



Current and Future of Emission & Energy Testing

AVL Emission Test Systems

Content:

- 1 Introduction** Emission and energy legislation, more effort and global trends
- 2 Euro-7 (Light-Duty)** Targets, Limit proposals, Simplifications
- 3 Overview global emission legislations** USA, China, RoW, Non-Road, Marina
- 4 other requirements** CO2, Green-NCAP, Break-, Tire- and Road-wear, VIAQ, ISO-17025
- 5 Solutions** Type approval solutions, R&D Solutions, Products
- 6 Conclusion**

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Global emission legislation trends



Euro-7 (Light-Duty) / Euro-VII (Heavy-Duty)

- *"Here we are setting new standards. In the past you did measure emission in the lab, now you can test it anywhere"* Panagiota Dilara (European Commission)
- Vehicles are as clean as possible under "all" EU driving conditions over the entire useful life



"Business as usual"

- *Business as usual due to long-term strategy. Focus on low NOx and PM emissions. Green-House-Gas Standard 2*



"China on its way to a "China unique" legislation

- *More challenging than EU and USA, since combining low pollutant- with low fuel consumption limits. Total fleet monitoring for China 6b trucks, which must report all 10 sec ECU data to the authority.*



Japan adopting UN-Regulations

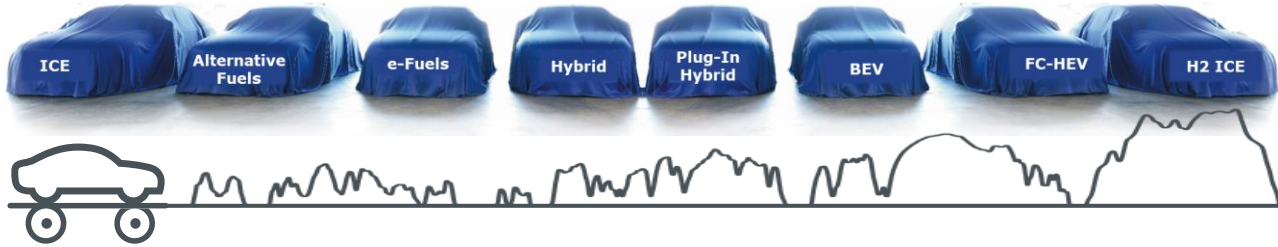


South-Korea – business as usual

Rest of World (RoW)






- *in some countries still fighting bad air quality. Closing fast the gap to western emission standards, like India, going directly from Euro-4 to Euro-6*

Testing requirements of different powertrains






Type approval testing is required for all vehicle types, nevertheless of powertrain type or energy source. A “car is a car” and it is driven by the same people in the same traffic. So all use the same drive cycle.

... depending on the type of powertrain and energy source, different measurements are performed.

What is measured ?	Pollutant	Consumption			Pure electric
	Emission 	Fuel 	Electricity 	Hydrogen 	Drive range 
ICE	✓	✓			
NOVC-HEV	✓	✓			
OVC-HEV	✓	✓	✓		✓
PEV			✓		✓
FC-HEV				✓	

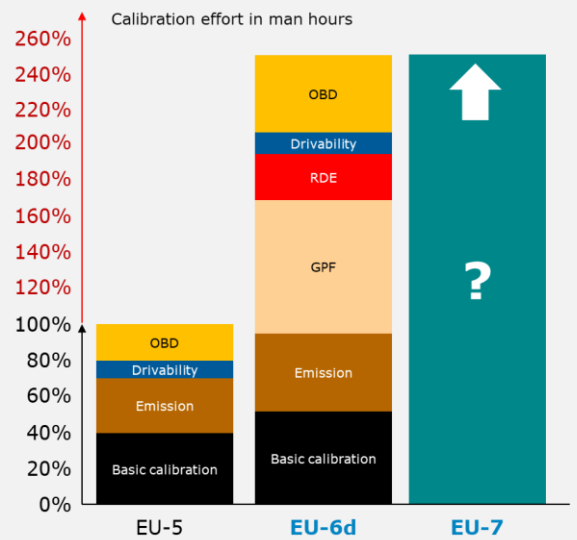
... all vehicles must perform a chassis dyno laboratory test, vehicles with an ICE have to do also RDE, and gasoline fueled vehicle Evaporative emission testing.

Where is it measured ?	Laboratory		Street
	Chassis Dyno 	Evaporative Testing 	RDE 
ICE	✓	✓	✓
NOVC-HEV	✓	✓	✓
OVC-HEV	✓	✓	✓
PEV	✓		
FC-HEV	✓		

Increase of effort: EU-6b → EU-6d → ? EU-7

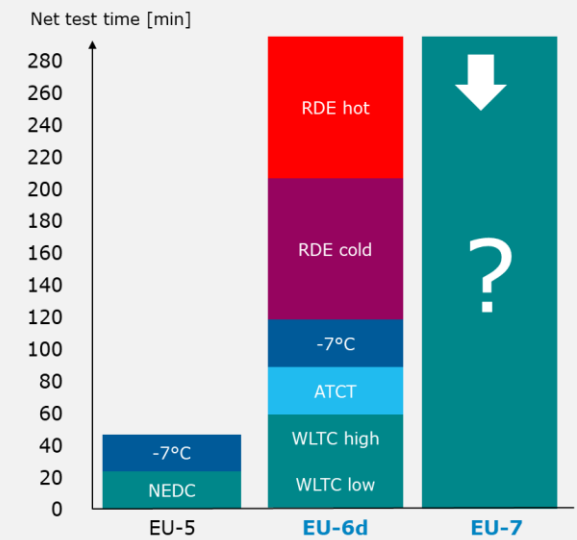


2-3 times more calibration effort



- Because of:
- Real Driving Emissions
 - Gasoline Particle Filter
 - Robustness calibration
 - CO2 reduction

8 times more type approval testing



- Because of:
- NEDC → WLTC
 - Low and High CO2
 - ATCT
 - RDE

3-10 times more test time OVC-HEV and BEV

Powertrain type	Test run	Hours
ICE NOVC-HEV	WLTC Class 3b	0,5
OVC-HEV	OVC-HEV - WLTC Class 3b - 5 Cycles	2,7
PEV (BEV) Shortened Procedure	PEV Shortened Test Procedure	4,2
PEV (BEV) Repeating Cycles	PEV - Repeating Cycles	10
FC-HEV	WLTC Class 3b	0,5

- Because of:
- ~ 1h ICE, NOVC-HEV, FC-HEV
 - ~ 3h Plug-In Hybrid
 - ~ 5h BEV shorten test
 - ~ 10h BEV repeating cycle

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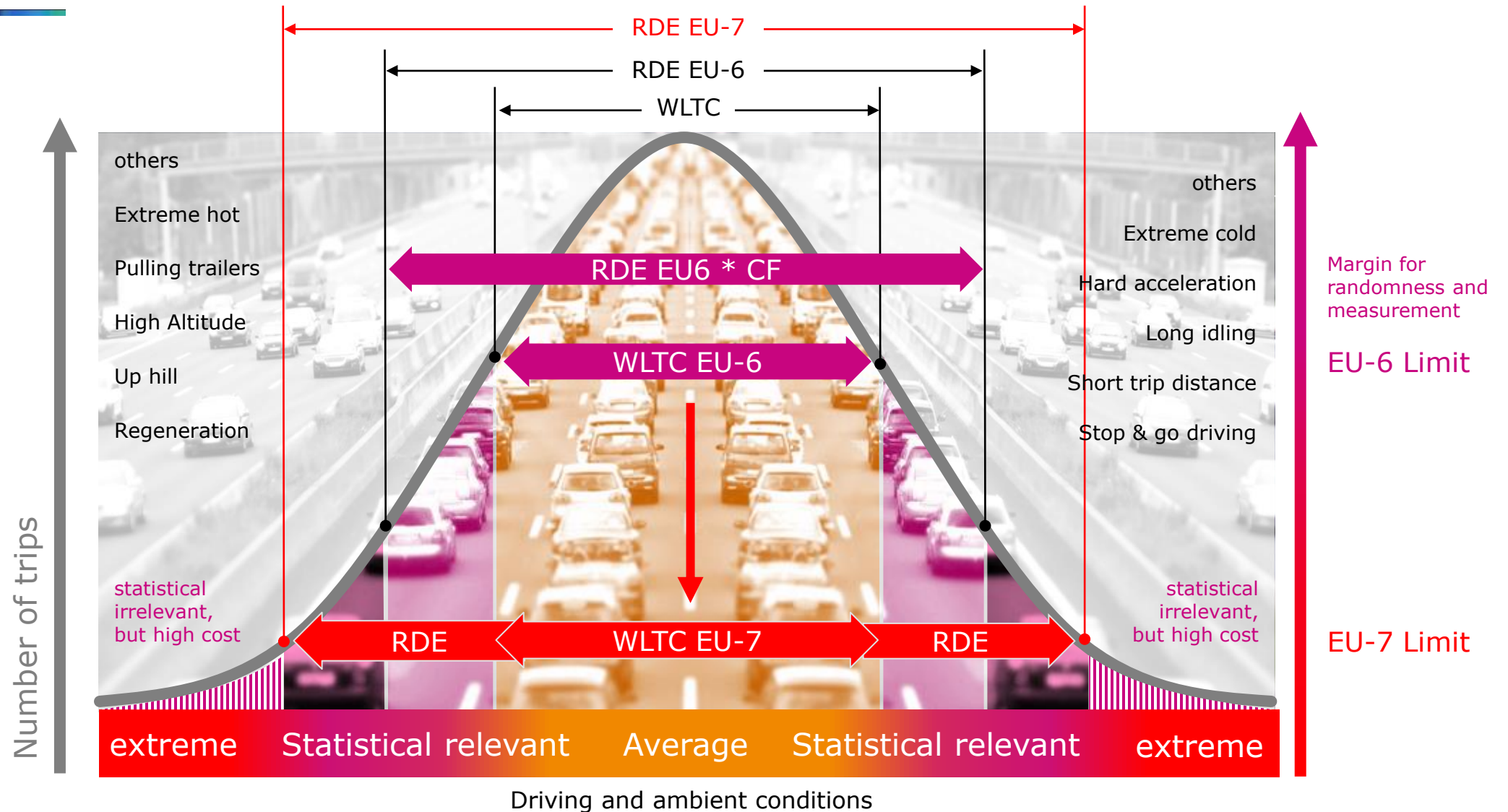
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Euro-7/VII: European Commission Targets



- as clean as possible under
 - “all” driving conditions
 - Near zero emissions in cities, clean in most parts of the engine map
- Fuel and technology independent
 - Harmonization between PC, LCV and Heavy Duty
- RDE focus on pollutant emissions
 - Laboratory testing focus on CO2 (GHG)
- Significant reduction of limits
- not before 2025, likely **2027/28**
 - EC proposal expected end of 2021

Euro-7: How do we drive – How do we test

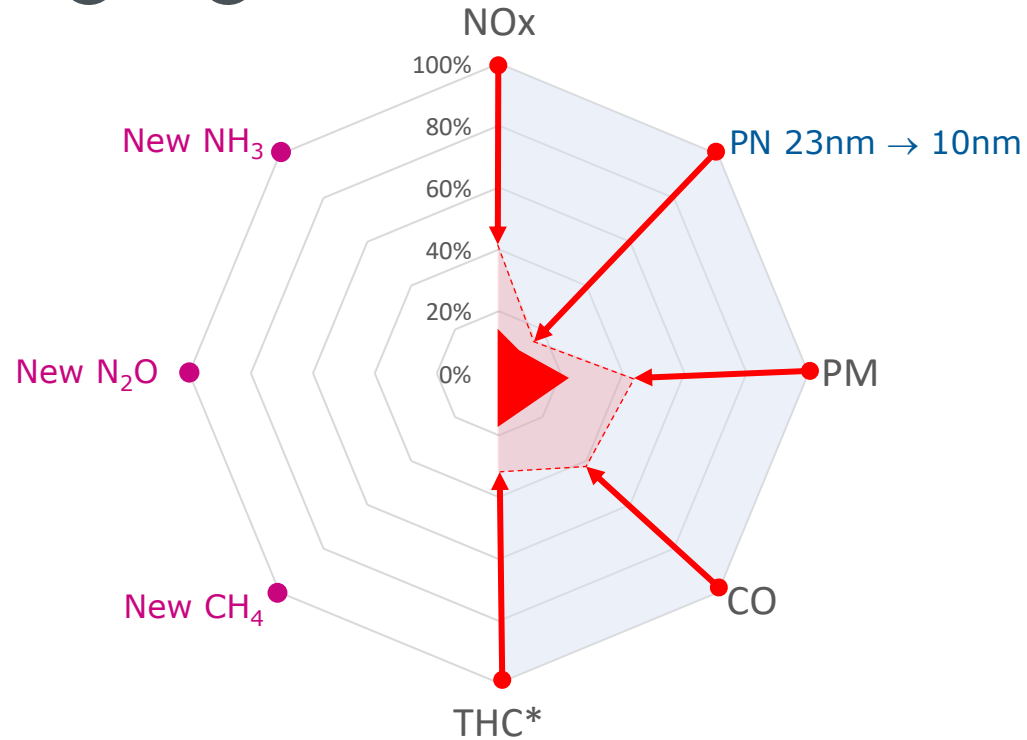


Euro-7/VII: CLOVE Limits proposal

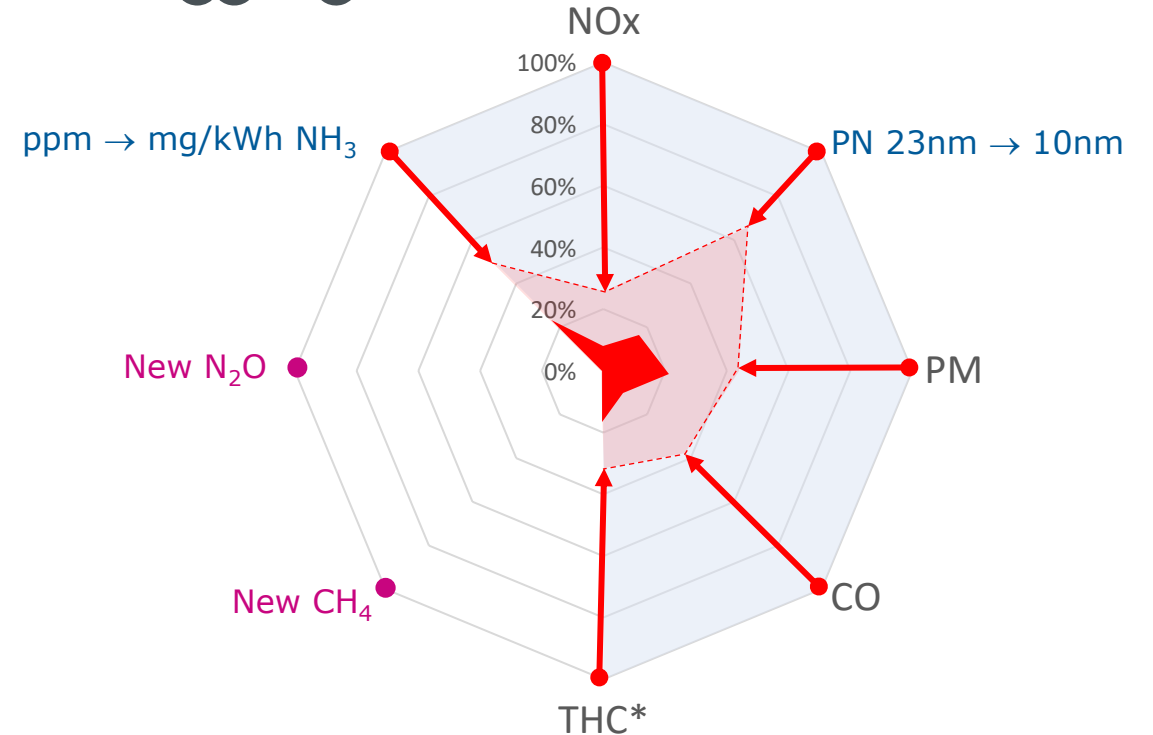
CLOVE proposal 27.10.2020



■ EU-6 ■ EU-7 A ■ EU-7 B



■ EU-VI ■ EU-VII A ■ EU-VII B



1. Significant reduction of limits and no CF, no other corrections, limits also apply during regeneration
2. New emission components limited and NO₂, HCHO, NMOG still in discussion
3. Modified criteria (metrics or measurement specification)

Euro-7/VII: Simplification



There is a discussion 2019-2021 about the new legislation of Euro-VII. It is also discussed to simplify the type approval testing effort. Please be aware, that this might change during the discussion process, shown here is the status as it is beginning in 2021.

Euro 7 – Testing Simplification Proposal (Status of discussion in beginning of 2021)

Topic	EU - 6			EU - 7 Proposal			Notes
	Type Approval	OEM Declaration	others	Type Approval	OEM Declaration	others	
Average emission	✓			✓			no change but lower limits
ATCT	✓			✗			that would be included in wide on-road PEMS testing
RDE	✓			✓			no boundary conditions, but wide on-road testing
CO idle test	✓			→	→	ISC+MaS	MaS and included in wide on-road PEMS testing
Crankcase emission	✓			→	✓	MaS	Declaration and check in MaS
EVAP	✓			✓			no change but lower limits, maybe also ORVR
Durability test	✓			→	✓		expanded to useful life (tbd), Declaration and checked by ISC and MaS
-7°C Temperature	✓			?			in discussion since it is included in wide on-road PEMS testing
OBD	✓			→	✓		Declaration + Introduction of a TCI and OBM (Note 1)
UNR-24	✓			→	→	MaS	? part of MaS (I/M)

Note 1: MIL (Mail function Indicator Light is for owner to seek repair
 OBD (On-Board Diagnostic) for workshop to enable repair, at TA it is a burdensome functional only test.
 TCI (Testing Conformity Indicator) only an indicator for readiness for compliance testing, manufacturer in control of technical details. it has 3 statuses.

- Vehicle in a proper state and ready for ISC or MaS
- Vehicle outside of normal use AES activated
- Vehicle not in a proper state, repair is needed

Euro-7/VII: Simplification



There is a discussion 2019-2021 about the new legislation of Euro-VII. It is also discussed to simplify the type approval testing effort. Please be aware, that this might change during the discussion process, shown here is the status as it is beginning in 2021.

Euro VII – Testing Simplification Proposal (Status of discussion in beginning of 2021)

Topic	EU - VI			EU – VII Proposal			Notes
	Type Approval	OEM Declaration	others	Type Approval	OEM Declaration	others	
WHTC & WHSC	✓			✓			no change
Off-Cycle Emission		✓		✗			that would be included in wide on-road PEMS testing
PEMS Testing			ISC	✓			ISC with boundaries, CF, MAW → Wide on-road for TA, ISC, MaS
Idle CO	✓			→	→	ISC+MaS	MaS and included in wide on-road PEMS testing
Crankcase	✓			→	✓	MaS	Declaration and check in MaS
OBD	✓			→	✓+OBM		Declaration + Introduction of a TCI and OBM (Note 1)
Durability	✓			→	✓	ISC+MaS	expanded to useful life (tbd), Declaration and checked by ISC and MaS
Replacement pollution control devices	✓			✓			in discussion, could be moved to a separate regulation
Engine power	✓			✓			no change
NOx control operation	✓			→	✓	ISC+MaS	Declaration and checked by ISC and MaS
CO2 verification	✓			✓			maybe also on-road testing and in-service verification

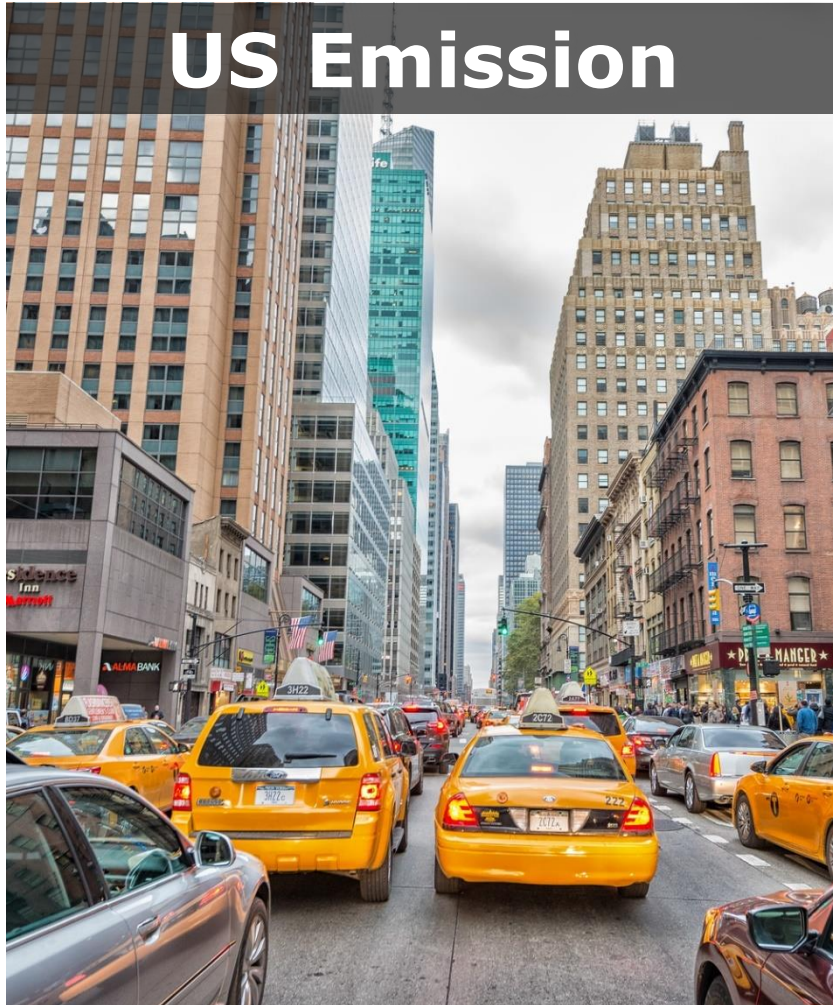
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US EPA/CARB Emission Legislation



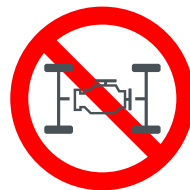
US Light-Duty vehicle:

- CFR-1065/1066 replace the technical part of CFR-86 regulation (since 2019 mandatory)
- Particulate measurement for all vehicles and fuels
- 1mg/mi PM (measurement uncertainty?)
- Some additional measurement specifications for diluted measurement, like preventing condensation, particulate measurement residence time (1.0 to 5.5s) and overall dilution factor (1:7 - 1:20)
- No legal "Real Driving Emission" testing requirement:
 - Different cycles (FTP-75, US06, SC03, HWFET) represents typical driving conditions.
 - ECU control strategy evaluations
 - PEMS Testing used for compliance evaluations (finding defeat devices)



US Heavy-Duty vehicle:

- Green-House-Gas 2 regulations to include vehicle simulation for Heavy Duty application
- Ultra Low NOx for California, 10 times lower from 0,2 to 0,02 g/bHPH
- PEMS Testing



California wants to ban new ICE vehicles starting in 2035:

- California Governor signed (23.9.2020) an executive order to ban sales of new LD-Vehicles in 2035 and Medium- and Heavy-Duty Vehicles in 2045. It is a reaction to the increase of deadly wildfires in CA and to fight greenhouse gas emissions. It would not prohibit people from owning ICE vehicles, nor from selling them on the used car market.

China Emission Legislation:



China is the largest automotive market on the world:

- China is already the most important market for the car industry, like Germany where 40% of high-end Mercedes produced in Stuttgart are shipped to China.

China Emission Legislation:

- 2020 China 6a is slightly below EU-6d and it has the same limits for all fuels.
- 2023 China 6b more stringent than EU-6d
- 2028+ China 7 most likely a unique Chinese legislation, drive cycles, ...

Focus on New Energy Vehicles (NEV):

- NEV vehicles are from Mild-Hybrid up to Battery electrical vehicles. Chinas NEV sales account for 60% of the global NEV market share.
- Methanol (M100) fueled vehicles are introduced as part of clean energy for coal-rich provinces (Methanol and Formaldehydes emission limits apply).
- Strong fuel reduction, which will make China-6b the most challenging standard in the world.
 - 2020 5.0 l/100km and 2Mill. NEV vehicles per year
 - 2025 4.0 l/100km and 20% of production is NEV
 - 2030 3.2 l/100km (in discussion)

Evaporative Emission (EVAP):

- Unique China EVAP is a mixture of EU, CARB (ORVR) and China requirements
- 0,7g/test limit, EU-6d is 2.0 g/test

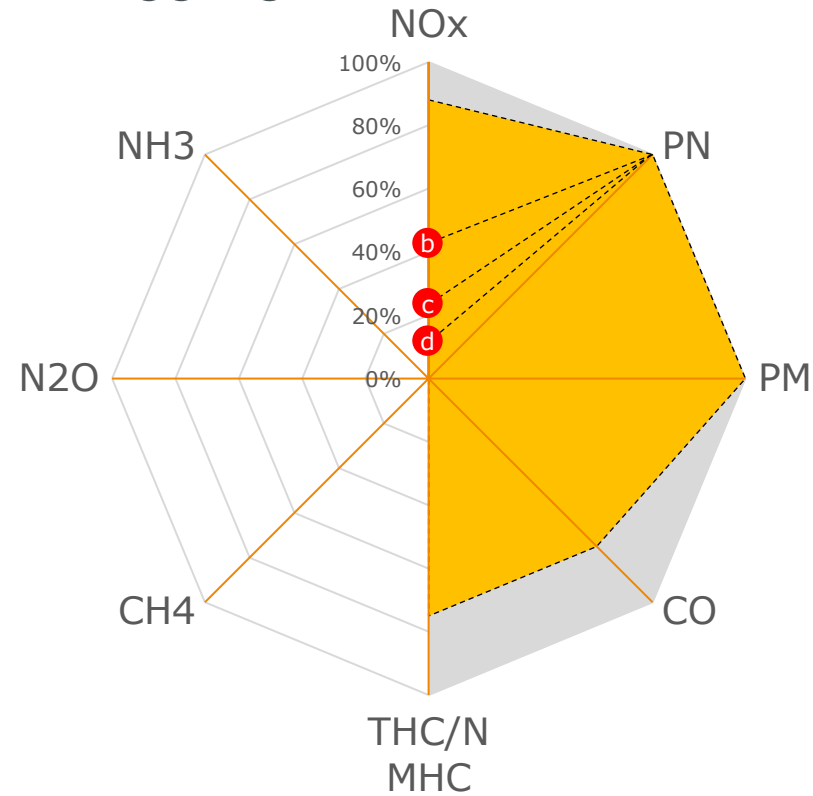
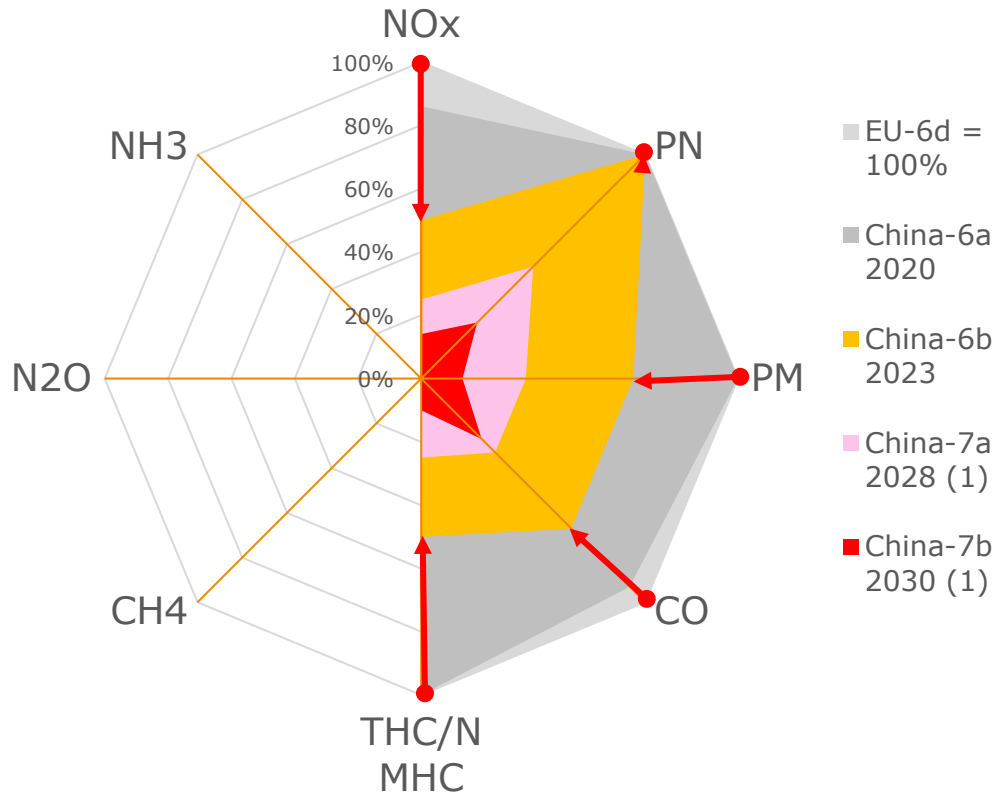
Total fleet monitoring :

- China 6b trucks must up-load all 10 sec several ECU data to the authority database.

CoP / ISC (GB-18285-2018):

- unique and "strange" Conformity of Production and In-Service Conformity tests for gasoline only.

China Emission Legislation:



- EU-VI = China-VI a (2021) = China-VI b (2023)
- China-VII a (2027), NOx 405mg/kWh
- China-VII b (2028) only NOx reduction 195mg/kWh
- China-VII c (2029) only NOx reduction 105mg/kWh
- China-VII d (2030) only NOx reduction 45mg/kWh

Rest of World Legislation:



Japan:

- One of the emission leading countries with emission standards equal to western emission standards.
- Japan's flows now also UN regulations.



South-Korea:

- South Korea follows for Gasoline vehicles US legislation and for Diesel EU legislation.
- RDE is limited to Diesel vehicles.



India:

- Still fighting bad air quality, but closing fast the gap to western emission standards
- Going directly from Euro-4 to Euro-6



UK:

- not anymore part of EU, but currently still following UN-Regulations and EU standards. Future?

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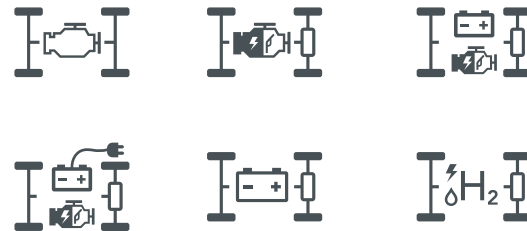
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CO2 (Green-House-Gas):



- Green-House-Gas emissions currently are the most important challenge.
- While for Light-Duty vehicle the focus is currently mainly on the powertrain, it is for Heavy-Duty and Non-Road engines on the fuel and primary energy.
- e-fuels is the only realistic solution for airplanes and ships. It also would be for road transportation the game changer, since it also would make the already existing vehicles CO2 neutral.

CO2 reduction by powertrain



- Efficiency optimization of ICE
- electrification of ICE
- Hybrid
- Plug-In Hybrid
- Battery Electric vehicles
- H2 Fuel-Cell vehicles

CO2 reduction by fuel

- CNG
- Bio-Fuel
- Bio-Gas
- Ethanol
- Methanol
- Ammoniac
- Electricity
- H₂
- e-Gas
- e-Fuel

Green-House-Gas:

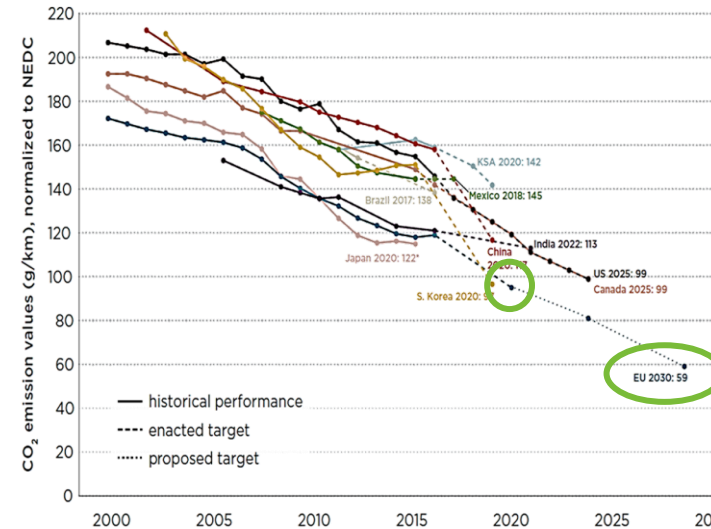


GHG



EU CO₂ fleet average emission targets (tail pipe):

- Each manufacturer or group has its individual target, based on the average weight of its sold vehicles.



2021 95g/km

2025 -15% (81g/km)

2030 -37,5% (59g/km)

EU Green-Deal is requiring larger reductions

Source: ICCT 2019, CO₂ Emission standards for passenger cars and light-commercial vehicles in the European union

EU:

- European leaders agreed on an EU-wide goal of cutting net GHG emissions by at least 55% by 2030. (11. Dec. 2020):

Green NCAP – Consumers Information



“Green Vehicle Index”

Provide comprehensive, simple rating information to consumers, fleet operators and other stakeholders: Stimulate real green cars to enter the market, Reduce Pollutant and Greenhouse Gas emissions, Restoring consumer confidence in test information, Spark competition among vehicle manufacturers, Transparency and making available detailed test result and analysis

Test Matrix Overview 2020 & 2021



Laboratory	Robustness (Laboratory & Real-World)	PEMS (Real-World)	Engine Load (Max Curve Mapping)
Approval test cycles under average ambient conditions (@ 14°C)	Custom-tailored tests with variations of vehicle settings, low and high engine load	Custom-tailored approval driving tests under real-world ambient conditions	Custom-tailored sweep test to visualise maximum engine load operation sampling
<ul style="list-style-type: none"> → WLTC+ cold (+ 14 °C) → WLTC+ cold ambient (-7 °C) → WLTC+ PEMS correlation → Driving Range (for info) 	<ul style="list-style-type: none"> → WLTC regular warm → BAB 130 motorway → PEMS+ warm Eco → PEMS+ warm Heavy load → PEMS+ cold start and 8 km warm-up → PEMS+ congestion simulation 	<ul style="list-style-type: none"> → PEMS+ regular cold (2x) 	<ul style="list-style-type: none"> → Sweep test to log maximum engine load versus engine speed (fully depressed accelerator pedal)

NCAP might adjusting test procedures yearly, so results are not comparable from one year to the other, from one car to the next, if tested differently.

All ICE based vehicle get a “bad” rating.



If Green NCAP becomes so popular as the Safety NCAP, it can have a significant impact on vehicle sales.

Non-Combustion particulate emissions



Break wear, tire and road wear particles:

- app. 50% of traffic related particles come from abrasion, since the number of vehicles with a particulate filter is getting larger.

Break wear particles:

- Development of an UN regulation, how to test and measure particles from braking is ongoing.
- It is not decided if it will become a component- or a vehicle-legislation.

Tier wear particles:

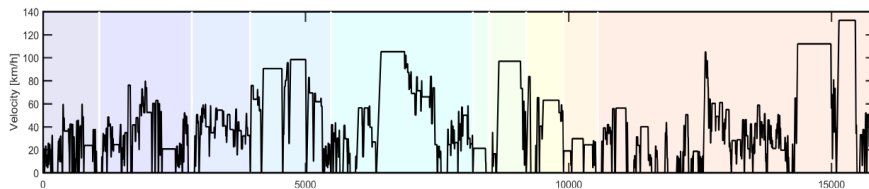
- European Commission has mandated the development of a tire wear test. OICA has expressed concerns about safety impact.
- Russia has requested the development of an UN regulation for road wear, since the very soft asphalt used in eastern regions.

Road wear particles:

- Russia has requested the development of an UN regulation for road wear, since the very soft asphalt used in eastern regions.

Electric vehicle discussion:

- There is a controversial discussion about electric vehicles, on one side there is less use of breaks due to recuperation, on the other side there is more tier and road wear due to higher weight and good acceleration.



Proposed break wear test cycle

Vehicle Interior Air Quality (VIAQ)



Vehicle Interior Air Quality (VIAQ):

- Development (2020-2025) of an UN regulation for vehicle interior air quality is ongoing. Driver and chair of the working group is Russia and South-Korea, both regions have already such a legislation in place.

Test condition:

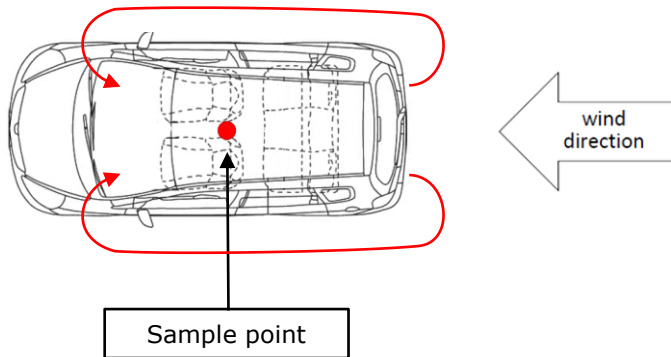
- Conditions -7°C to $+30^{\circ}\text{C}$ and 30% to 90% rH, 85 to 110 kPa
- Idle test in an open area, with simulated or natural wind of 2 ± 1 m/s, constant speed test on paved road with a slope up to 6%.

Test procedure:

1. Idle test
2. Test at constant speed of 50 km/h and 130 km/h (optional: 90 or 110 km/h)

Measurement:

- Sample location between the head rests of the front seats.
- focus are the emissions from the tailpipe entering the vehicle (no out-gassing of materials)
- **CO, NO and NO₂ is agreed**
- **CH₂O, PM_{2.5}, PM₁₀ is in discussion**
- Saturated hydrocarbons (C₂H₆...C₇H₁₆) and CH₄ is already in a Russian legislation



EN ISO/IEC 17025:2017

ISO-17025



ISO-17025 is a general laboratory competence standard:

1. Competence of test laboratories
2. Competence of calibration laboratories.

There are significant differences between a calibration and test laboratories requirements

ISO 17025:2017

- It is more a management standard, than a technical standard.
- It becomes more and more important for emission laboratories (e.g.: mandatory for ISC).
- Is well accepted worldwide. There are significant changes in the third revision (2017), including quality requirements (processes, documentation, ...), technical requirements (equipment, traceability, uncertainty, ...)
- Accreditation is valid for a well-defined quantity, at a defined testing range with a defined measurement uncertainty (there are exceptions for a complex test laboratory)
- It accepts if other "well recognized standards" are followed, like emission legislations !!!
- It requires a 17025 calibration for significant signals (i.e.: impact on result), not for all.

AVL and ISO 17025

- Often the discussion is only about "calibration laboratory". For test bed operators the test laboratory part is more important.
- AVL can deliver nearly all products 17025 calibrated, most from our own accredited calibration laboratories, some via external calibration institutes. However, it is optional and with extra costs. We can't do currently onsite calibration.
- We have a clear recommendation what should be ISO-17025 calibrated and where is a factory calibration sufficient for the entire emission chassis dyno facility.

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LD Vehicle: Chassis Dyno (Certification + R&D)



		ICE EU-6	Hybrid + BEV	H2-FC	EU-7	R&D							
Automation Software: PEMS Integration Road-2-Lab RDE driver's aid BEV Shortened Test Repeating Cycles Hybrid UNR-101, CFR1066 Result reporting Driver's aid Worldwide legislation US CFR-1066 WLTP (EU-6 2nd Act) Automation System (iGEM) Dyno Control (VECON) SCARDA System						CVS Systems: Tailpipe pressure control FlowSonix dilution air flow CVS for repeating tests CVS		E-Power Systems: Battery Emulator Vehicle charging monitor Battery charging stations e-Power analyzer charging e-Power analyzer test Engine On/Off detection 12V current clamp					
						Gaseous Analyzers: Pre-Post AMA R2, SESAM Additional Analyzers Low-Range, FTIR, QCL AMA Diluted bench							
						Particulates: Pre-Post Micro Soot Pre-Post APC PN counter 10nm PN counter 23nm PM sampler		other Devices: H2 consumption UNR-24 Opacity meter CO Idle workshop analyzer Crankcase pressure Calibr. and test devices					
Safety: Safety Generation - H2 High Voltage safety Battery safety Basic Safety Systems						Testbed Systems: 2nd chassis dyno axle Vehicle restrain system Cooling Fan Chassis dyno (1 axle)		Testbed Conditioning: Altitude Simulation US SC03 Sun simulation Humidity conditioning Temp.: -7, 10, 14, 23, 35°C		Soak Room Devices: Temp.: -7, 10, 14, 23, 35°C Tier pressure sensor Oil temperature sensor Coolant temp. sensor		PM Filter Weighing: PM management system PM Filter weighing balance PM Filter conditioning	
										Gas Supply: Gas management system Gas supply Calibration Gas (1%)			

Solutions: for Development



Emission development effort:

- 2 to 3 times more development and calibration effort, since Real Driving Emissions, Gasoline Particle Filter, Robustness calibration and CO2 reduction



Exhaust aftertreatment systems:

- for low emission complex exhaust aftertreatment systems are required. Today the exhaust aftertreatment is its own "chemical factory" in the vehicle.



Real Driving Emission (RDE) challenge:

- RDE in a wider range of the engine map operation and under different ambient conditions, like short trips, aggressive driving and cold start, ...



Front Loading:

- With the largely increased development effort and challenges more and more virtual simulation work will be done, like for Front-Loading of the engine calibration.








Road-2-Lab:

- Development goes from virtual over all types of testbeds towards the road. With RDE requirements reproduction and simulation of real road tests becomes important. Road tests needs to be simulated, but also real road tests must be reproduced in laboratories, what we call Road-2-Lab.

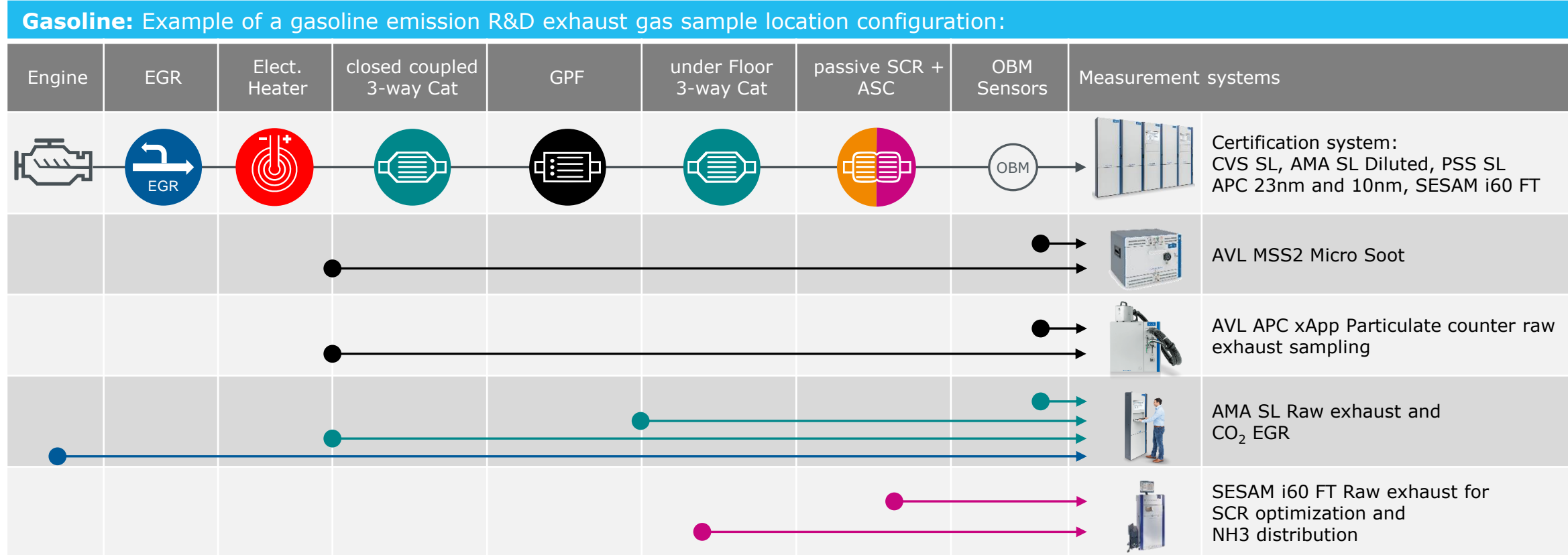
Development: Emission calibration tasks

For development work, no requirements exist on which testbed type the work is done, nor how emission are measured. The best testing environment is used to fulfill the development task in good quality and most efficient. Also, simulation is widely used. Beside the base development for the combustion process and the mechanical engineering, ECU calibration is a mayor work effort in the development.

Example of typical development and calibration tasks in engine and vehicle development					
Tasks		Description	Conditions	Test cell type	Measurement
	Base engine and ECU calibration	Base engine and exhaust aftertreatment system calibration, cold start calibration for heat-up and warm up strategy of exhaust aftertreatment systems. On 48V Hybrid systems electric heated catalyts , ...	-7°C – +30°C	Engine Test bed Chassis Dyno or Powertrain	CVS, PTS, APC, AMA Pre- and Post Cat AMA MSS
	Cold start	Cold Start Heat-up and Warm up strategy	Cold start test without drive off	Engine Test Bed Vehicle cold start place	Pre- & Post-Cat AMA APC, MSS
	3-way Cat and DOC	Basic calibration, closed coupled and under floor cats.	-7°C – +30°C	Engine Test bed Chassis Dyno	CVS, Pre- and Post Cat AM A
	SCR layout and control strategies	SCR layout and control strategy, AdBlue injection, validation of homogenous mixing. SCR will also be seen on Gasoline future low emission vehicles, depending on limit value as passive SCR (no AdBlue injection) or active (AdBlue injection).	Full temp. range	Engine test bed or powertrain	Pre- & Post-Cat FTIR
	GPF / DPF	DPF / GPF characterization for filter efficiency, loading capacities and regeneration requirements, typically done at stationary operation on engine test beds.	stationary operation	Engine Test Bed	Pre- & Post-PF APC Pre- & Post-PF MSS Smoke Meter or Opacimeter
	Start & EO GPF / DPF calibration	Engine-out PM emission and smoke maps (Diesel) for particulate filter loading models in the ECU for active and passive filter regeneration.	Dynamic tests, Temperatures down to -40°C	Chassis Dyno, Powertrain, In-vehicle	PN-PEMS, MSS
	RDE Calibration	RDE in a wider range of the engine map operation and different ambient conditions, inside RDE conditions and outside, like short trips, aggressive driving and cold start, ...	-10°C – +40°C -30°C for AES Altitude 0 – 1300 – 2400m	Chassis Dyno, Powertrain, Specific RDE cycles, Road-2-Lab	CVS, PTS, APC, AMA Pre- and Post Cat AMA FTIR, MSS
	RDE Validation	Robustness evaluation		Road	PEMS

Development: R&D measurement configuration - Gasoline

For the development towards zero impact emission, not only the final emitted emission from the tailpipe must be measured, but also at several additional sample point within a complex exhaust aftertreatment systems. The sample point and which exhaust components should be measured, depends in the configuration and type of exhaust aftertreatments systems. Below is an example given for gasoline engines.

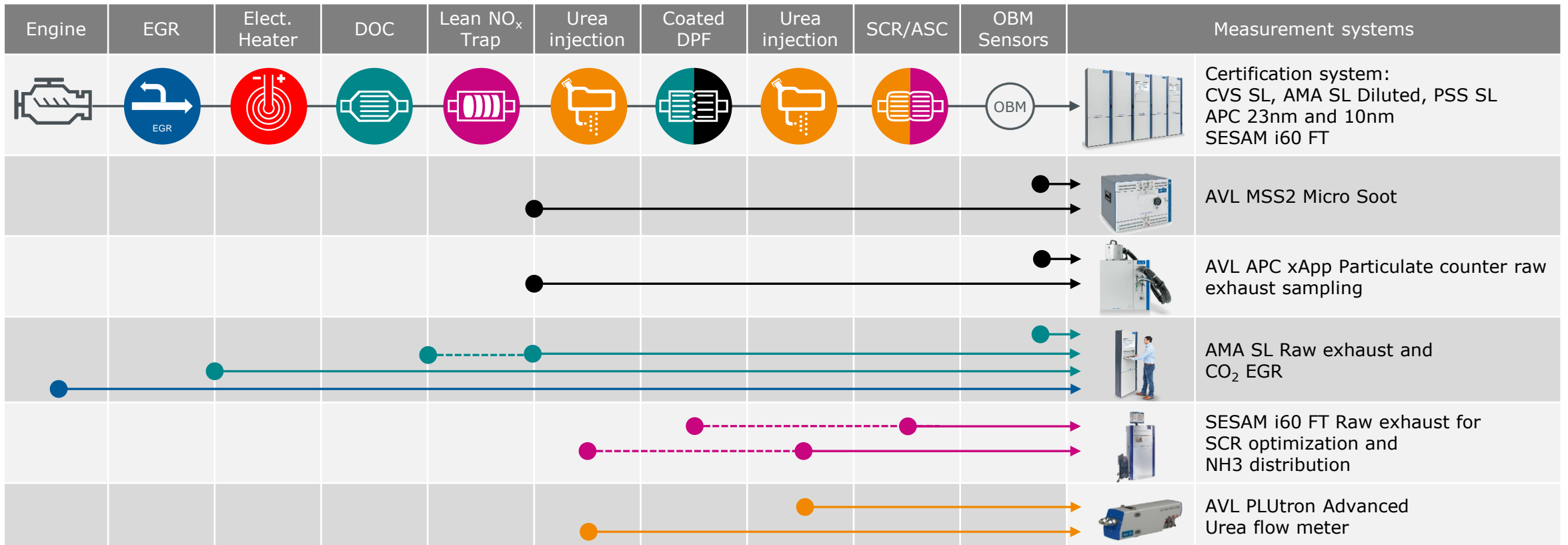


EGR: Exhaust Gas Recirculation, GPF: Gasoline Particulate Filter, passive (no AdBlue) SCR Selective Catalytic Reaction Cat, ASC Ammoniac Slip Cat, OBM On-Board Monitor

Development: R&D measurement configuration - Diesel

For the development towards zero impact emission, not only the final emitted emission from the tailpipe must be measured, but also at several additional sample point within a complex exhaust aftertreatment systems. The sample point and which exhaust components should be measured, depends in the configuration and type of exhaust aftertreatments systems. Below is an example given for Diesel engines.

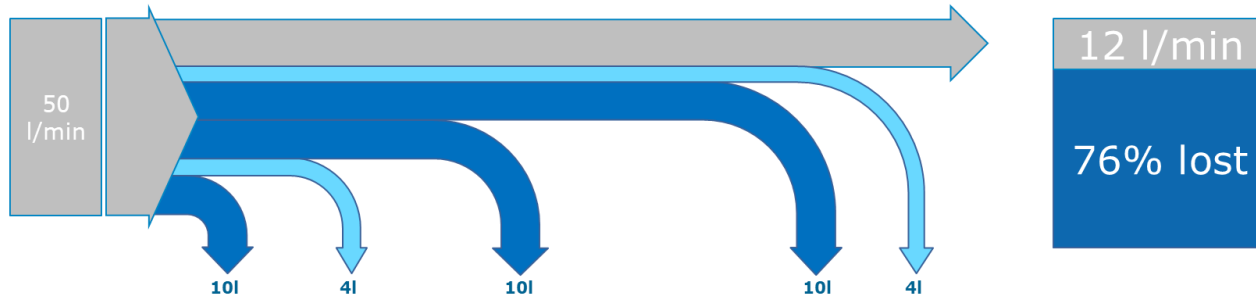
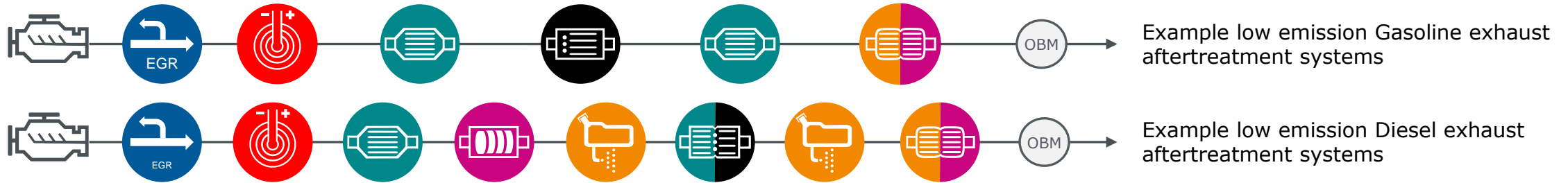
Diesel: Example of a Diesel emission R&D exhaust gas sample location configuration



EGR: Exhaust Gas Recirculation, DOC: Diesel Oxidation Cat, DPF: Diesel Particulate Filter, SCR Selective Catalytic Reaction Cat, ASC Ammoniac Slip Cat, OBM On-Board Monitor

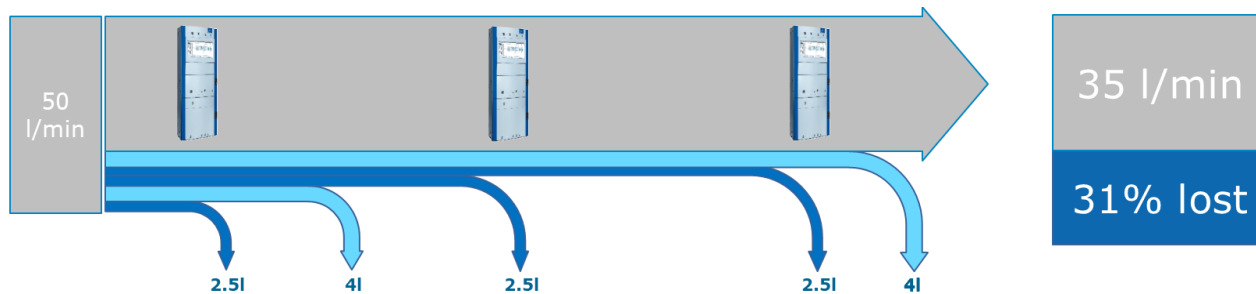
Development: Extracted exhaust sample flow

With the large number of sample locations and emission measurement devices, also the amount of extracted sample volume must be reduced.



Conventional emission bench

- On a small gasoline engine running at idle up to 76% of the exhaust might be used by emission measurement systems. Only 12% might reach the CVS system



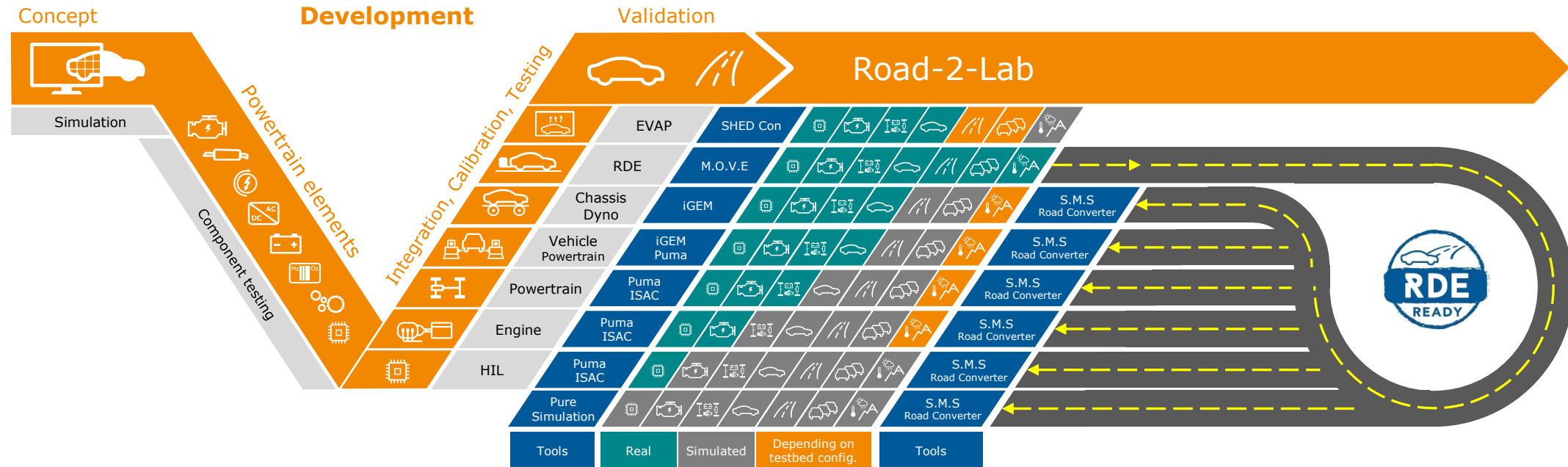
AMA SL: reduction of flow rates

- No relevant influence on the unit under test because of minimized sample extraction rates
 - Raw exhaust: 2.5 l/min
 - EGR: 1.0 l/min

Development: Front loading and Road-2-Lab

Typically, development goes from virtual over all types of testbeds towards the road.


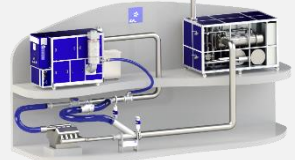
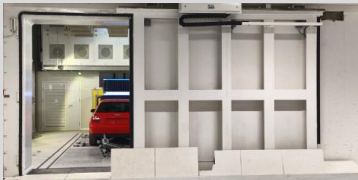

With the largely increased development effort and challenges more and more virtual simulation work will be done, like for Front-Loading of the engine calibration.



With RDE requirements reproduction and simulation of real road tests becomes more important, than it was in the past. While a RDE test results in a real-life result, with all the randomness of "real" life, it can not be used for development. In order to find the cause of a problem, to develop a solution and validate it, the key element is that you can reproduce it as often as needed. That can't be done on the road due the randomness, even the same route will have different traffic and ambient conditions. Second, in the laboratory much more measurement devices and sensors can be used, which never could be used in the vehicle on the road. Depending on the development or validation task and the availability of different test bed environments, a real road tests can be reproduced in a laboratory, that is what we call Road-2-Lab. The same technology also can be used to run a virtual generated road test, like from a map or a random cycle generator.

Development: Altitude testing

Mountain roads at higher altitude is a challenge for combustion engines. The lower ambient pressure results in lower air density, lower amount of oxygen for combustion resulting in less engine power. In former days also engine cooling was an issue, due to higher load during driving up-hill and lower air density which reduces cooling efficiency. Altitude development and validation testing was all the time a part of vehicle development and operation. With Off-Cycle Not-to-Exceed (NTE) emission requirements and lately with RDE a focus is nowadays on altitude emission testing.

Altitude requirements		Description	Test requirements		Altitude emission testing possibilities:
m	ft		Operation	Emission	
5.883	19.300	Worlds highest motorable road. Umling La, India	✓		 <p>1. Software Stimulation: Pure software or Hardware in the Loop (HiL) simulation works very well for engine testing, especially for Heavy-Duty Diesel engines.</p>
~2.750	~9.020	China 6 WNTe emission limit 72kPa	✓	✓	
2.400	7.870	RDE extended 2 condition in China	✓	✓	 <p>2. Altitude Simulation: For engine intake and exhaust a pressure is stimulated, which correlates with the required altitude. Other engine openings, sealings and ECU sensors must be considered. The rest of the engine is at ambient conditions. It is a good compromise between costs and results for engine tested. For vehicle testing it is less practicable.</p>
~1.700	5.580	HD and NRMM NTE/Off-Cycle requirements	✓	✓	
1.300	4.270	RDE extended condition	✓	✓	 <p>3. Altitude Chamber: The entire test cell is brought to a pressure condition, which correlates to the simulated altitude. So, the whole engine/vehicle is exposed to the pressure condition. It is the best testing simulation, but also has the highest effort and costs.</p>
700	2.300	RDE moderate condition	✓	✓	
0	0	Sea Level	✓	✓	
-393	-1.289	Worlds lowest motorable road. Hifgway-90, Israel	✓		 <p>4. Altitude Testing: A Vehicle is driven up a mountain, or a test laboratory is built up at a mountain, like a high-altitude laboratory.</p>
-4000	-13.120	Mining engine operation. Mponeng, South Africa	Mining		

Emission measurement systems, need often additional boost sample pumps, depending on the pressure difference between sample point and system location.

Product Highlights



Lab Management Suite

“Manage & Control”

- Management of a test facility and its workflow
- Chain of custody and traceability

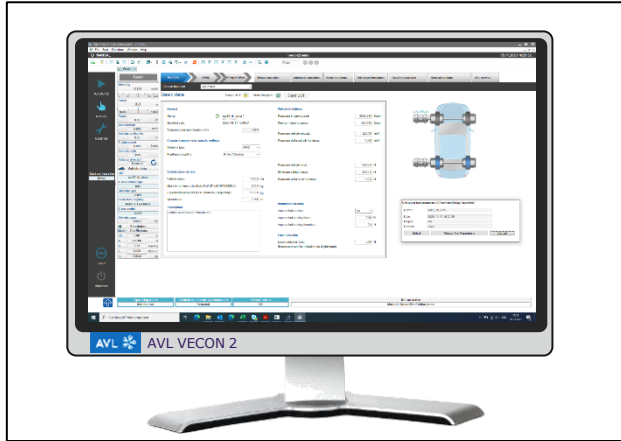


AVL iGEM2 Emission Automation

“One for all”

- for all applications
- for all testbed types
- for all powertrain types
- for all fuels

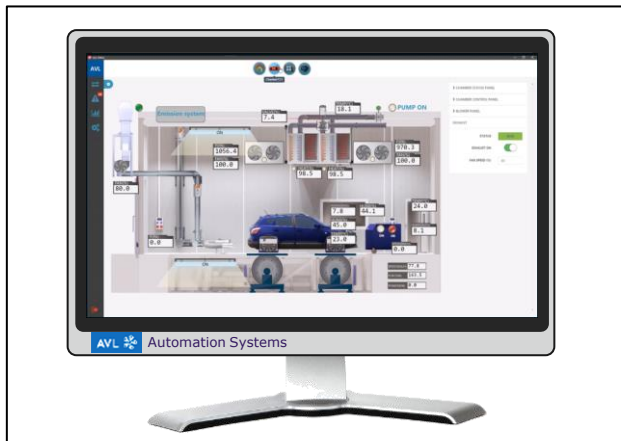
Product Highlights



AVL VECON 2 Chassis Dyno Control

“Keep it rolling”

- Controlling the entire chassis dyno operation accordingly to legislation
- Workflow support and all diagnostic operations included.

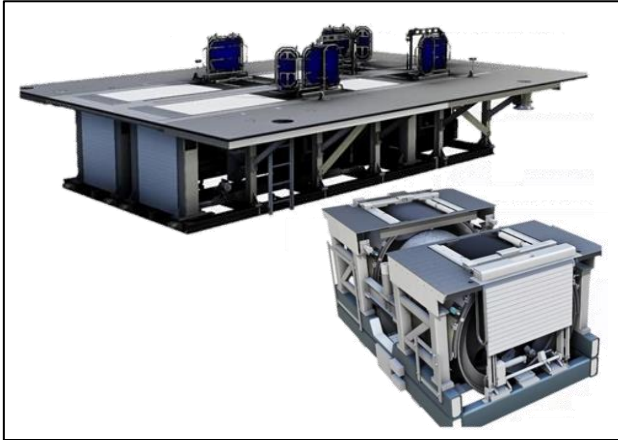


AVL THEIA Test Cell Climatic Control

AVL SCADA system

- Controlling and monitoring of testbed conditioning and building facility.
- Industry 4.0 solution for safe and remote operation.

Solutions: Product Highlights



AVL RoadSim Chassis Dyno

“Best performance”

- 48” the new “next Generation” of AVL chassis dyno rollers
- Optimized for hybrid and pure electric vehicles



AVL WLTP and RDE Blower

“including Drivers Aid mounting”

- AVL WLTP and CFR-1066 compliant cooling fan (48,000 m³/h, 135 km/h (160 peak))
- AVL Dual Blower for RDE and US SC03 testing (230,000 m³/h up to 200 km/h)

Solutions: Product Highlights



AVL AMA SL

“Emission has a new dimension”

- Less Space
- Less Sample flow
- Less TCO
- Less Energy consumption



SESAM i60 FT D1 for Diluted measurement

“The only one on the market”

- Euro-7 additional components, like Nitro Oxide, Ethanol, Methanol, Acetaldehyde, Formaldehyde
- optional additional gases for R&D

Solutions: Product Highlights



AVL APC xApp™ Particle Counter

“down to 10nm for EU-7”

- Second generation APC for Euro-7 down to 10nm particle
- dual line measurement option for 10nm and 23nm with external second CPC



AVL X-meter™ Battery

“Energy measurement”

- Multi-channel e-Power analyzer
- High-voltage probe concept with comfortable and safe operation

Solutions: Product Highlights



AVL MOVE iS+ System

“The industry Standard”

- -10 to + 45°C, up to 3000m
- NO/NO₂, CO/CO₂, N₂O (optionally)
- PN selectable 10nm and 23nm
- to become EU-7 and CEN ready

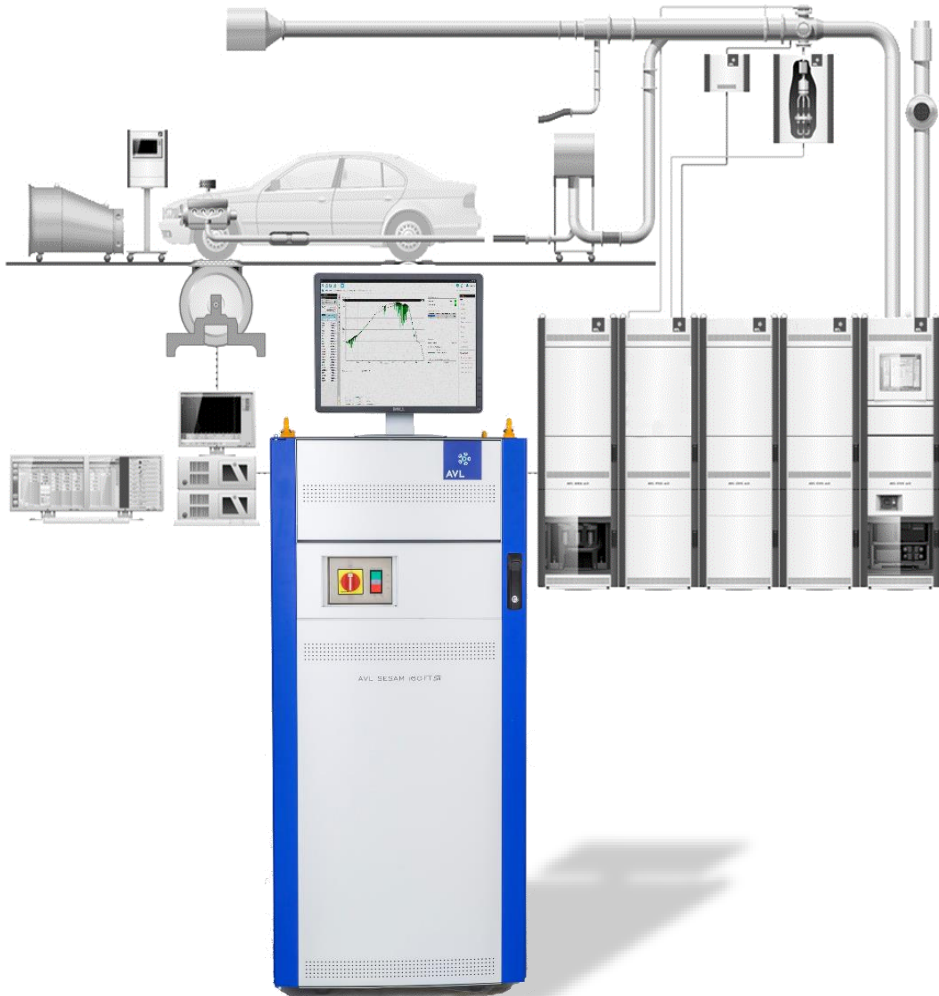


AVL EVAP test System

“World Wide EVAP Standard”

- VV-VT SHED chamber
- ORVR Fuel load system
- CANLOAD system

AVL SESAM i60 FT D1



SESAM i60 FT for diluted measurement

FTIR for diluted measurement of relevant gas components for:

- Post Euro-6 (Euro 7) additional criteria candidates
- GTR-15 (WLTP) Additional pollutant
- CFR-1066 (partly)
- China 6/VI Methanol standard

Emission Component		Range [ppm]	MDC[ppb]
N2O	Nitrous oxide	0 – 200	20
C2H5OH	Ethanol	0 – 300	50
CH3OH	Methanol	0 – 300	30
HCHO	Formaldehyde	0 – 200	20
CH3CHO	Acetaldehyde	0 – 100	50

Tailpipe Pressure Control – TPC 40 m³/min



Market drivers/(Customer`s) pain:

- Requires tailpipe pressure control for a **wider engine portfolios**
- Completion of TPC option for CVS SL 40 m³/min

Customer benefits/USPs:

- Cover a **wider range of UUT** with CVS flow rate up to **40 m³/min**
- **Higher performance** to cover higher pressure drop in a complex CVS piping systems
- Ensure high accurate air flow measurement with well-proven design sieve section for laminar air flow condition upstream of the Flow Sonix

AMA SL Low Emission Bench



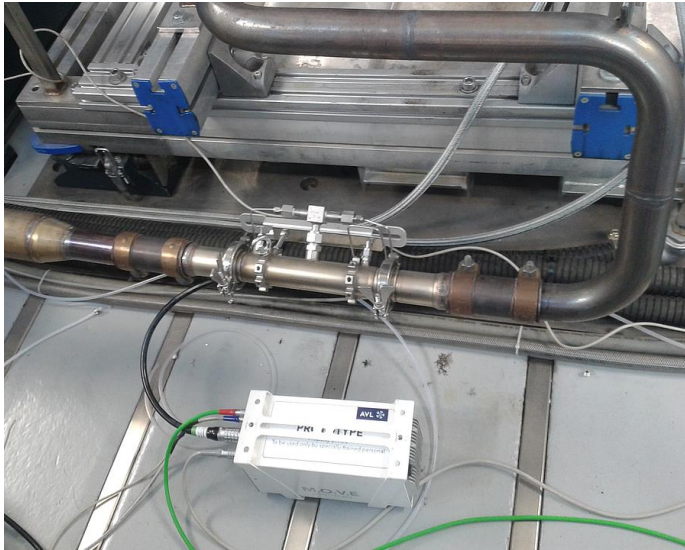
Market Drivers/Customer Pain:

- **Lower emissions** from internal combustion engines due to hybridization approaches
- **CARB Low NOx** emission regulation requires lower measuring ranges

Customer Benefits/USPs:

- **Configurable emission bench** with analyzers with extended measurement ranges
- Specially tuned analyzers:
 - ✓ **CLD** with range down to **1 ppm** (i60: 3 ppm)
 - ✓ **QCL** with range down to **1 ppm** (i60: 5 ppm)
 - ✓ **FID** with range down to **1 ppm** (i60: 3 ppm, in combination with BMD or DAR)
- First deliveries of optimized analyzers into **CARB project**

Exhaust gas flow measurement



- Proven technology from road testing
- Very cost effective alternative to existing SickFlow system(ULTRASONIC) with similar technical performance
- Easy to use and integrate in existing test cell
- Fully integrated in AVL PUMA(iGEM Vehicle) since 1.5.3
- Available options (mounting, heating, heating planks, stand alone power supply...)



Maintenance check

- w/o vehicle
- transfer CFV calibration to UFM

Steady state measurement

- with vehicle
- verify system integrity

Dynamic offset correction

- during emission test
- match tailpipe CO₂ and CO to bag

Included in iGEM VEHICLE product
No separate articles

RDE PEMS Testing (Certification + R&D)



Automation Software:

Data Management
PEMS Validation
Road-2-Lab
Online Tools
Euro-7 adjustments
Hybrid Functionality
Result reporting
Worldwide RDE
WLTP (EU-6 2nd Act)
RDE Reporting RDE 4
RDE Reporting 1, 2, 3
M.O.V.E Software

ICE EU-6	Hybrid + BEV	EU-7	R&D
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Exhaust Flow:

M.O.V.E EFM exhaust flow

E-Power Systems:

e-Power analyzer test
Engine On/Off detection

Gaseous Analyzers:

FID iS+ (LD)
Additional pollutants ???,
N2O
FID iS+ (HD)
Gas PEMS iS+

Particulates:

AVL MSS 2
PN PEMS 10nm
PN PEMS 23nm
PM Measurement HD

other Devices:

Power Generator
Plurea
Quality station

Safety:

High Voltage safety
Basic Safety Systems

Testbed Systems:

Ambient Conditions
GPS
System Control
E-BOX iS+

Ambient Conditions:

CEN Norm PEMS
SORDE Conditions
Altitude: ≤ 1600 (2400)m
Temperature: -7 ... +35°C

Pre-Test conditions:

Pre-Hot-Test conditions 6-36h
Pre-Test conditions 6-36h

PM Filter Weighing:

PM management system
PM Filter weighing balance
PM Filter conditioning

Gas Supply:

Gas supply
Calibration Gas (1%/2%)

AVL M.O.V.E System Control

THE AVL SOLUTION

AVL M.O.V.E System Control is a robust and flexible platform for central device integration and data acquisition.



- Robust design for mobile use
- Wide operating temperature range (-20 ... 60 °C)
- GPS and ambient sensor (T, P, rH)
- Online acquisition of OBD/ECU values
- Seamless and automated RDE process with the AVL PEMS Data Management Solution™
- Central operation of the measurement devices
- Time-saving with automated device checks
- Exact test execution according to legislative requirements
- Creates a backup of the current Main test every 2 min.
- Option to implement further sensors and measuring devices for customized testing
- ISO-Fix mounting Option

AVL M.O.V.E GAS PEMS iS+



- Featuring the new AVL NDIR analyzer
- Measures CO, CO₂ and N₂O simultaneously
- Enhanced protection against ammonia and its side products

Customer Benefits/USPs:

- Optimized and complete solution for global RDE
- Unique N₂O measurement
- Extended range in operating temperature
- High measurement accuracy and low drift

TECHNICAL DATA

Measurement principle	NDUV (NO/ NO ₂), NDIR (CO/CO ₂ / N ₂ O*)
Measurement ranges	NO: 0 – 5,000 ppm NO ₂ : 0 – 2,500 ppm CO: 0 – 5 vol. % CO ₂ : 0 – 20 vol. % N ₂ O: 0 – 2,000 ppm
Zero drift/8 hrs.	NO/NO ₂ : 2 ppm, CO: 20 ppm, CO ₂ : 0.1 vol. % N ₂ O: 20 ppm
Ambient operating temperature	-10 °C to +45 °C

AVL M.O.V.E PN PEMS iS+



PN PEMS with AVL EPC
(Electrical Particle
Counter) Technology

Customer Benefits/USPs:

- Outstanding robustness against vibrations, tilting, shocks and extended environmental conditions
- Highest long-term sensor stability based on a unique continuous zero point monitoring
- Flexibility between 10nm and 23nm
- Particle Size for measuring can be selectable

Content:

- 1** **Introduction** Emission and energy legislation, more effort and global trends
- 2** **Euro-7 (Light-Duty)** Targets, Limit proposals, Simplifications
- 3** **Overview global emission legislations** USA, China, RoW, Non-Road, Marina
- 4** **other requirements** CO2, Green-NCAP, Break-, Tire- and Road-wear, VIAQ, ISO-17025
- 5** **Solutions** Type approval solutions, R&D Solutions, Products
- 6** **Conclusion**

Conclusion: „Time to get ready“



1 Euro-7/VII

- most likely still an open discussion until end of 2021, but for sure very challenging.
- While it is unclear how challenging it will become for the vehicle development, there is already a better picture about test- and measurement requirements.
- Laboratory testing (Chassis Dyno, Engine test bed and EVAP) is well prepared, PEMS Testing will be, most likely, a big challenge

2 There will be emission “as long as” we have transportation

- A zero-emission transportation and mobility is only a hypothetical assumption.
- Some environmental groups, will all the time find something new and bad, it is their business (and often also income)

3 Ban of ICE vehicles in the cities is the threat

- City access for ICE based vehicles is a game changes.
- A too early ban of ICE would even result in higher CO2

4 Future of testing

- Testing of hybrids and electro vehicles is more effort, more time and more complex than testing of a pure ICE vehicle. Plug-In hybrids combine very well the complexity of ICE testing with the complexity of electric vehicle testing i.e.: Complexity2.
- Maintain your competency on emission testing and gain competency on e-mobility testing, you will need it.

for more Information see

Post Euro-6 Webinar 1: Legislation Trends



Post Euro-6: EC Targets (March 2020)

- 1 Vehicles shall be as clean as possible under "all" EU driving conditions over the entire useful life, with a focus on near-zero emissions in cities.
- 2 Pollutants shall be mainly controlled by RDE testing and On-Board Monitoring. Fuel independent limits.
- 3 Laboratory testing will focus on GHG and such pollutants, which can't be measured on the road.
- 4 New or modified criteria emissions: $PN_{2.5\mu m} \rightarrow PN_{10\mu m}$, NH_3 in g/km, other in discussion
- 5 not before 2025, maybe 2027/28 after an EU-6e


Post Euro-6 – commission targets and advisory group meeting discussions

AVL Engineering | AVL E | 05 Mar 2020 | 15

<https://www.avl.com/web/guest/-/the-vehicle-powertrain-challenge-post-euro-6-emission-testing>


Euro-7 legislation state of summer 2020

Post Euro-6 Webinar 2: Certification testing



AVL Solution – Chassis Dyno


Challenge Solution Added Issues



AVL Engineering | AVL E | Post Euro-6: Certification | 02 Jul 2020 | 13

<https://www.avl.com/web/guest/-/post-euro-6-emission-testing-the-impact-on-emission-and-energy-measurements-on-chassis-dyno-testbeds>

Post Euro-6 Webinar 1: R&D testing systems



Gasoline: Zero Impact Scenario

Engine	EGR	Electr. Heater	closed coupled 3-Way Catalyst	Coated Gasoline Particle Filter	Underfloor 3-Way Catalyst	Ammonia Slip passive SCR	OBM Sensors	Measurement Systems
			HC TWC	cGPF	UP TWC	ASC/psCR	AM	Certification system: CPS SL, AMA SL diluted PSS SL, APC 23nm and 10nm SESAM 160 FT Diluted
				Pre-GPF			Tailpipe	AVL MSS2™ Micro Soot Sensor
				Pre-GPF			Tailpipe	AVL APC xApp™ Particle Counter
EGR CO2			Pre-Cat		Mid-Cat		Tail Pipe	AMA SL Raw
						Pre- and Post-SCR		SESAM 160 FT Raw SCR Optimization, Measurement of NH3

An exhaust aftertreatment scenarios for Post-Euro-6 and zero impact emissions

AVL Engineering | AVL, Linde, Mahle | Post Euro-6: Certification | 02 Jul 2020 | 14

<https://www.avl.com/web/guest/-/post-euro-6-emission-testing-how-r-d-emission-testing-can-look-like>

Contact Us

더 자세한 내용에 대해 궁금한 점이 있으시면,
AVL의 담당자에게 문의하십시오.

krmarketing@avl.com

Thank you



www.avl.com