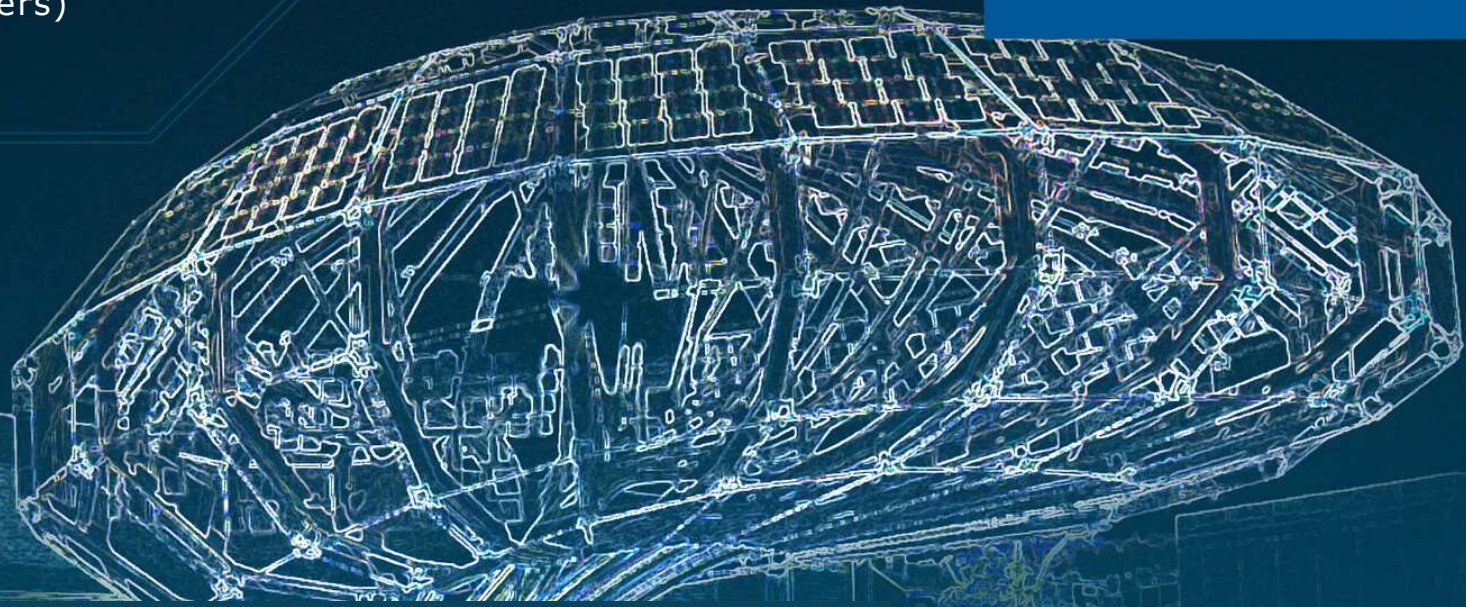
AVL List GmbH (Headquarters)



Emission Regulation Trends

AVL India Seminar May 2018
Overcoming BS6 & RDE Challenges with 2020 getting Closer

Engeljehringer, Kurt

Notes

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Approved by:	
Project Leader:	
Version:	1.0
Release date:	05.03.2018
Security level:	Public
Customer:	
Project:	
Task ID:	
Department:	Emission Test Systems

Content

India

- 2020 from Bharat IV to VI, with UNR-83 and 90km NEDC
- 2020 RDE monitoring and 2023 RDE Limits (TA and COP)
- 2021 Fuel consumption target reduced 5.5 to 4.7 l/100km

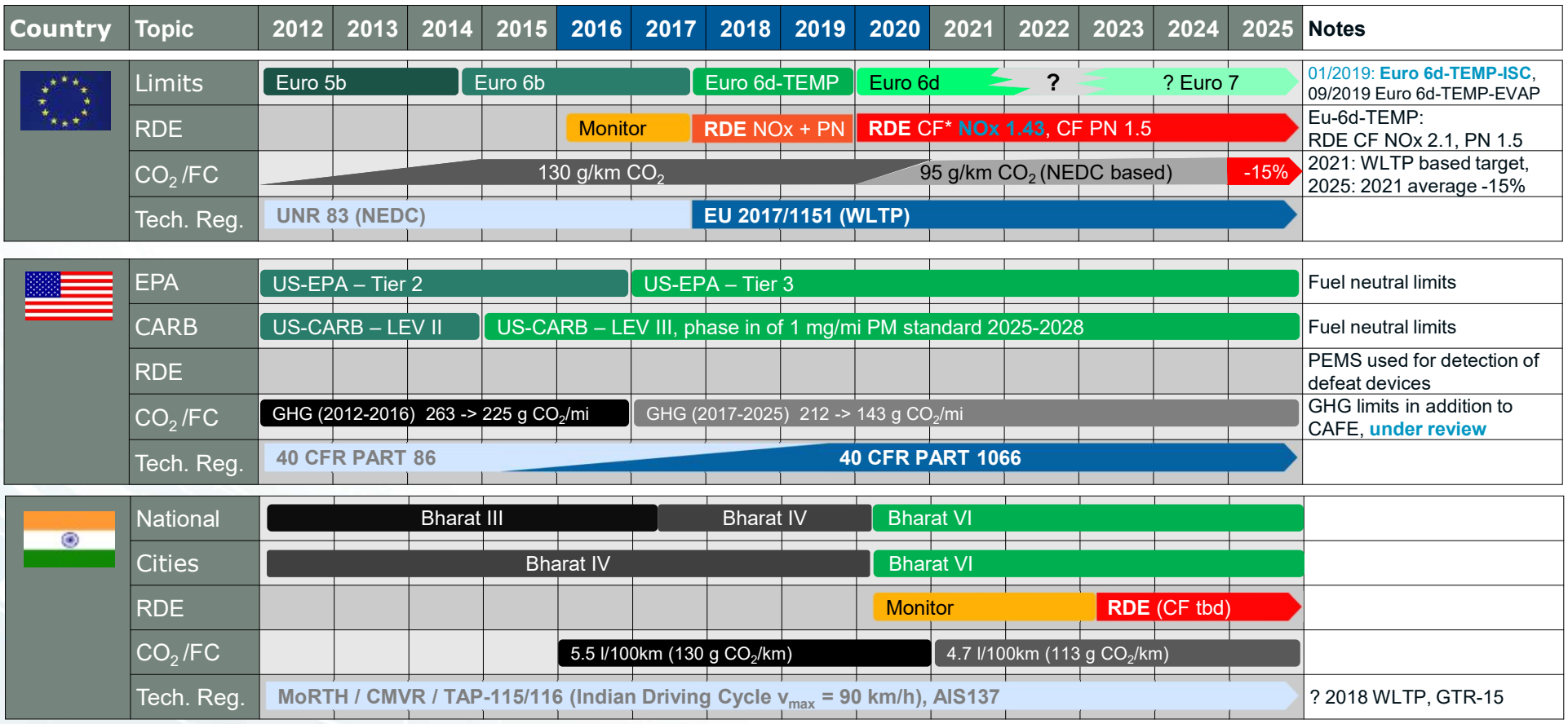
Europe

- WLTP laboratory test procedures
- Real Driving Emission “normal condition of use”
- In-service compliance comming
- Further CO2 reduction (130 → 95 → ??g/km)

USA

- 5 standardized cycles represent real driving emission
- Use of PEMS testing for defeat device screening
- Moderate CO2 reduction

Emission legislation – passenger cars



Implementation dates for new types if applicable

Status 05.03.2018

Emission legislation – passenger cars

			EU-1	EU-2	EU-3	EU-4	EU-5a	EU-5b	EU-6b	EU-6c
			1992	1996	2000	2005	2009	2011	2014	2017
Test Cycle			ECE 15.04	ECE 15.05	NEDC	NEDC	NEDC	NEDC	NEDC	WLTC
Positive Ignition Engines (Gasoline)	CO	mg/km	2720	2200	2300	1000	1000	1000	1000	1000
	HC	mg/km			200	100	100	100	100	100
	HC + NOx	mg/km	970	500						
	NOx	mg/km			150	80	60	60	60	60
	NMHC	mg/km					68	68	68	68
	PM only GDI	mg/km					5	4,5	4,5	4,5
	PN	#/km							6E12	6E11
Compression Ignition Engines (Diesel)	CO	mg/km	2720	1000	640	500	500	500	500	500
	HC + NOx	mg/km	970	700	560	300	230	230	170	170
	NOx	mg/km			500	250	180	180	80	80
	PM	mg/km	140	80	50	25	5	4,5	4,5	4,5
	PN	#/km						6E11	6E11	6E11

no change | change | important

no change | change | important

Legislation Evaluation:

- Since EU-3 changes were moderate
- Mainly focusing on Diesel PM and NOx

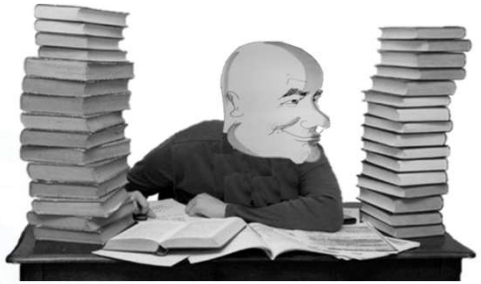
With EU-6c:

- Major changes coming from WLTP

With EU-6d-temp:

- Biggest changes ever coming from RDE

UNECE/EU Light Duty Evolution & Revolution



20 pages

1970 Euro-0

180 pages

2005 Euro-4

800 pages

RDE
180 pages

GTR-15 (WLTP)
350 pages

ECE R83.07
270 pages

2017: UNR-83 + GTR-15 + RDE

643 pages

RDE
European-WLTP
UNR-83

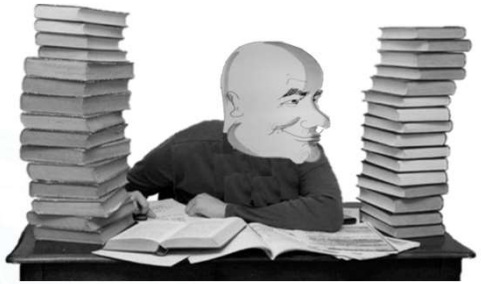
2017: EU-6d-temp

RDE 3
?? pages

UNR 83.07
270 pages

India Bharat-VI

UNECE/EU Light Duty Evolution & Revolution



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270 pages

2017: UNR-83 + GTR-15 + RDE

643 pages

RDE
European-WLTP
UNR-83

2017: EU-6d-temp

1380 pages

RDE 4 and
WLTP 2
420 pages

RDE 3
47 pages

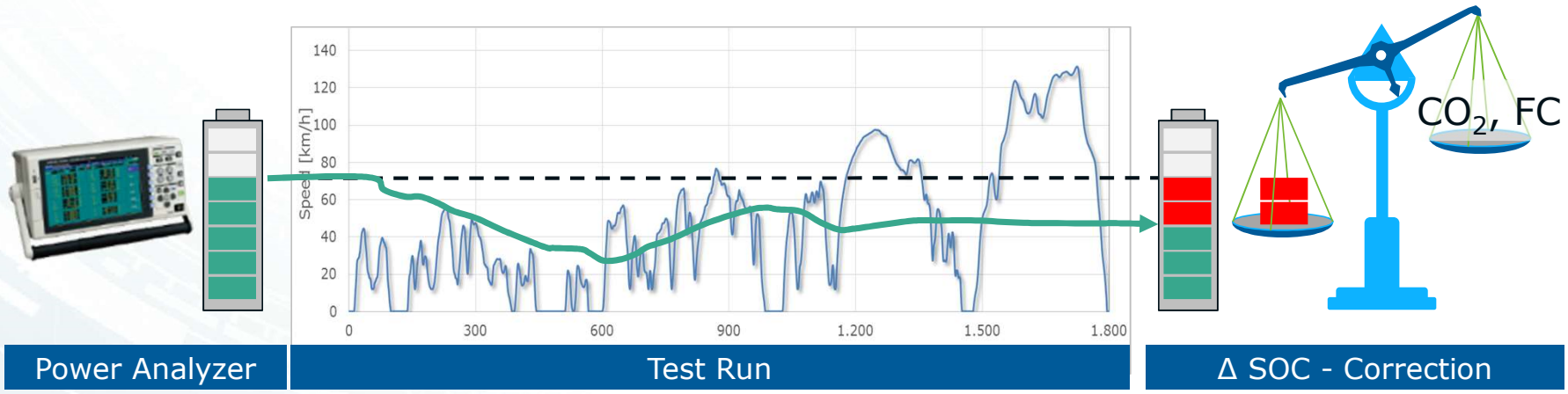
GTR-15
RDE 1+2

UNR 83.07
270 pages

2018+

Hybrid testing: NOVC (Not Off Vehicle Charging)

Hybrid related naming's			Electrification Functionality						
Technology name	EU related emission regulation naming	US related emission regulation naming	Engine Start/Stop	E-Boost Systems	Regenerative braking	Drive with E-Motor only	External Battery charging	Pure electric driving	Electric driving only
Full - Hybrid	NOVC Hybrid Not off vehicle charging	Hybrid electric vehicle	●	●	●	●			

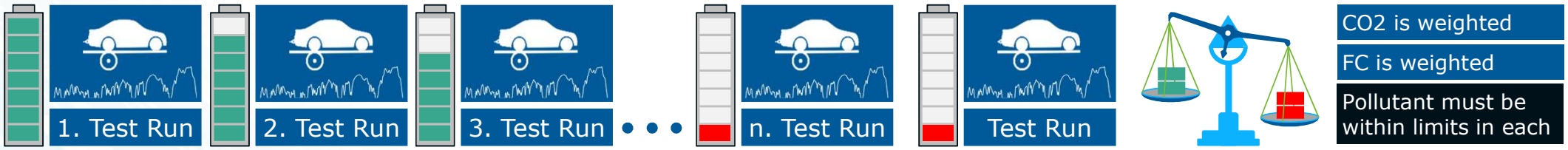


Power Analyzer | Test Run | Δ SOC - Correction

Hybrid testing: OVC (Plug-In)

Hybrid related naming's		
Technology name	EU related emission regulation naming	US related emission regulation naming
Plug-In - Hybrid	OVC Hybrid Off vehicle charging	Plug-In Hybrid, Grid connected EV

Electrification Functionality						
Engine Start/Stop	E-Boost Systems	Regenerative braking	Drive with E-Motor only	External Battery charging	Pure electric driving	Electric driving only
●	●	●	●	●		

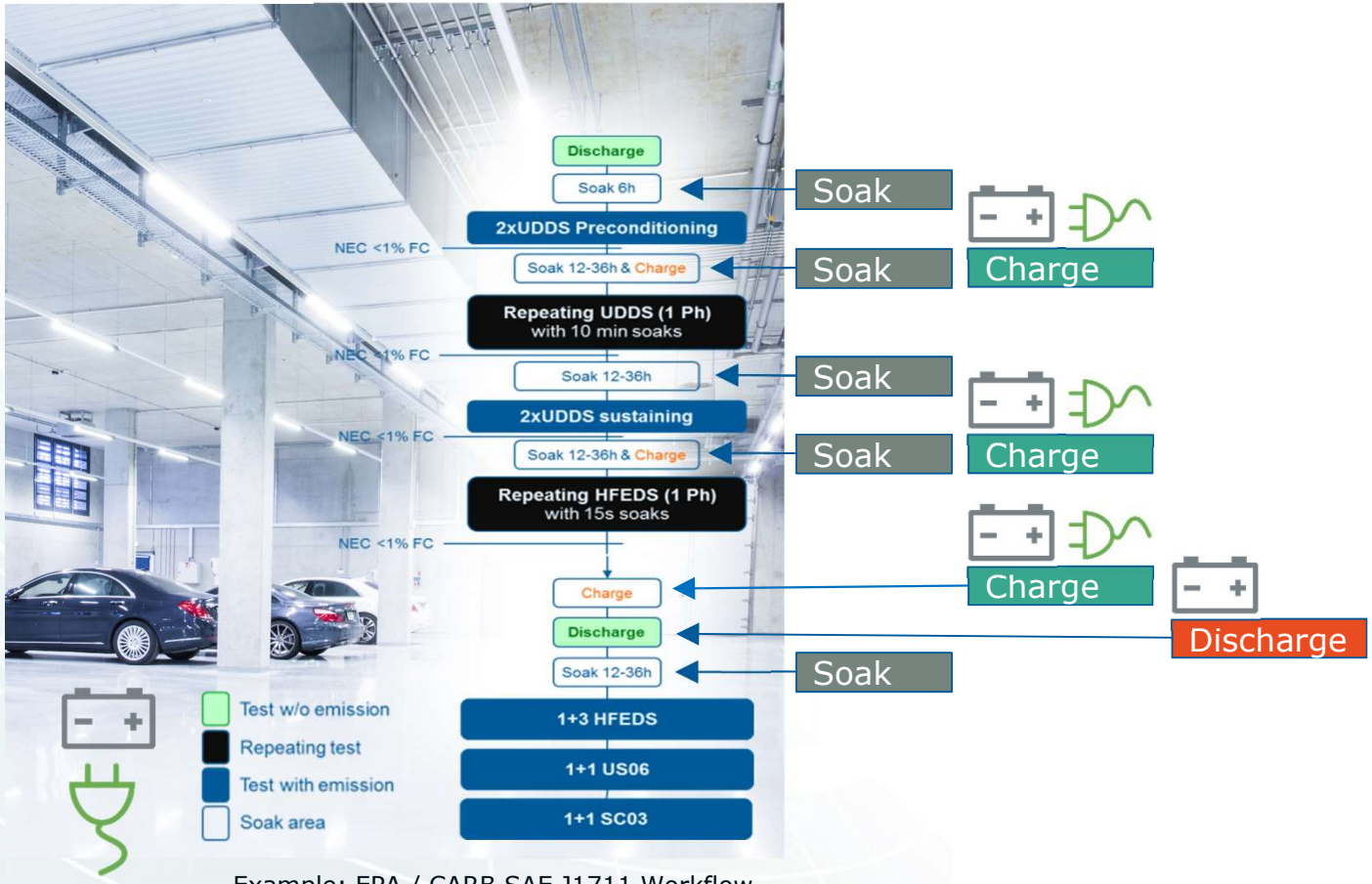


Additional Measurements:

- RANGE - Electric range / OVC range
- ELECTRICITY - Power consumed from main to reach this range.
- FUEL CONSUMPTION – Charge DEPLETING and Charge SUSTAINING

Hybrid testing and E-Vehicles

Hybrid Testing: Soak Area becomes part of the "testbed"

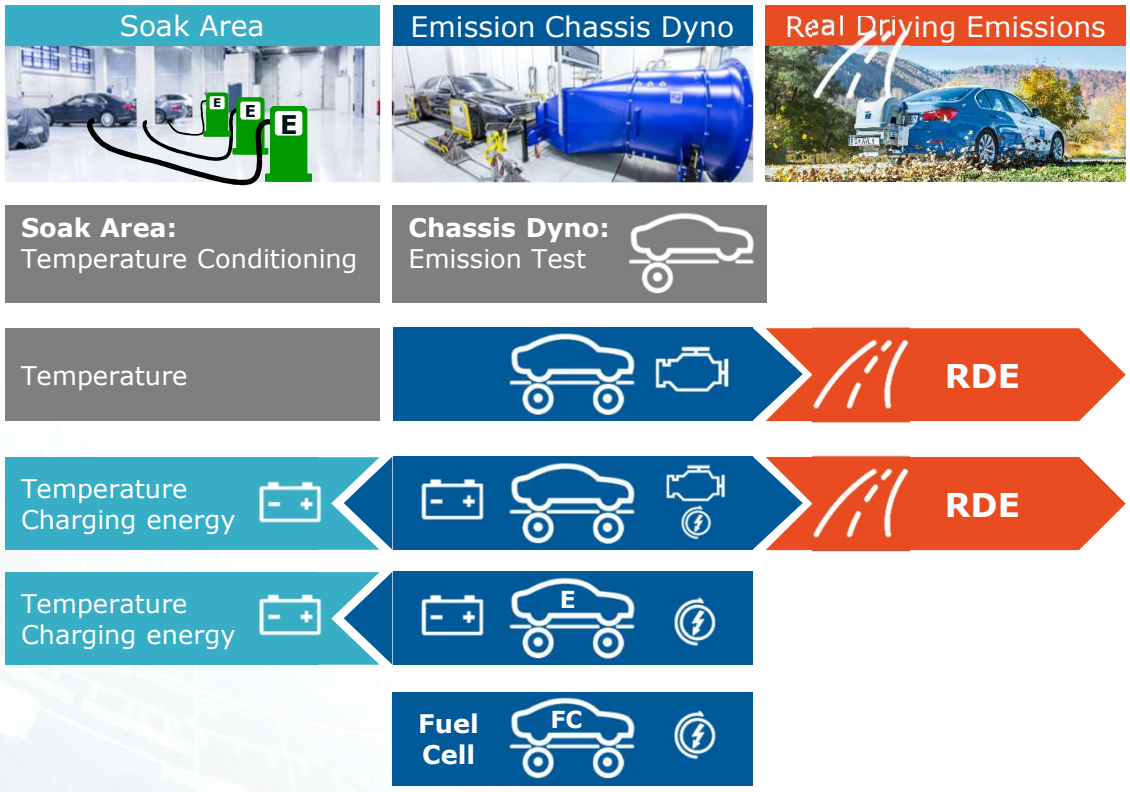


Example: EPA / CARB SAE J1711 Workflow

Plug-In Hybrid vehicles (OVC):

- For Plug-In Hybrid vehicles (OVC) the hybrid batteries will be charged and discharged during soak times.
- That requires to:
  - measure SOC and Energy flow
  - record the data
  - link the data to the test vehicle data base
  - integrate this data in the final emission test report of the vehicle
  - most likely that needs to be done for several vehicles in parallel

Light-Duty Emission LAB 2.0



Since 50 years a vehicle was temperature conditioned and afterwards an emission test cycle was done. (1966 CARB Test procedure)

RDE extends emission testing to real driving conditions on the road.

Electrification extends emission testing into the Soak area, which becomes part of the measurement

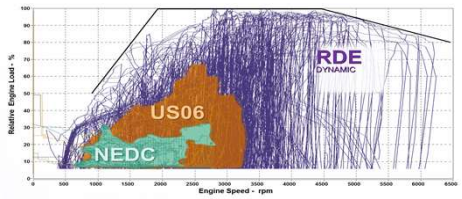
E-Vehicles must also run a regular emission test cycle (Energy consumption and driving range measurement)

Fuel-Cell Vehicles must also run a regular emission test cycle for H2 consumption evaluation


RDE
HP DK 207
PEMS Installation

Impact to Emissions - Examples

Drive Cycles:



Vehicles must be clean in a much larger area of the engine map:

- NEDC → WLTC
- Real Driving Emissions

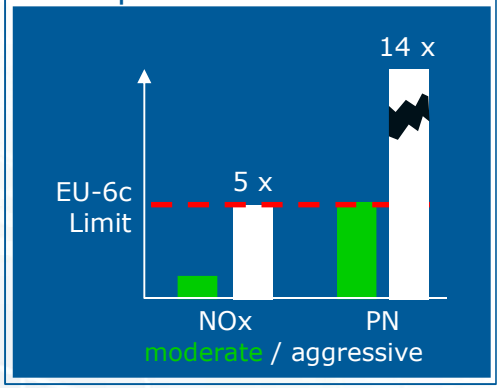
Example:

Drive Style:

Drive style has a large impact (by factors) on emission:

- aggressive
- moderate

Example:

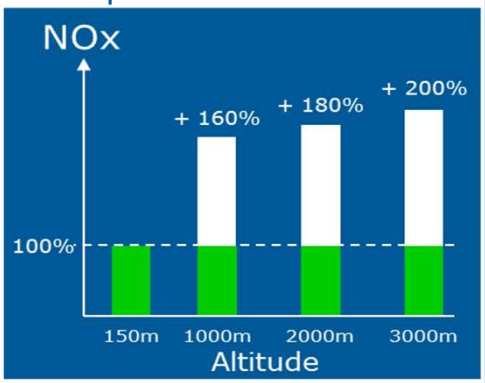


Altitude:

Impact of altitude:

- physical
- calibration, like when EGR is switched off

Example:

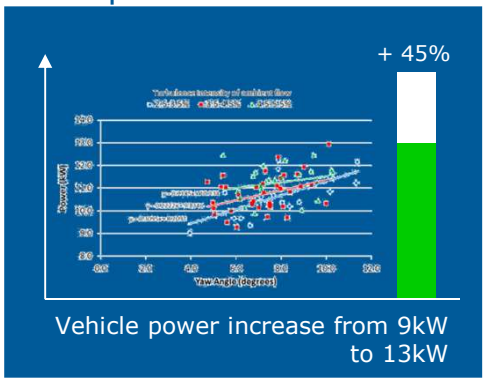


Wind:

Impact of wind is:

- crosswind
- traffic turbulences
- drafting (Windschatten)

Example:

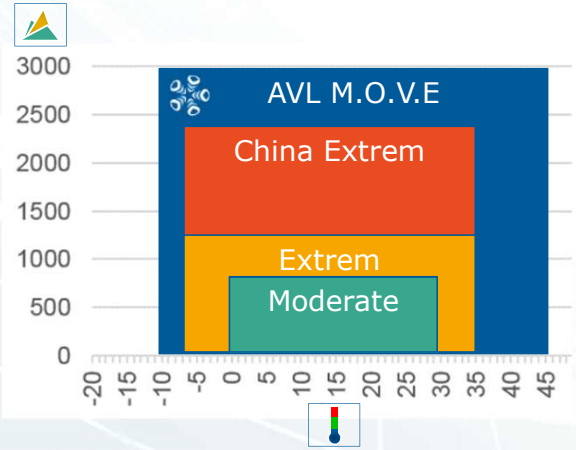


Technical Regulations: RDE

Application

Standard

Real Driving Emissions (2016/427 1st package, 2016/646 2nd package, 3rd package)



Light duty vehicle on Real Driving Emission testing:

- Portable Emission Measurement System (PEMS) to measure CO2, CO, NOx, PN, Exhaust flow, Speed and GPS data.
- Implementation: EU 2016, Korea 2018, China 2019, India 2020, Japan 2021

Limits:

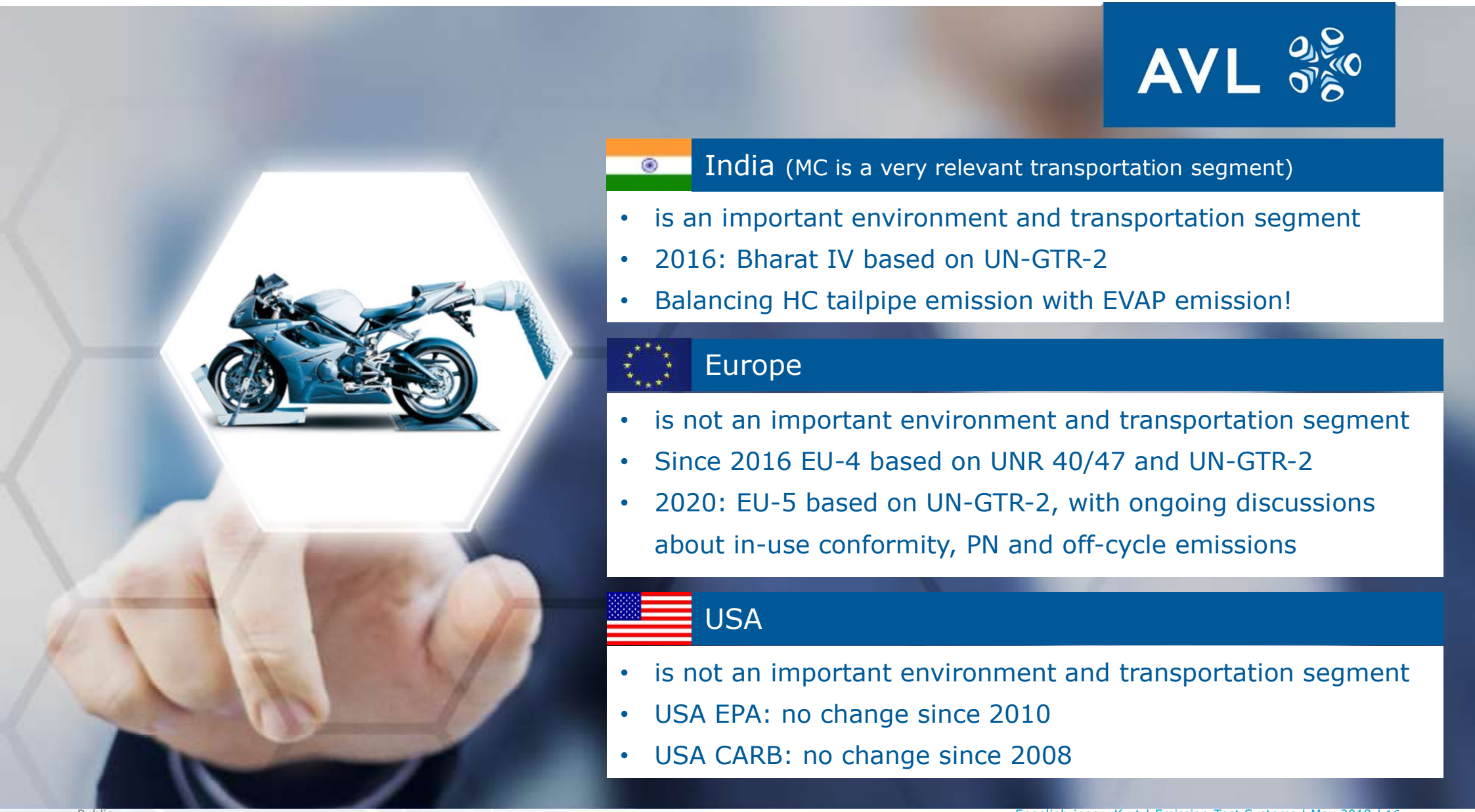
- CF NOx: 2.1 → 1.5 CF PN: 1.5 → 1.x (in discussion)
- 2 calculation options, EMROAD (JRC) or CLEAR (TU-Graz)

RDE Test requirements:

- 30min conditioning drive, 5-56h soak time, cold test and hot start test
- RDE Drive between 90 to 120min in normal traffic.
- 34% Urban (<60km/h), 33% Rural (60 ... 90km/h), 33% Motorway (>90km/h)
- max. Speed 145km/h (can be extended to 160km/h on test track)
- positive altitude gain < 1200m/100km
- OVC Hybrid test in Charge–Sustaining mode
- Periodical Regeneration w/o Regeneration use ki-factors

Ambient conditions:

- 0°C to 30°C (extended range -7°C to 35°C)
- up to 700m (extended range 1300m) (China 2400m)



India (MC is a very relevant transportation segment)

- is an important environment and transportation segment
- 2016: Bharat IV based on UN-GTR-2
- Balancing HC tailpipe emission with EVAP emission!

Europe

- is not an important environment and transportation segment
- Since 2016 EU-4 based on UNR 40/47 and UN-GTR-2
- 2020: EU-5 based on UN-GTR-2, with ongoing discussions about in-use conformity, PN and off-cycle emissions

USA

- is not an important environment and transportation segment
- USA EPA: no change since 2010
- USA CARB: no change since 2008

India Standards

India Motorcycle Standard [g/km]

Standard	Application	Description	Test Cycle
Bharat III	2010	All 2W	IDC Type1
		3W PI	
		3W CI	
Bharat IV	2016 TA: 2017 AV	2W Class1, Subclass 2-1 PI	WMTC
		2W Subclass 2-2 PI	
		2W Subclass 3-1, 3-2 PI	

Description	PM	CO	NOx	HC+NOx	
				EVAP [g/test]	
				< 2,0	< 6,0
All 2W		1		1	1
3W PI		1,25		1,25	1,25
3W CI	0,05	0,5		0,5	0,5
2W Class1, Subclass 2-1 PI		1,403	0,39	0,79	0,59
2W Subclass 2-2 PI		1,97	0,34	0,67	0,47
2W Subclass 3-1, 3-2 PI		1,97	0,2	0,4	0,2

Source: Delphi worldwide emissions standards PC-LDV

Eu-4 and EU-5 Standards

EU-4: 2016 based on UN-ECE-Regulation 40/47 and GTR-2

Introduction of PM limits for CI and GDI engines, only

Vehicle Category	Vehicle Category Name	Propulsion Class	Mass of [mg/km] CO	THC	NOx	PM		Test Cycle
			L_1	L_2	L_3	L_4		
L1e-A	Powered cycle	PI/CI/Hybrid	560	100	70	-		ECE R47
L1e-B	Two-wheel moped	PI/CI/Hybrid	1.000	630	170	-		ECE R47
L2e	Three-wheel moped	PI/CI/Hybrid	1.900	730	170	-		ECE R47
L3e [1)] L4e	Two-wheel motorcycles with and without side-car	PI/CI/Hybrid v_{max} < 130 km/h	1.140	380	70	-		WMTC, Stage 2
L5e-A L7e-A	Tricycle Heavy on-road quad	PI/CI/Hybrid v_{max} ≥ 130 km/h	1.140	170	90	-		WMTC, Stage 2
		CI/CI/Hybrid	1.000	100	300	80		WMTC, Stage 2
L5e-B	Commercial tricycle	PI/PI/Hybrid	2.000	550	250	-		ECE R40
		CI/CI/Hybrid	1.000	100	550	80		ECE R40
L6e-A	Light on-road quad	PI/PI/Hybrid	1.900	730	170	-		ECE R47
L6e-B	Light quadrimobile	CI/CI/Hybrid	1.000	100	550	80		ECE R47
L7e-B	Heavy all terrain quad	PI/PI/Hybrid	2.000	550	250	-		ECE R40
L7e-C	Heavy quadrimobile	CI/CI/Hybrid	1.000	100	550	80		ECE R40

EU-5: 2020 based on UN-ECE GTR-2

open discussion until 2017 (Effect study) in-use conformity, off-cycle emissions and PN

Vehicle Category	Vehicle Category Name	Propulsion Class	Mass of [mg/km] CO	THC	NHMC	NOx	PM [2)]	Test Cycle
			L_1	L_{2A}	L_{2B}	L_3	L_4	
L1e-A	Powered cycle	PI/CI/Hybrid	500	100	68	60	4,5	Revised WMTC [3)]
L1e-B-L7e	All other L-category vehicles	PI/PI/Hybrid	1.000	100	68	60	4,5	Revised WMTC
		CI/CI/Hybrid	500	100	68	90	4,5	Revised WMTC

Source: Delphi worldwide emissions standards PC-LDV

USA Standards

USA: EPA Motorcycle Standard [g/km]

Year	Class	Disp. (cc)	HC corp. ave	CO	HC+NOx	
					corp. ave	max
06+	I	50-169	1,0	12		
06+	II	170-279	1,0	12		
06-09	III	≥ 280	1,0	12	1,4	5,0
10+	III	≥ 280		12	0,8	5,0

USA: CARB Motorcycle Standard [g/km]

Year	Class	Disp.	HC		CO	HC+NOx	
			corp. ave	max		corp. ave	max
88-03	I & II	50-279	1,0	2,5	12		
88-03	IIIa	280-699	1,0	2,5	12		
	IIIb	700+	1,4	2,5	12		
04-07	III	≥ 280			12	1,4	2,5
08+	III	≥ 280			12	0,8	2,5

Source: Delphi worldwide emissions standards PC-LDV

India

- 2020 direct from Bharat-IV to Bharat-VI
- 2020 from UNR-49 to GTR-4

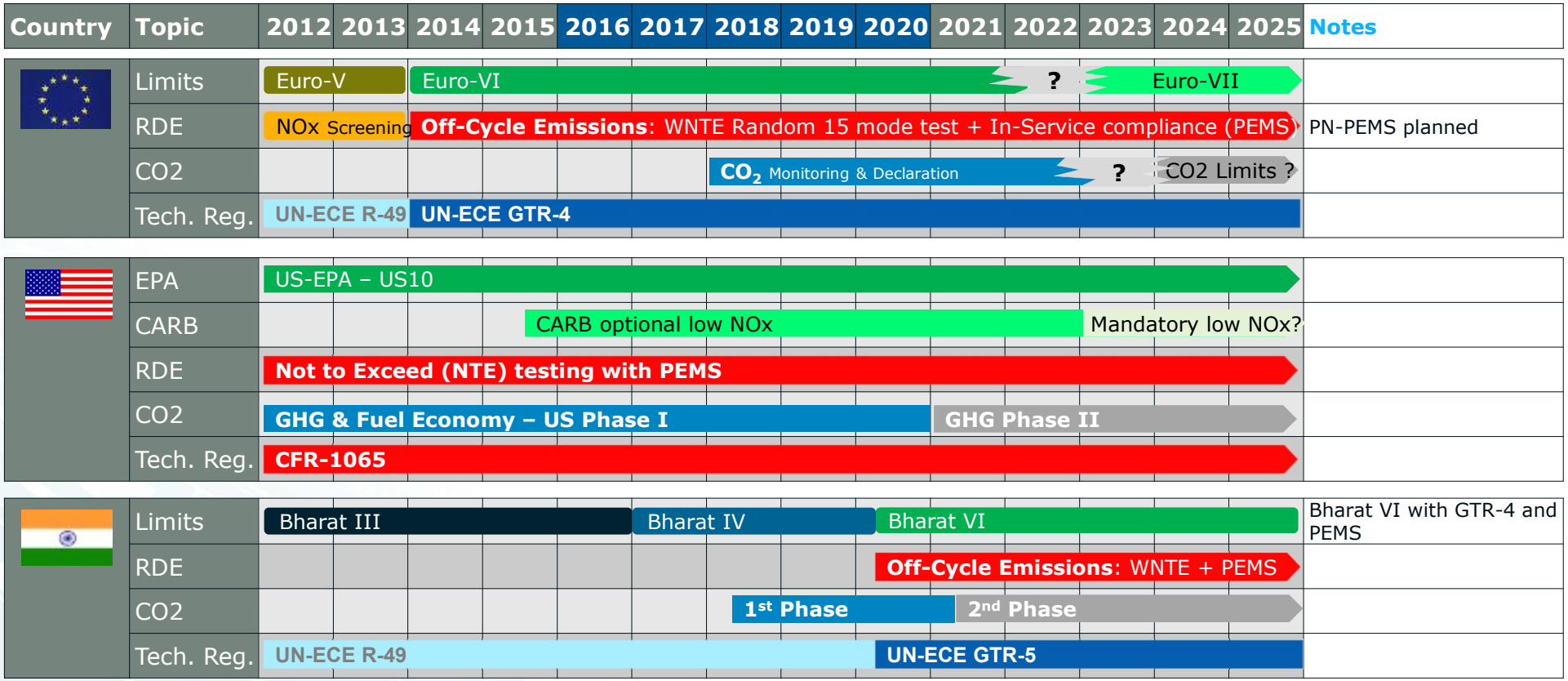
Europe EU-VI

- Euro VI trucks and busses are clean
- Test Cycle + Off-Cycle and PEMS testing
- CO2 Monitoring / Declaration / Limit (?) based on vehicle
- Hybrid test procedures

USA US-10

- CARB Low NOx Option (reduction by a factor of 10)
- PEMS (NTE) testing
- GHG Phase II

Emission Legislation – Heavy Duty Engines



Emission Legislation – Heavy Duty Engines

			EU-I 1992	EU-II 1996	EU-III 2000	EU-IV 2005	EU-V 2008	EU-VI 2013
Test cycles EU-I+II 13-Mode EU-III+IV ESC EU-VI WHSC	CO	g/kW-h	4,50	4,00	2,10	1,50	1,50	1,50
	THC	g/kW-h	1,10	1,10	0,66	0,46	0,46	0,13
	NMHC	g/kW-h						
	CH4	g/kW-h						
	NOx	g/kW-h	8,00	7,00	5,00	3,50	2,00	0,40
	PM	g/kW-h	3,60	0,15	0,10	0,02	0,02	0,01
	NH3	ppm				25	25	10
	PN	#/kWh						8 E11
	CO2, FC	g/kW-h						no
	NO2	g/kW-h						
Test cycles EU-III+IV ETC EU-VI WHTC	CO	g/kW-h			5,40	4,00	4,00	4,00
	THC	g/kW-h						0,16
	NMHC	g/kW-h			0,78	0,55	0,55	
	CH4	g/kW-h			1,60	1,10	1,10	
	NOx	g/kW-h			5,00	3,50	2,00	0,46
	PM	g/kW-h			0,16	0,03	0,03	0,01
	NH3	ppm				25	25	10
	PN	#/kWh						6 E11
	CO2, FC	g/kW-h						no
	NO2	g/kW-h						

no change | change | important

Starting with EU-III up to EU-VI:

- All the time big changes in Heavy Duty legislations.
- Resulting in clean vehicles on the road


ZDF
MERCEDES ACTROS
250
mg/km NOx
643
mg/km NOx
C220
Quelle: TNO

Emission Legislation – Heavy Duty Engines

Application:	Country:	Main Topics:

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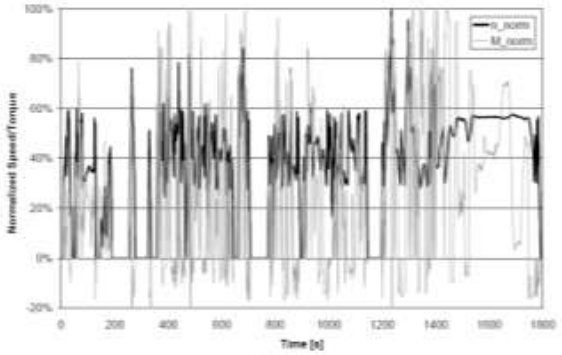
GAS & PM PEMS

Euro VI 2013 & Bharat-VI 2020:

- Particle Number (PN) limit established in addition to the Particulate Mass (PM) limit for Diesel engines.
- GTR-4 (Global Test Procedure) from UN-ECE.
- WHSC (World Harmonized Stationary Cycle) - Hot test
- WHTC (World Harmonized Transient Cycle) - 2 Tests one cold and one hot
- “Real Driving Emissions” limits by:
  - Random 15 mode stationary “Off Cycle Emissions” (OCE) test
    - app. 1700m and temperature up to 38°C (depending on altitude)
  - “In-Service” on-road tests in vehicle with PEMS (Portable Emission Measurement Systems)
    - CO2, CO, NOx, THC, PM (PN in discussion for EU)
    - Mix of urban (0-50 km/h), rural (50-75 km/h) and motorway (> 75 km/h) conditions
    - Temperature and Altitude as defines for off cycle emission requirements
    - Limits are based on the laboratory limits multiplied by 1.5 (CF)
    - Result calculation by “Work based window”

TECHNICAL REGULATIONS – UN-ECE GTR-4

Application:	Standard	Standard Test Cycles:



World Harmonized Transient Cycle (WHTC):

- 2 Tests one cold and one hot
- „Soak time“ between cold and hot cycle 10 +/- 1 min
- Weighting factors 14% cold test and 86% hot test

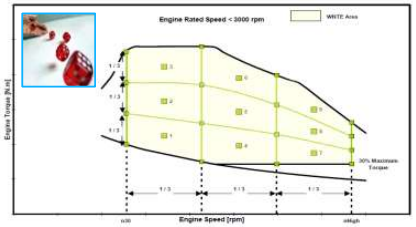
Mode	Normalized Speed (per cent)	Normalized Load (per cent)	WF for reference	Mode length (s) incl. 20 s ramp
0	Motoring	-	0.24	-
1	0	0	0.17/2	210
2	55	100	0.02	50
3	55	25	0.10	250
4	55	70	0.03	75
5	35	100	0.02	50
6	25	25	0.08	200
7	45	70	0.03	75
8	45	25	0.06	150
9	55	50	0.05	125
10	75	100	0.02	50
11	35	50	0.08	200
12	35	25	0.10	250
13	0	0	0.17/2	210
Sum			1.00	1895

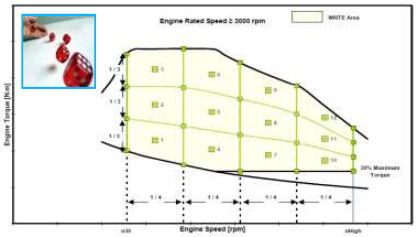
World Harmonized Stationary Cycle (WHSC):

- Hot test
- Engine conditioned before the test for 10min in mode 9
- Ramped Modal Test, the listed weighting factors are only for reference but not any more used like in the old stationary cycles.

TECHNICAL REGULATIONS – UN-ECE GTR-4

Application:	Standard	Off Cycle Compliance:





Off Cycle Emissions (OCE):

- Euro VI regulation introduced a off-cycle emissions (OCE) testing requirements. OCE measurements, performed during the type approval testing, follow the NTE (not-to-exceed) limit approach.
- A control area is defined within the engine map. This is divided into grids. A 15 mode ramped modal stationary test is done by 3 randomly selection grids, each with 5 randomly selected points.
- Emissions must apply over a wide range of ambient conditions.

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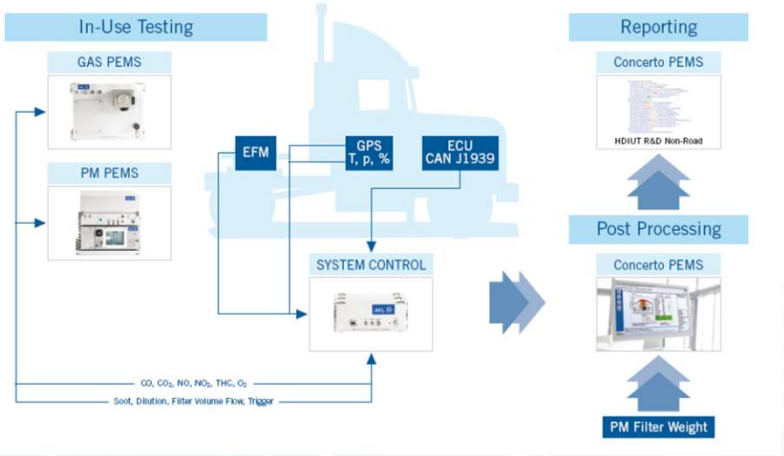
GAS & PM PEMS

In-Service Emissions conformity (compliance):

- “Real Life” Emission test on the road by PEMS (Portable Emission Measurement System).
- First in-service test should be conducted at the time of type approval testing
- CO2, CO, NOx, THC, PM (PN in discussion for EU)

HEAVY DUTY – PEMS TESTING

AVL M.O.V.E GAS & PM PEMS



In-Service Emissions conformity (compliance):

- "Real Life" Test on the street with PEMS (Portable Emission Measurement System). First in-service test should be conducted at the time of type approval testing
  - CO2, CO, NOx, THC, PM (PN in discussion for EU)
  - Exhaust flow rate, Speed, n, M and GPS data.

PEMS Test

- EU testing is conducted over a mix of urban (0-50 km/h), rural (50-75 km/h) and motorway (> 75 km/h) conditions, with exact percentages of these conditions depending on vehicle category.

Ambient conditions

- Temperature and Altitude as defines for off cycle emission requirements

Limits and Result calculation

- Limits are based on the laboratory limits multiplied by 1.5
- EU Result calculation by "Work based window"
- US Result calculation by NTE-Events (during ≥30seconds operation with high enough engine torque, speed and power

OFF CYCLE EMISSIONS COMPLIANCE

Application:	Standard	Main Topics: in principle very similar between US and EU regulation

Legislation Requirement

ECE/TRANS/180/Add.10

10. STATEMENT OF OFF-CYCLE EMISSION COMPLIANCE

In the application for certification or type approval the **manufacturer shall provide a statement** that the engine family or vehicle **complies with the requirements** of this OCE gtr. In addition to this statement, compliance with the WNTE limits **shall be verified through additional tests** and certification procedures defined by the Contracting Parties.

10.1. Example statement of Off-Cycle Emission compliance

The following is an example compliance statement:
"(Name of manufacturer) attests that the engines within this engine family comply with all requirements of the OCE gtr. (Name of manufacturer) **makes this statement in good faith, after having performed an appropriate engineering evaluation of the emissions performance** of the engines within the engine family **over the applicable range of operating and ambient conditions.**"

10.2. Basis for Off-Cycle Emission compliance statement

The **manufacturer shall maintain records at the manufacturer's facility which contain all test data, engineering analyses**, and other information which provides the basis for the OCE compliance statement. The manufacturer shall provide such information to the Certification or Type Approval Authority upon request.

Example of execution

1. NTE Compliance Statement

[redacted] states that all the engines in 2014 Model Year engine family [redacted] comply with the not-to-exceed emission standards specified in subpart B of Part 1039 for all normal operation and use when tested as specified in §1039.515 (test procedure provisions in 40CFR 86.1370-2007).

2. NTE Test Program

[redacted] contracted with AVL to conduct demonstration testing at the AVL test facility in Graz, Austria. The demonstration testing was conducted in October 2012. A single NTE test zone envelope and associated test points were selected to represent the three planned engine family power ratings [redacted] engine was selected for NTE testing and represents the engine family. NTE test data is available upon request.

2.2. Environmental Operating Conditions

The engine was tested at the conditions listed in Table 2.2.

Temperature / Altitude	38°C	34°C	30°C	25°C	10°C
Sea-level	✓			✓	✓
2500'		✓			
5500'			✓		

Table 2.2: Ambient Conditions

3. Conclusion

Based on the results from the testing described above, [redacted] concludes that engine family [redacted] complies with all NTE emission requirements.

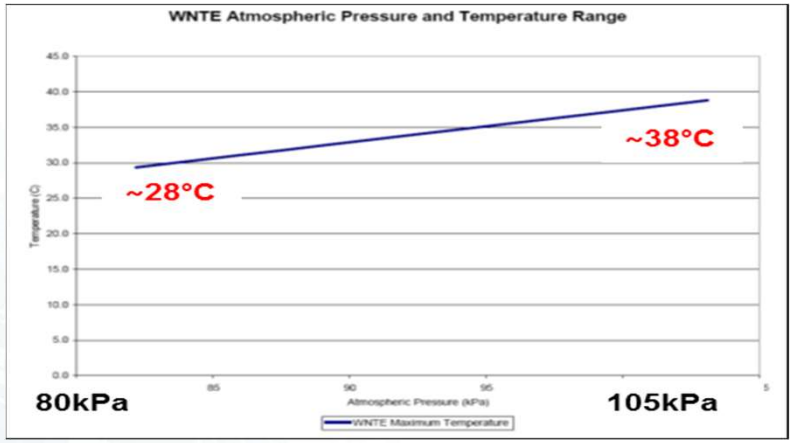
OFF CYCLE EMISSIONS COMPLIANCE

Application:	Standard	Main Topics: in principle very similar between US and EU regulation

Legislation Requirement

- Absolute air pressure down to 82.5kPa
- ... which is app. 1700m altitude
- Engine coolant temperatures within 70°C to 100°C
- Ambient temperature less or equal to

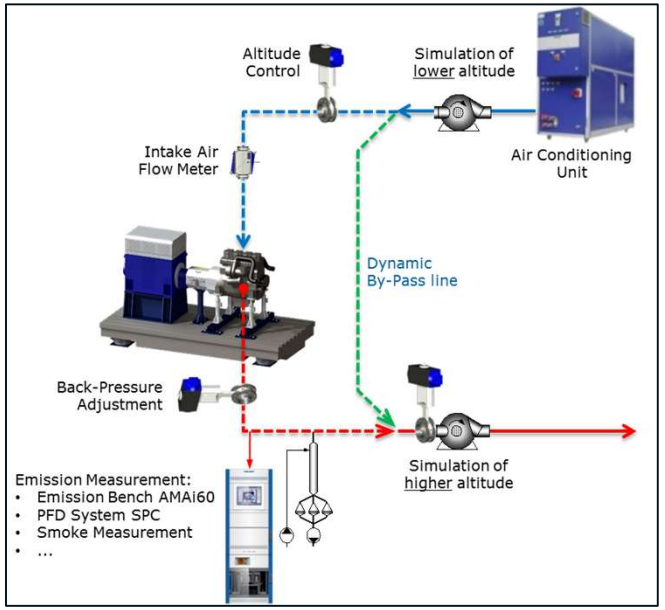
$$T[K] =< -0.4514 * (101.3 – pb[kPa]) + 311$$



- in addition for OBD purpose also -7°C

Solution stationary and transient testing

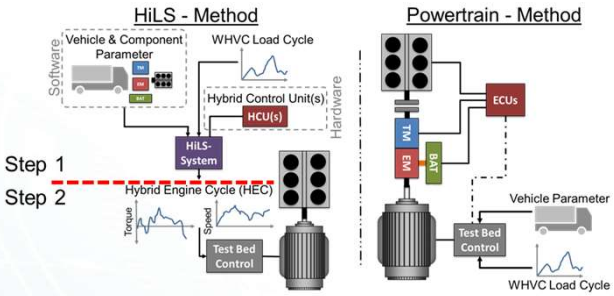
- Intake air temperature control
- Intake air Humidity control
- Altitude simulation of engine intake air and tailpipe pressure adjustment



- Alternative: High altitude chamber

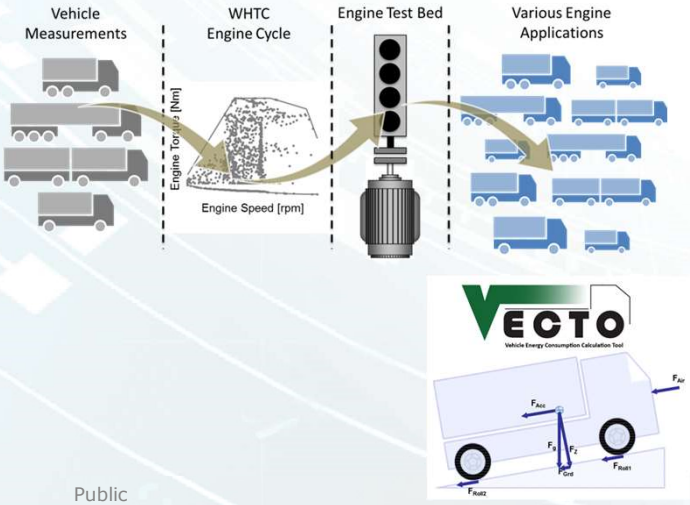
HEAVY-DUTY HYBRID, CO2 AND FC TESTING

Hybrid Heavy Duty test procedure – from engine to powertrain



- For hybrid powertrains the total powertrain, energy storage and powertrain control units must considered.
- In order to avoid testing on a chassis dynamometer, a HILS (Hardware-in-the-loop simulation) was developed in Japan. In the WHVC cycle, the influence of the hybrid components on the engine operation is tested. 2 Variants exists:
  1. By HILS an engine test cycle is generated and tested on an engine testbed.
  2. The whole hybrid powertrain is tested on a powertrain testbed

CO2 and Fuel consumption labeling – from engine to vehicle



- Contrary to exhaust emissions, fuel consumption and CO2 emissions are not part of the GRPE mandate. Therefore, regional regulations are under development.
- EU: develops a vehicle based procedure, based on transport work and a simulation tool VECTO (TU-Graz) with 5 different test cycles representative for different vehicle categories. Implementation planed for 2018 for Trucks and 2019 Buses
- USA: Green House Gas rule developed by EPA and NHTSA. There are separate limits values for engine and vehicle. CO2 and FC are calculated with a simulation tool GEM.
- Japan: since 2015 fuel economy limits are based on a simulation approach. FC is calculated from engine testbed data and vehicle class generic vehicle parameters, which are base on JE05 and a motorway cycle.
- China: regulates on base of a modified WHVC to be run on a chassis dyno.

India

- 2020 Bharat-IV with GTR-11 (NRSC and NRTC)
- 2023/24 Bharat-V with PEMS ISC

Europe Stage-V

- All power categories are regulated
- Not To Exceed (NTE)
- In-Service Monitoring (ISM) PEMS testing reporting
- NOx- and PM Control Diagnostic
- PN Limit
- CO2 reported, indication for CO2 limitation in future

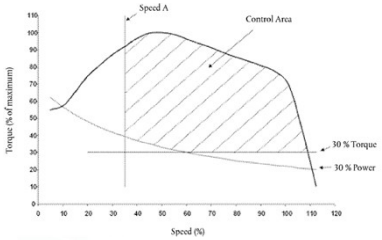
USA Tier 4

- PEMS in discussion
- GHG and CO2

Emission Legislation – Non-Road Engines

Country	Topic	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Notes
EU	Limits	III-B	Stage - IV						Stage - V							
	RDE		NTE						Off-Cycle + in-service monitoring (PEMS)							
	CO2						CO_2 Monitoring & Declaration									
	Tech. Reg.	ISO	GTR-11 (NRSC + NRTC test cycles)													
US	Limits	Tier-4														
	RDE									PEMS in Discussion (NRIUT)						Currently no progress
	CO2	GHG Regulation and CO2 Monitoring & Declaration														
	Tech. Reg.	CFR-1065														
India	Limits	CEV/TREM III								BS IV			Stage V			
	RDE												PEMS			ISC with PEMS, CF tbd
	CO2															
	Tech. Reg.	ISO 8178								GTR-11 (NRSC + NRTC test cycles)						

EU Stage V



NTE (Not to Exceed) on test beds

- For electronically controlled engines of categories NRE, NRG, IWP, IWA, and RLR.
- When an engine is tested … emissions sampled at any randomly selected point within NTE area … shall not exceed the applicable emission limit values … by a factor of 2.0.
- The technical service shall select random load and speed points within the control area for testing (NRSC C1 cycles up to three points; NRSC D2, E2 and G2 one point).

AVL M.O.V.E GAS

In service monitoring (ISM)

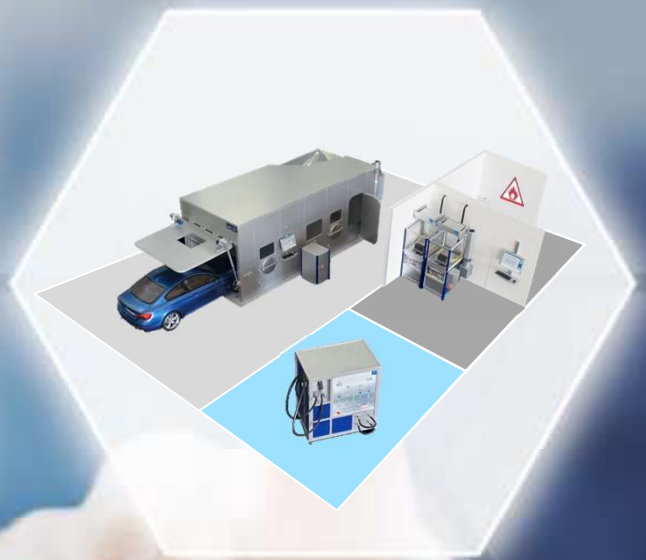
- PEMS (Portable Emission Measurement System)
- Gaseous emissions only (CO, HC, NOx, CO2), PM/PN is not in the scope
- Monitoring and reporting, but no limits.

NOx control diagnostics (NCD)

- NOx control and diagnostics (NCD)
  - Low reagent level, Reagent quality monitoring, Reagent dosing activity, Failures that might be attributed to tampering, impeded EGR valve, Removal or deactivation of any sensor that prevents the NCD from diagnosing failures
- Particulate control diagnostics (PCD)
  - Removal of the DPF or substrate, failures attributed to tampering, electrical failures, removal or deactivation of any sensor or actuator.
- Operator warning / inducement system

ISO 8178 - Parts

Part	Title and Topic	Notes
1	Test bed measurement systems for gaseous and particulate emissions	3rd edition 2017: with up-dates and alignment with CFR-1065, Formulas were moved to Part-4 and transient testing implemented from Part-11
2	Measurement of gaseous and particulate exhaust emission at site	only when Part-1 is not possible and agreed by involved parties. 2nd edition published in 2008. Will be up-dated with PEMS testing
3	Definitions and methods of measurement of exhaust gas smoke under steady-state conditions	Edition 1994 with Opacity and FSN filter smoke number. Revision started 2017: moving Opacity to Part-9, maybe adding BC
4	Test cycles for different engine applications	3rd edition 2017: Implementations of formulas from Part-1 and transient test cycle from Part-11
5	Test fuels	3rd edition 2015, 2017 revision started
6	Report of measuring results and tests	2013 revision started, draft approved in 2017.
7	Engine family determination	Engine variations with similar characteristics and design represented by one engine of the "engine family". 2nd edition 2015.
8	Engine group Determination	"Engine group" are engines of the same type, but modified when put into service. Still must comply with emission limits. 2nd edition 2015.
9	Text cycles and test procedures for test bed measurement of exhaust gas smoke emissions from compression ignition engines operating under transient conditions	2nd edition 2012, 2017 revision started: Implementation of opacity measurement from Part-3 relevant parts from Part-10. (done by AVL)
10	Test Cycles and test procedures for field measurement of exhaust gas smoke emissions from compression ignition engines operating under transient conditions	1st edition 2002, 2017 revision started: Smoke measurement moved to Part-9.
11	Test-bed measurement of gaseous and particulate exhaust emissions from engines used in non-road mobile machinery under transient test conditions	"Withdrawn" (Edition from 2006). Content implemented in other parts, like transient cycle and formulas in Part-4, measurement in Part-1



2019 Large changes coming up in Europe and Japan

There are no plans currently to change the EVAP requirements from UNR-83:

- However ARAI takes part in the GTR-19 task force discussions

EVAP: Evaporative Emission

EVAP measuring evaporative emissions (mainly from fuel) form the complete vehicle, but only gasoline vehicles

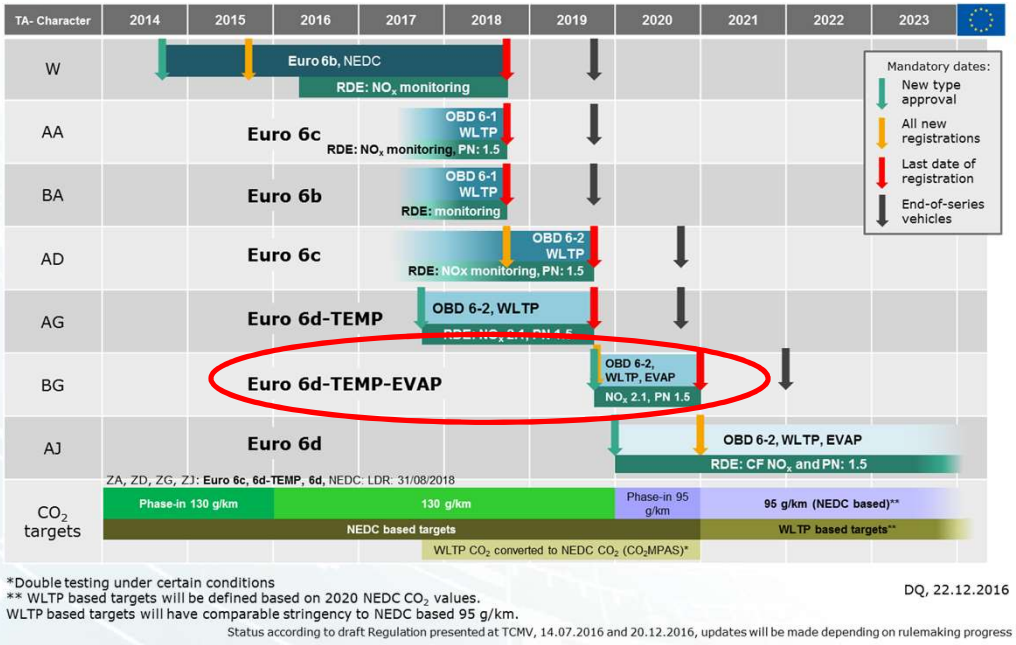
+ Point Source running a tailpipe emission cycle and measuring EVAP from selected points
+ Running Loss running an tailpipe emission cycle inside a SHED and measuring EVAP
+ Permeation test measuring the permeation of fuel system components

EVAP outlook

Current: little changes in worldwide EVAP legislation, therefore installed base 10 to 15 years old

Mid Term (2019): WLTP/EVAP EU, Japan and China will up-date its legislation, with modified or new test procedures

EU Legislation

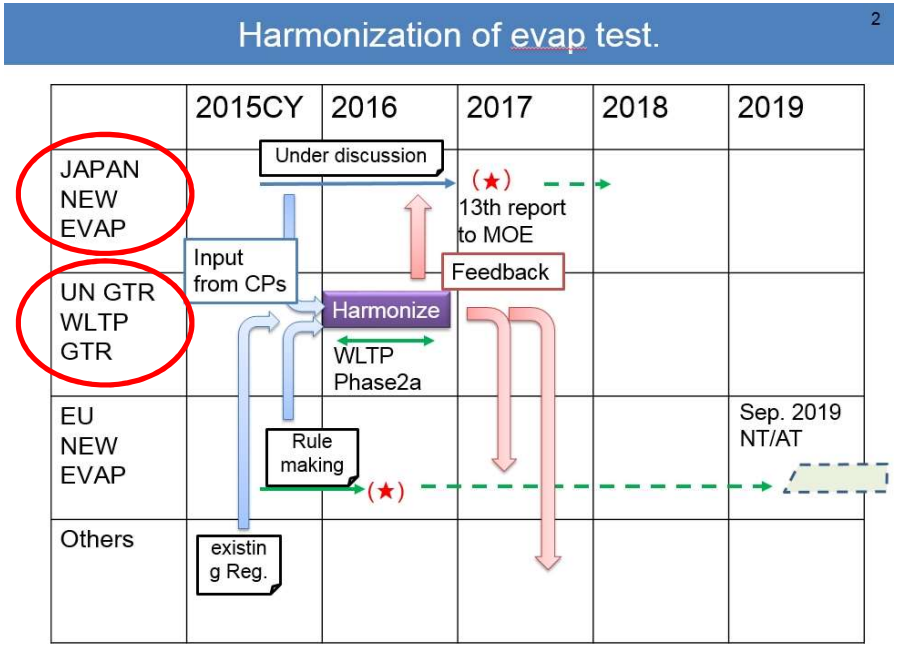


*Double testing under certain conditions
** WLTP based targets will be defined based on 2020 NEDC CO_2 values.
WLTP based targets will have comparable stringency to NEDC based 95 g/km.

DQ, 22.12.2016

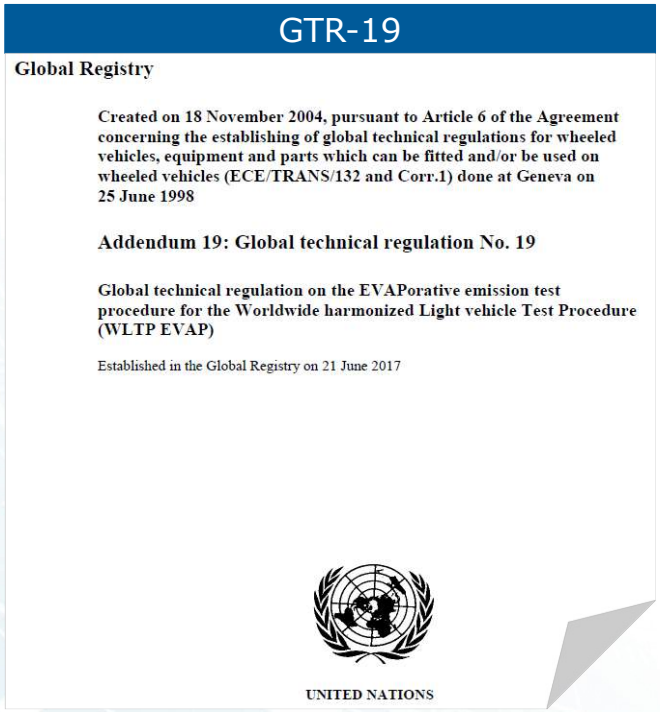
Status according to draft Regulation presented at TCMV, 14.07.2016 and 20.12.2016, updates will be made depending on rulemaking progress

Road map WLTP, GTR, EU and Japan



Long Term (2022): a new worldwide (except USA) Global Technical Regulation (GTR) will be established

UNR: GTR-19


GTR-19

Global Registry

Created on 18 November 2004, pursuant to Article 6 of the Agreement concerning the establishing of global technical regulations for wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles (ECE/TRANS/132 and Corr.1) done at Geneva on 25 June 1998

Addendum 19: Global technical regulation No. 19

Global technical regulation on the EVAPorative emission test procedure for the Worldwide harmonized Light vehicle Test Procedure (WLTP EVAP)

Established in the Global Registry on 21 June 2017

UNITED NATIONS

Main GTR-19 topics:

- Effective control of evaporative emissions in real life and improved durability
  - replacing UNR-83 (NEDC) with WLTP test procedures
  - **Fuel tank aging**
  - **Carbon Canister fuel aging**
  - **Sealed fuel tank systems (mainly for plug-in hybrids)**

- not in the scope currently
  - no running losses test (running losses SHED nor Point Source)
  - no refueling emission tests

In 2028 India wants to be aligned with global harmonized emission legislations

So lets have a look at what UN-ECE and EU is currently doing and planning

Euro-5 and Euro 6 Legislation

REGULATION (EC) No 715/2007 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

Article 4 - Manufacturers' obligations

... the technical measures taken by the manufacturer must be such as **to ensure that the tailpipe and evaporative emissions are effectively limited**, pursuant to this Regulation, **throughout the normal life of the vehicles under normal conditions of use**.

Article 5 – Requirements and tests

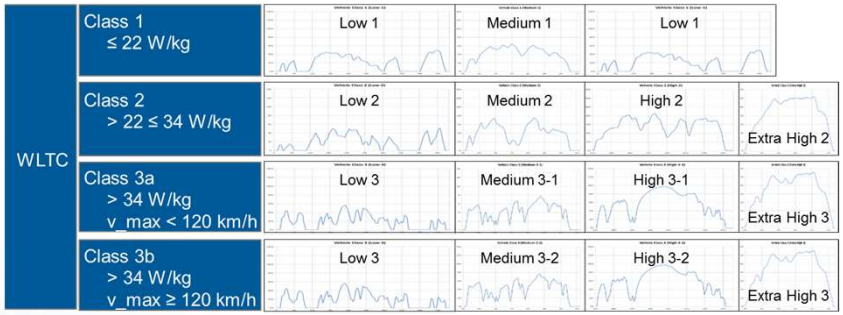
The use of defeat devices ... shall be prohibited. The prohibition shall not apply where:

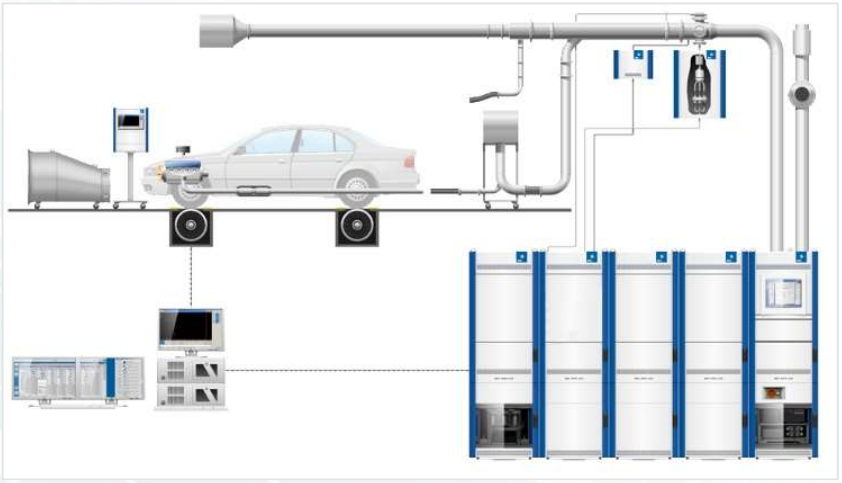
- **the need is justified for protecting the engine against damage**
- the device does not function beyond engine starting, or
- the conditions are included in the test procedures ...

Article 13 – Penalties

Member States shall lay down the provisions on **penalties** applicable for infringement by manufacturers of the provisions of this Regulation and **shall take all measures necessary to ensure that they are implemented. The penalties provided for must be effective, proportionate and dissuasive.**

Technical Regulations: UN-ECE GTR-15





Test cycle and driving validation

- New Drive Cycle – WLTC (Worldwide harmonized Light duty Test Cycle):
- Different drive cycles for 4 vehicle classes C1, C2, C3a and C3b, which depends on the Power/Weight ratio of the vehicle and the max. velocity.
- Longer (20 → 30 min), Faster 34 → 46km/h avg. and 120 → 131 km/h max.
- Higher Dynamic, Less Idle
- Individual shifting points for each vehicle for manual transmissions.
- 3 or 4 Phases

Road and Engine Load for testing

- More detailed definition of road load determination and testing simulation on the chassis dynamometer. (Avoiding fuel consumption optimization)
- Testing of a "Low CO2" and "High CO2" emitting vehicle per vehicle family
- Electric energy flow evaluated also for the 12V vehicle battery and no battery charging during soak time.

Vehicle preparation and conditioning

- More accurate definition of the temperature 23°C +/-5°C, during soak , engine start (+/- 3°C) and test execution (+/-5°C).

Test and measurement procedures

- Bag analyzing sequence optimized (calibration and checks once per test run)
- PM/PN Background correction

GTR-15: Drive Cycle - WLTC (Class 3b)

Time [sec]:	1800
Distance [km]:	23,3
Phases:	4
Speed [km/h]	
- average:	46,5
- max:	131,3
Pos. Acceleration [km/h/s]	
- average:	0,2
- max:	1,7
Idle [sec]:	235 13%
Urban [sec]:	993 55%
Rural [sec]:	300 17%
Highway [sec]:	273 15%

NEDC

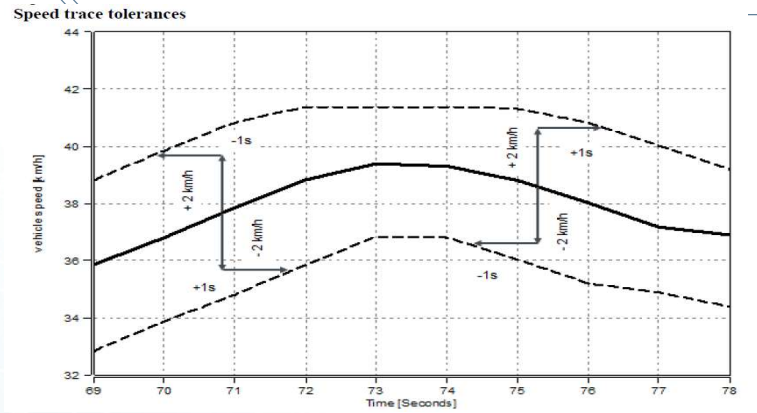
Time [sec]:	1220
Distance [km]:	11,0
Phases:	2
Speed [km/h]	
- average:	32,5
- max:	120,0
Pos. Acceleration [km/h/s]	
- average:	0,1
- max:	1,1
Idle [sec]:	334 27%
Urban [sec]:	654 54%
Rural [sec]:	150 12%
Highway [sec]:	83 7%

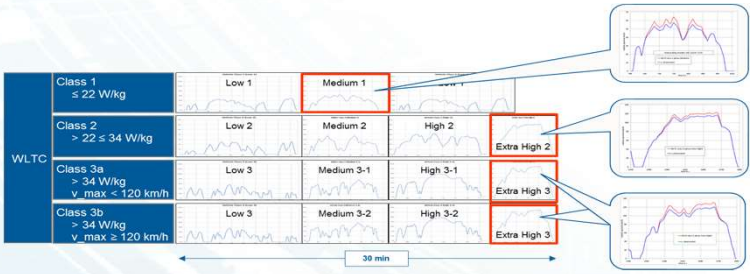
There are 4 different drive cycles for 4 vehicle classes:

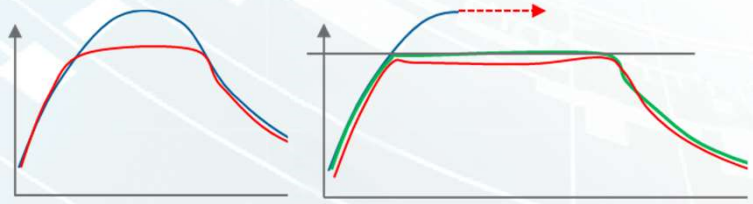
- Class 1: ≤ 22 W/kg
- Class 2: > 22 ≤ 34 W/kg
- Class 3a: > 34 W/kg and v_max < 120 km/h
- Class 3b: > 34 W/kg and v_max ≥ 120 km/h

Gear shift points are calculated for each individual model with a manual transmission (= driver makes the decision when to switch)

GTR-15: Drive cycle - modifications







Driving tolerances

- Drive cycle tolerances are the same as before, +/- 2km/h and +/- 1sec
- Driving Trace Indexes must be calculated and reported (monitoring), but will not be used to make a pass/fail decision on the test run.
  - Energy rating
  - Distance rating
  - Energy economy rating
  - Absolute speed changing rating
  - Inertia work rating
  - Root mean squared speed error

Downscaling of Drive cycle

Drivability problems may occur for low power vehicles in certain parts of the WLTC, with high vehicle speed and high accelerations.

- Downscaling procedure will be applied to improve drivability
- The standard speed curve is downscaled by a mathematically method, which is specific for the individual vehicle tested.

Cars with limited max. speed = “Capped speed” vehicles

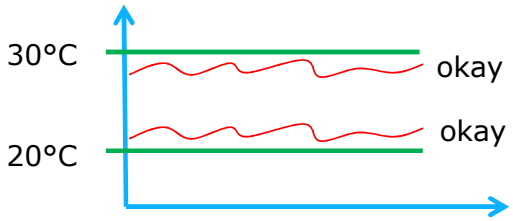
- Low power cars which can not follow the speed profile (even after downscaling) shall drive with full open throttle, driving tolerance violations are okay.
- Cars with a “Capped Speed” will run an modified drive cycle. Where the max speed of the drive cycle is the “Capped speed” but extended to still cover the “same drive distance”, as the original WLTC.

GTR-15: Temperature Conditioning

Soak Area (23°C)

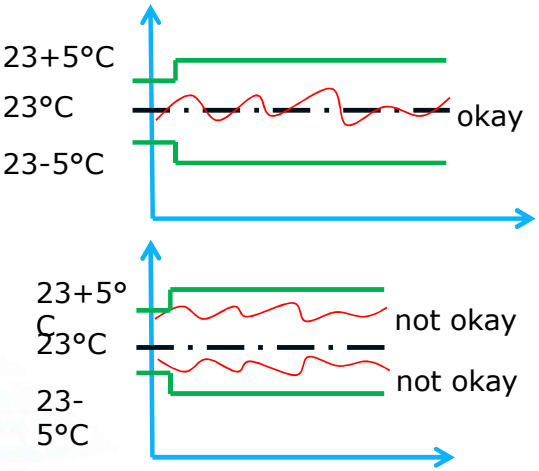
Emission Chassis Dyno

UN-ECE R-83 (Temperature Range)



- Temperature in soak-Area and test cell be shall be between 20 and 30°C and relative stabile.
- Humidity (5.5 - 12.2g H2O/kg dry air) shall be measured at the vehicle cooling fan outlet

GTR-15 (Temperature Set Value)



- Temperature in Soak-Area and Test bed have a set point of 23°C and an tolerance of +/-5°C.

Soak-Area:

- Set point 23°C +/-3°C (1Hz data 5min running average)

Test-Cell:

- Set point 23°C +/-3°C when the test is started
- Set point 23°C +/-5°C (1Hz data)

- Humidity (5.5 - 12.2g H2O/kg dry air) shall be measured at the vehicle cooling fan outlet

CO2 Testing requirements (EU)

CO2 tested for a "CO2 Low" and "CO2 High" vehicle configuration

CO2 emission has to be tested for a vehicle expected to have the lowest CO2 and for a vehicle expected to have the highest CO2-Emission, per vehicle family.
Individual vehicle CO2 emissions can be interpolated.

CO2 targets (130g/km, 95g/km) are still based on NEDC and UNR-83 testing

For pollutant emissions WLTC with WLTP have to tested and for CO2 OEM may chose to:

- run separately NEDC for CO2 emissions, or
- to predict NEDC result from the WLTC test data, by using the CO2mpas tool from JRC, to reduce testing burden.

14°C ATCT

Ambient Temperature Correction Test at 14°C (for EU)

WLTC	at 14°C with for 14°C corrected road load dyno parameters
Soak area:	14°C Trep ± 3°C (1Hz data as 5min running average)
Soak Time:	Preconditioning → max 10min to Soak area for min 9h → ATAC
Test cell:	14°C Trep ± 3°C at test start and ±5°C during test (1Hz)
Intake air humidity:	3.0 ≤ H ≤ 8.1 g H2O/kg dry air
Family Correction Factor:	FCF = CO2 Type-I@14°C / CO2 Type-I@23°C
Individual vehicle CO2:	CO2_ind = CO2_ind@23°C × FCF

Before: 1 vehicle was tested in a 20min NEDC test

+ 10 min since WLTC Test, (one test less per shift)

+ 1 more vehicle, CO_2low and CO_2high

+ 30min Ambient Temperature Correction Test 14°C

+ 90min RDE cold test

+ 90min RDE warm test

= app. 15 times more work load of testing

+ low emission under "normal conditions" of use

Guidance on AES and Defeat Devices

EC 715/2007 Evaluation of Auxiliary Emission Strategies and Defeat Devices)

EUROPEAN COMMISSION

26.1.2017

Brussels, 26.1.2017
C(2017) 352 final

COMMISSION NOTICE

of 26.1.2017

Guidance on the evaluation of Auxiliary Emission Strategies and the presence of Defeat Devices with regard to the application of Regulation (EC) No 715/2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6)


Remote Sensing


Vehicle Chasing


SEMS


Chassis Dyno


RDE


EVAP Emission

Extended documentation package (since May 2016)

- Manufacturer declaration that the vehicle does not contain any defeat device
- Extended BES/AES description
- Software versions and checksums

Evaluation and acceptance of AES

- AES for engine protection is limited to "catastrophic" engine damages and if better technologies are available it shall be used
- Check of parameters used to modulate emission control systems
- Check for EGR modifications (only under certain conditions)
- Check if intentional shifting of particle size below 23 nm, so it is not measured
- Check dual injection systems for gasoline vehicles that were not type approved as GDI

Defeat device recognition for member states surveillance testing (JRC proposal)

- Vehicle selection based on market share.
- "It is worth noting that ... also includes other types of emissions tests such as Evaporative emissions"

Screening the environmental performance

- Remote fleet monitoring with "Simplified Emissions Measurement Systems" (SEMS)
- Remote Sensing Devices (RSD) at fixed locations or as chasing test

Testing for Defeat Devices (with the need to keep a non-predictable character)

- Lab-Test with limited modified test — CF 1.0
- Lab-Test or Road-Test with conditions different than the legislative cycle — CF 1.1
- Road-test with uncontrolled parameters (e.g. RDE compliant testing) — CF 1.5
- "Surprise testing" to detect a defeat device (e.g. including Evaporative emissions) — CF 2 ... 5

→ if any test fails, vehicle is classified as „Suspicious" vehicle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