



# **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**

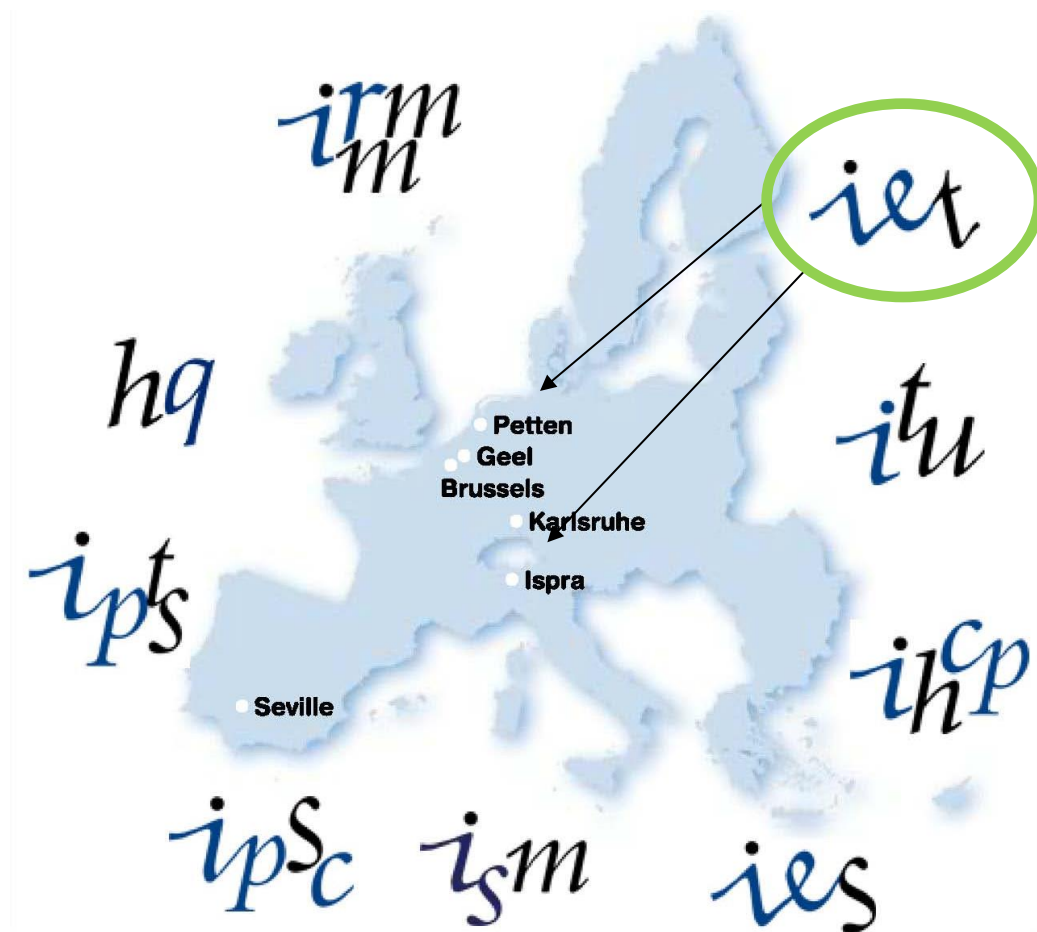
**Martin Weiss, Francesco Riccobono, Pierre Bonnel, Adolfo Perujo**

**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?



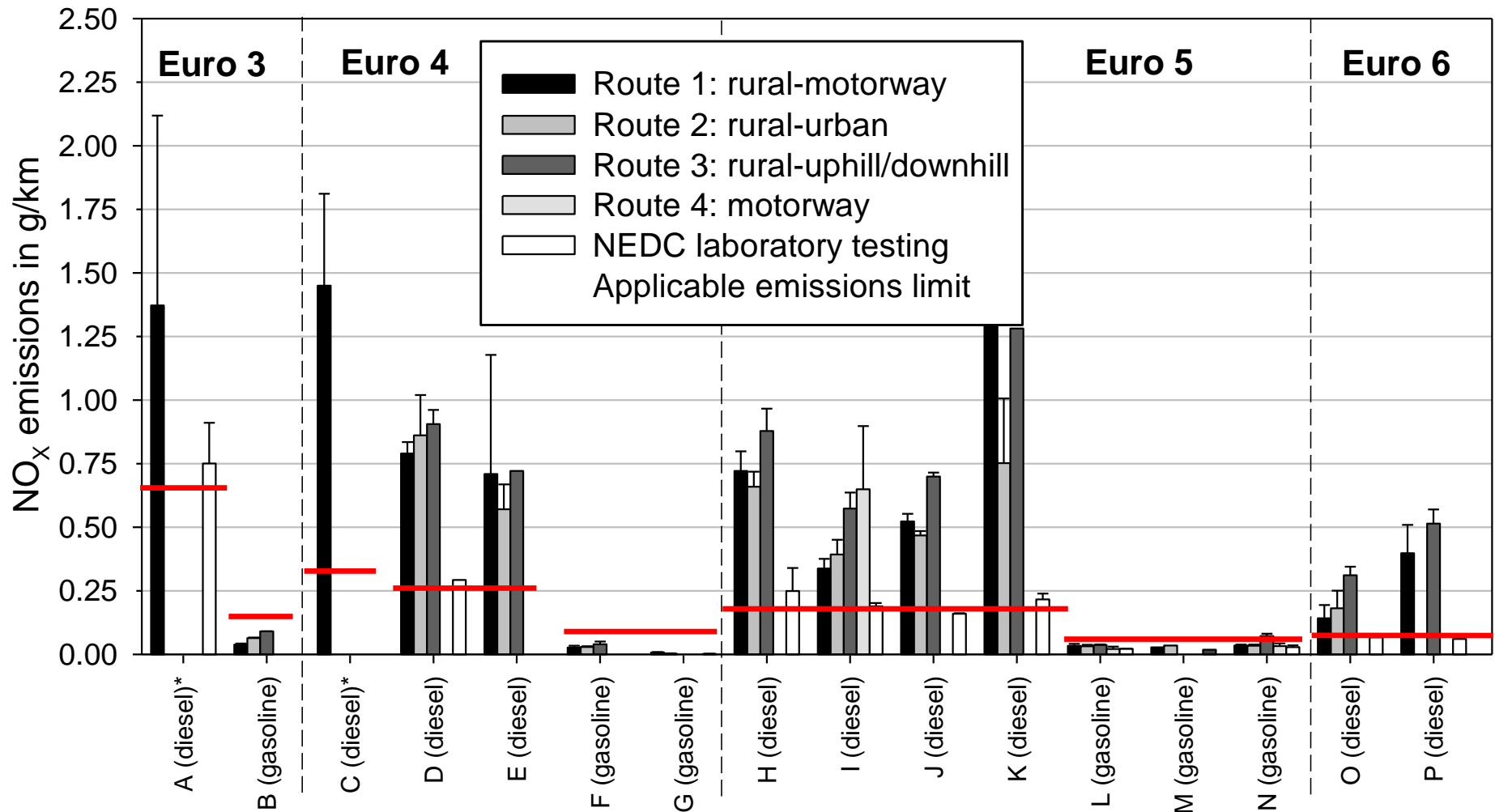
## Practicality and costs

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

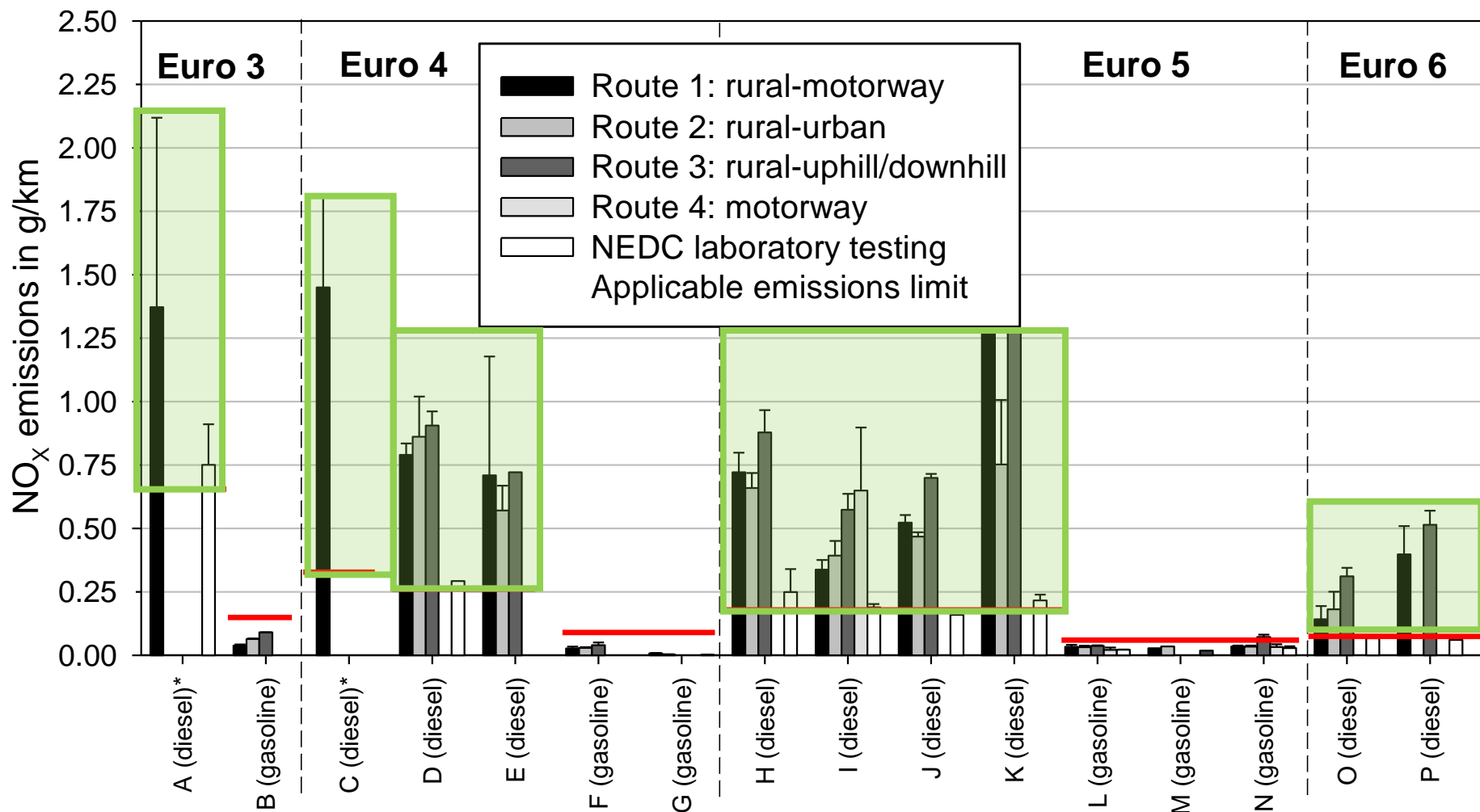
## Effectiveness (mainly light-duty vehicles):

- 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



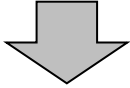
# History of in-use testing



- **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



- **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



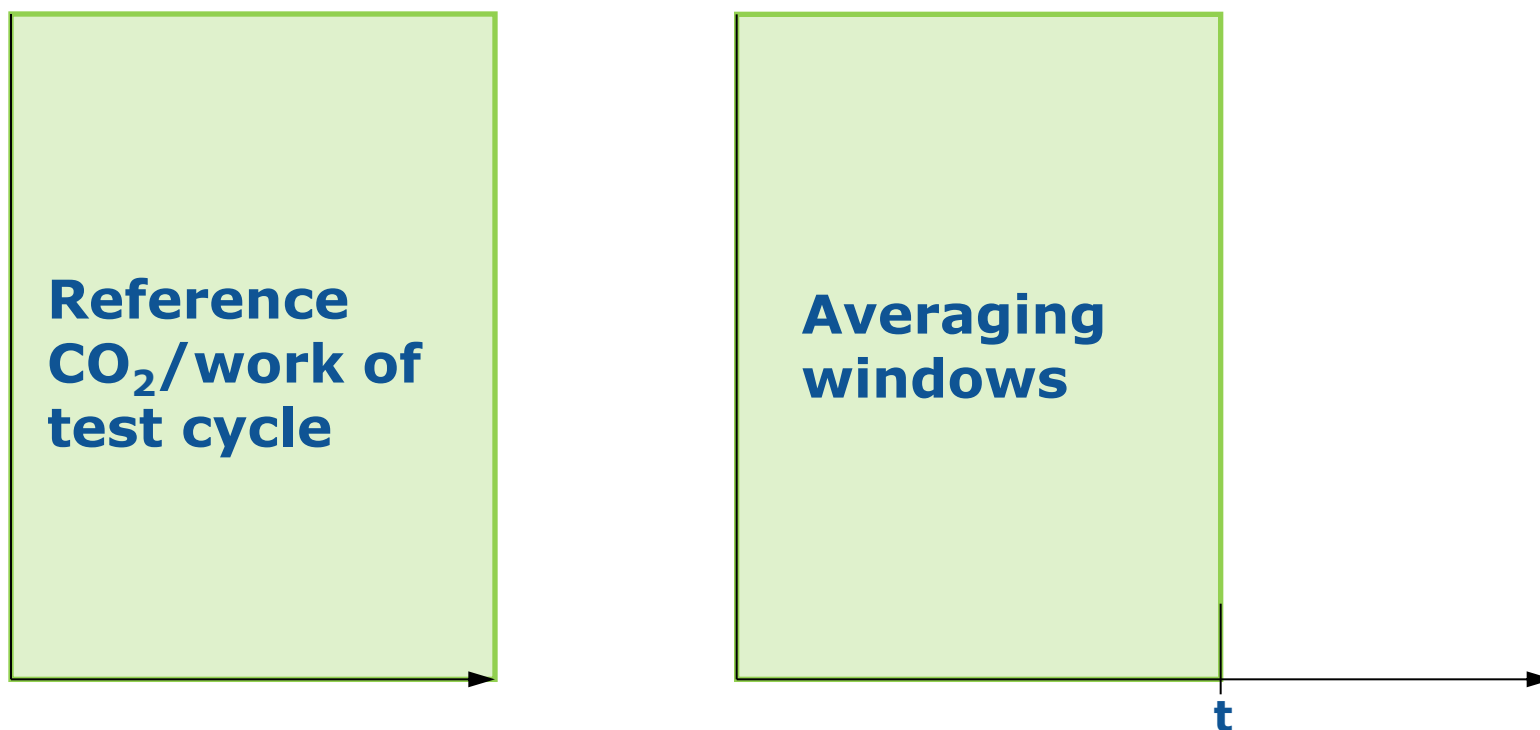
# Moving average windows

**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**

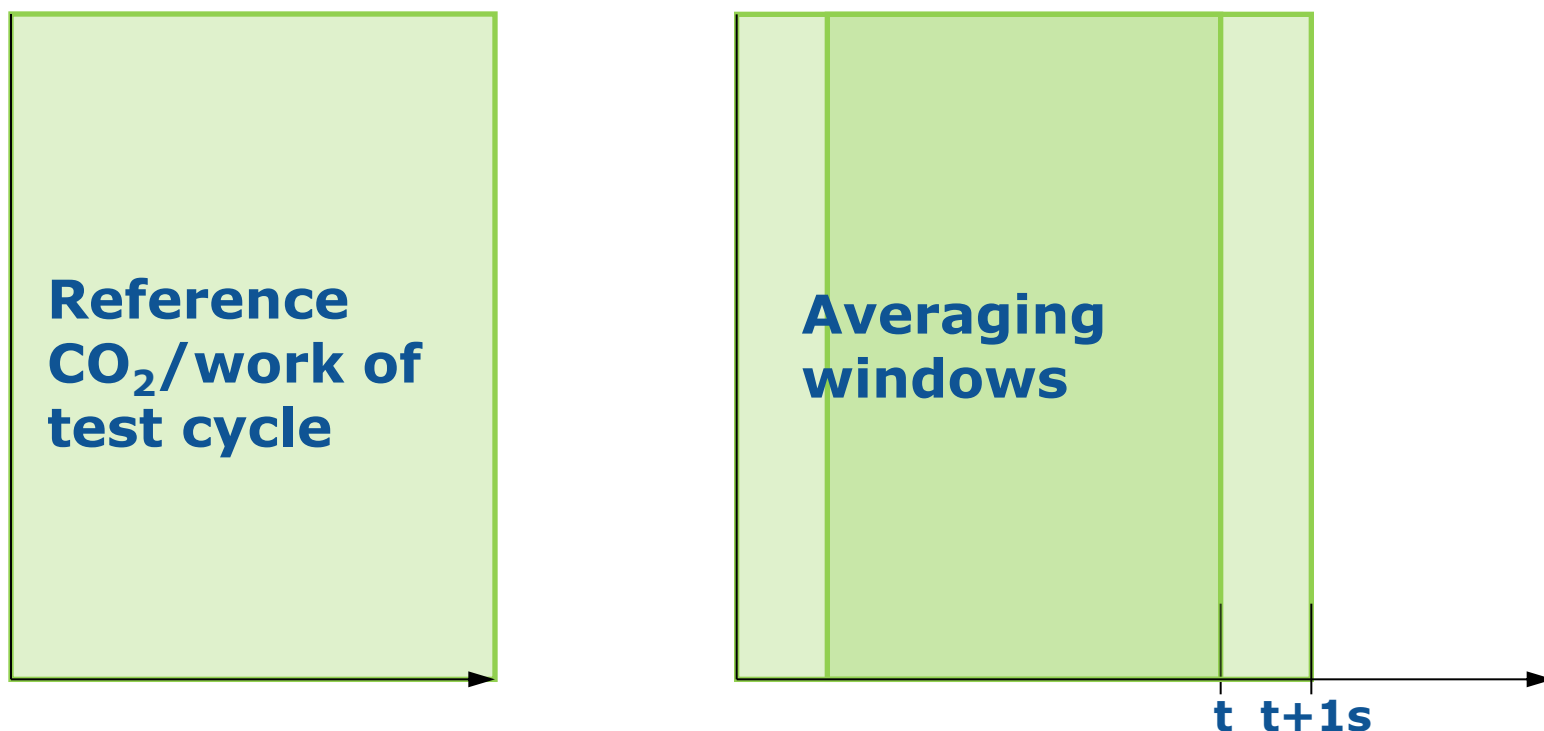
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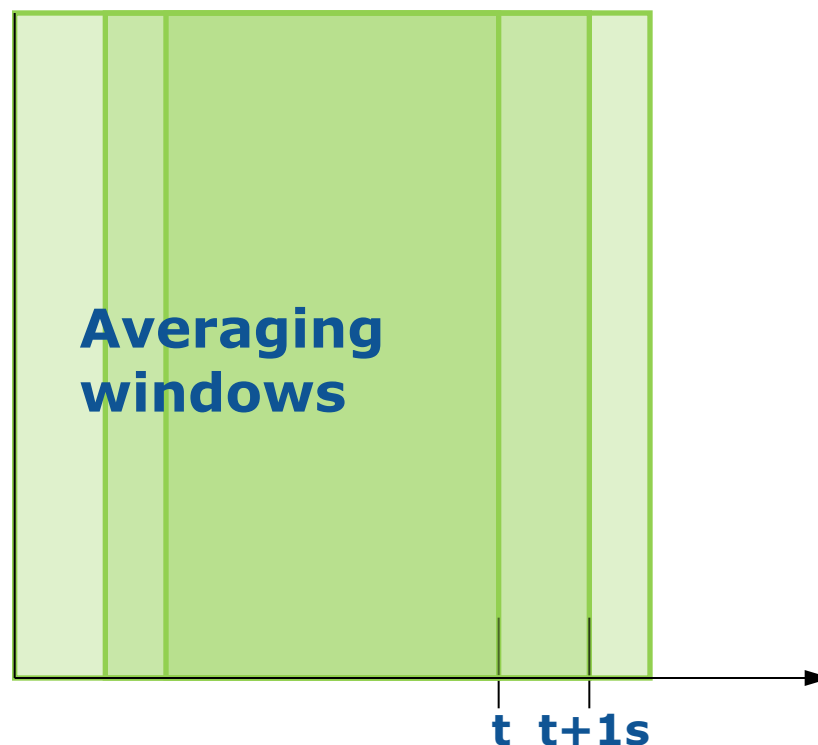
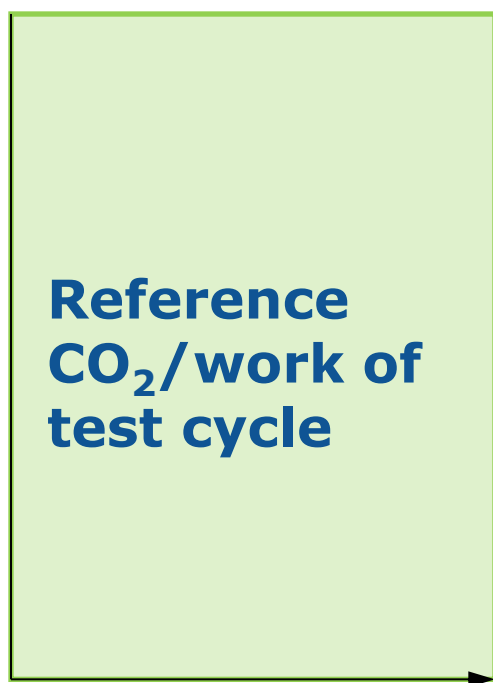
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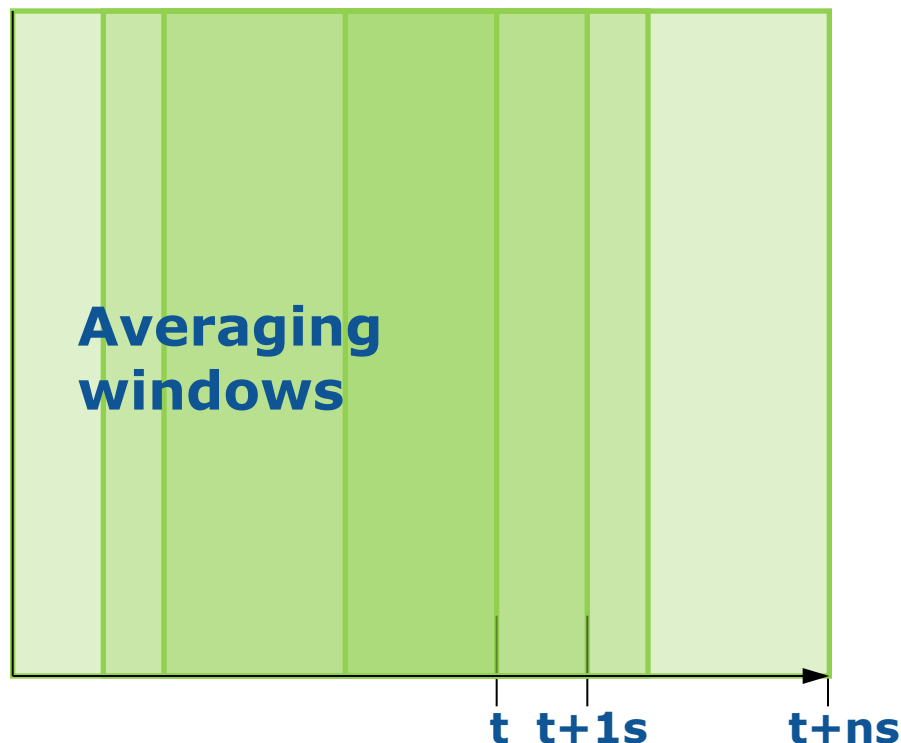
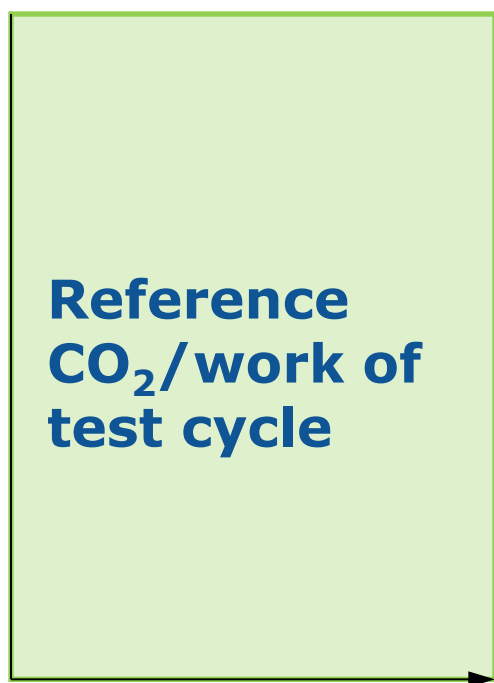
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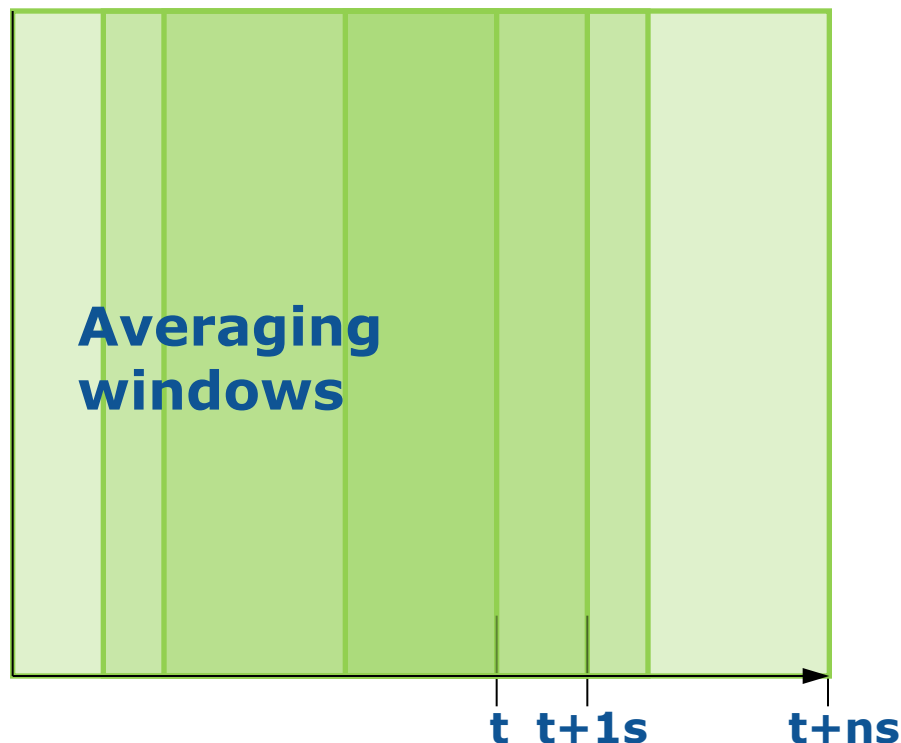
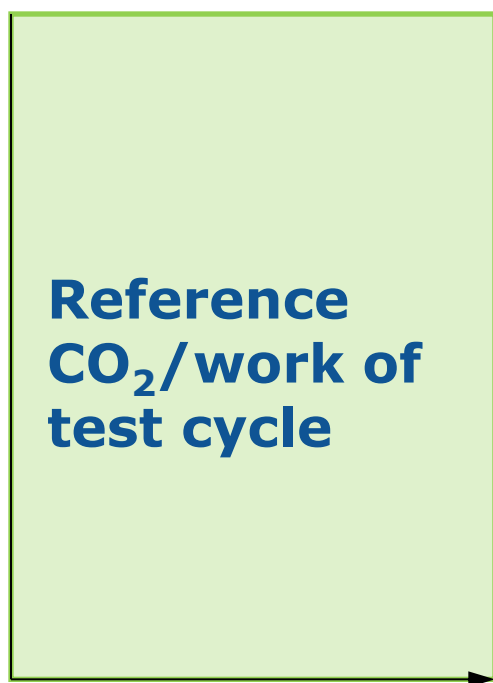
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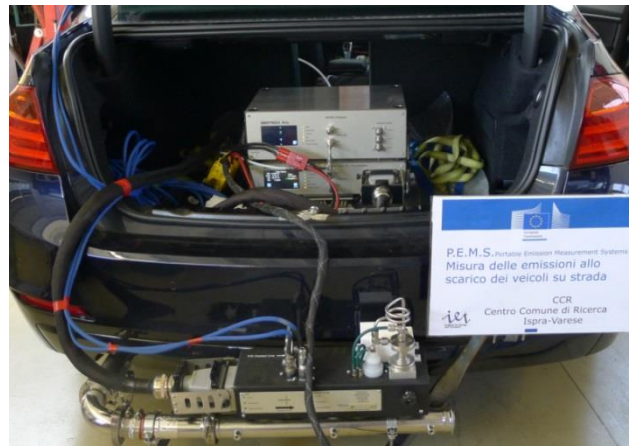
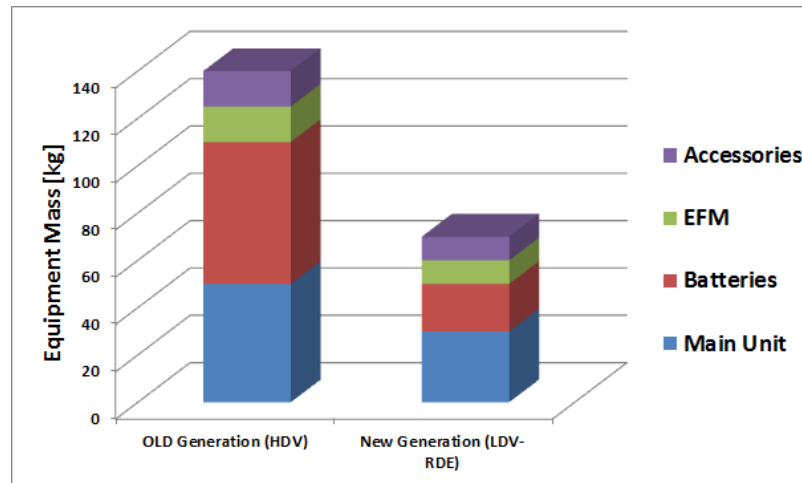
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# Light-duty vehicles

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



# Light-duty vehicles



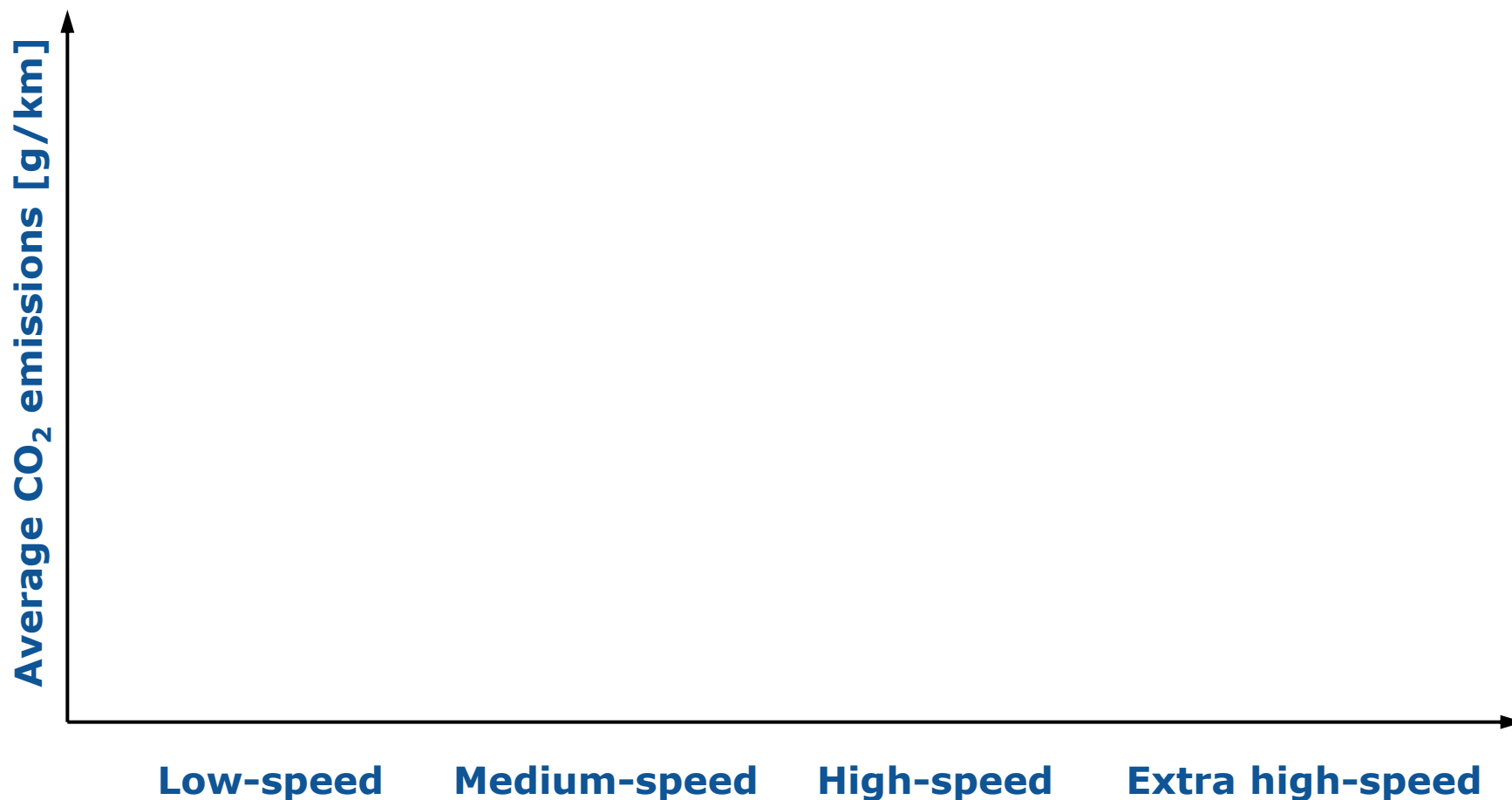
- **PEMS equipment:**
  - **Size, installation, and measurement performance**
  - **Safety**
- **Boundary conditions of on-road tests**
  - **Non-dynamic, dynamic and controlled, dynamic and uncontrolled**
- **Data evaluation**
  - **To some extent uncontrolled driving dynamics, wind, road grade, vehicle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



# PEMS: data analysis (JRC approach)



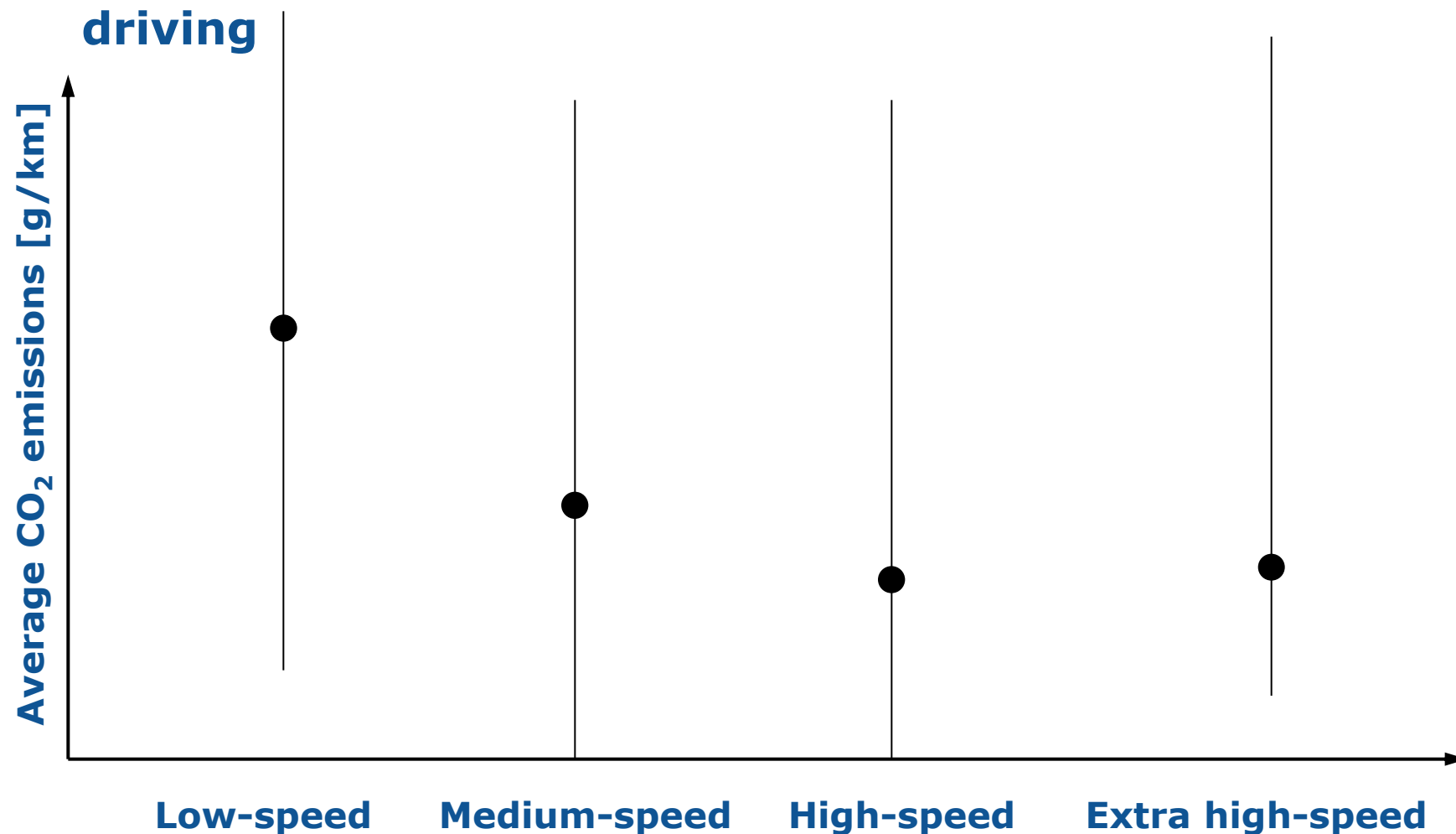
- Moving averaging window approach
- Routes contain equal shares of urban, rural, motorway driving



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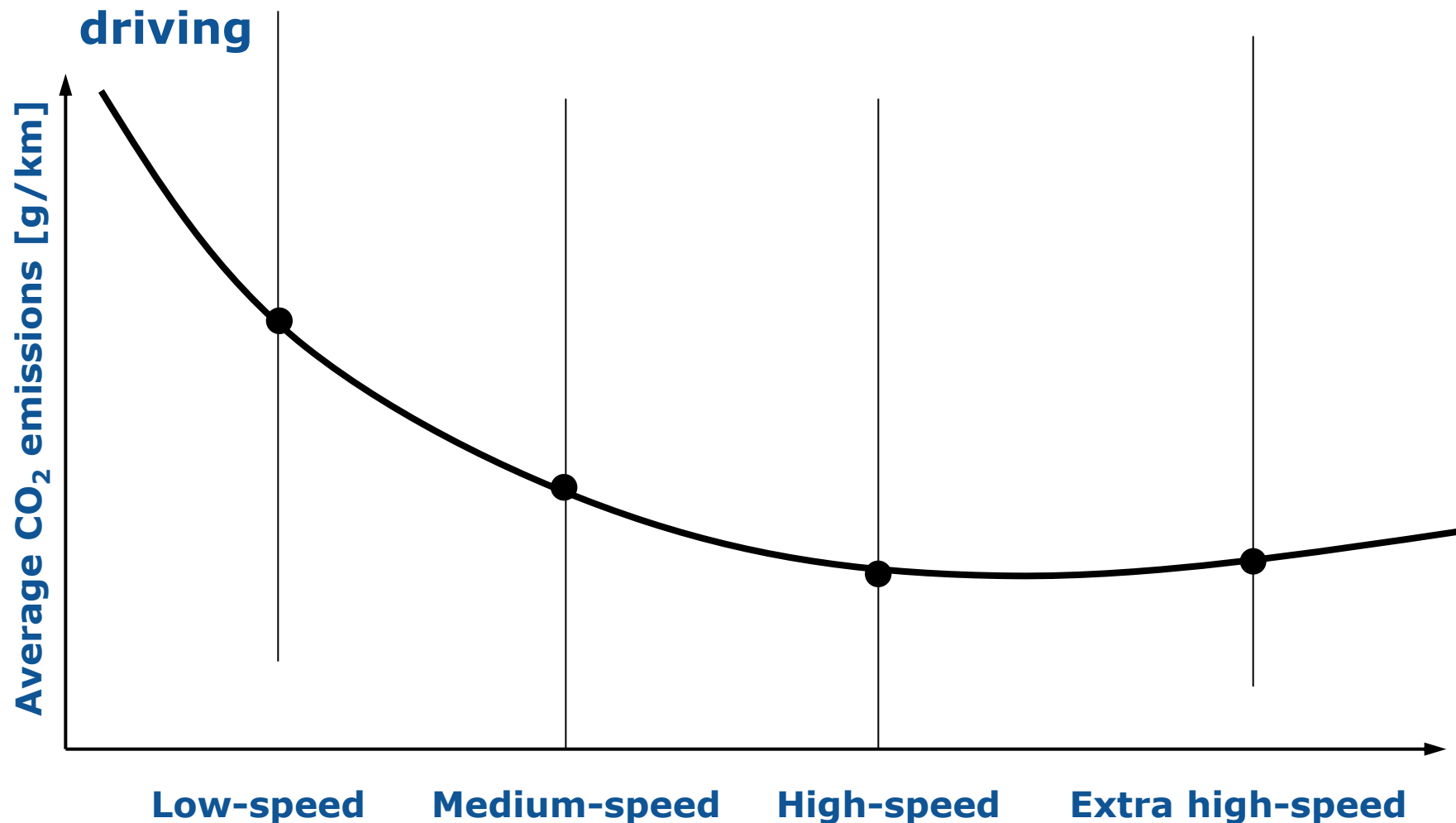


- Moving averaging window approach
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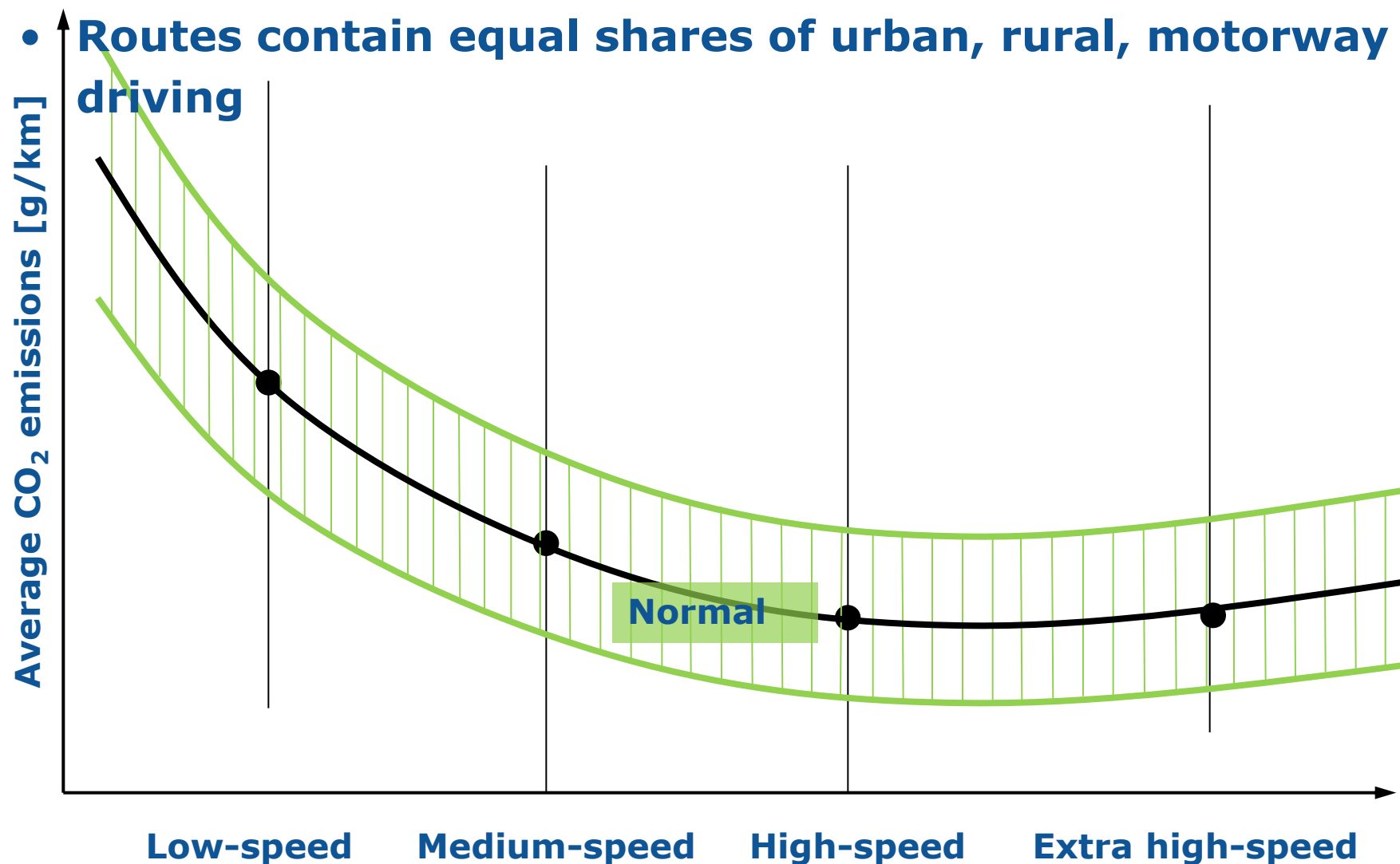
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- Moving averaging window approach
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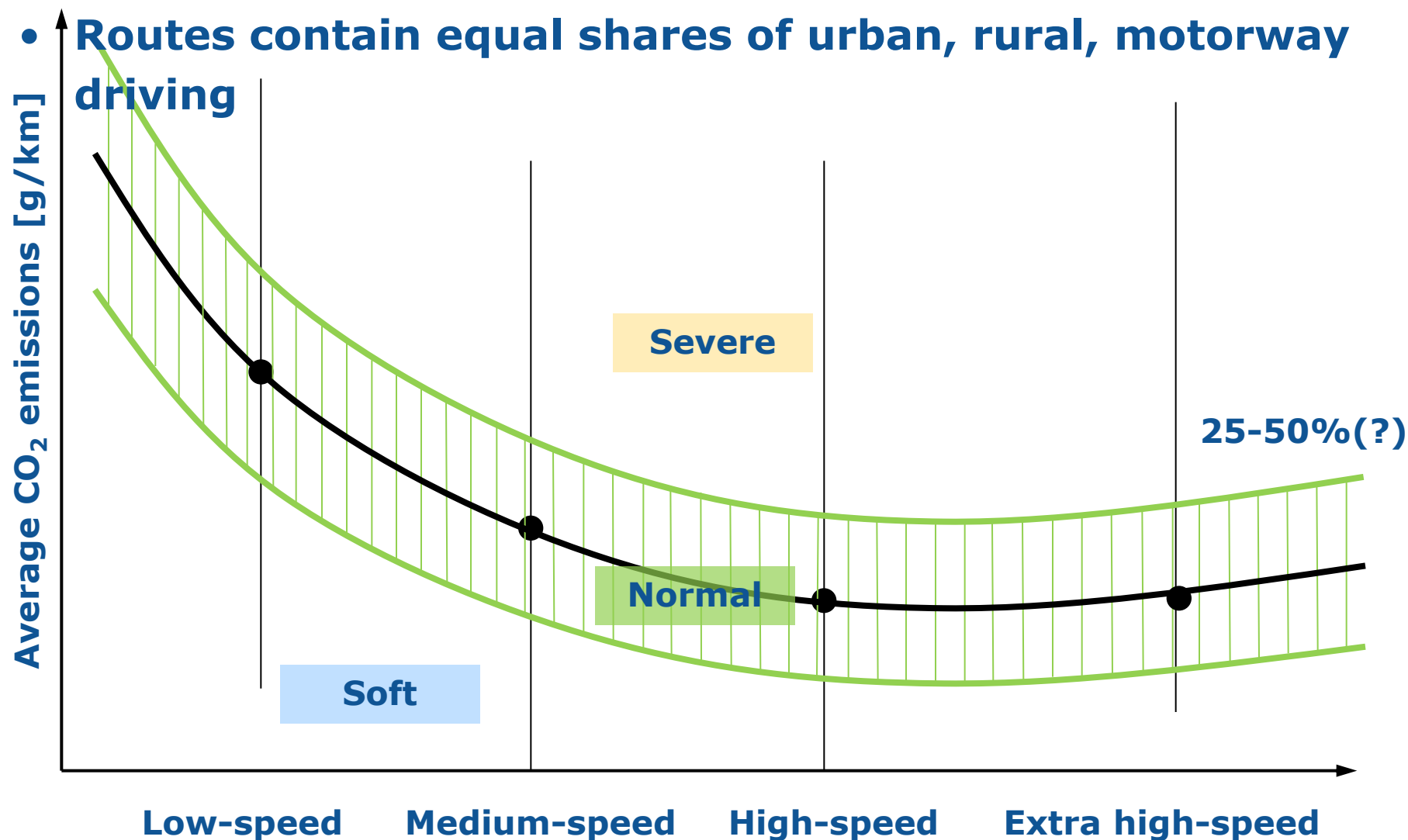
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# Heavy-duty vehicles



- **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**

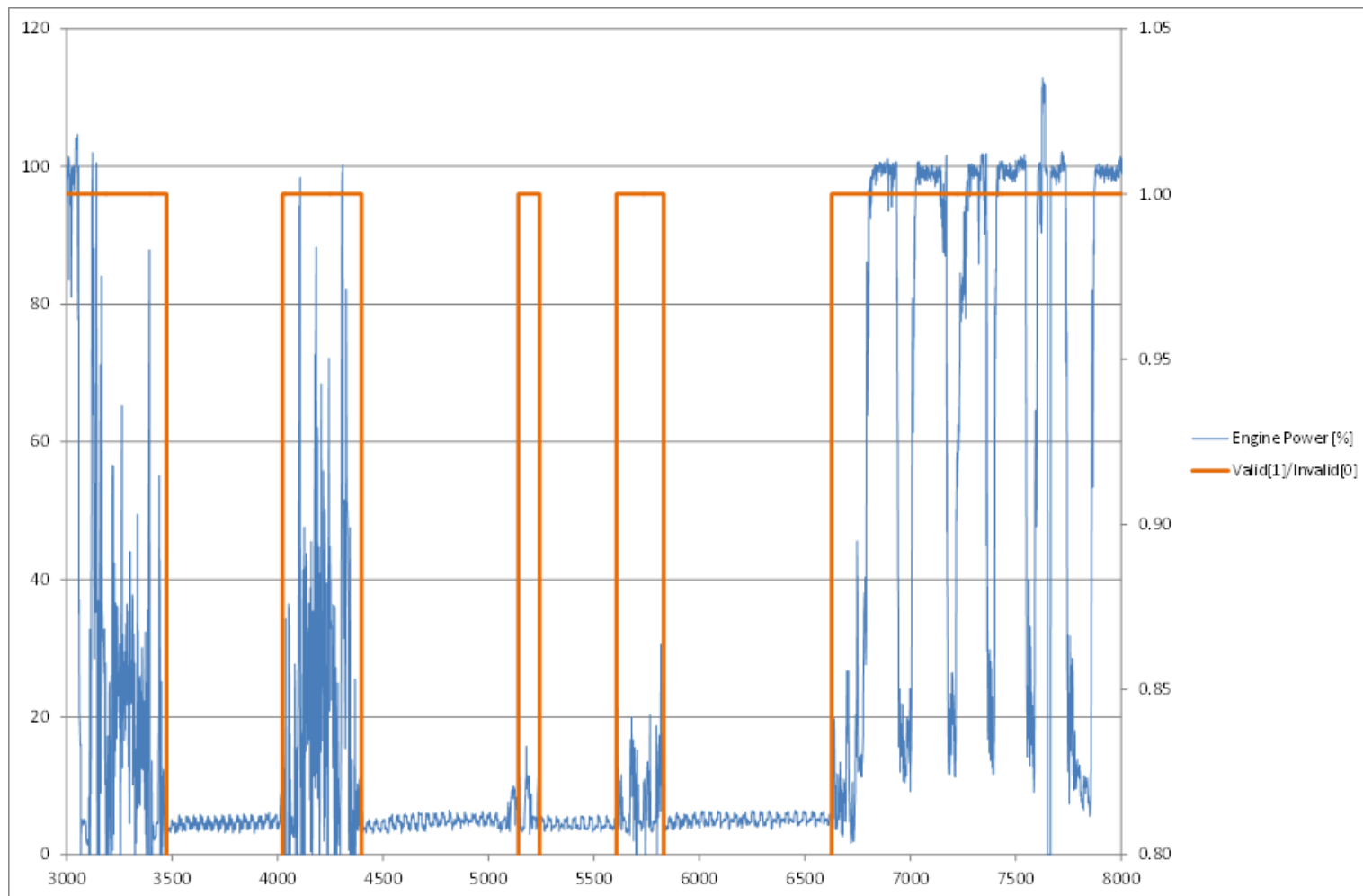
## **In-service conformity – pilot testing**

- **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 ( $T_{coolant} < 343\text{ K}$ ) and data outside permissible ambient conditions*

# Non-Road Mobile Machinery

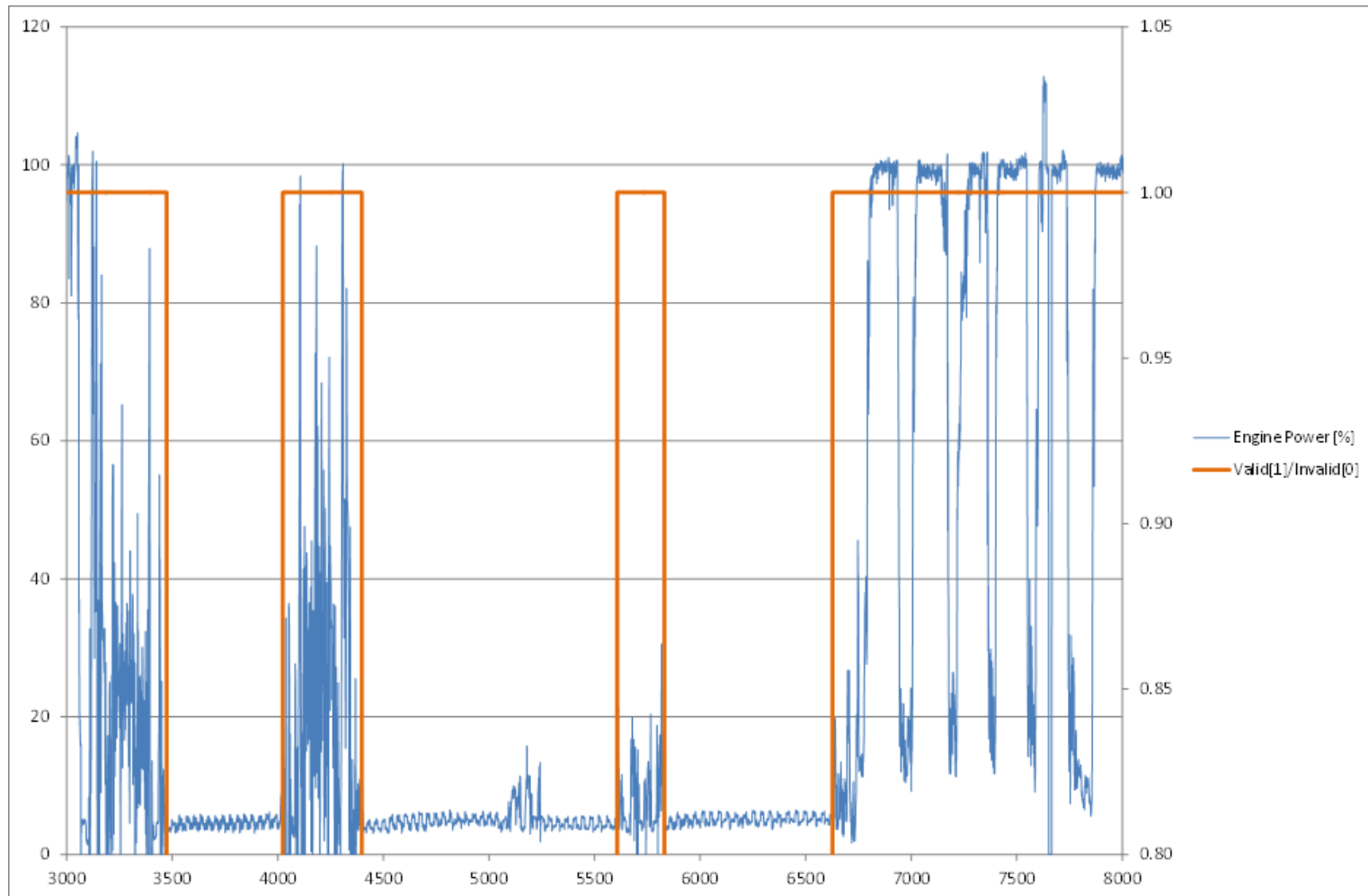
***Step 2: Separating work (power >10%) from idling; considering non-working events <2min as working events***





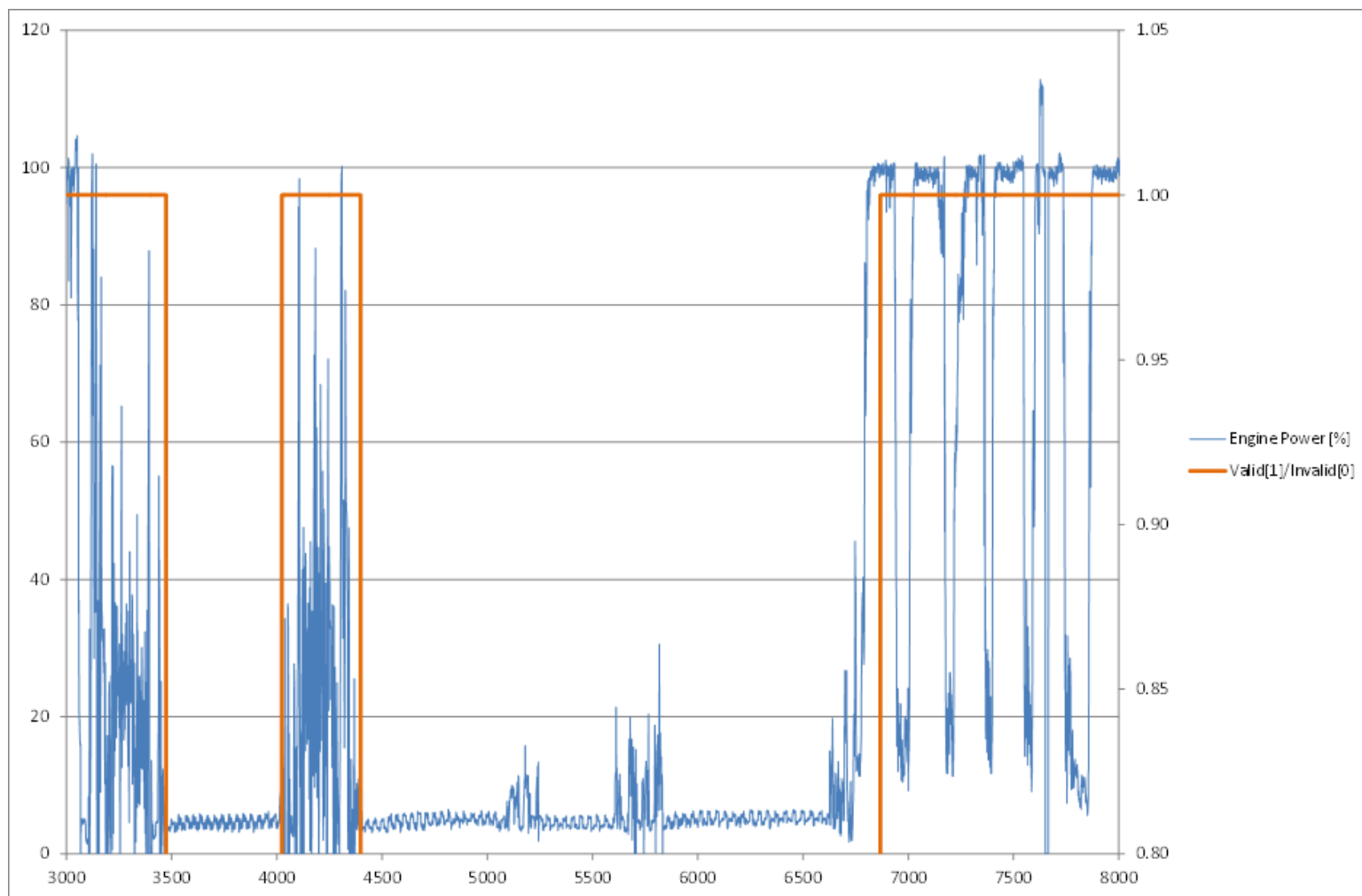
# Non-Road Mobile Machinery

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



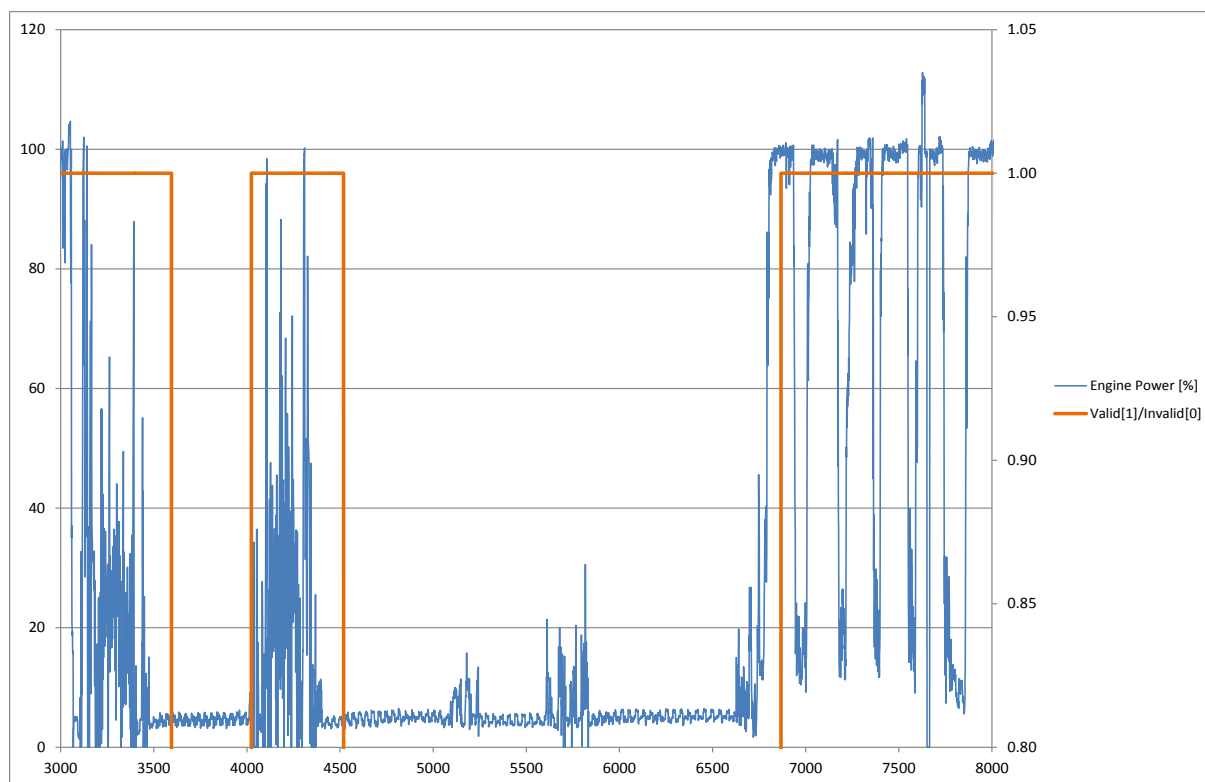
# Non-Road Mobile Machinery

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



# Non-Road Mobile Machinery

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

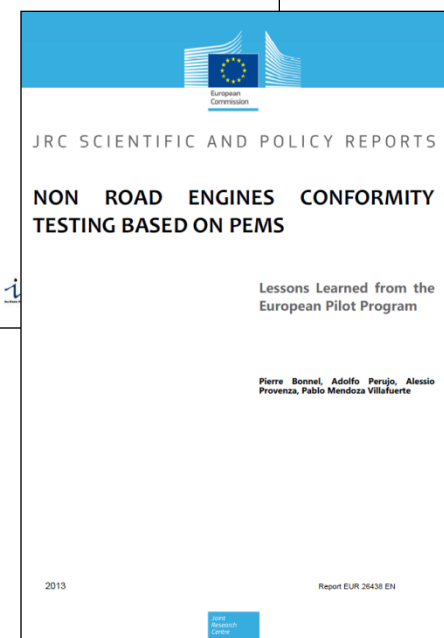
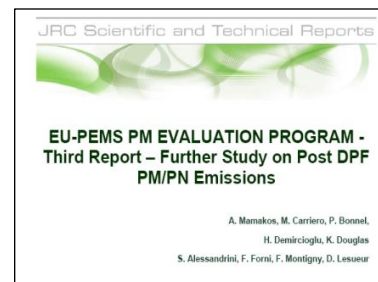
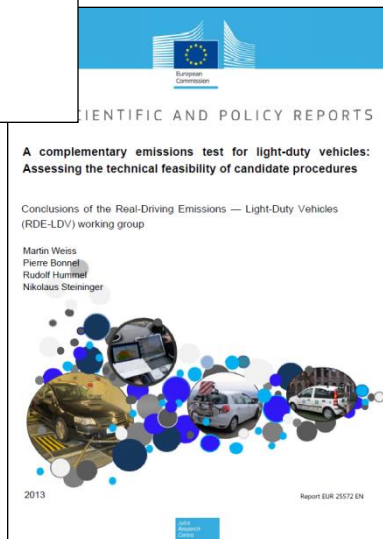
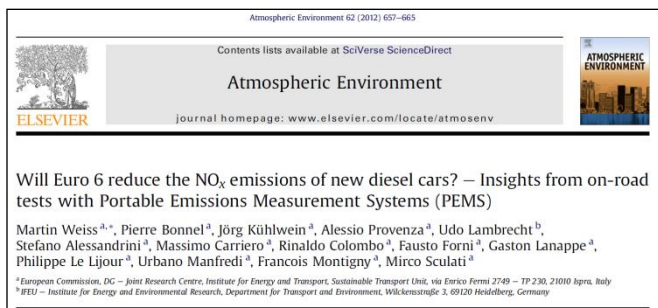
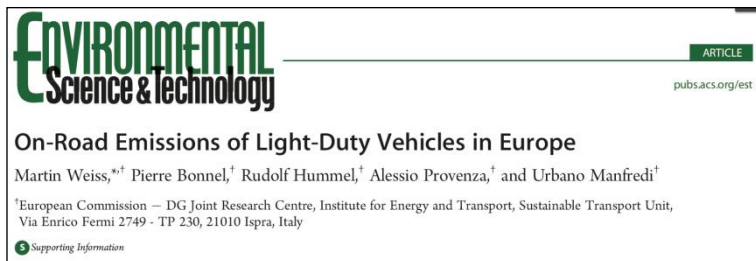


### **Averaging window approach:**

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

- **Light-duty vehicles testing from Sept. 2014 onward; binding not-to-exceed limits for light-duty 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 – in-service conformity testing likely from 2017 onward**

# Thank you!



## Contacts:

### Heavy-duty and NRMM:

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Francesco Riccobono ([francesco.riccobono@jrc.ec.europa.eu](mailto:francesco.riccobono@jrc.ec.europa.eu))

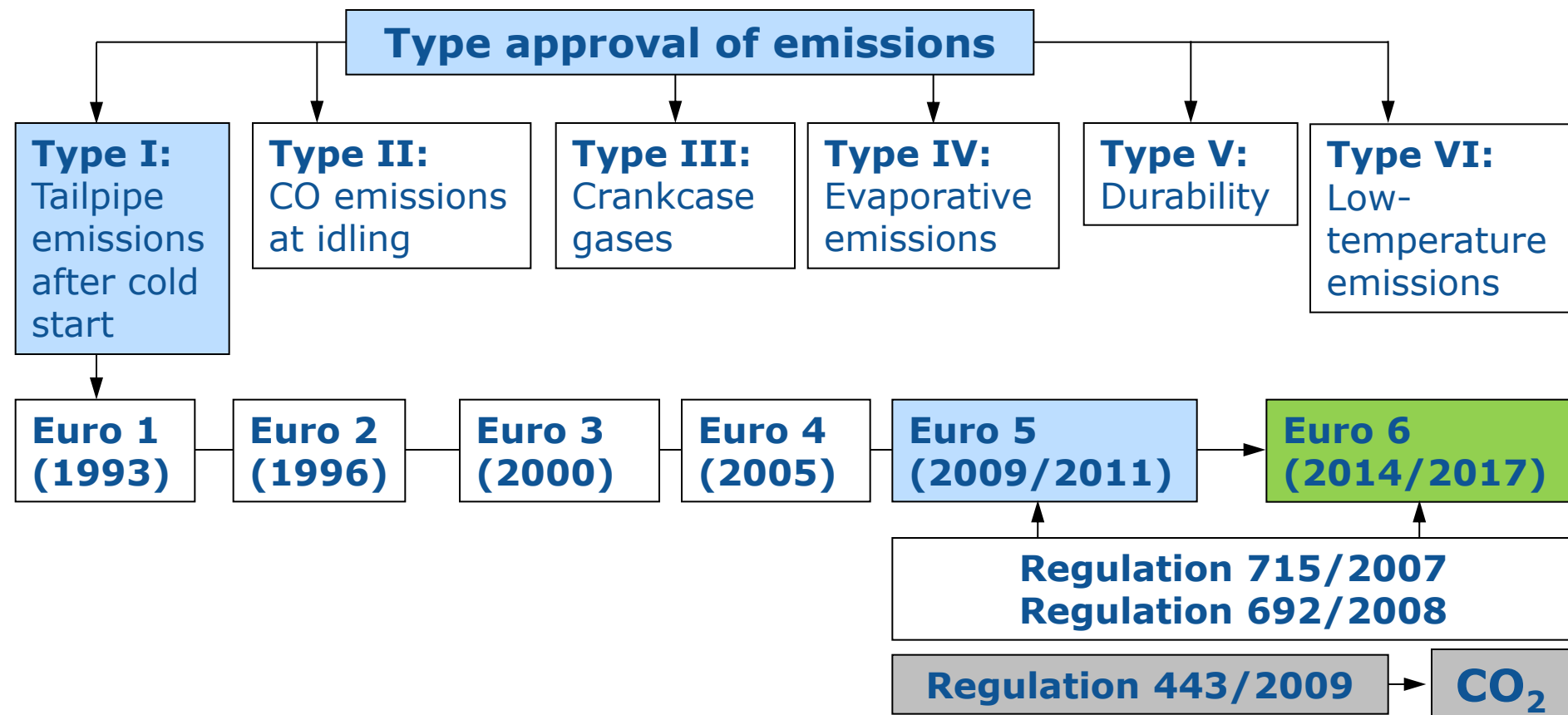
Barouch Giechaskiel ([barouch.giechaskiel@jrc.ec.europa.eu](mailto:barouch.giechaskiel@jrc.ec.europa.eu))

# 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

- **NO<sub>x</sub>, CO (THC, PM)**
- **PN feasibility study**
- **Random cycle testing?**



Type approval of engines

Euro VI

ISC

Stage IV/V

ISC ?

Real-driving emissions?

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