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European Automobile Manufacturers Association

ELECTRIFICATION IN HEAVY DUTY EMISSION REGULATIONS

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Background

INTRODUCTION

- Introducing some level of electrification may be necessary for OEMs due to HDV CO_2-limits from 2025.
- A comprehensive regulation should cover as many fuels and technologies as possible, i.e. covering all possible levels of electrification, from Micro/Mild-hybrids (e.g. stop/start) to BEV+Range Extender (REX).
- Currently, Euro VI emission regulation provides a sound set of provisions and procedures for vehicles being merely propelled by internal combustion engines (ICE). Electrified hybrid powertrains was not included in existing regulatory framework.
- The electrification of powertrain needs corresponding regulation that allows to type-approve a complete hybrid powertrain system in a way that is representative of how such a vehicle / powertrain system would be used in practice.

OVERVIEW OF EU- AND UN-ECE-REGULATIONS – REFERENCES

Regulation No.	Topic	HD Electrification
2007/46	Framework Directive	Template for information documents to be published this year
2018/858	Framework Directive, *date of entry into force: 01.09.2020*	
595/2009	Emission framework	Partial consideration of electrification
582/2011	Emissions regulation for ICE	No consideration of electrification
UN-ECE R49-06 series	Emissions regulation for ICEs	No consideration of electrification
UN-ECE R85	Measurement of Net power	Covers electrification
2017/2400	HDV CO_2 declaration	Ongoing discussions to cover electrification
2019/1242	HDV CO_2 standards	Electrification covered

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Definitions & scope

DEFINITION OF HYBRIDS

Article 3, Definitions, of Directive 2007/46/EC*

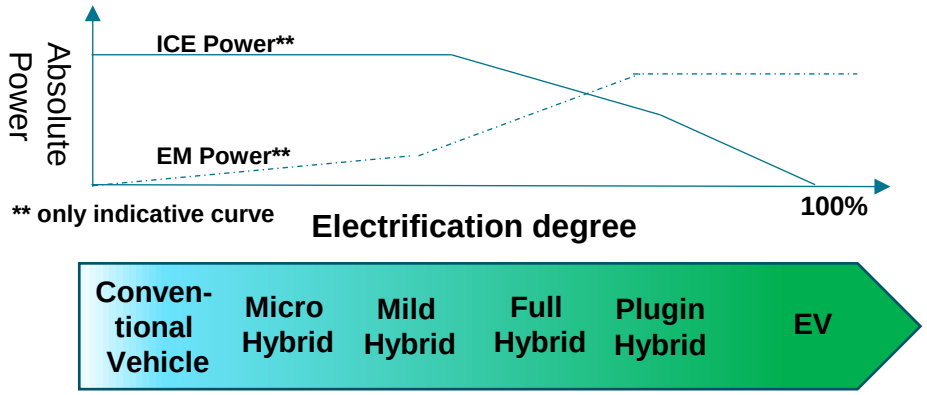
(14) 'hybrid motor vehicle'
means a vehicle with at least two different energy converters and two different energy storage systems (on-vehicle) for the purpose of vehicle propulsion;

(15) 'hybrid electric vehicle'
means a hybrid vehicle that, for the purpose of mechanical propulsion, draws energy from both of the following on-vehicle sources of stored energy/power:

- **a consumable fuel**
- **an electrical energy/power storage device (e.g. battery, capacitor, flywheel/generator, etc.);**

*no similar definition in 2018/858

DEFINITIONS HYBRID VEHICLES USED IN CO_2 DISCUSSIONS



Hybrid powertrain classes:

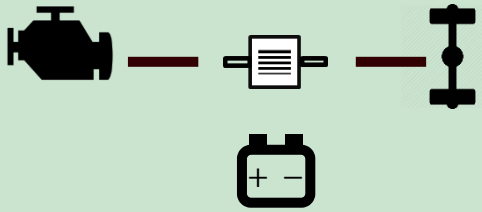
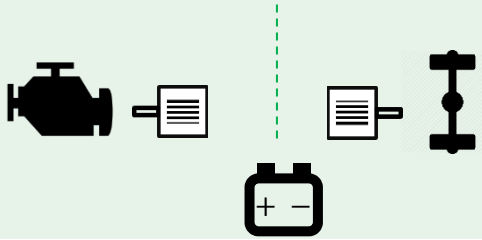
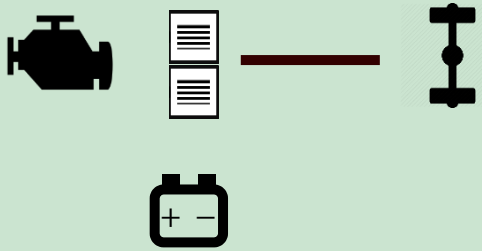
	Micro Hybrid	Mild Hybrid	Full Hybrid	Plug-in Hybrid
Brake energy recovery	✓	✓	✓	✓
Recovered electrical brake energy used for engine stop-start *and/or* auxiliary power	✓	✓	✓	✓
Electric motor assists ICE by providing part of propulsion power		✓	✓	✓
Capable of vehicle propulsion by using only electric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

HYBRID ARCHITECTURES USED IN CO_2 DISCUSSIONS

Name	Visualization	Description
Parallel		Electric machine directly coupled into powertrain, power to drive wheels can either come from Engine, Electrical Motor or both. (ICE mechanically linked to wheels)
Serial		Combustion engine used to drive a generator. Electric generator energy used to power the electric motor, directly or indirectly via a battery. (ICE disconnected from wheels)
Dual		A system with two electrical machines that can be both used together with ICE for either assist with power or use engine power to generate electricity with one of the EM for auxiliaries and/or optimizing operating point of engine and assisting ICE with the other EM. Also possible to switch off ICE and the vehicle can drive in a pure electric mode.

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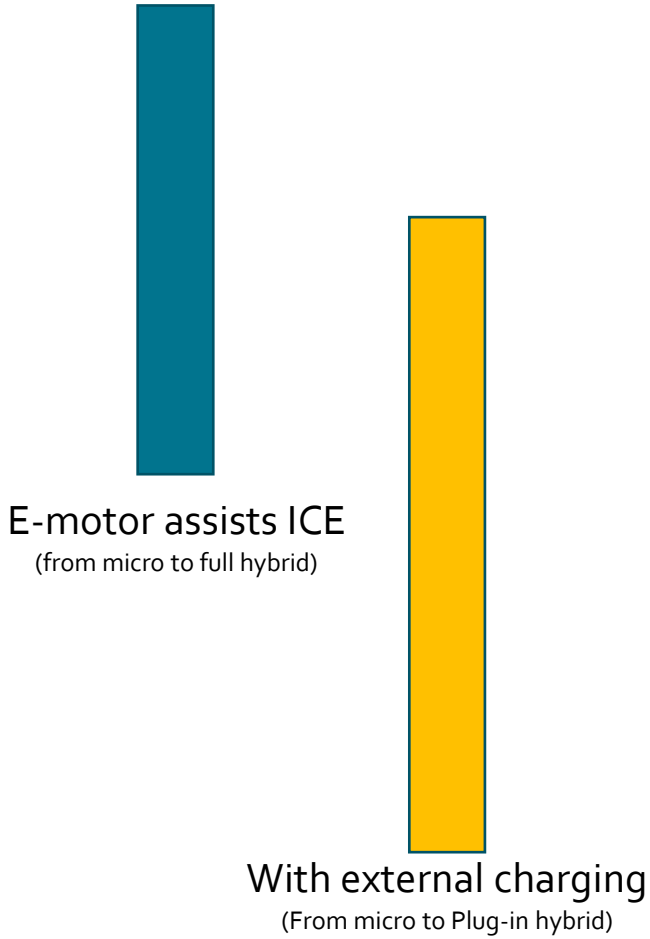
Current issues

HDV ELECTRIFICATION FROM EMISSION REGULATION ASPECTS

- **Standard ICE within scope of Euro VI HD regulation in vehicle with hybrid system (HDH_1.1)**
- **Standard ICE partially within scope of Euro VI HD regulation in vehicle with hybrid system (HDH_1.2)**
- **Unique ICE, not within scope of Euro VI regulation, used only with hybrid system (HDH_2)**
- **BEV + HD range extender (ICE can be either within or not within Euro VI HD regulation, HDH_1 and HDH_2)**
- **BEV + LD range extender (ICE can be either within or not within LD regulation, HDH_3)**



HDV TECHNOLOGY AND EMISSION REGULATIONS

Technology	Covered by Euro VI engine type approval	Covered by Euro VI ISC/PEMS	Covered by Euro VI OBD	Covered by HD CO2
ICE	YES	YES	YES	YES
ICE-”Light HD”	YES	Possible	NO (LD OBD option for N2)	Possible
HDH_1.1 (Euro VI engine)	YES	NO	NO	NO
HDH_1.2 (”Light HD” engine)	YES	NO	NO	NO
HDH_2 (non-Euro VI engine)	NO	NO	NO	NO
HDH_3 (LD engine)	NO	NO	NO	NO

An updated regulation should preferably provide YES or N/A in all cells of the table

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Proposals

POSSIBLE SOLUTION FOR HEV ELECTRIFICATION (FROM EMISSION REGULATION ASPECTS)

- **Short term**
  - Classification of hybrids in "info doc" needs to be supported
  - ICE must be HDH_1.1 and HDH_1.2
  - Hybrid technology covers from micro hybrid to range extender/serial hybrid
  - No modification of WHTC at this stage (R49 Annex IV will not be modified) even though stop-start functionality will be used during hybrid application. This will cover the worst situation (any state of charge, SOC*)
  - Procedures/definitions for ISC/PEMS must be defined
  - OBD updates

- **Long term**
  - All architectures and degrees of hybridization covered (HDH_2 & HDH_3)

*according to ISO 7000/2632

PREREQUISITES FOR SHORT TERM MODIFICATION OF ISC FOR ELECTRIFICATION

- **Existing ISC procedure should be kept**
  - Backwards compatibility e.g. for non-EU markets adopting EC/ECE regulations
  - Backwards compatibility e.g. for ICE-only vehicles
  - The application of the vehicle will be the same regardless of ICE-only or HDH

- **The vehicle shall be tested with normal application conditions, and emissions shall be compliant at any applicable SOC**

- **“Power” and “Work” for ISC/PEMS needs to be defined**
  - Evaluation shall be HDH technology neutral
  - No need for new PEMS trip definition
  - Trip composition includes any type of propulsion power

SHORT TERM PREREQUISITES - HEV

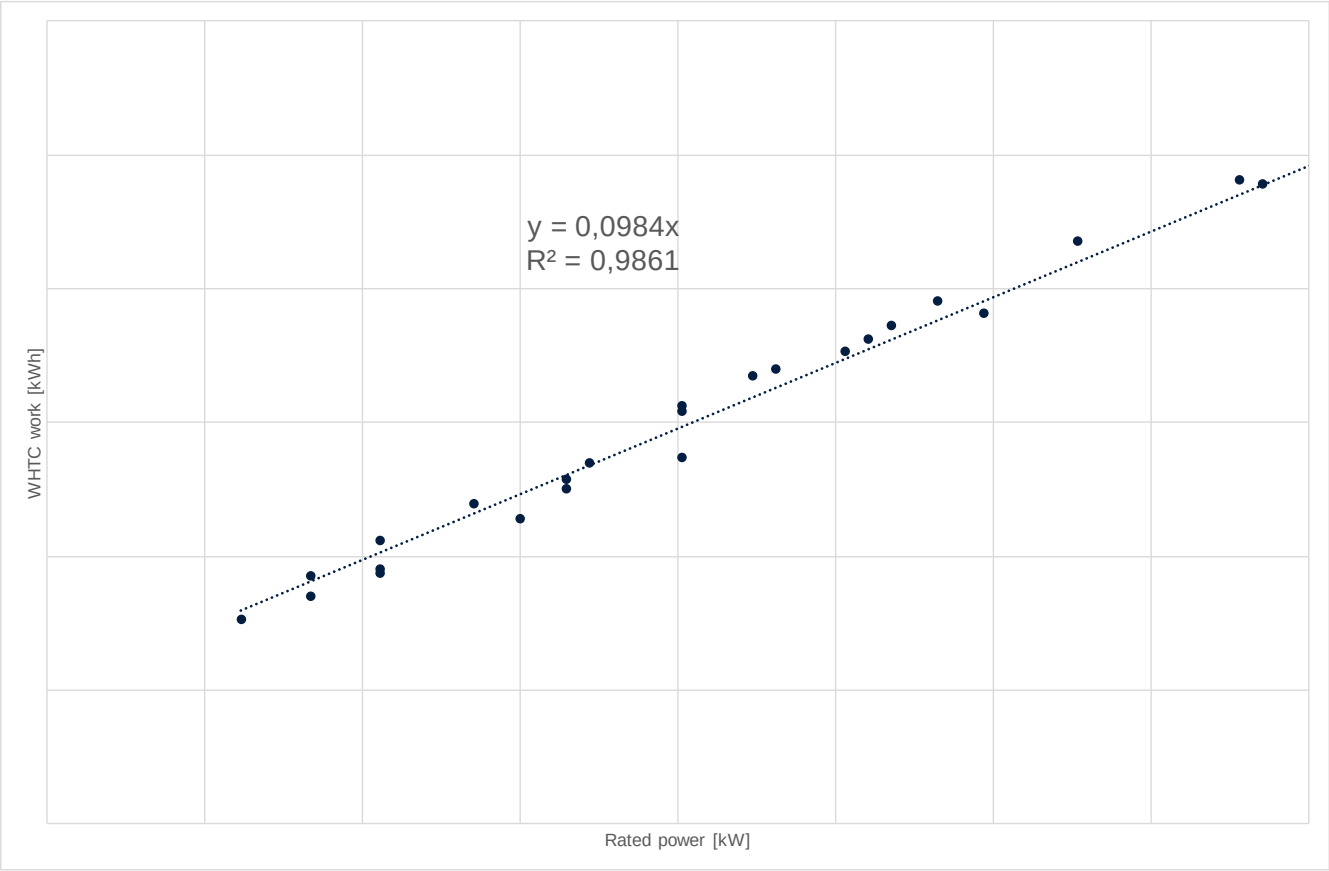
All hybrids have an energy storage system (battery). The state of charge (SOC) of the energy storage must be considered for PEMS-testing provisions

- Type approval PEMS testing shall be carried out with lowest and highest applicable SOC. This will cover the worst case scenarios for all HDH types.
- Lowest and highest applicable SOC are declared by the manufacturer.
- Family structures for different powertrain and energy storage combinations need to be defined
- ISC test shall be performed at any applicable SOC

MAXIMUM POWER AND MOVING WINDOW METHOD

- **Maximum power**
  - For parallel hybrids, the internal combustion engine (ICE) rated power (R85) should be considered as the maximum power
  - For serial hybrids the electric engine (EE) rated power (R85 30 min) should be considered as the maximum power
- **Moving working window length**
  - For parallel hybrid, window length should be based on ICE WHTC work
  - For serial hybrids, a generic window length is needed which can be based on declared values of the electric engine.
    - For conventional HD engines ("baseline") the generic WHTC work is very proportional to rated power
- **Test duration, 4-8x WHTC work**
  - For parallel hybrids, accumulated work should be based on ICE + EE work
  - For serial hybrids, accumulated work should be based on EE work
- **Moving average window work**
  - Emissions with ICE off will be zero.
  - For parallel hybrids, moving average window work should be accumulated work done by ICE and EE, emissions should be calculated for each window as: NOx / W_{ICE}
  - For serial hybrids, moving average window work should be accumulated work done by EE, emissions should be calculated for each window as: NOx / W_{ICE}

GENERIC WHTC WORK



For serial or range extender hybrids, we can calculate a generic WHTC work depending on declared values of the electric engine (R85 30 min rated power)

The relationship between rated power and average power in the WHTC is about 19 to 20 %.

The figure 19% must be divided by 2 since WHTC length 0,5 h

The corresponding factor, to be multiplied with rated power, is consequently 0,095 – 0,1

Looking at actual OEM data we see a factor of 0,0984

WHTC_work = 0,0984*rated_power

R^2 = 0,9861

VALID WINDOWS

The valid window criteria only applies to MAW's having any ICE work

$P_{avg\_ICE} / P_{ICE\_rated} \geq 10\%$

For average power calculation the "the engine running time period" has to be taken!

All pure electric powered windows will automatically be valid and have zero emissions.

SOME DEFINITION NEED TO BE CHANGED

- **Test start: the first ignition of the internal combustion engine, or the vehicle speed is higher than 1 km/h which ever comes first**

- **Trip composition: need to be changed to: 15 minutes after test start (engine start is the wording right now)**

- **Test end: is reached when the vehicle has completed the trip (as required for a valid test i.e. work, trip composition etc).**

COLD START

Considering different configurations of hybrids with a wide range of SOC, the ICE engine can start at any location of the test trip, how to evaluate the data needs to be considered.

However: cold engine operation is defined by ICE engine coolant temperature and

1. **If the ICE starts when the vehicle starts moving (=> with lowest applicable SOC), no changes (majority case)**
2. **If the vehicle starts in e-mode => cold start is only postponed => step E procedure can be applied**

Note: the data needs to be re-arranged in post processing => mainly because of urban window rule

But with hybrids there also some other specific cases that need consideration – relevance and possible solutions are still in discussion

- **What about if we have multiple short cold engine running periods – not reaching criteria warm engine?**
- **What about if cold start happens so late that the cold start window is very short?**
- **What about if engine never starts during a PEMS test?**
- **For PHEV, depending on HDH concept, the cooling of the battery pack could warm up the engine coolant circuit**

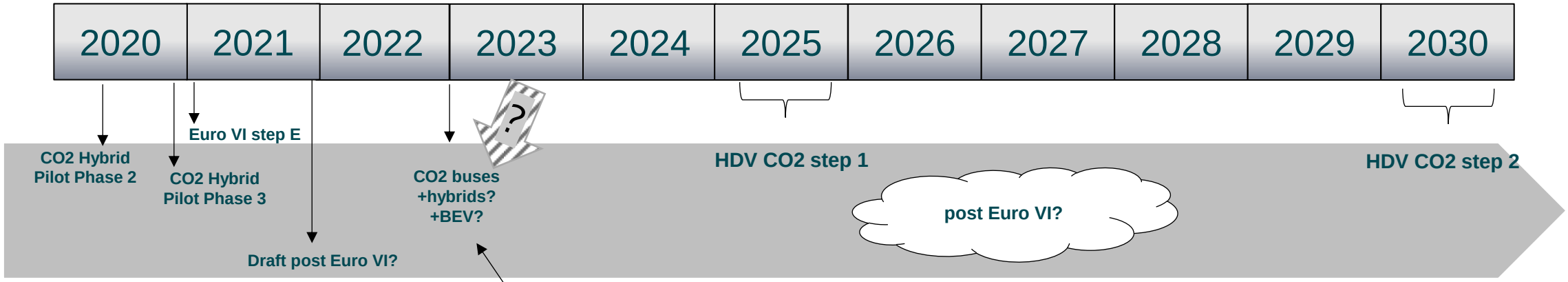
Vehicle starts in e-mode => battery cooling warms up the coolant without any engine operation (exhaust system remains cold…)

VERIFICATION DURING TA

Signal need to be checked during certification:

For electric engine, the average load at each operating condition in Nm calculated shall not differ from the average measured load at that operating condition by more than 7 per cent when determining the engine power according to Regulation No. 85.

TIMELINE



VECTO implementation schedule

Functionality	Available in beta versions
AMT Shift strategy	Algorithms finalised. Consolidated final VECTO release related to „VECTO further development project" in early December 2019
AT Shift strategy	
ADAS in the loop	
Dual Fuel	Final set of generic parameters for gear shifts and ADAS tbd in VECTO board.
W/EHR (needs HEV functions)	
Declaration mode heavy buses (primary vehicles) including update of AAUX model and micro-hybrids	February 2020
VTP mode heavy buses	March 2020
Declaration mode heavy buses (complete(d) vehicles) including „CO2-Factor method"	April 2020
Declaration mode medium lorries	February 2020
VTP mode medium lorries	February 2020
Declaration mode and VTP Medium buses	Open
Hybrids (electric components)	~~Alpha version in December 2019~~ Beta version in April 2020
Hybrids (parallel + serial architectures)	
Hybrids (power-split + other mixed architectures)	Method and date open. Dedicated VECTO Hybrids meeting suggested to discuss best way to go ahead

Alignment of technical content in emission and CO_2 regulation required

The first hybrid VECTO, but only for parallel and serial HEV, is scheduled for 2020-04.

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 was discussed within SAE 1979 committee in February 2020
    => i.e. not yet 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

- **ACEA OBD-experts have started developing amendments, including above issues, within ISO/SAE**

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www.acea.be
+32 2 732 55 50
communications@acea.be

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