

Pollutant Emissions from Road Transport: State of Play of the European Union Regulations

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The Joint Research Center at a glance

- **In-house science service of the European Commission.** Independent, evidence-based scientific and technical support for many EU policies (fisheries, cybersecurity, migration, taxes, energy efficiency, etc.)
- **~370 million € annual budget**
- **~2750 staff** ~70% researchers, >2000 publications per year
- 42 large scale research facilities including **9 emission test laboratories** (VELA labs)
- **Sustainable Transport Unit:** vehicle emissions, CO₂ from road transport, electric mobility, connected and automated mobility, transportation innovation.

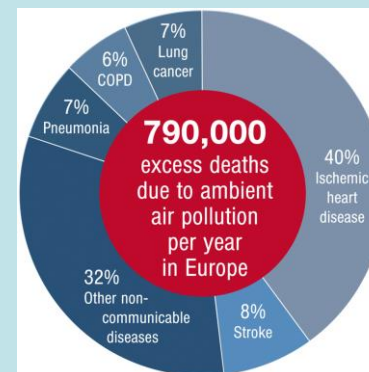
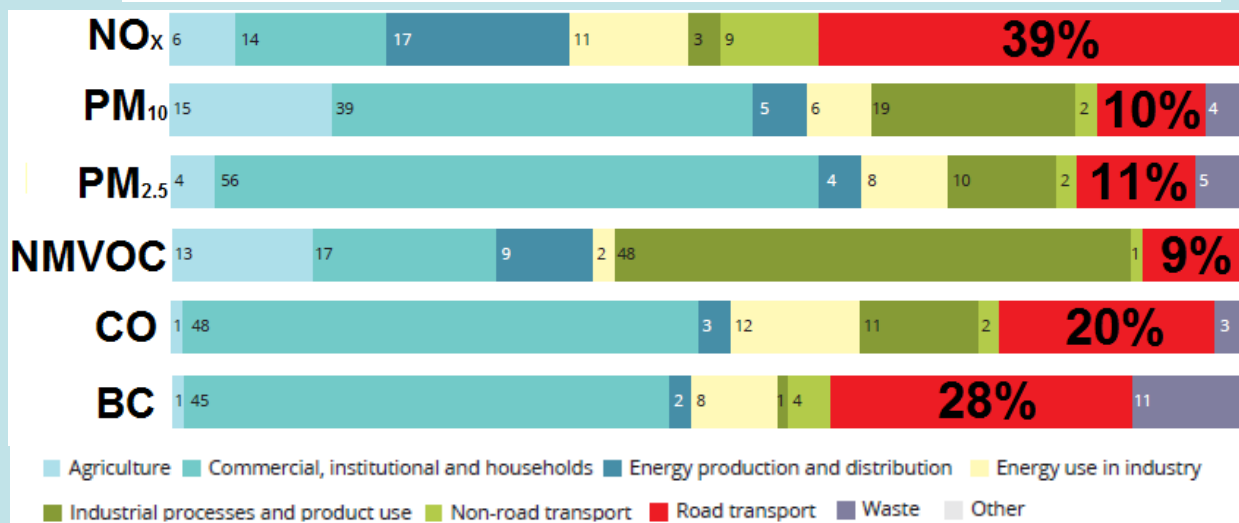


Air quality in Europe

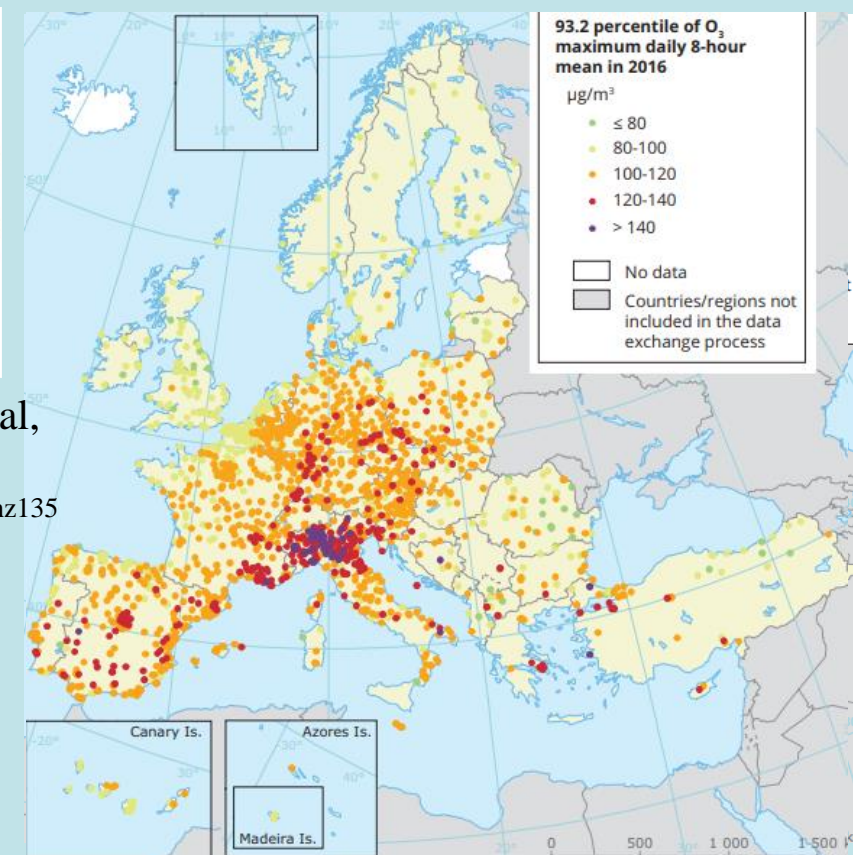
Premature deaths attributable to PM_{2.5}, NO₂ and O₃ in the EU-28, 2015

		PM _{2.5}	NO ₂	O ₃
	Population (1 000)	Premature deaths	Premature deaths	Premature deaths
EU-28	506 030	391 000	76 000	16 400

Contribution to EU-28 emissions from main source sectors in 2016



European Heart Journal,
March 2019
<https://doi.org/10.1093/eurheartj/ehz135>



Recent activities on road transport emissions in the EU

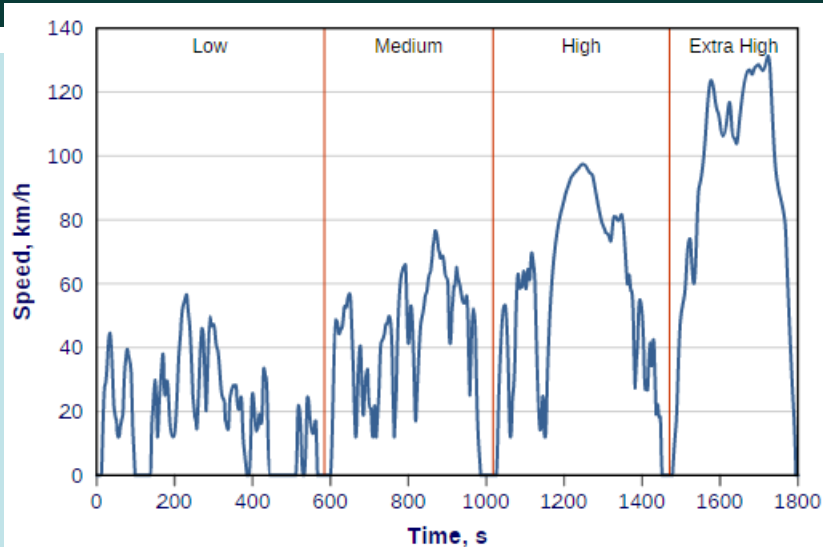
- **Amended Emissions Legislation at EU level**

- New/revised emission testing procedures: LDV new chassis dynamometer test procedure (WLTP), Real Driving Emissions (RDE) regulation, amended HDV PEMS test, In-Service Monitoring NRMM
- New Type Approval and market surveillance regulation adopted in 2018, in force from 2020

- **Since 2015, investigations by EU Member States on vehicle emissions**

- Environmental performance assessment
- Need of information sharing regarding testing methods, defeat devices, recalls and remedial actions was identified

LDV – Laboratory test Type I



Worldwide harmonized Light vehicles Test Procedures (WLTP). EU 2017/1151

- Euro 6 limits remain
- Test cycle: WLTC class 3b
- Improved RL determination
- Reduced flexibilities + enhanced technical specs. for lab equipment
- Amended preconditioning and soaking
- Individual GS strategy
- Battery SOC, Ki, Amb Temp corrections for CO₂

Euro 6 limits M1/N1 Cl 1	PI	CI
NO _x [mg/km]	60	80
CO [mg/km]	1000	500
THC [mg/km]	100	-
HC + NO _x [mg/km]	-	170
NMHC [mg/km]	68	-
PM [mg/km]	4.5	4.5
PN [# /km]	GDI: 6e11	6e11

	NO _x	THC	CO	PN	CO ₂
NEDC → WLTC	↑	↓	↓	≈	↑↑



LDV – EU-RDE overview

- EU-RDE aims at securing on-road emissions in real world driving throughout the normal life of LDV (PC & LCV).
- Emission limits based on **Not-To-Exceed principle** – CF accounts for measurement uncertainty. Annual review for CF to bring it down to 1 (if possible).

$$NTE_{\text{pollutant}} = CF_{\text{pollutant}} \times \text{EURO-6}$$

- 2011: kick-off meeting of RDE working group
- 2011-2015: evaluation of candidate procedures
development of PEMS test procedure

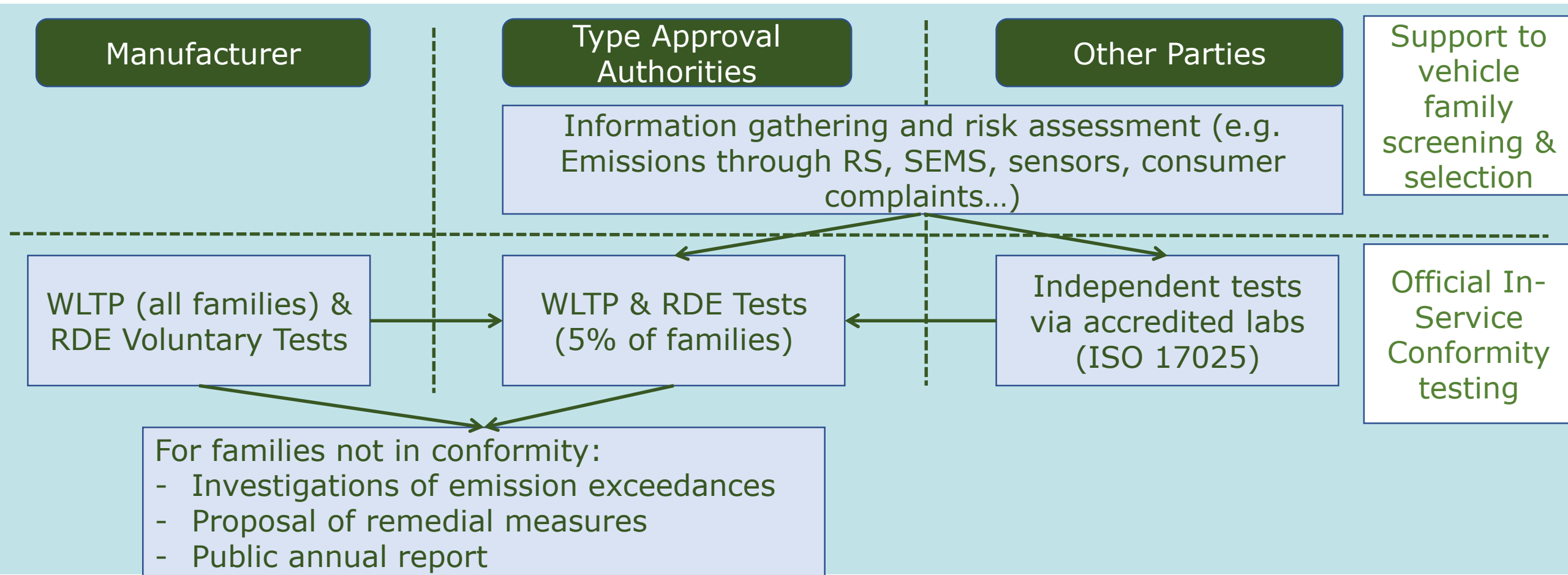
LDV – EU-RDE overview

- **RDE1: Regulation 2016/427**
 - Specifications PEMS equipment / PEMS validation
 - Emission calculation + ex-post evaluation methods (MAW & PB)
- **RDE2: Regulation 2016/646**
 - NOx CF 1.5 (temporary 2.1)
 - Compliance during urban driving and the entire RDE trip
 - Additional BC: trip dynamics + cumulative positive elevation gain
- **RDE3: Regulation 2017/1154**
 - Coverage of cold start
 - Evaluation of hybrid vehicles
 - PN emissions CF 1.5 // coverage regen. events

LDV – Highlights 4th RDE Package (EU 2018/1832)

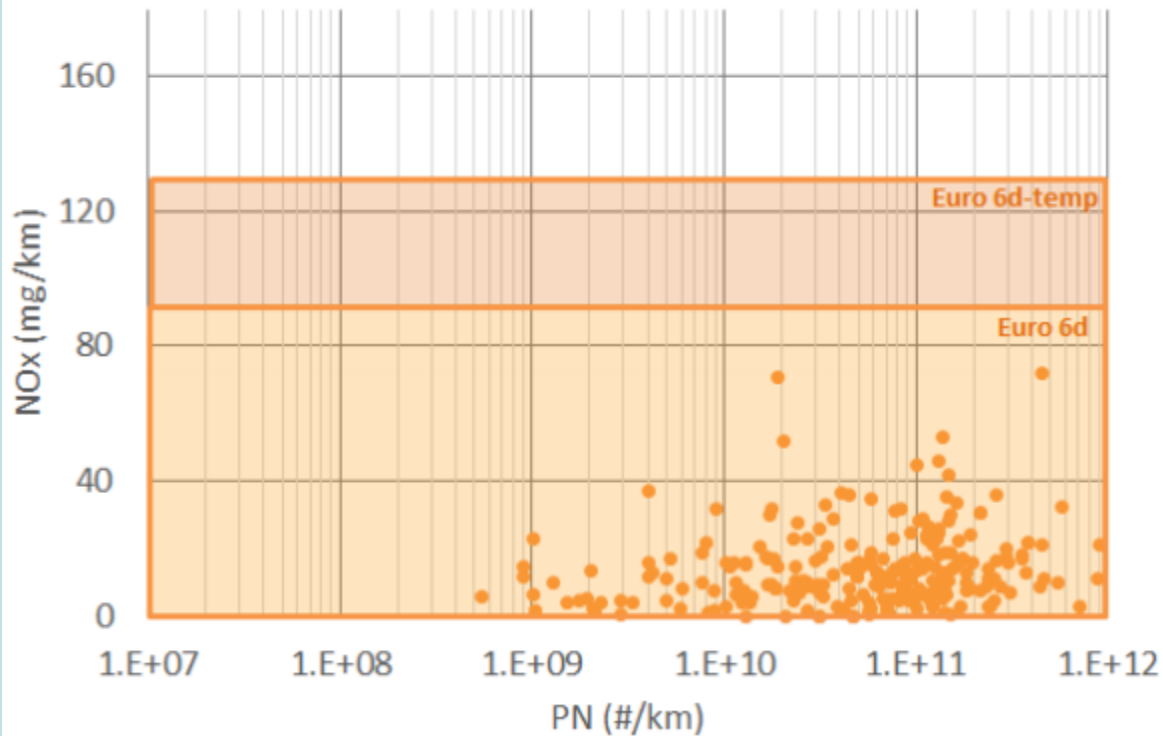
- **Reviewing RDE procedure and adapting provisions to ensure practicality and effective emissions testing**
 - Revised data evaluation methods: MAW for assessing trip validity only. Raw emissions within certain CO₂ limits
 - revision of NO_x CF: 1.43 from 2020
 - Revised data evaluation for hybrids
 - Provisions for Extended Documentation Package
- **Provisions for In-Service Conformity (ISC)** In force from 01/2019
 - ISC is the procedure to test that vehicles comply with their emission limits throughout their normal life under normal conditions of use
 - Defines the responsibilities of the industry, the authorities and accredited labs for testing in-service vehicles (ISO17025)
 - Procedures for vehicle screening and selection
 - Procedures for vehicle family statistical pass-fail

LDV – ISC schema

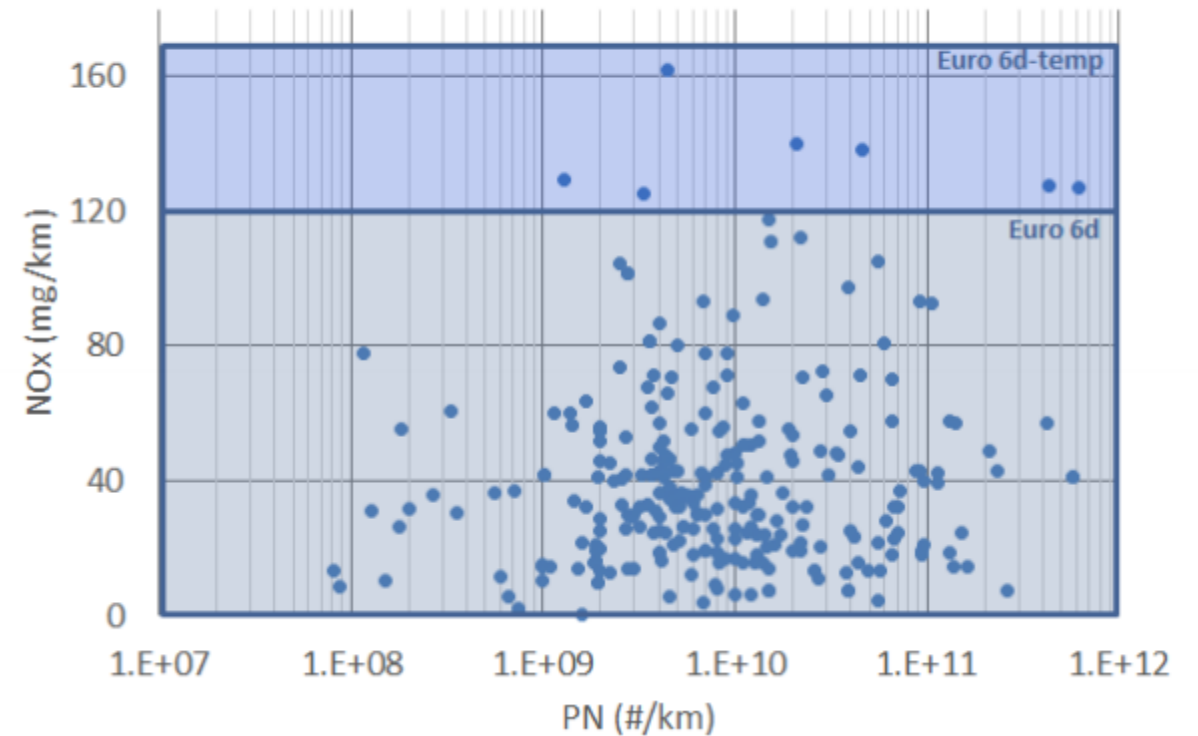


LDV – RDE-ISC benefits

Petrol cars



Diesel cars



LDV – Remaining Challenges

- **To deploy techniques and schemes for ISC screening data (RSD, other...) prior to ISC family selection**
- **To ensure that the compliance of the worst real-world emitters is checked**
- **To have efficient tools to identify the illegal strategies, the durability issues (by manufacturers) and possibly illegal behaviors by users (tampering)**

HDV – Legislative framework

- Euro VI emission standards since 2013 (EC 595/2009, EC 582/2011).
- TA of engine performed on engine test bench World Harmonised Transient Cycle (cold and hot conditions) and World Harmonised Stationary Cycle

	Limit values							
	CO (mg/kWh)	THC (mg/kWh)	NMHC (mg/kWh)	CH ₄ (mg/kWh)	NO _x ⁽¹⁾ (mg/kWh)	NH ₃ (ppm)	PM mass (mg/kWh)	PM number (#/kWh)
WHSC (CI)	1 500	130			400	10	10	$8,0 \times 10^{11}$
WHTC (CI)	4 000	160			460	10	10	$6,0 \times 10^{11}$
WHTC (PI)	4 000		160	500	460	10	10	⁽²⁾ $6,0 \times 10^{11}$

- Mandatory PEMS-based test to check the conformity of heavy-duty engines during the normal life of those engines: “In Service Conformity” (ISC) requirements. (EC 2016/1718)

HDV – ISC testing procedure

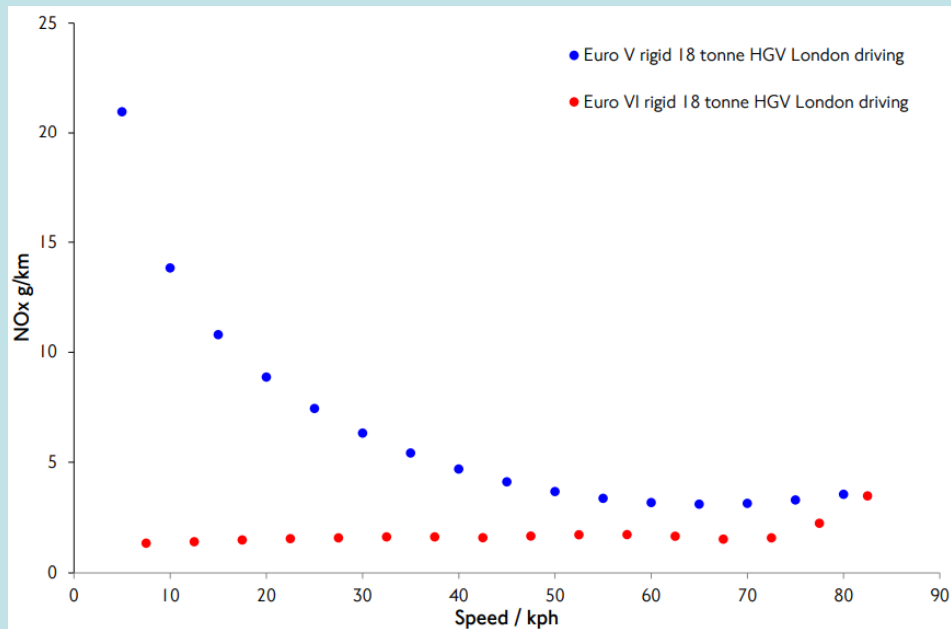
- The ISC test shall be representative for vehicles operated on their real driving routes, with their normal load and with the usual professional driver of the vehicle.
- After TA of an engine family the manufacturer shall perform ISC testing on this engine family within 18 months from first registration of a vehicle fitted with an engine from that family (in service for at least 25,000 km).
- ISC is repeated at least every 2 years for each engine family periodically on vehicles over their useful life period.

HDV – ISC Data Evaluation (Euro VIId)

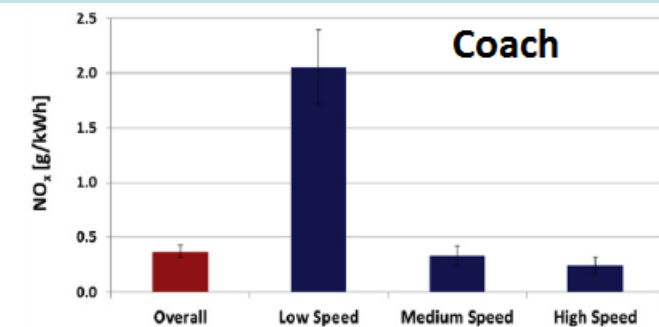
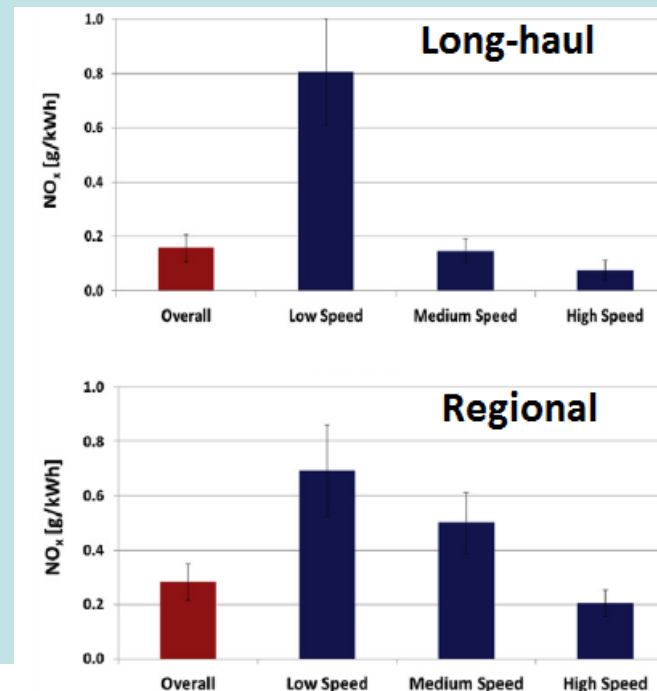
- The result of the test shall give sufficient confidence that the engines - if extracted from the vehicle – would comply with the applicable emissions limits on the type approval transient cycle (WHTC)
- Data exclusions: cold start ($< 70\text{ C}$ coolant T), power operation when engine power $< 20\%$ of max engine power
- The conformity factor (CF) of the ISC test is the 90th cumulative percentile of all the valid window's
- If $CF_{\text{test}} \leq \text{Euro VI limit} \times 1.5$ (PEMS uncertainty) then **Pass**

HDV – EURO VI ISM benefits

TfL^(*) “has now tested examples of heavy-duty buses (MLTB cycle) and heavy-duty goods vehicles (TfL Suburban Cycle) at Euro VI. In each case, the results have been impressive, with emissions of NO_x significantly reduced from vehicles at Euro V. This is especially true at lower road speeds, which is clearly advantageous for urban and suburban areas.”



Comparison of Euro V vs. Euro VI NO_x emissions over a range of road speeds: 18 t rigid HGV 100% payload



<https://doi.org/10.1016/j.atmosenv.2018.12.042>

(*) Courtesy of Transport for London (<http://content.tfl.gov.uk/in-service-emissions-performance-of-euro-6vi-vehicles.pdf>)

NRMM – Non-Road Mobile Machinery

- NRMM: mobile machine, transportable equipment or vehicle with or without bodywork or wheels, not intended for the transport of passengers or goods on roads, and includes machinery installed on the chassis of vehicles intended for the transport of passengers or goods on roads: construction equipment, railroad engines, inland waterway, vessels, and off-road recreational vehicles, snowmobiles, engines below 19 kW or over 560 kW
- EU NRMM regulation (2016/1628) stage V lays down gaseous and particulate emission limits for NRMM + prescribes In-Service Monitoring to be performed over their normal operating duty cycles with PEMS
- The Commission shall conduct pilot programmes with a view to developing appropriate testing procedures for those engine categories and sub-categories where these are not in place

NRMM – Methodological challenges

- PEMS mounting and operations on small machineries (e.g.: sweeper, tiller)
- Measurement of emissions:
 - Uncertainty in concentration
 - Uncertainty in exhaust mass flow rate with EFMs
- Data processing:
 - Reference magnitudes (i.e. work and CO₂)
 - Working and not working events

EC Regulation 2018/858

- Replace current TA framework (Directive 2007/46/EC) from September 2020 + market surveillance provisions to improve enforcement
- Focus on harmonization of procedures to avoid divergence in the application of regulation & transparency
- Reinforce requirements of competence of Technical Services + establish mandatory periodic audits
- Designates EC as MS authority entitled to perform investigations on emissions compliance, technical competence

JRC Role within EC Regulation 2018/858

- **Tests and inspections** by laboratory tests, on-road tests, for statistically relevant samples, supplemented by documentary checks.
- **Tests** will cover the type approval requirements
- **Tests and inspections** according to:
 - Established principles of risk assessment;
 - Substantiated complaints;
 - Any other relevant information (Forum, published testing results, info on new technologies, reports from on-road remote sensing)



JRC Role within EC Regulation 2018/858

- Compliance assessment - Article 9
- Assessment of Technical services – Article 10
- Reporting to Forum – Article 11
- Participate to the procedure initiation in case of non-compliances



JRC Role: **Emission's** Market Surveillance

Emissions compliance tests for Market Surveillance:

- Relevant emissions requirements (non exhaustive):
 - Light-Duty Euro 6d-TEMP, Euro 6d (WLTP, RDE)
 - Heavy-Duty-Duty Euro IV c, d and e (PEMS for ISC),
 - Non-Road Stage V (PEMS for ISM).
- State of Play:
 - Pilot activity since 2017, annual report
 - Set-up EU scheme to collect emissions screening data
 - Accreditation for WLTP and RDE tests + Staff training
 - Definition of test protocols and internal procedures
 - Establishing coop. agreements/framework contracts



JRC Role: Emission's Market Surveillance



JRC SCIENCE FOR POLICY REPORT

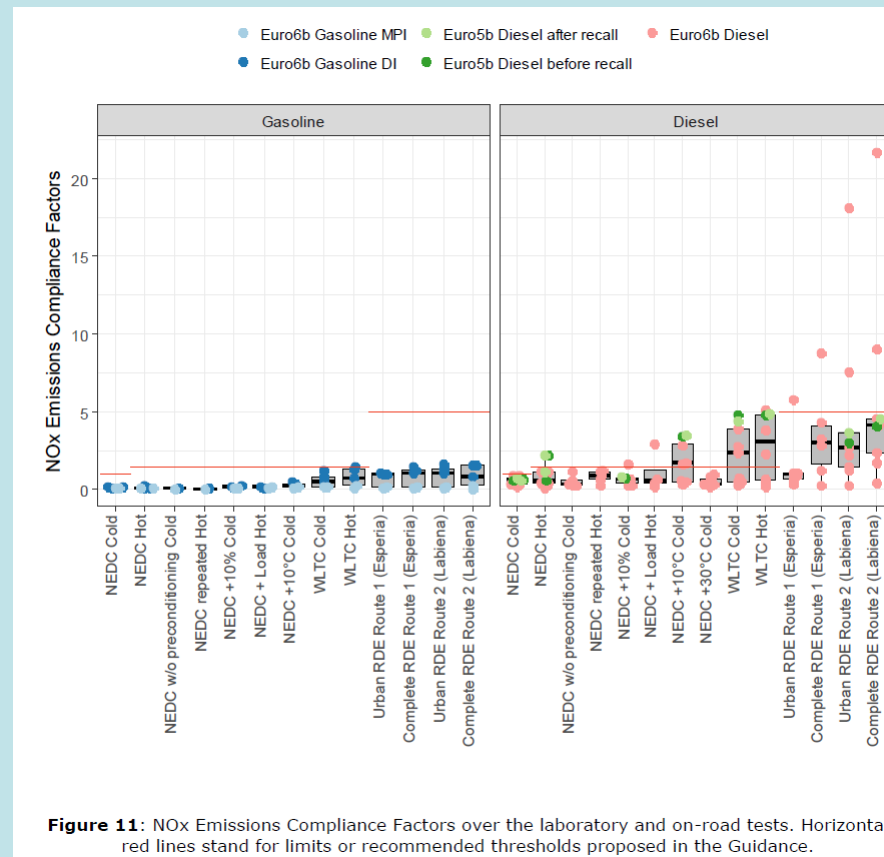
Joint Research Centre 2017
light-duty vehicles emissions
testing

*Contribution to the EU
market surveillance:
testing protocols and
vehicle emissions
performance*

M. Clairotte, V. Valverde, P. Bonnel,
B. Giechaskiel, M. Carriero, M. Otura,
G. Fontaras, J. Pavlovic, G. Martini,
A. Krasenbrink
2018



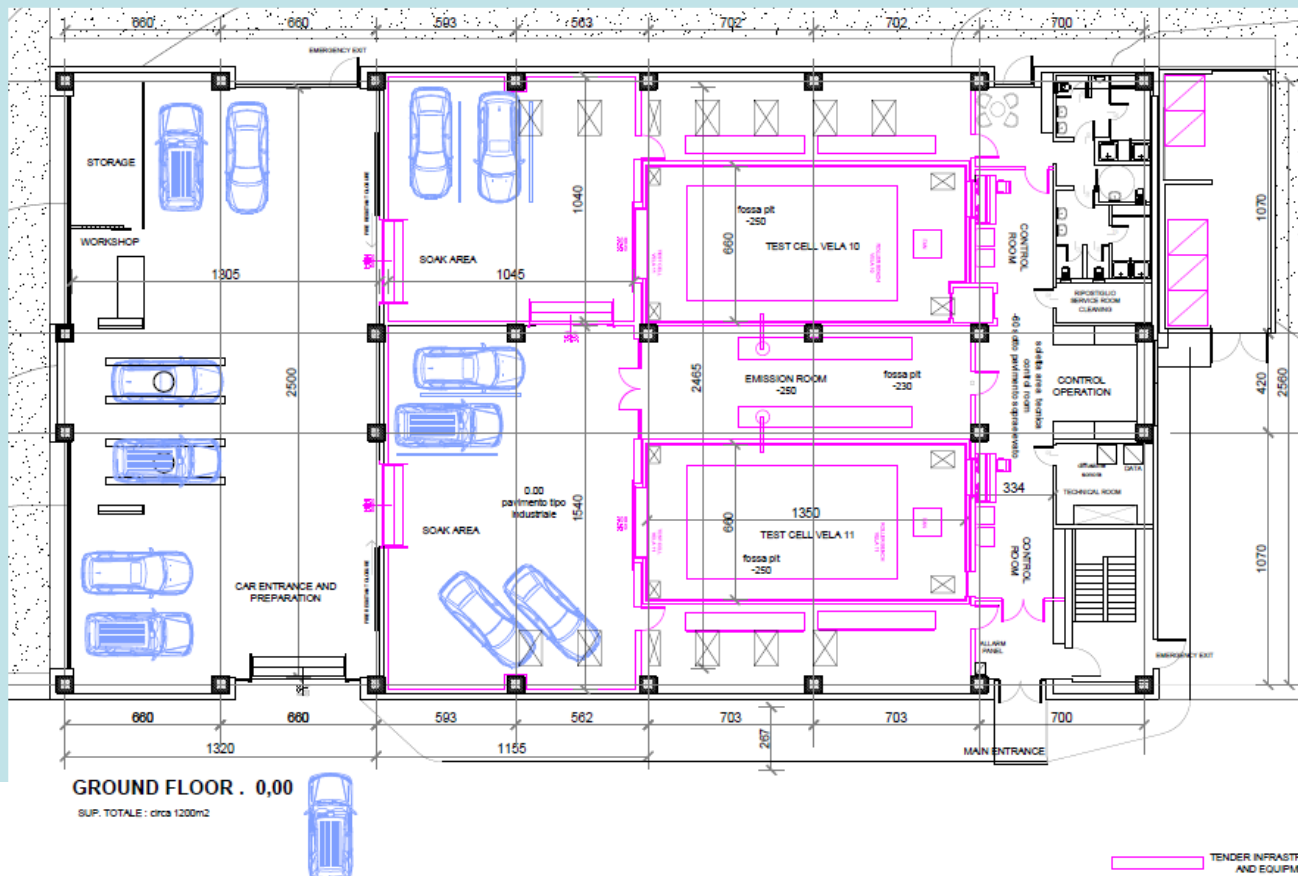
- Vehicle testing to check emissions compliance of vehicles representative of the latest technologies in the laboratory and on-road
- Development and validation of testing protocols to detect defeat devices



<https://ec.europa.eu/jrc/en/publication/annual-reports/jrc-annual-report-2017>

JRC Role: Emissions Market Surveillance

New Vela 10 & 11 Laboratories



JRC Role: **Vehicle safety** Market Surveillance

Vehicle safety compliance tests for Market Surveillance

- Based on EC/UN regulations specifications.
- State of Play:
 - Planning of the test activities to be performed
 - Analysing of the existing options to where perform the tests
 - Building up of technical skills to perform the tests
 - Studying the possibility of co-op. agreements/framework contracts
 - Participating in UNECE WPs and IWG



Conclusions

- Strong steps ahead on performant regulations to curb criteria pollutant emissions from LDV, HDV, NRMM (although early discussions on post-Euro 6/VI have already started)
- Challenges for efficient enforcement (appropriate screening methods, adequate ISC testing, ISO accreditation, tampering, budget, human resources, etc.)
- Adjust to the new role of JRC within new TA framework

Acknowledgments

- Pierre Bonnel, V. Valverde, A. Zardini, R. Suarez, C. Astorga, J. Pavlovic – LDV
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- A. Perujo, Roberto Gioria – NRMM
- Market Surveillance team
- VELA lab technicians and managers

Thanks for the attention



EU-RDE emissions calculations

RDE4 emissions calculation

For the complete RDE trip and for the urban part of the RDE trip (k=t=total, k=u=urban):

$$M_{RDE,k} = m_{RDE,k} \cdot RF_k$$

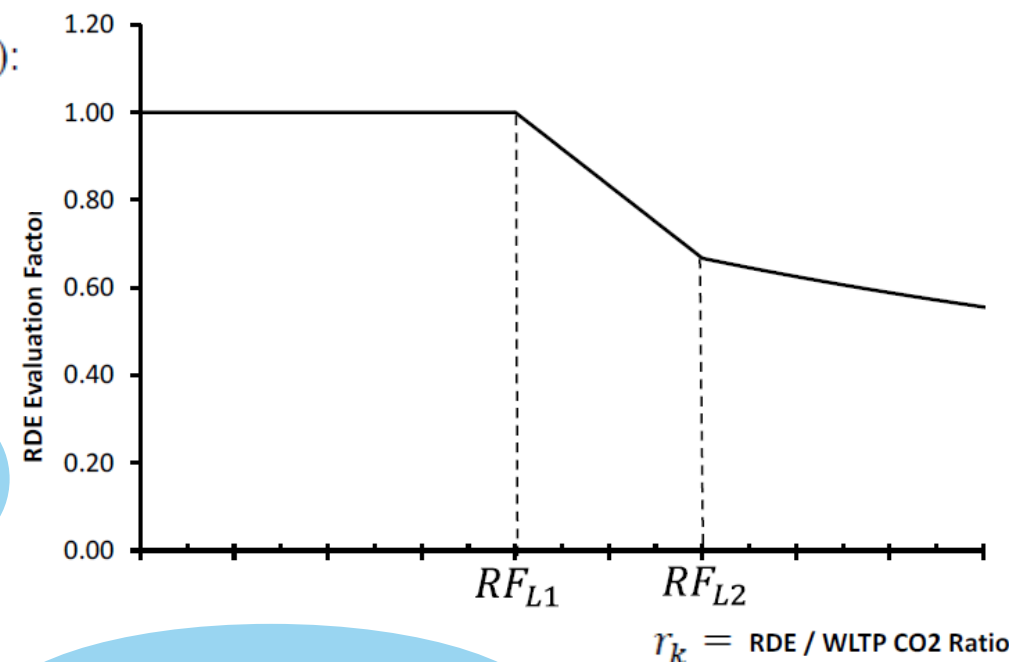
Final RDE *raw RDE* *RDE eval fact.*

ICE / NOVC-HEV: $r_k = \frac{M_{CO_2,RDE,k}}{M_{CO_2,WLTP,k}}$

*Low & Medium WLTP phases for
URB CO₂*

OVC-HEV: $r_k = \frac{M_{CO_2,RDE,k}}{M_{CO_2,WLTP-CS,t}} \cdot \frac{0,85}{IC_k}$

$$IC_k = \frac{d_{ICE,k}}{d_{ICE,k} + d_{EV,k}}$$



ratio of usage of ICE
RDE/WLTP

Euro 6D-TEMP: $RF_{L1} = 1,20$ and $RF_{L2} = 1,25$;
Euro 6D: $RF_{L1} = 1,30$ and $RF_{L2} = 1,50$;

Revision clause