

# In-use testing in the European vehicle emissions legislation

PEMS 2014 International Conference & Workshop 3-4 April 2014
Center for Environmental Research & Technology UC Riverside, USA

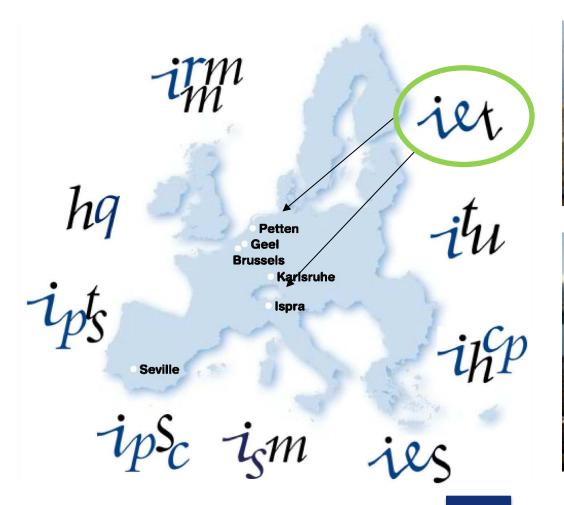
Martin Weiss, Francesco Riccobono, Pierre Bonnel, Adolfo Perujo

**European Commission DG - Joint Research Centre (JRC) IET - Institute for Energy and Transport** 

# **The Joint Research Centre**



JRC - the European Commission's in-house science service to support EU policy making







# Why in-use testing?



### **Practicality and costs**

 in-use testing of heavy-duty engines and NRMM: PEMS avoids extracting engines from vehicles

# Why in-use testing?



### **Practicality and costs**

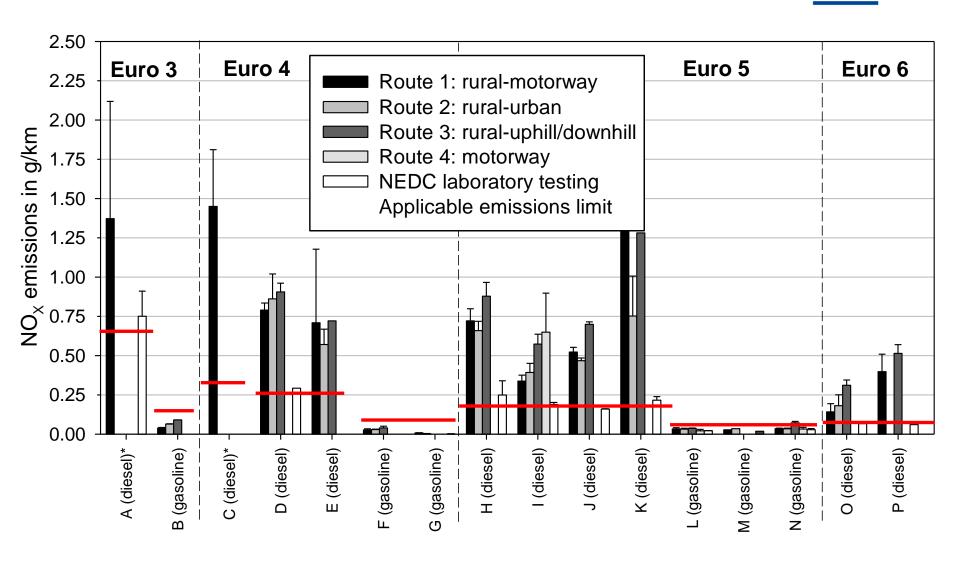
• in-service conformity testing of heavy-duty engines and NRMM: PEMS avoids extracting engines from vehicles

### **Effectiveness (mainly light-duty vehicles):**

 In-use testing of on-road emissions forces the optimal design of after-treatment technologies and limits the use of defeat strategies

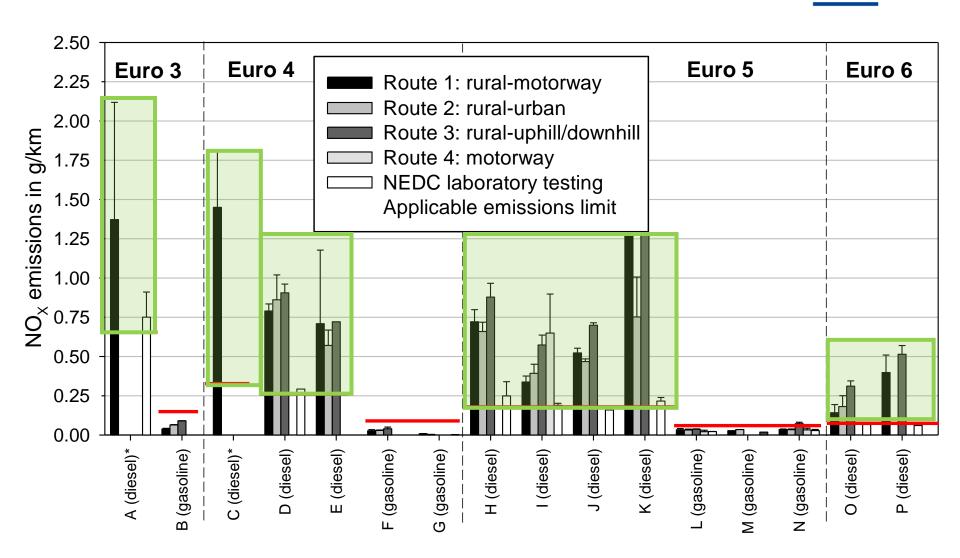
# Why in-use testing?





### **PEMS - Light-duty vehicles**





# History of in-use testing



- End 1990s to 2003: US-EPA first rules and development of instrumentation
- 2004-2005: Feasibility to check conformity of heavy-duty engines with PEMS
- 2007-2008: Heavy-duty PEMS pilot program
- 2007-present: PEMS tests of light-duty vehicles
- 2011: PEMS based in-service conformity and type approval for heavy-duty Euro V and VI engines (Regulations 582/2011 and 64/2012)
- 2010-2012: Non-road mobile machinery PEMS pilot program
- 2011-2014: Real-driving emissions (RDE) working group
- 2014: RDE test procedure

# Challenges of in-use testing

\*\*\*\*

European

- Wide range of operating conditions
- Need to contain variability in
  - Non-dynamic: altitude, ambient temperature
  - Dynamic and controlled: road grade, vehicle payload
  - Dynamic and uncontrolled: wind, vehicle speed and acceleration, engine load
- Accuracy and intrusivity of PEMS



- PEMS performance requirements
- Boundaries for test conditions
- Data evaluation
  - Excluding cold start and data outside permissible operating conditions
  - Averaging window principle



Moving averaging window approach: Averages over subsets of tests; duration in line with type-approval cycle

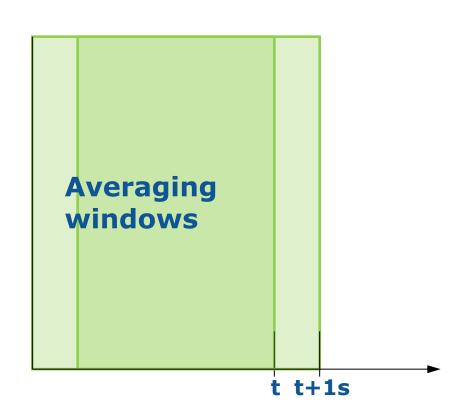


Moving averaging window approach: Averages over subsets of tests; duration in line with type-approval cycle

Reference CO<sub>2</sub>/work of test cycle **Averaging** windows

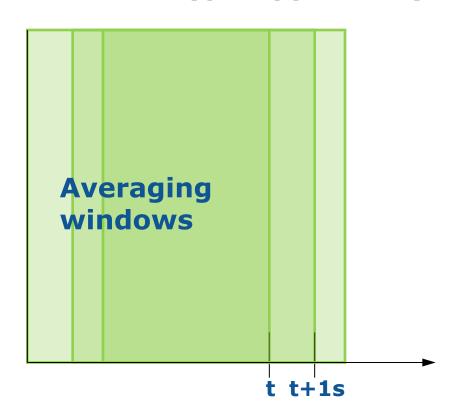


Moving averaging window approach: Averages over subsets of tests; duration in line with type-approval cycle



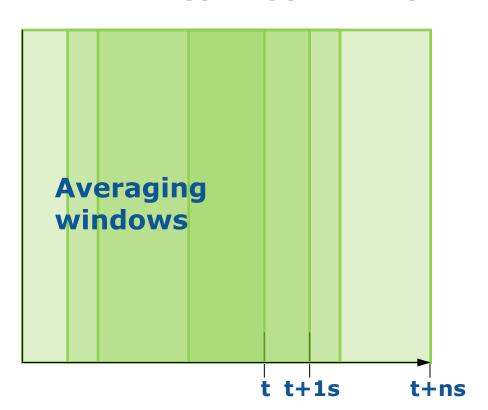


Moving averaging window approach: Averages over subsets of tests; duration in line with type-approval cycle



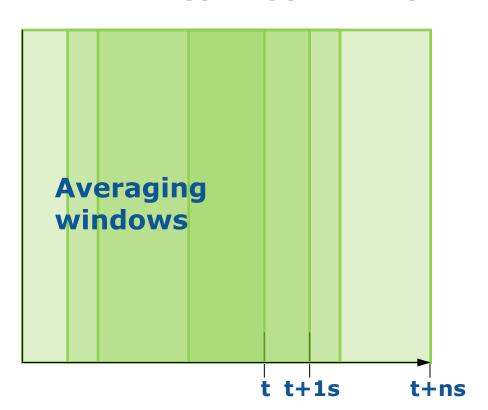


Moving averaging window approach: Averages over subsets of tests; duration in line with type-approval cycle





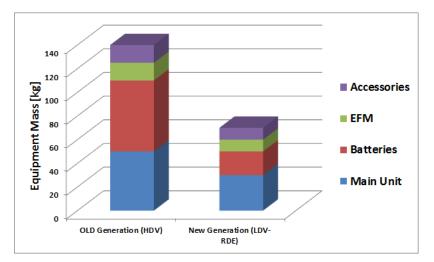
Moving averaging window approach: Averages over subsets of tests; duration in line with type-approval cycle



# Light-duty vehicles



- PEMS equipment:
  - Size, installation, and measurement performance
  - Safety









# Light-duty vehicles



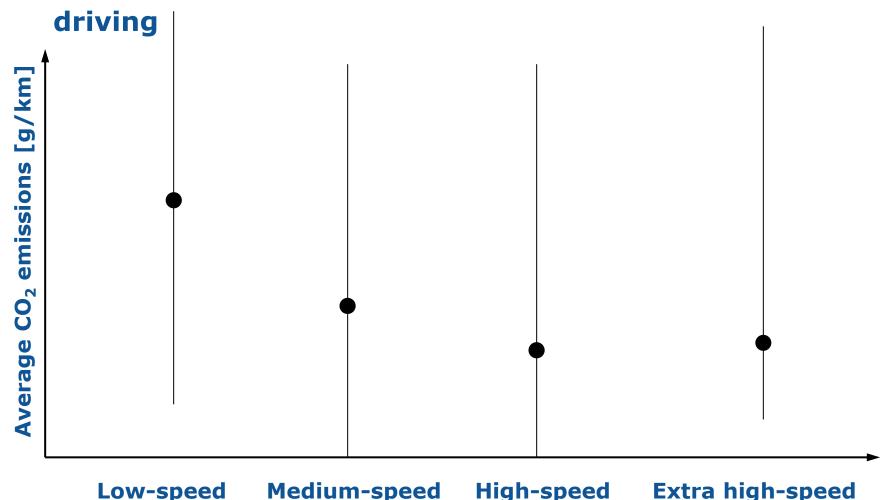
- PEMS equipment:
  - Size, installation, and measurement performance
  - Safety
- Boundary conditions of on-road tests
  - Non-dynamic, dynamic and controlled, dynamic and uncontrolled
- Data evaluation
  - To some extent uncontrolled driving dynamics, wind, road grade, vehicle payload
  - Correct evaluation of emissions performance

- Moving averaging window approach
- Routes contain equal shares of urban, rural, motorway driving

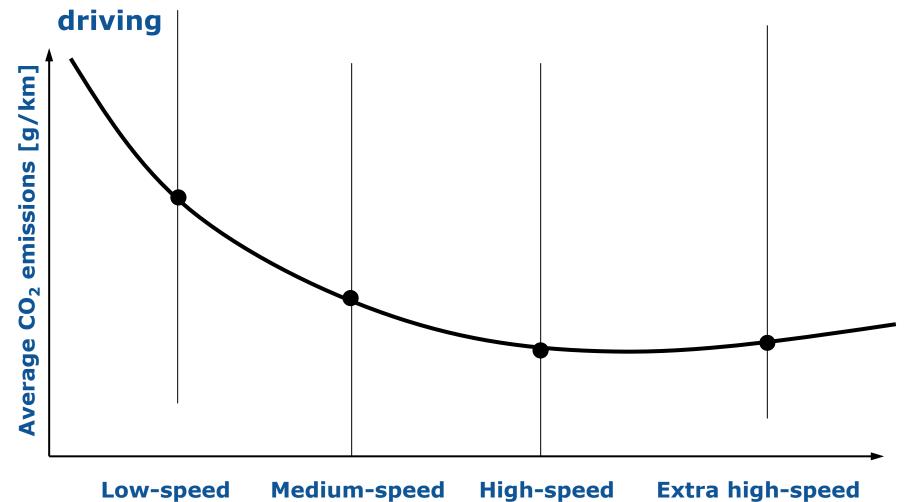




- Moving averaging window approach
- Routes contain equal shares of urban, rural, motorway



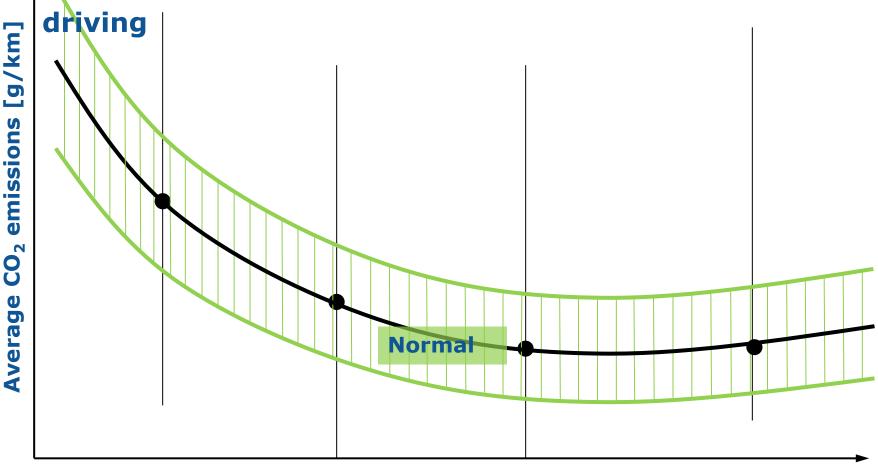
- Moving averaging window approach
- Routes contain equal shares of urban, rural, motorway





Moving averaging window approach

Routes contain equal shares of urban, rural, motorway



Low-speed

**Medium-speed** 

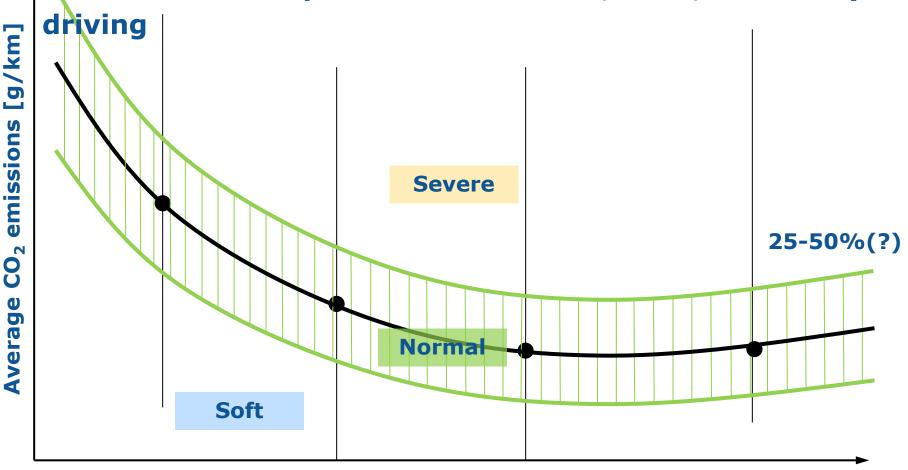
**High-speed** 

**Extra high-speed** 



Moving averaging window approach

Routes contain equal shares of urban, rural, motorway



Low-speed

**Medium-speed** 

**High-speed** 

Extra high-speed

# Heavy-duty vehicles



- Regulations 595/2009 implemented by Regulation 582/2011
- In-Service Conformity (NOT a real-driving off-cycle test)
- Gaseous pollutants only
- Route composition urban, rural, motorway
- Exclusion of cold start and events below 20% of rated engine power
- Average window analysis reference quantity: Work over the WHTC
- Not-to-exceed limit of 1.5 for 90% of valid windows
- Assessment of the heavy-duty PEMS regulations until end 2014
- PEMS-PM evaluation program launched in 2008
- PEMS-PM pilot program to be completed until end 2014



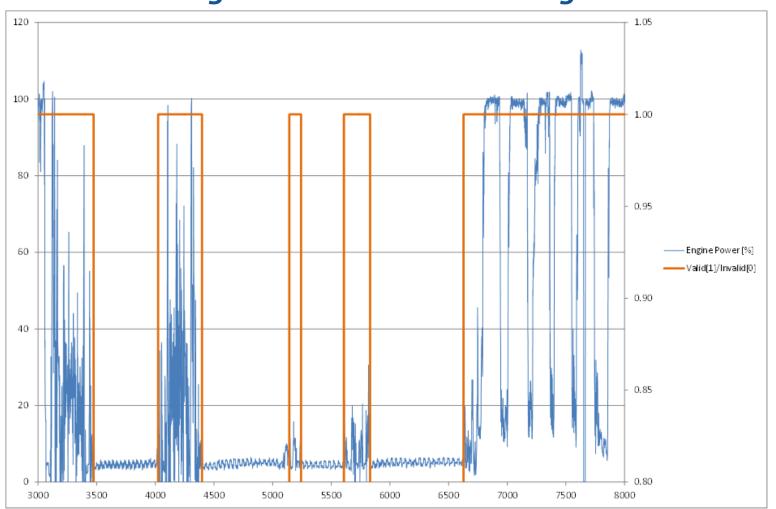
### In-service conformity – pilot testing

- Applicable to variable speed engines of categories Q and R (56 to 560 kW)
- NRMM test procedure based on the Euro VI legislation for heavy-duty vehicles
- Problem: no trip but long idling interrupted by work

Step 1: Excluding cold start (T coolant <343 K) and data outside permissible ambient conditions

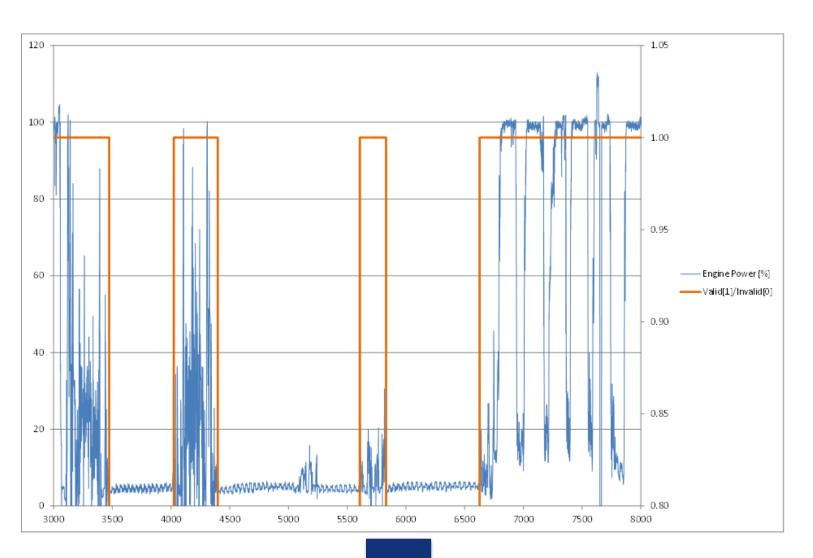


Step 2: Separating work (power >10%) from idling; considering non-working events <2min as working events



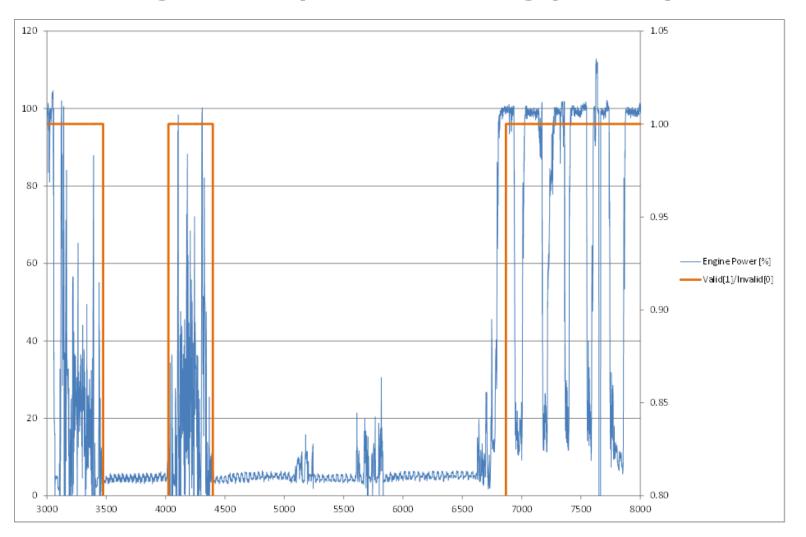


### Step 3: Merging short working (<2min) events with non-working



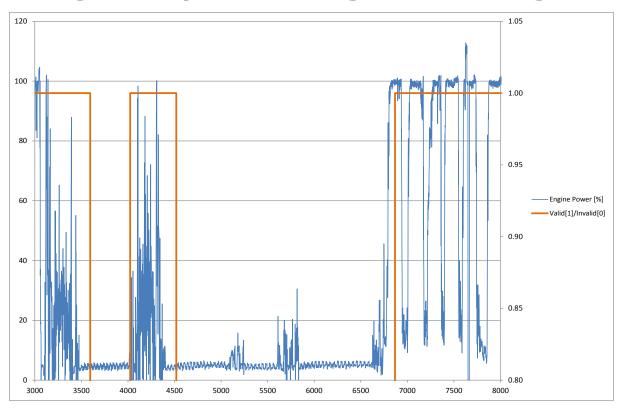


#### Step 3: Excluding 3 min of post non-working (take off) data





#### Step 4: Including 2 min post-working data of idling events



#### **Averaging window approach:**

- Excluding windows with power below 20% of engine rated power
- Pass-fail decision based on the 90-percentile of windows

### **European in-use testing**



- Light-duty vehicles testing from Sept. 2014 onward; binding not-to-exceed limits for lightduty vehicles (gaseous pollutants and PN) from Euro 6c 2017
- Assessment of heavy-duty regulation and pilot program PEMS-PM completed by end 2014 – amendments of Regulation 582/2011 in 2016/2017
- NRMM pilot program completed in 2013; adaptations of heavy-duty regulation – inservice conformity testing likely from 2017 onward

# Thank you!



Commission



pubs.acs.org/est

#### On-Road Emissions of Light-Duty Vehicles in Europe

Martin Weiss, \*\* Pierre Bonnel, \* Rudolf Hummel, \* Alessio Provenza, \* and Urbano Manfredi

<sup>†</sup>European Commission — DG Joint Research Centre, Institute for Energy and Transport, Sustainable Transport Unit, Via Enrico Fermi 2749 - TP 230, 21010 Ispra, Italy

ENTIFIC AND POLICY REPORTS

A complementary emissions test for light-duty vehicles:

Assessing the technical feasibility of candidate procedures

Conclusions of the Real-Driving Emissions - Light-Duty Vehicles

(RDE-LDV) working group

Martin Weiss Pierre Bonnel

Rudolf Humm

Atmospheric Environment 62 (2012) 657-665

Contents lists available at SciVerse ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Will Euro 6 reduce the NO<sub>x</sub> emissions of new diesel cars? — Insights from on-road tests with Portable Emissions Measurement Systems (PEMS)

Martin Weiss a.\*, Pierre Bonnela, Jörg Kühlweina, Alessio Provenza, Udo Lambrechtb, Stefano Alessandrini a. Massimo Carriero a. Rinaldo Colombo a. Fausto Forni a. Gaston Lanappe a. Philippe Le Lijour a, Urbano Manfredi a, Francois Montigny a, Mirco Sculati a

ion, DG – Joint Research Centre, Institute for Energy and Transport, Sustainable Transport Unit, via Enrico Fermi 2749 – TP 230, 21010 Ispra, Italy \*European Commission, DG – Joint Research Centre, Institute for energy and transport, заминише станура сыть.
\*BEU – Institute for Energy and Environmental Research, Department for Transport and Environment, Wilckensstraße 3, 69120 Heidelberg, Germa

#### **Contacts:**

**Heavy-duty and NRMM:** 

Adolfo Perujo (adolfo.perujo@ec.europa.eu)

#### **Light duty vehicles:**

Pierre Bonnel (pierre.bonnel@jrc.ec.europa.eu) Martin Weiss (martin.weiss@jrc.ec.europa.eu)

#### Particulate emissions - PEMS:

Francesco Riccobono (franscesco.riccobono@jrc.ec.europa.eu) Barouch Giechaskiel (barouch.giechaskiel@jrc.ec.europa.eu)



**JRC** 

A. Mamakos, M. Carriero, P. Bonnel H. Demircioglu, K. Douglas S. Alessandrini, F. Forni, F. Montigny, D. Lesueu **HEAVY-DUTY ENGINES CONFORMITY TESTING BASED** ON PEMS Pierre Bonnel - Janek Kubelt - Alessio Provenza JRC SCIENTIFIC AND POLICY REPORTS

NON ROAD ENGINES CONFORMITY **TESTING BASED ON PEMS** 

> Lessons Learned from the **European Pilot Program**

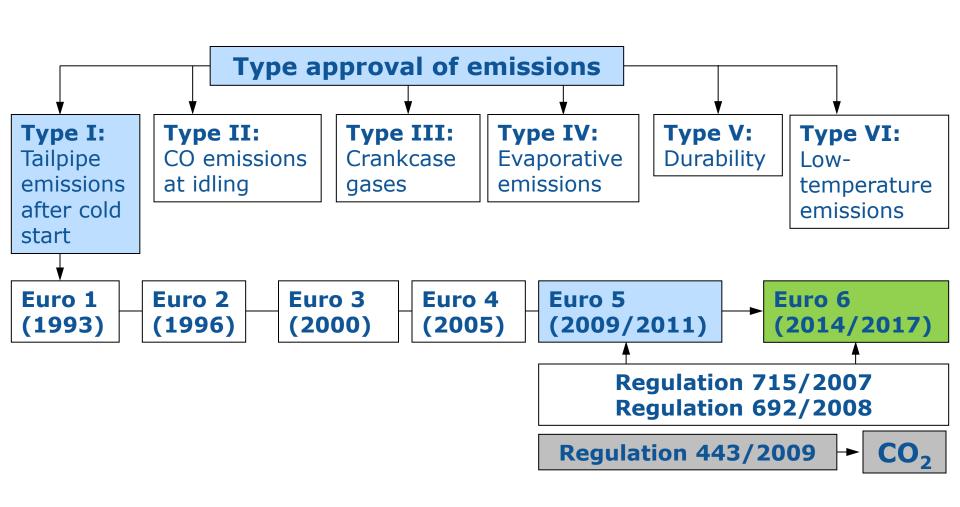
Report EUR 26438 EN

### Complementary slide: European emissions legislation



**Comprehensive framework developed over 35 years** 

**Light-duty vehicles: Category M and N vehicles** 



# **Complementary slide: Regulations & Activities**









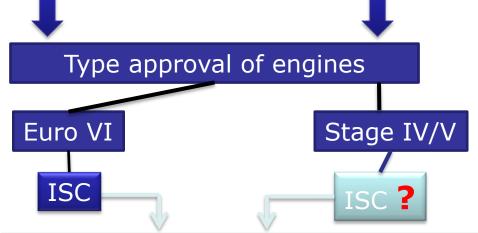


Type approval of vehicles

Euro 6

### Real-driving emissions

- NOx, CO (THC,PM)
- PN feasibility study
- Random cycle testing?



#### Real-driving emissions?

- so far only conformity testing
- assessment of HDV provisions
- industry-run PEMS-PM pilot program