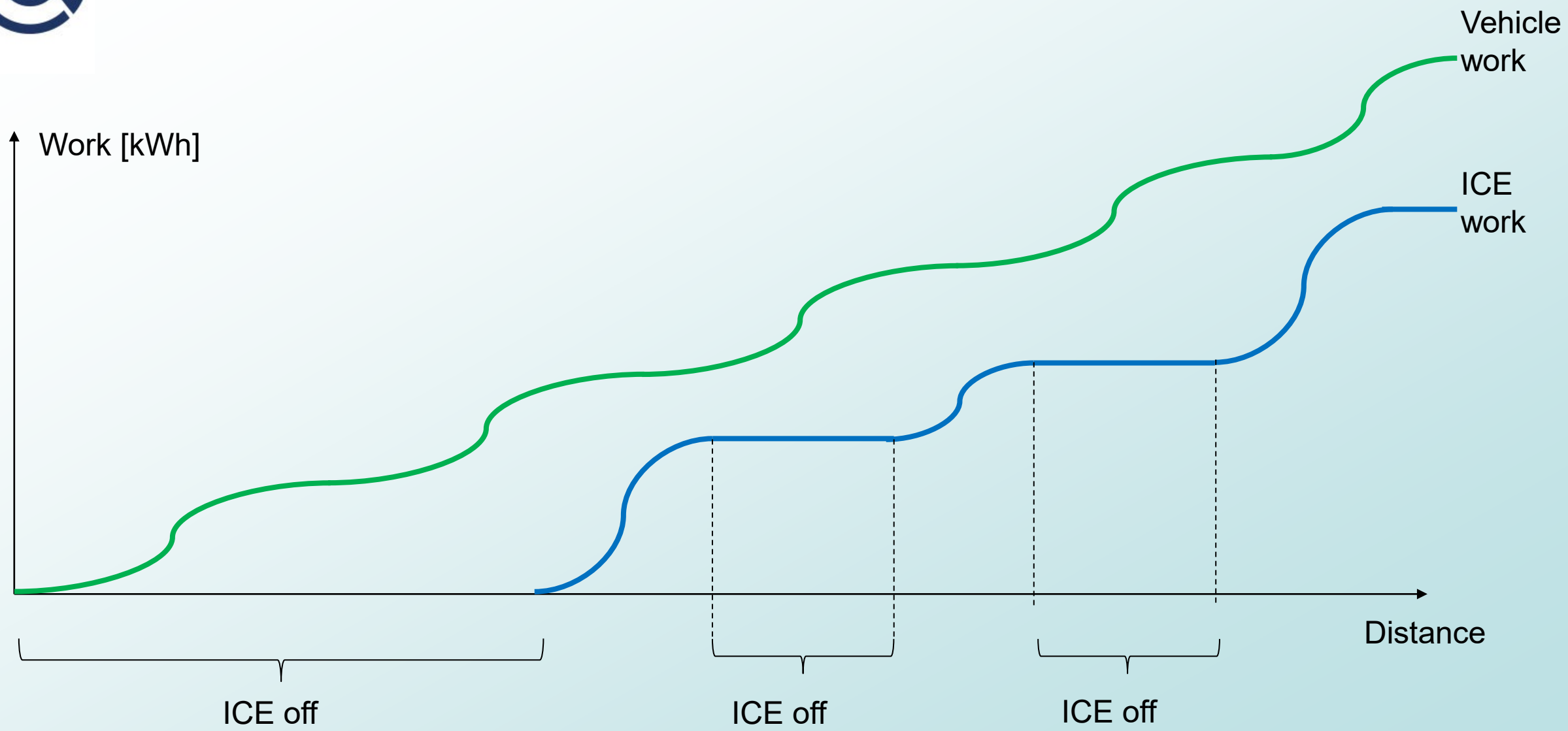
- Need to update with performance criteria for hybrids
  - Example: is max power = ∑(ICE+EM)?
  - This may not always be the case

- Current focus on maximum power performance
  - Need to widen the scope to also cover energy efficiency

R49 issues

- Current R49 is based on the assumption that ICE is the only power source directly propelling the vehicle
- This will not be the case for hybrids where, depending hybrid powertrain configuration, the ICE operational cycle will be very different from a conventional vehicle
- Need to introduce test cycles and standards suitable for a multitude of different hybrid ICE applications

Example HDH ISC test (schematic)



Issues for PEMS testing hybrid vehicles

	ICE	Parallel hybrid	Serial hybrid	MAW related*
Propelling power	ICE	ICE+EM	EM	x
Emissions	Emissions/work done by ?			x
Test duration	4-8x WHTC of ?			x
Power threshold	10% of ?			x
Urban window	Consisting of ICE/EM?			x
Cold start definition	Cold start assumed as vehicle start			

*MAW related = specifically related to the use of MAW method for evaluation of emission compliance

Issues for PEMS testing hybrid vehicles

- General principles used for modifying PEMS testing of hybrid vehicles
  - A vehicle should be tested without considering the powertrain, and without considering SOC, i.e. the vehicle application and its intended transport mission shall be assumed independent of powertrain configuration
  - The ISC test criteria for ICE-only shall be kept as much as possible

- The vehicle shall be tested during normal application conditions, and emissions shall be compliant at any applicable SOC
  For example: a range extender is not expected to start with an empty battery whereas a parallel hybrid could
  - Thus, type approval PEMS testing should be carried out with lowest applicable SOC for parallel hybrids, and at any applicable SOC for serial hybrid (range extenders)

- ISC test should be performed at any applicable SOC at normal use

Issues for PEMS testing hybrid vehicles

Discussion on evaluation method for in-service emissions

- The moving average working window and 90th percentile method is a statistic method based on a sufficient amount of data, this is the reason for requiring 4-8x WHTC reference work, i.e. to accumulate enough windows
- If wheel-work based trip duration has reached 8xWHTC and if accumulated work of the ICE during total test is still less than 4xWHTC reference work of ICE, the emission evaluation using the moving average window method can be questionable
- It is important to understand that the trip duration requirement of 4-8x WHTC reference work is the work performed to propel the vehicle. For ICE-only vehicles this is equal to ICE work, thus one can design the trip based upon the vehicle and general load, traffic situation, etc.
- With hybrid vehicles, ideally similar principles should be used, or at least to ensure performing PEMS tests without designing every trip based upon variations in hybrid configuration/strategy and SOC etc.
- What is actually important for test duration and trip composition is the “wheel work"
  - For ICE-only vehicles ICE, work will be directly proportional to the wheel work
  - For hybrids, ICE work will depend on the configuration but work into gearbox will be the same

Issues for PEMS testing hybrid vehicles

Other issues

- A hybrid vehicle could have a common cooling system for ICE, EM and/or REESS; the vehicle can start with EM (BEV-mode), and the engine coolant temperature could get high, but the ICE and exhaust aftertreatment could be cold once the ICE starts. Thus, the evaluation start criteria could be different comparing to ICE-only vehicles.

- Test start and trip composition currently refers to “the first ignition of the internal combustion engine” and/or “engine start”. This is defined with the assumption of an ICE-only vehicle.

OBD & CAN-communication issues

- Engine speed, torque etc input for PEMS
  - UN-ECE R49-06 specifies that engine speed, reference engine maximum torque and actual engine torque are to be available on CAN (SAE 1979) for use as PEMS-input
  - Engine torque parameters as they apply to electric motors is discussed within SAE 1979 committee => i.e. not standardized

- IUPR, In-Use Performance Ratio
  - Driving cycle dependent
  - UN-ECE R49-06 Amendment 3 addresses the issue but for hybrid vehicles it is not clear when “driving cycle” ends (and next cycle starts)
  - REX not covered

- MI = Malfunction indicator & DTC = Diagnostic Trouble Code
  - Operating sequence dependent
  - UN-ECE R49-06 Amendment 3 addresses the issue but for hybrid vehicles it is not clear when “operating sequence” ends (and next sequence starts)
  - REX not covered

Batteries

- IWG EVE is has already started activities on standards for batteries

- Battery performance standards:
  - Performance related criteria and test methods are needed
  - Currently, EU is developing test methods for next amendment to (EC) 2017/2400 (CO_2 declaration for HDV). The methods is partly based on UN-ECE GTR No. 4 (HILS) and partly on ISO 12405-4:2018.
  - US is looking at SAE standards
  - Harmonization is highly preferred

- Battery durability standards:
  - Durability standards shall be based on performance standards
  - Durability needs to be defined based on utilization. Battery utilization is very different in a commercial HDV compared to an LDV.
  - Battery utilization is also very different in a hybrid application (depending on type of hybrid) and a pure battery electric powertrain
  - Expected lifetime is very different between and LDV and HDV
  - A unique and adapted battery durability GTR for HD application is needed

Pure electric vehicles

- No issues with regards to pollutant/critera emissions
- OBD: some CAN signals may need to be standardized
- Battery standards/requirements: as previous slide

Conclusions

- There are already HD hybrids on the market but new technology development is or will be hindered by lack of updated regulations
- Pragmatic updates of existing regulations are suggested
- Harmonization needed