



RDE – Challenges in developing an on-road test procedure for light-duty vehicles

Real-Driving Emissions Conference

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IET - Institute for Energy und Transport

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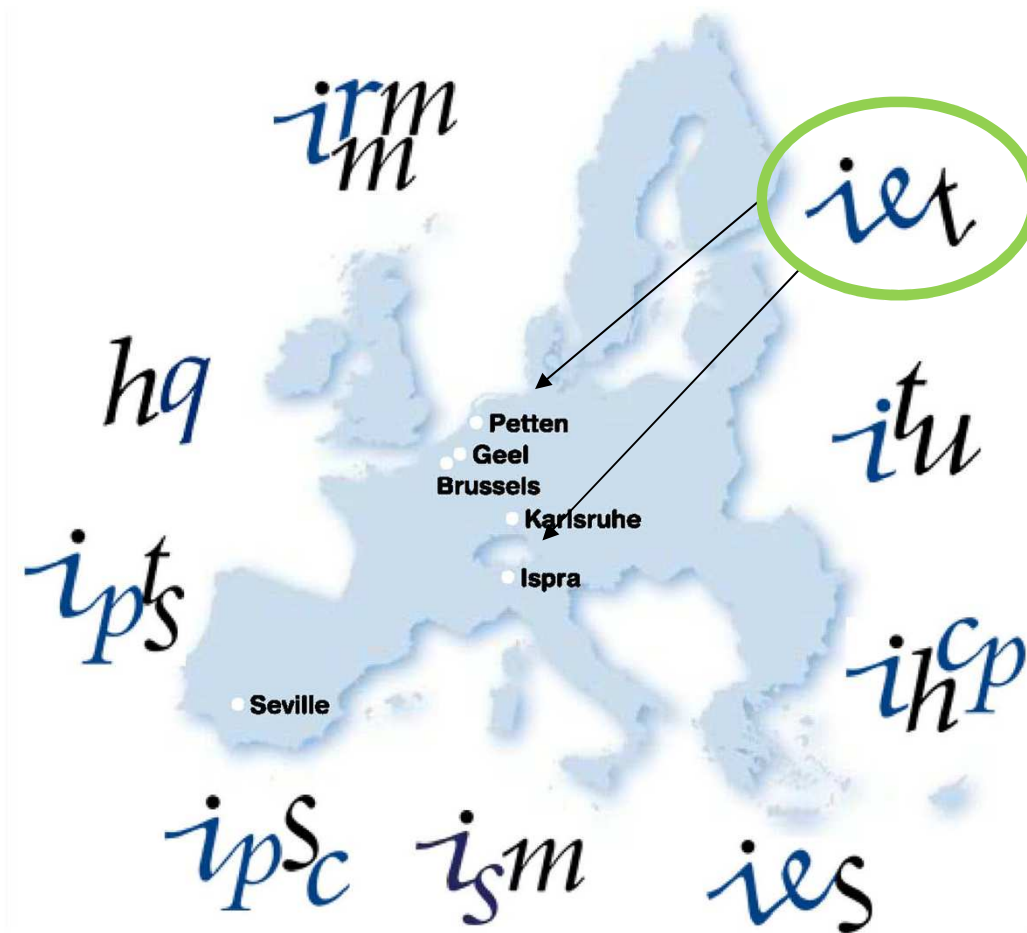


- **Background**
- **Why PEMS on-road testing as RDE procedure?**
- **PEMS testing of light-duty vehicles with PEMS**
- **PEMS data evaluation – key elements and principles**

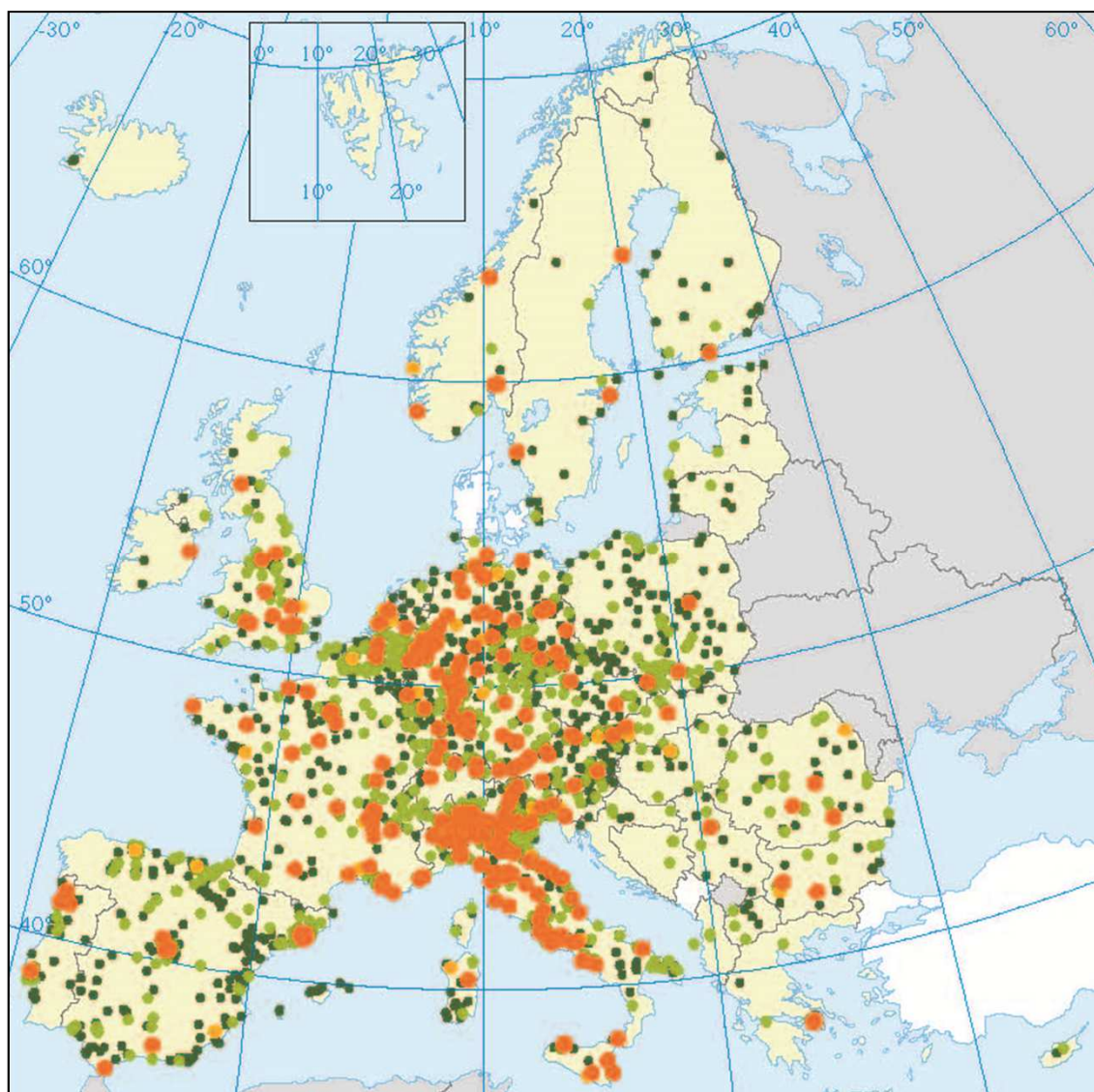
The Joint Research Centre



JRC - the European Commission's in-house science service





Background



Annual mean, nitrogen dioxide, 2009, based on daily averages with percentage of valid measurements 75 % in $\mu\text{g}/\text{m}^3$

-  ≤ 20
-  20–40
-  40–42
-  ≥ 42

-  No data
-  Outside data coverage

Background



Expectations in emissions legislation

- **Balancing environmental objectives with societal (mobility) and economic (competitiveness, jobs) objectives**
- **Emissions legislation = Limits + Tests:**
 - **practical: technically feasible, simple, transparent, cheap**
 - **effective: clean vehicles during use (not only in the lab)**
 - **flexible: to accommodate future vehicle technologies, state of knowledge, social demands**
- **PEMS offers multiple advantages over conventional vehicle testing in the laboratory**

Practicality and costs

- **In-use conformity testing of heavy-duty engines and NRMM: PEMS avoids extracting engines from vehicles**

Effectiveness of vehicle testing (light-duty vehicles):

- **Real-world on-road emissions**
- **Forcing optimal design of complex emissions control**

Regulations & Activities



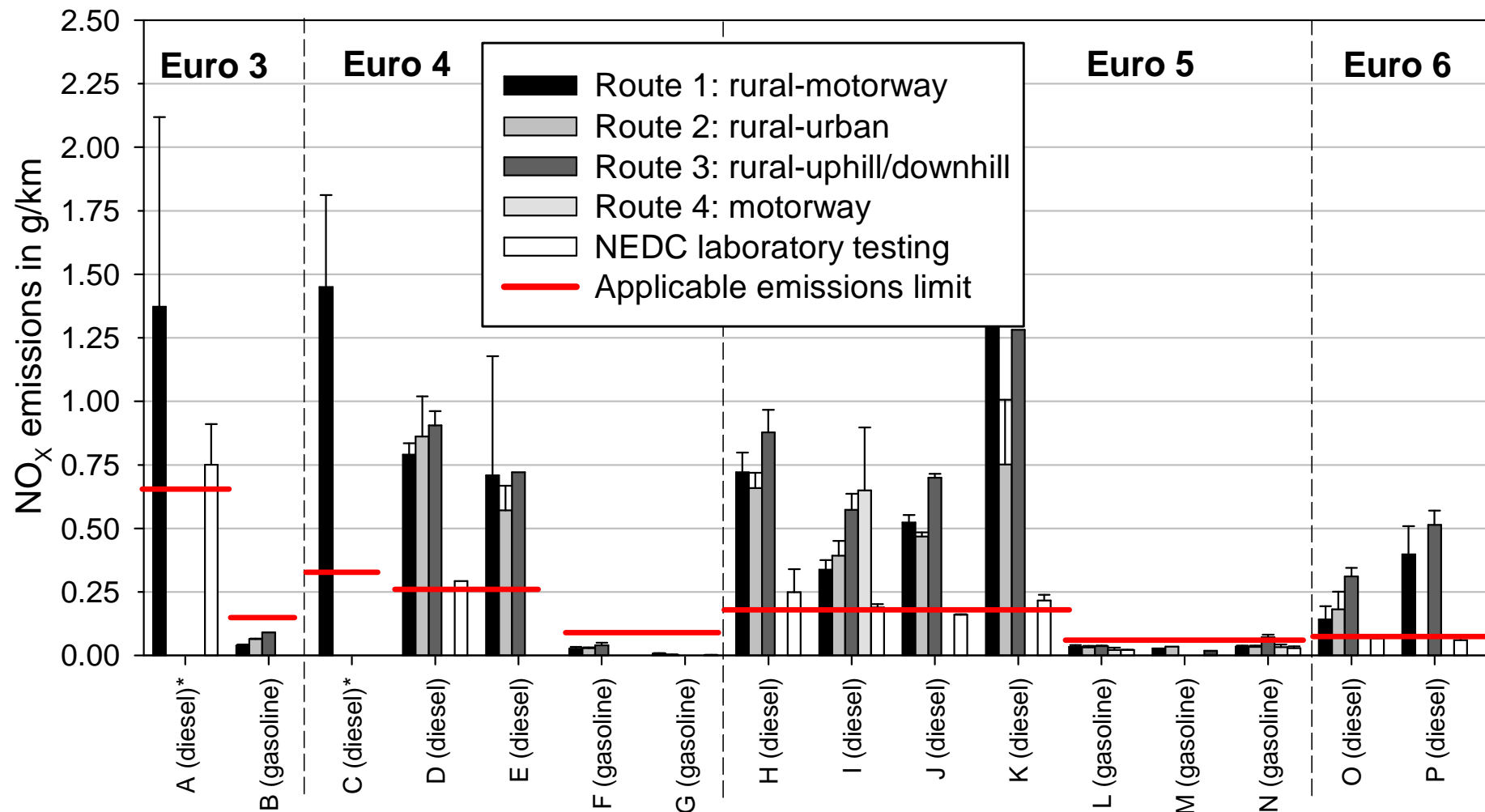
Heavy-duty vehicles

NRMM

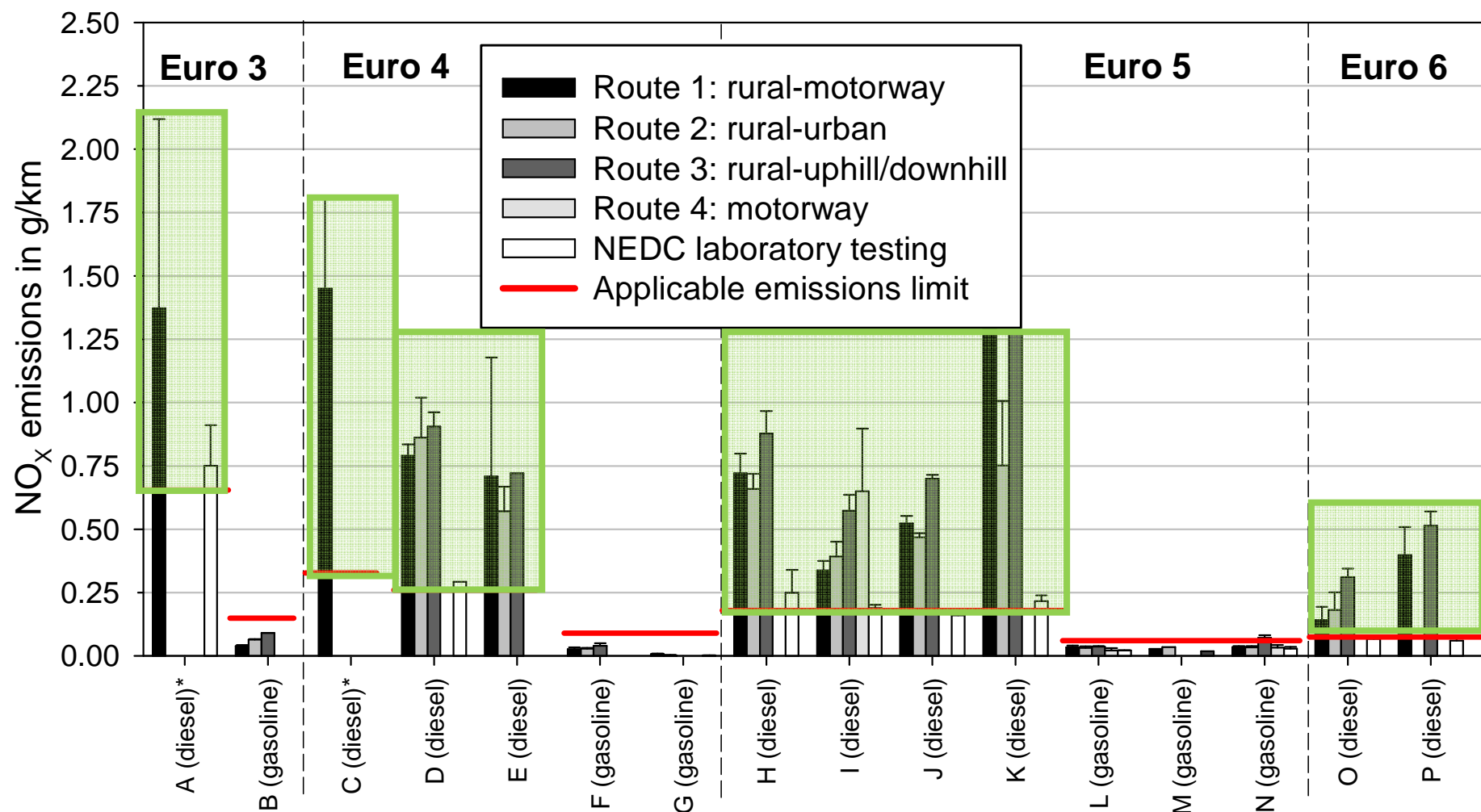
Light-duty vehicles

- Regulation 715/2007 defines Euro 5/6 limits and aims "to ensure that real world emissions correspond to those measured at type approval. The use of portable emission measurement systems and the introduction of the 'not-to-exceed' regulatory concept should also be considered."

History: RDE test procedure



History: RDE test procedure



History: RDE test procedure



- **Real-driving emissions (RDE) working group to establish a complementary test procedure**
- **JRC coordinates the technical work**
- **Candidate procedures: Fixed test cycles**

Random test cycles

PEMS on-road testing

Vehicle modeling

History: RDE test procedure



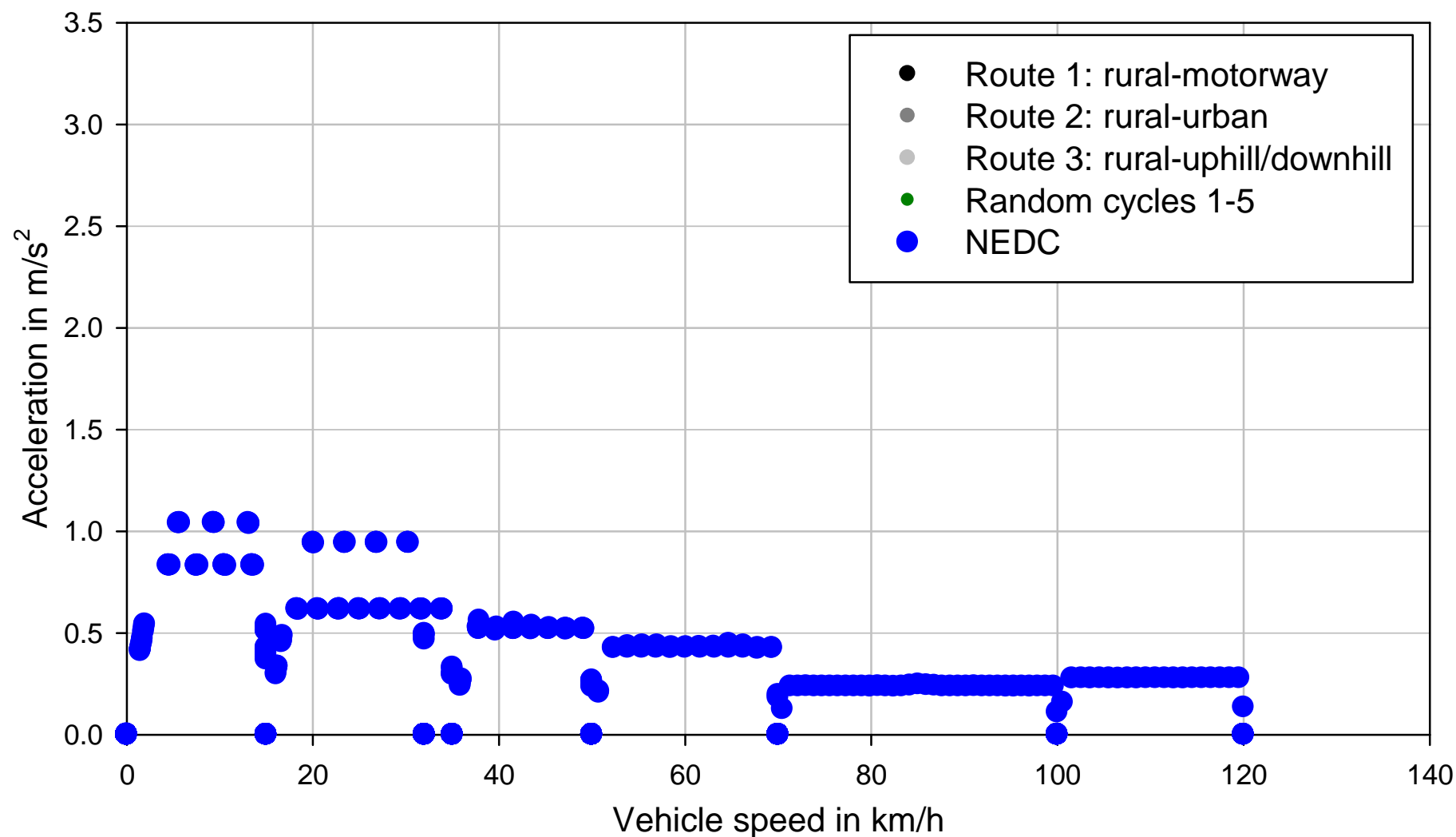
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Random test cycles

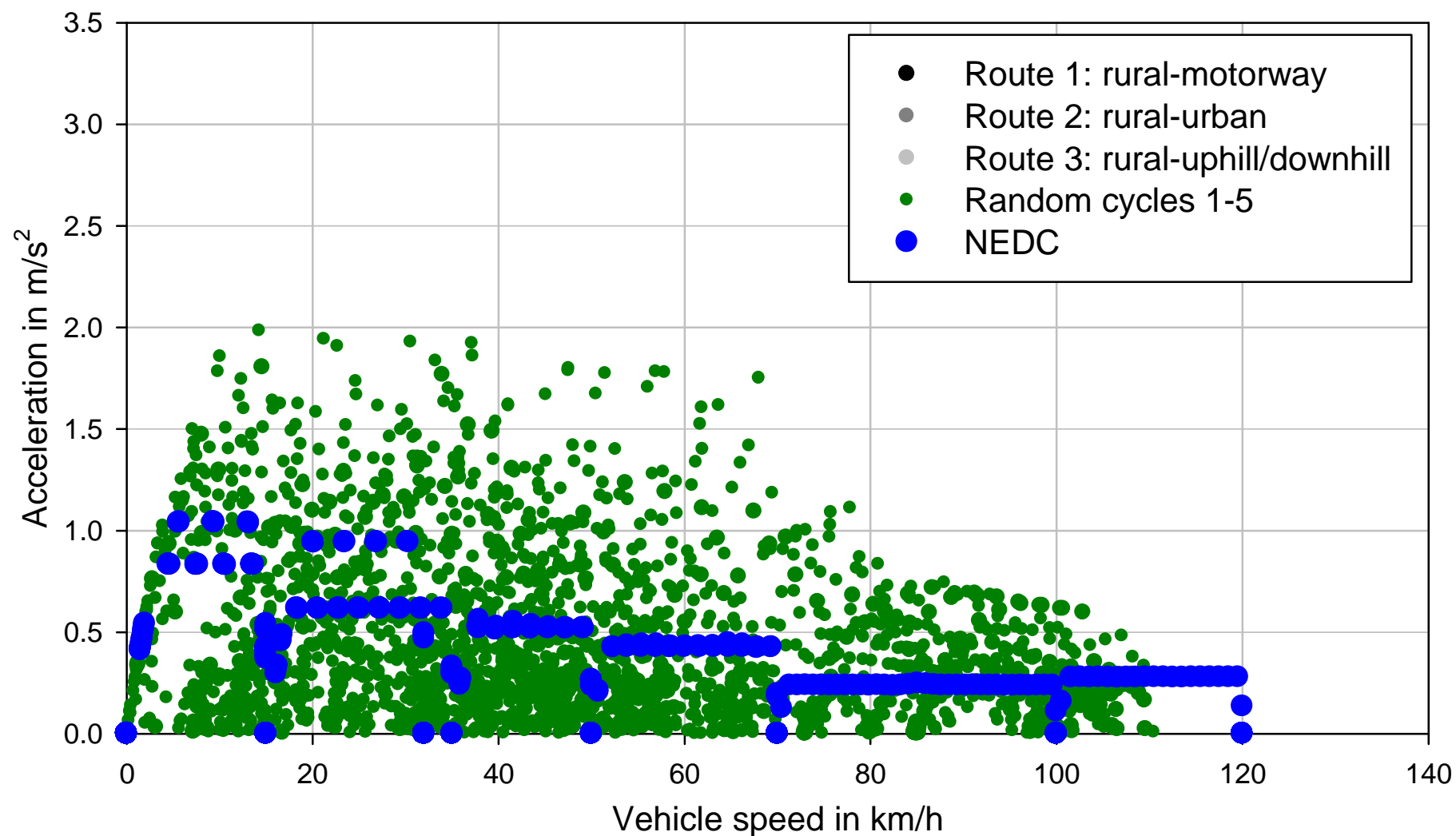
PEMS on-road testing

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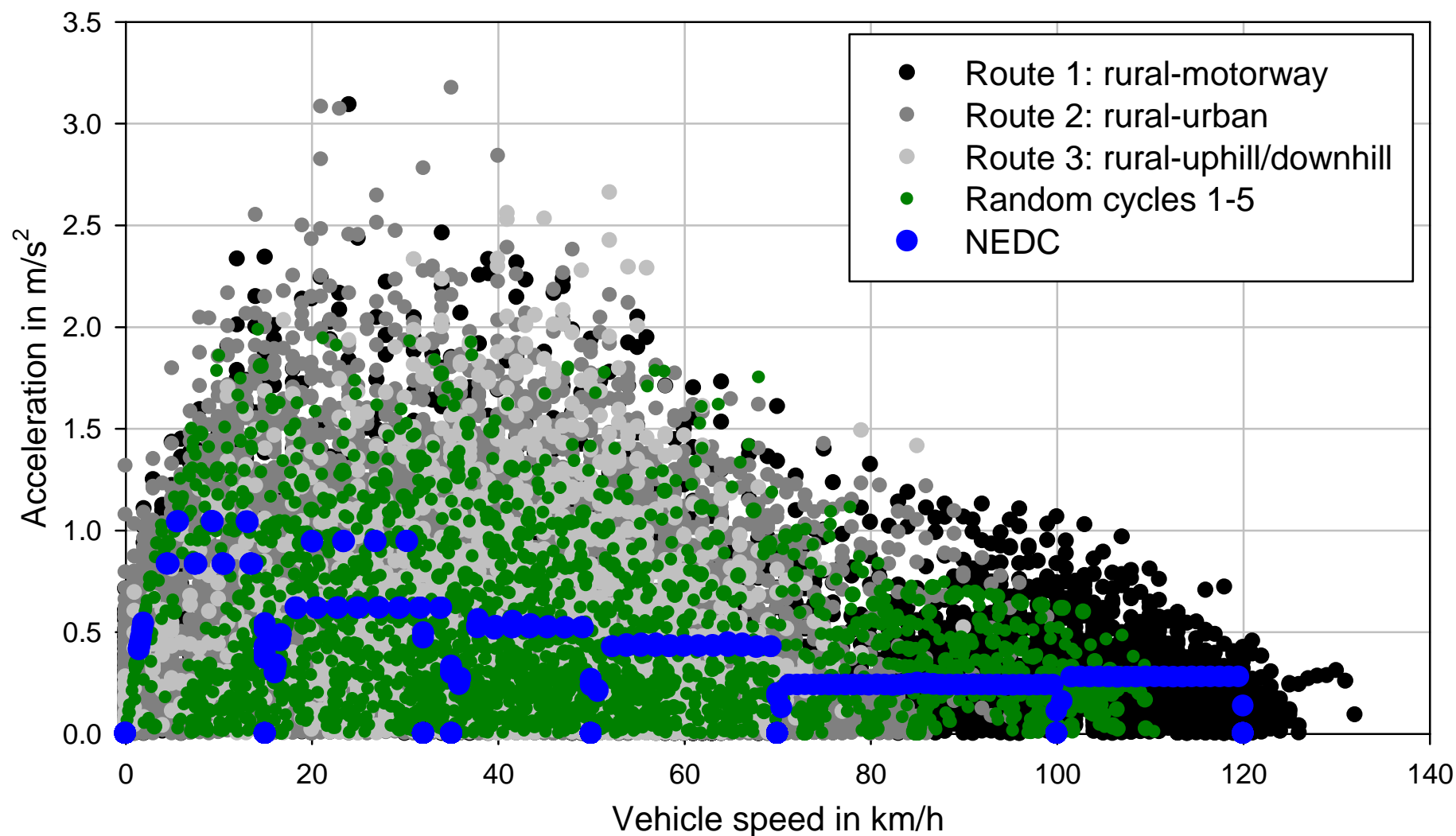
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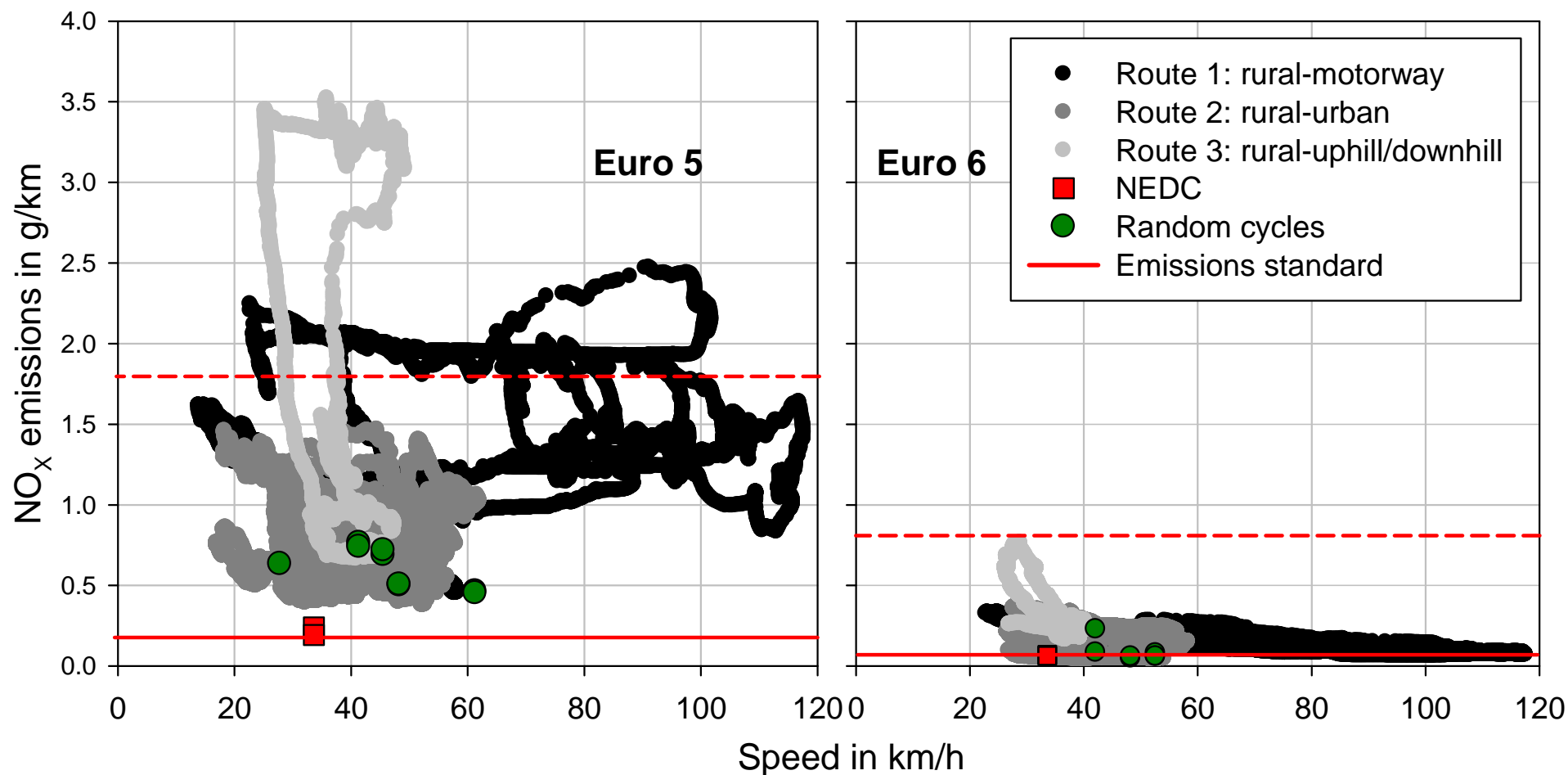
History: RDE test procedure



History: RDE test procedure



History: RDE test procedure



History: RDE test procedure



Random cycles	PEMS on-road testing
+ prevents changes in driver's behavior	+ wider coverage of driving conditions
+ controlled climatic conditions	+ test difficult to detect
+ long-term experience	+ prevents defeat strategies

- **RDE working group develops on-road testing with PEMS as complementary test procedure**

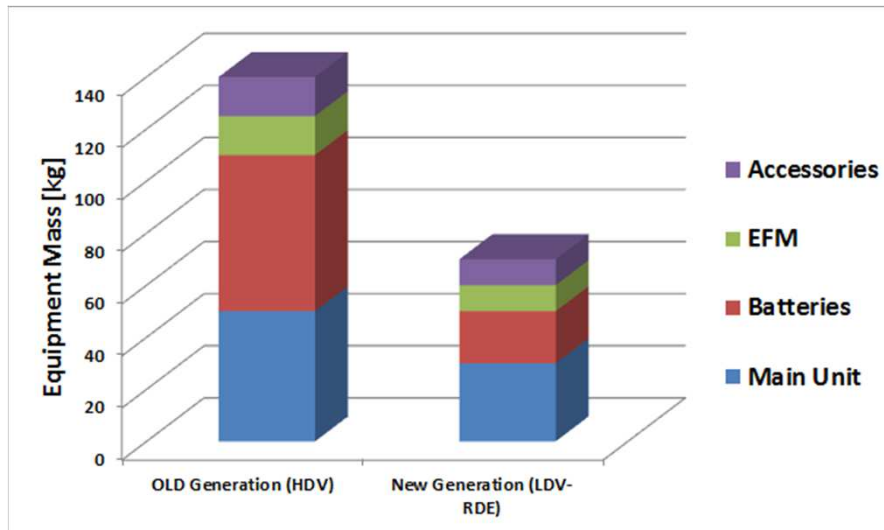
Challenges in PEMS on-road testing



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

PEMS: analytical equipment

- First generation: 100-150 kg
- Second generation: 60-80 kg



PEMS: analytical equipment



Measurement performance

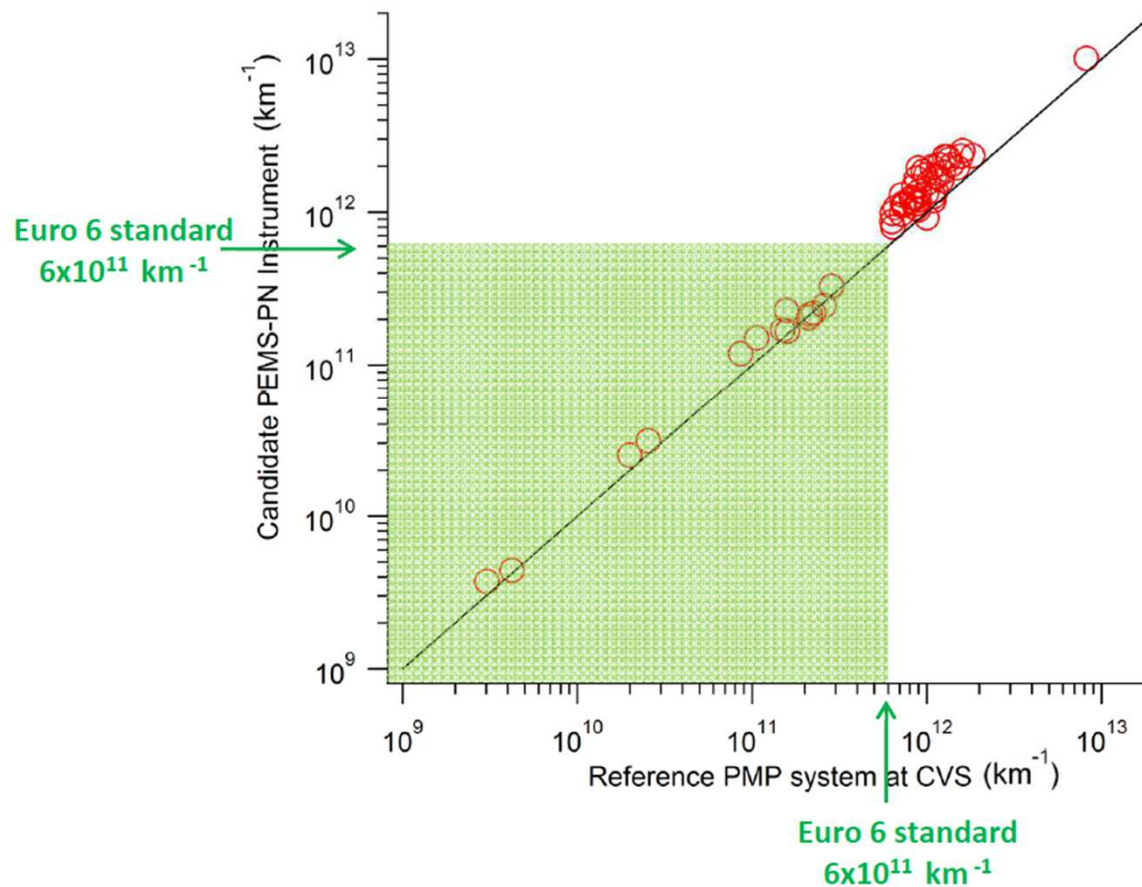
- **Measurement allowance program in the US**
- **Performance in line with laboratory analytical equipment**
- **Negligible effects of vibrations, temperature variability**
- **PEMS-PN: first evaluation of portable number counting equipment against reference (PMP) laboratory system to be completed by end 2013**
- **PEMS PM not applicable as such to LDVs (equipment size and mass)**

PEMS: analytical equipment



- PEMS-PN instrument evaluation exercise

PEMS-PN vs CVS



PEMS: analytical equipment



Installation and Safety

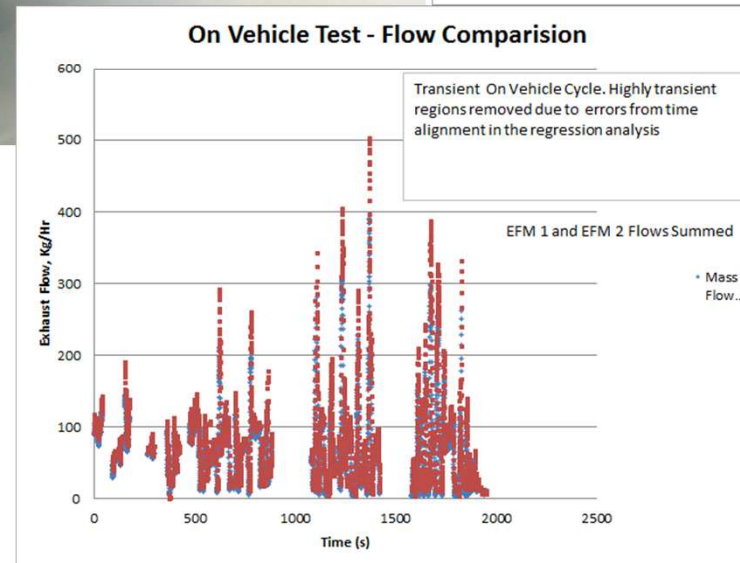
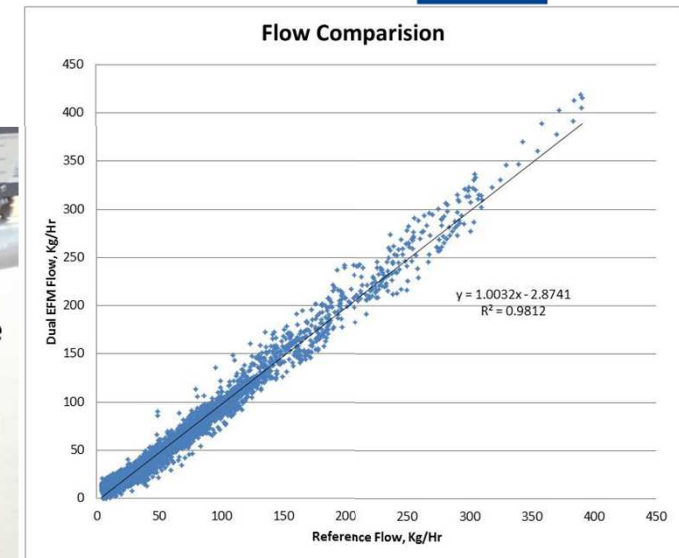
- **Correct anchoring/fixing of equipment**
- **FID (THC analyzer) fuel bottle**
 - **Measurement of THC with FID 'frozen'**
- **Minimizing modification to the vehicle**
 - **Mass of PEMS and accessories (batteries)**
 - **Aerodynamics modifications (e.g. exhaust flow meter, routing heated line, weather station)**



PEMS: analytical equipment



- Minimizing the influence of equipment and increasing safety: Reduced EFM



Source:
sensors

PEMS: boundary conditions



- **Boundary conditions for temperature and altitude**
- **Time or distance over which pollutant emissions are regulated (expected: type approval cycle as reference)**
- **Metrics (expected: g/km)**
- **Urban, rural, motorway driving**
- **Managing driver's behaviour and randomness (differences in fuel consumption and emissions)**
- **(A posteriori) verification of realized test conditions based on indicators (generic values for the entire test or indicators provided by the data evaluation method)**
- **Tests not achieving a sufficient coverage could be repeated or complemented by additional tests**

PEMS: data analysis



**Three data evaluation tools under evaluation
(TU Graz, TNO, JRC)**

- **Clear tool: weighing of driving data (TU Graz)**
- **TNO tool: speed binning of driving data**
- **JRC tool: Moving averaging windows**

PEMS: data analysis (JRC approach)

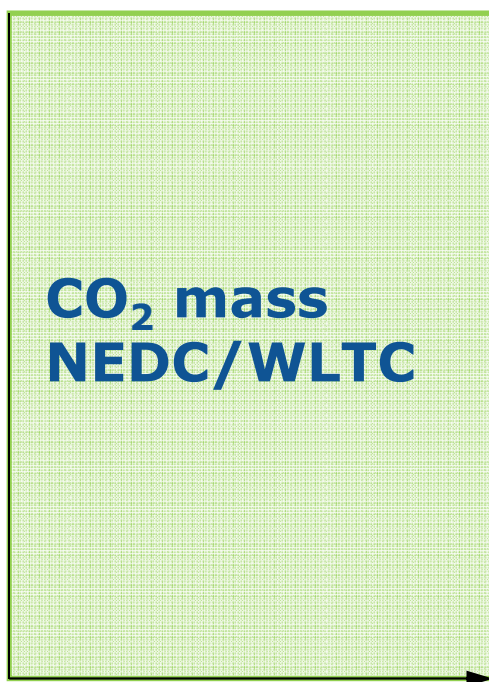


Moving averaging window approach

PEMS: data analysis (JRC approach)



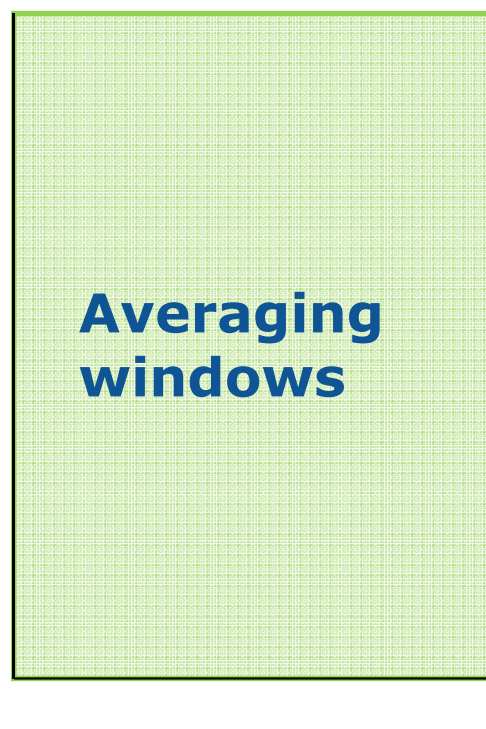
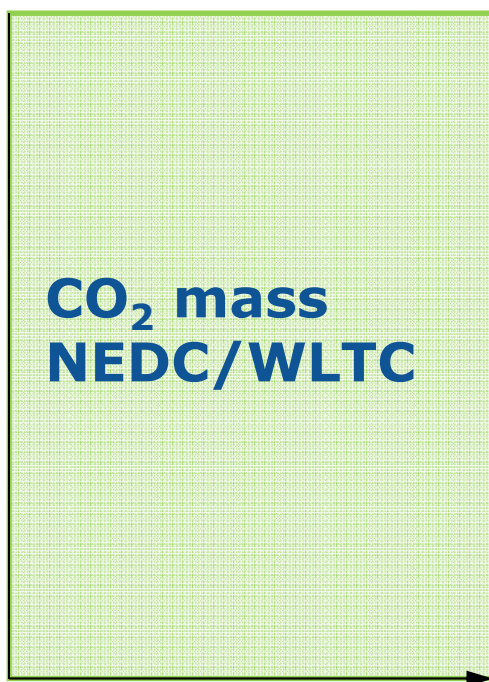
Moving averaging window approach



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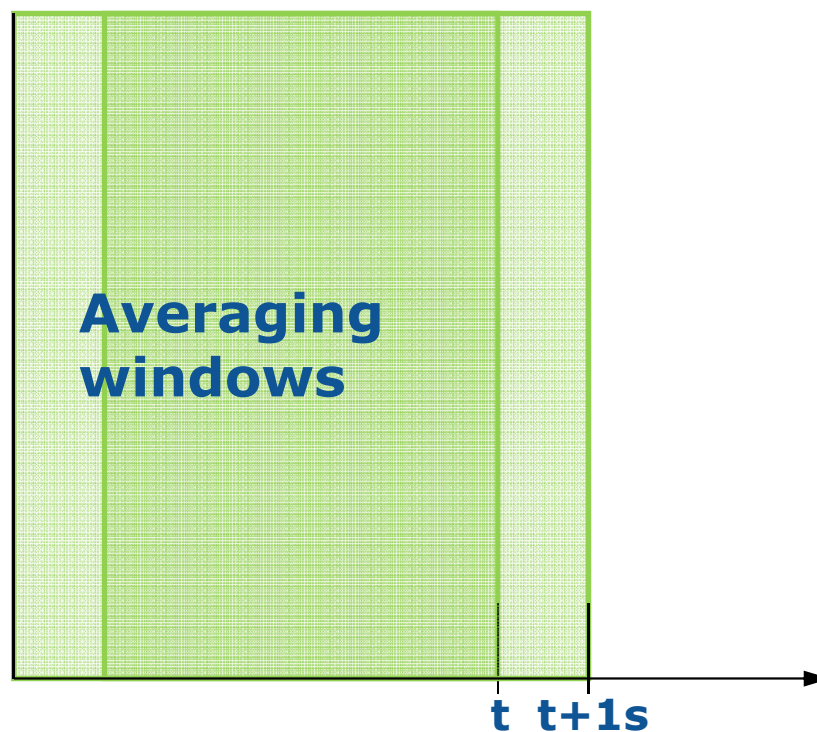
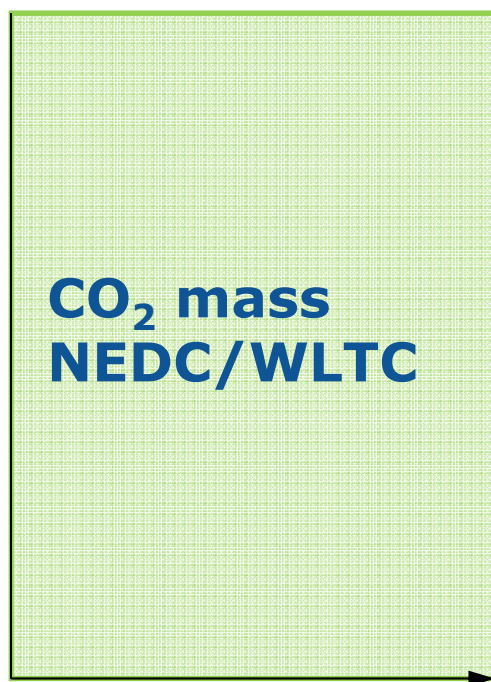
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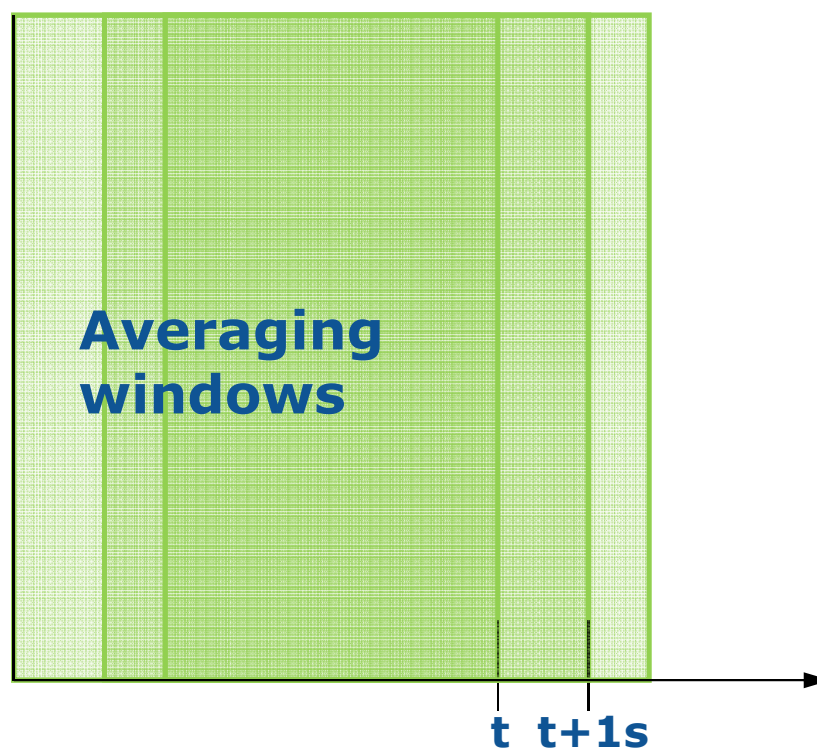
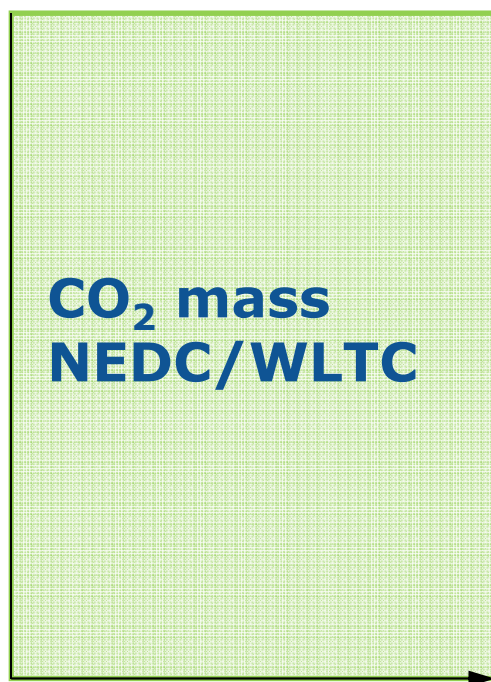
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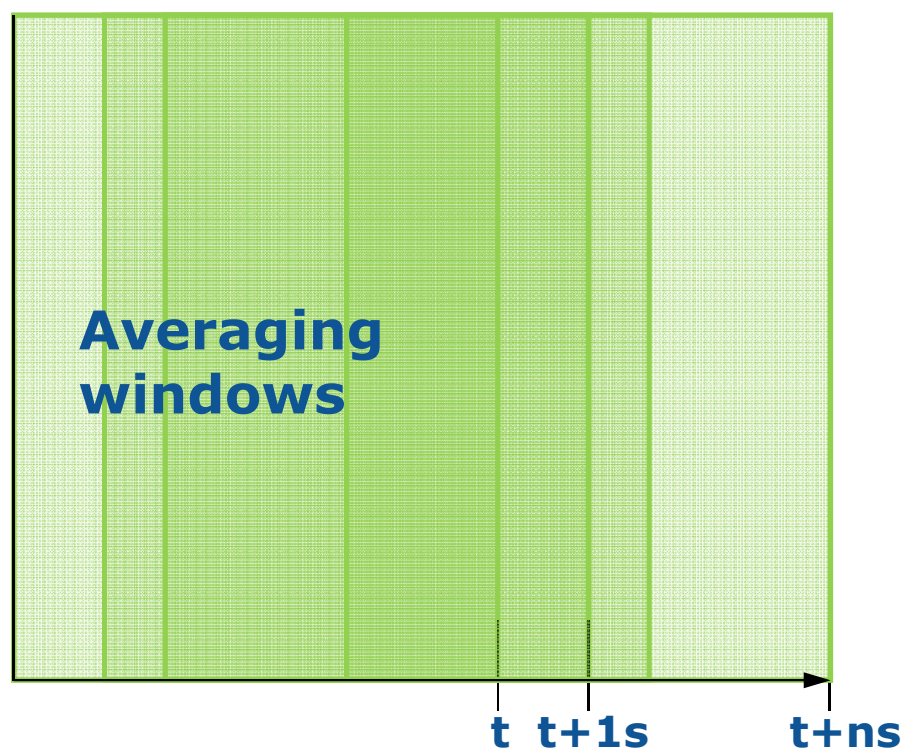
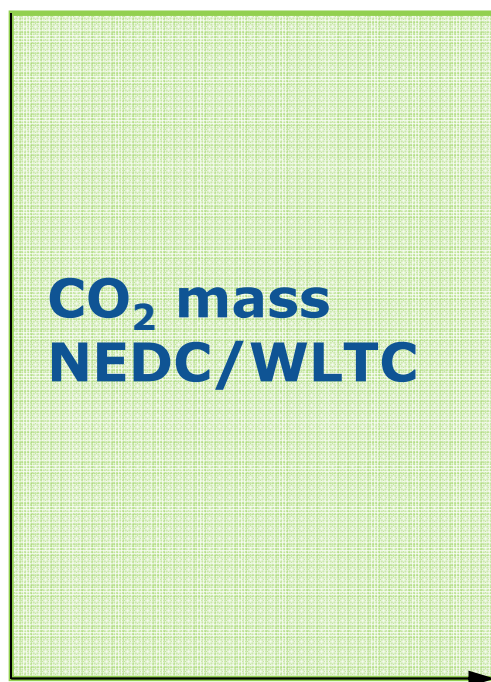
Moving averaging window approach



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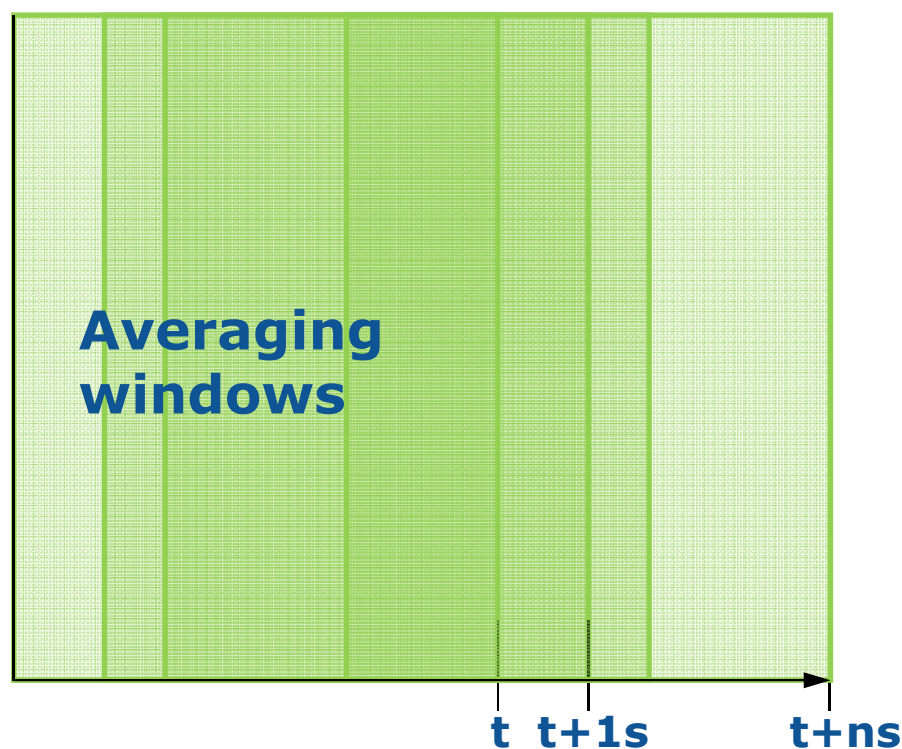
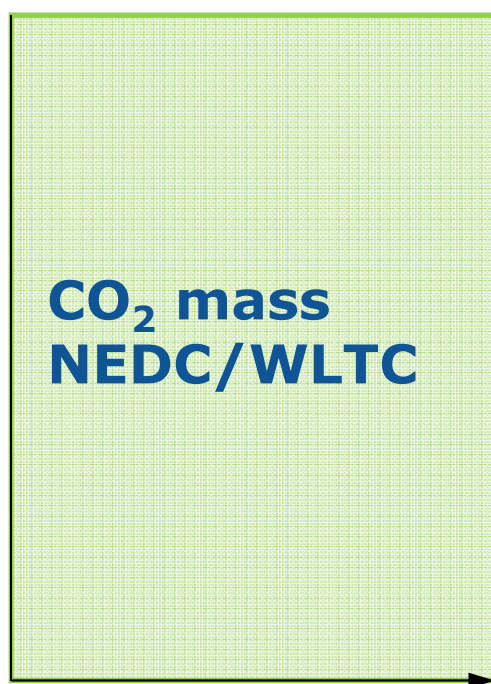
Moving averaging window approach



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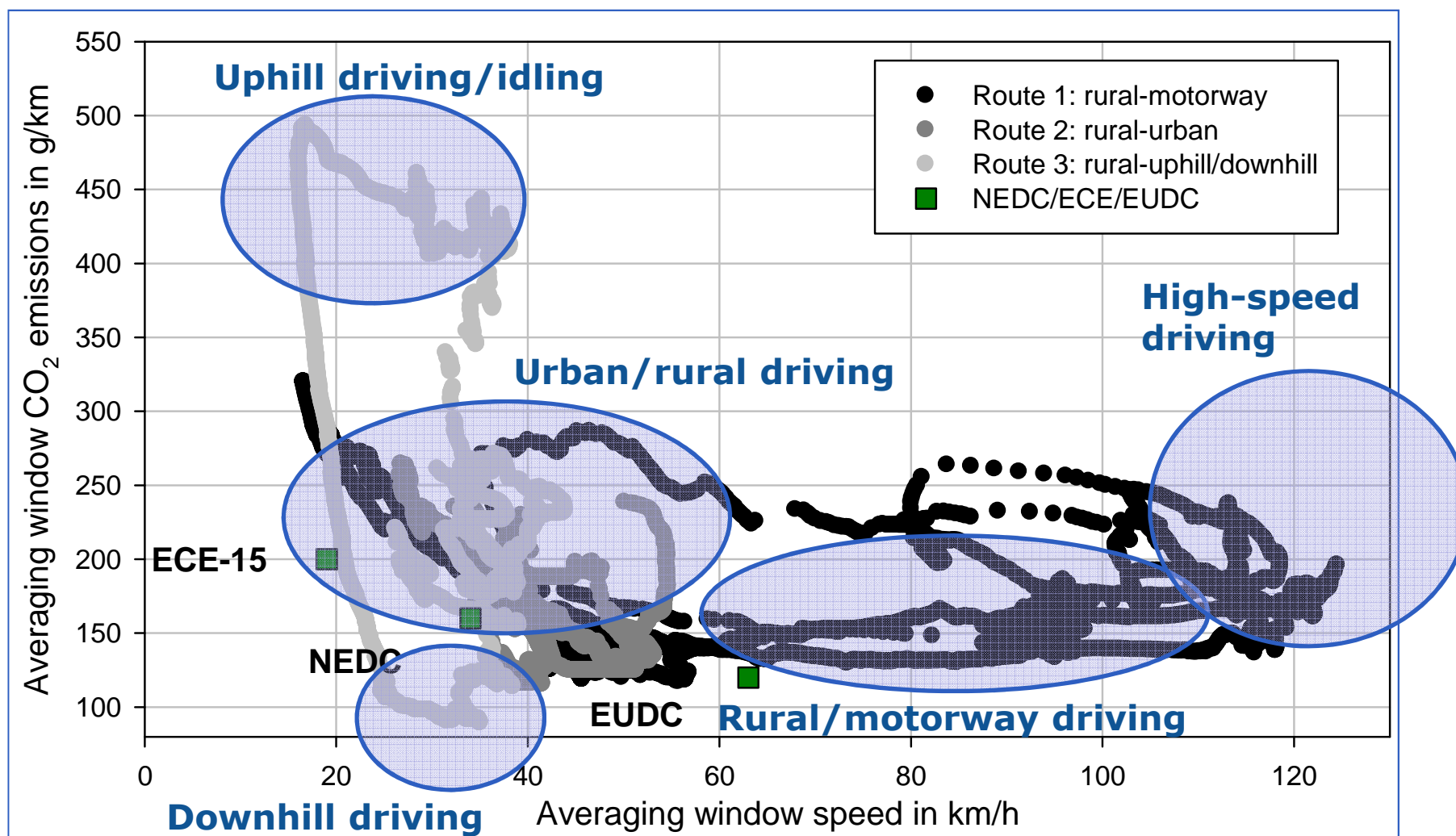


Moving averaging window approach



How to determine the severity of on-road driving?

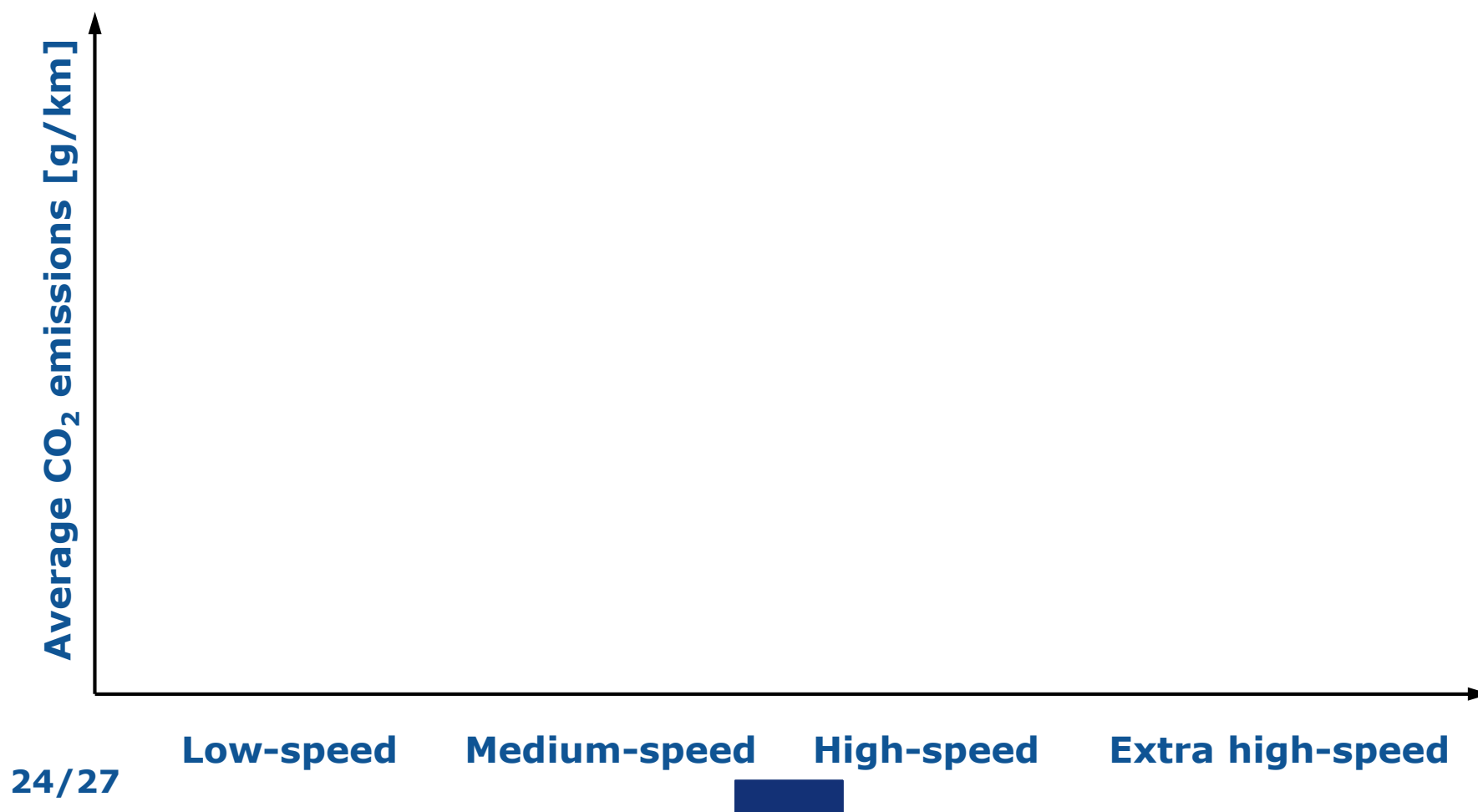
PEMS: data analysis (JRC approach)



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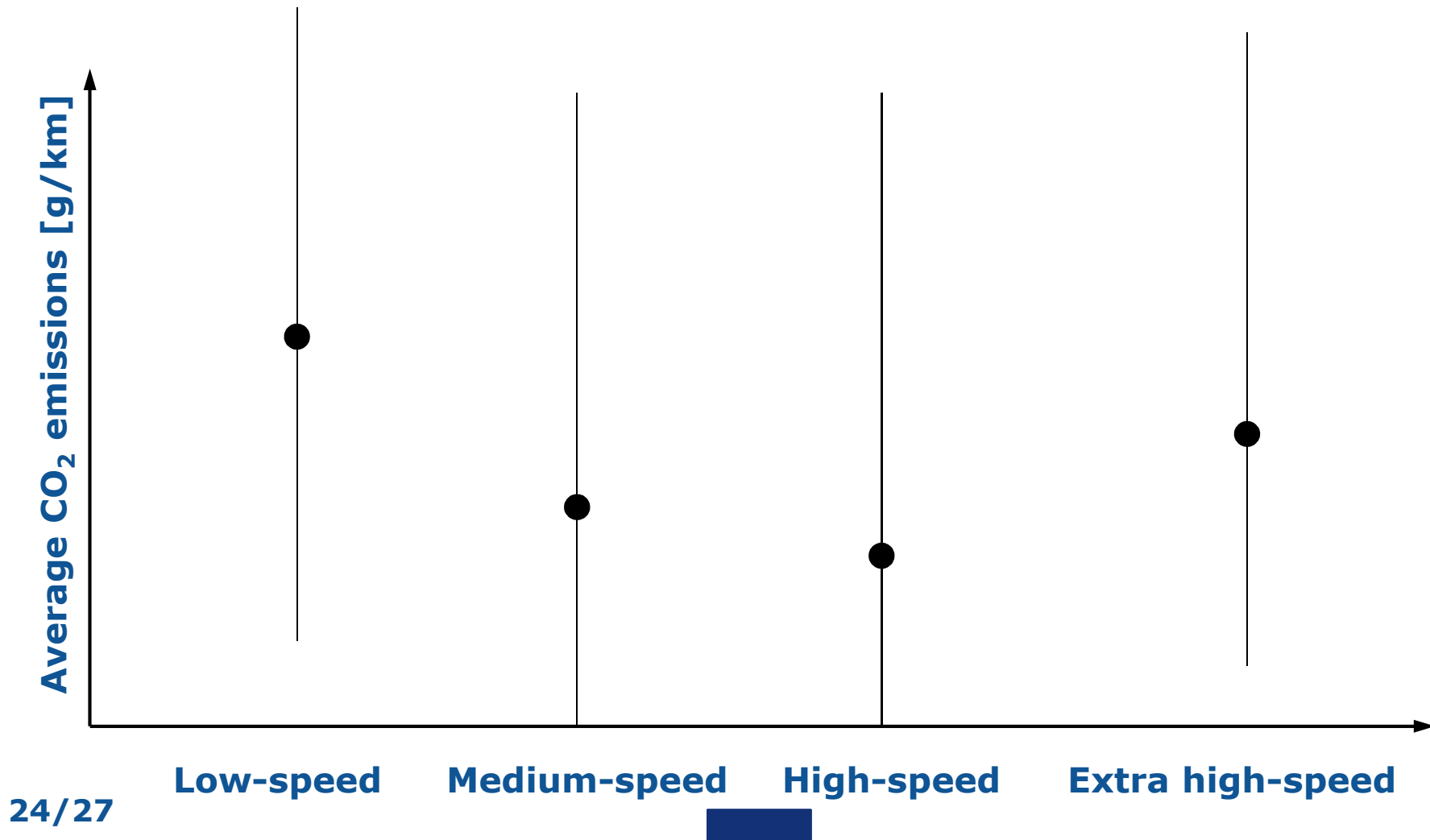
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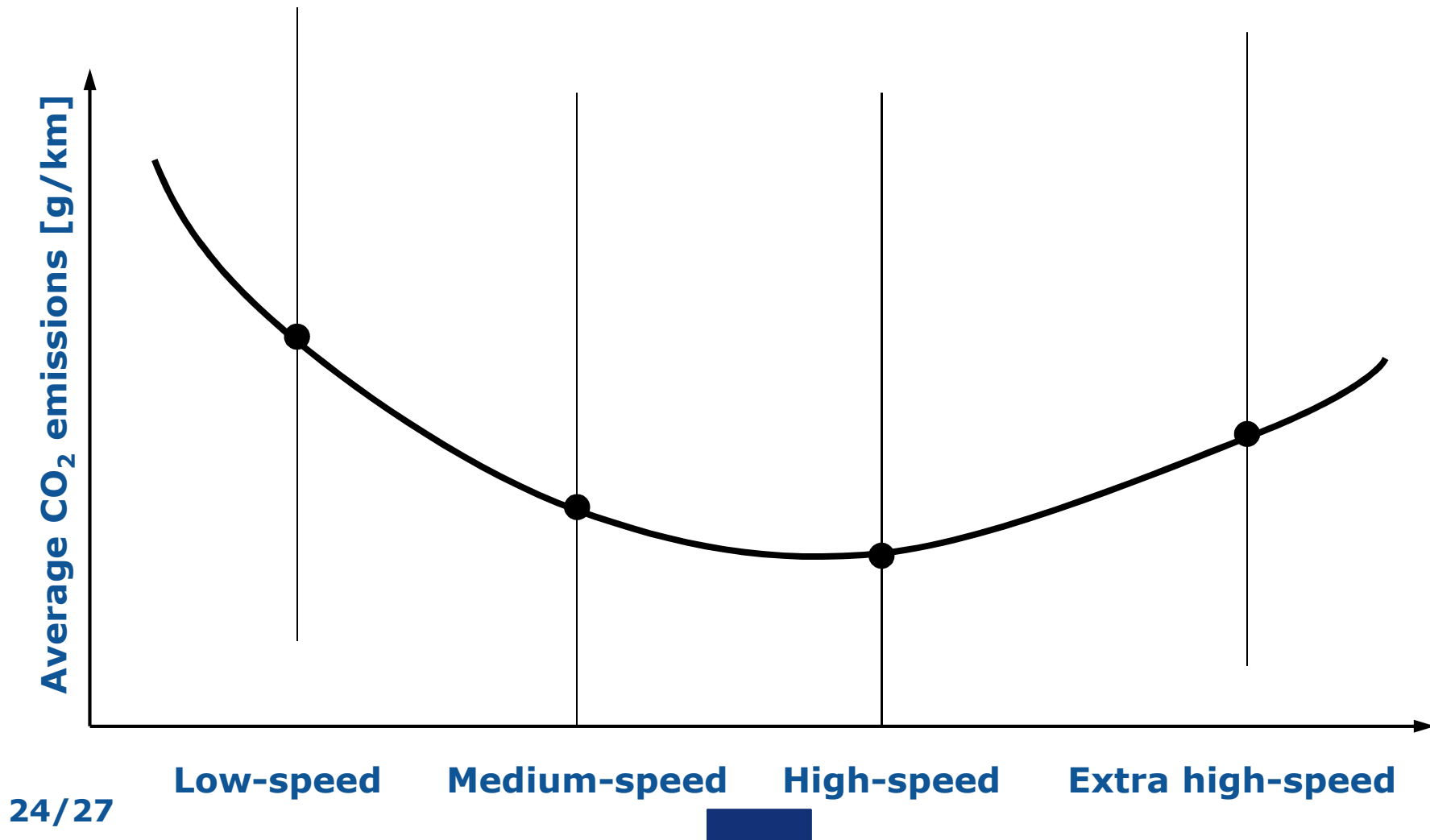
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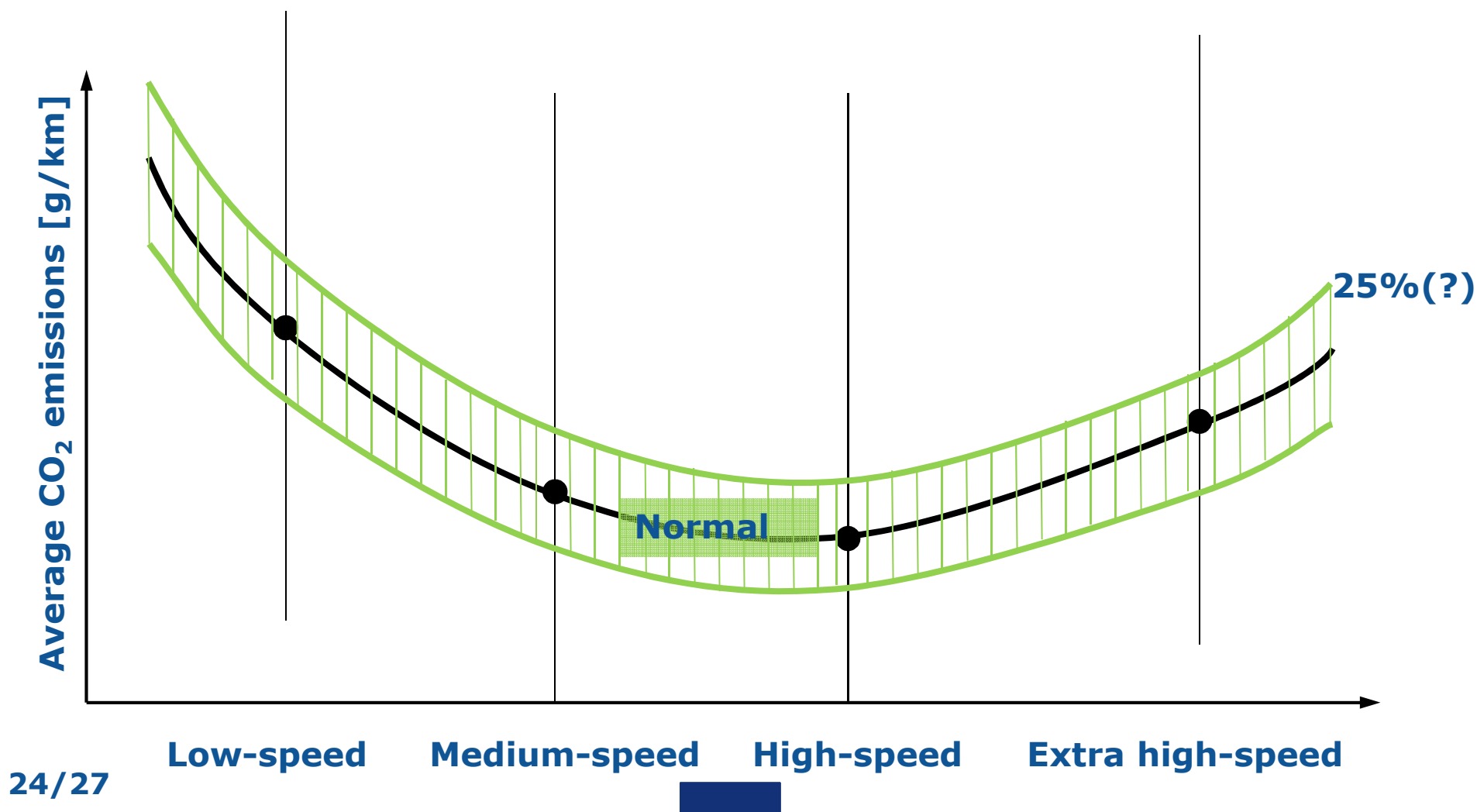
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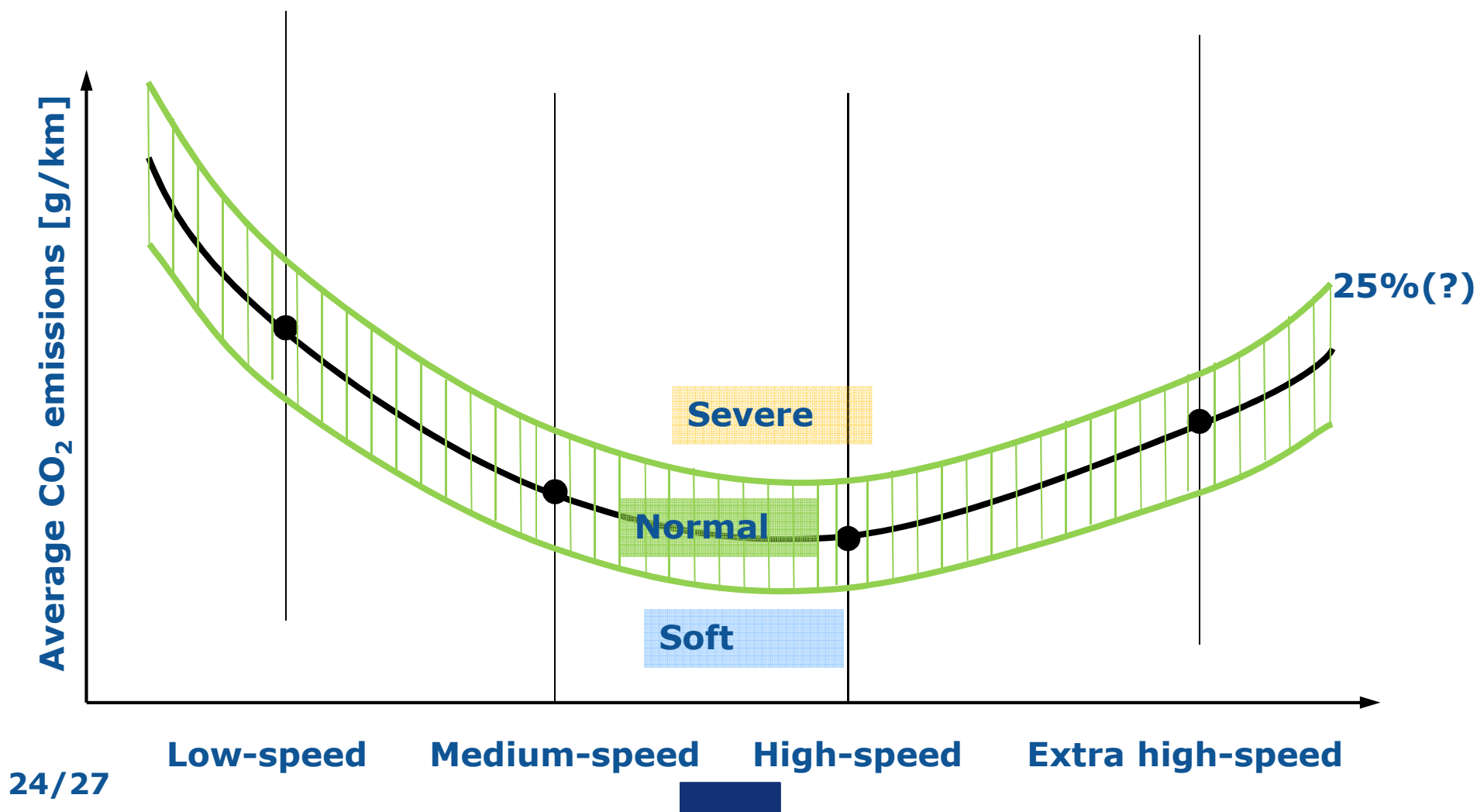
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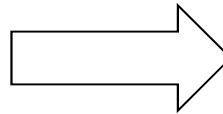
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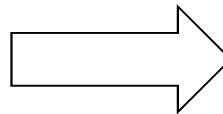


**Wide coverage of
operating
conditions**



**Relaxed not-to-
exceed limits**

**Narrow coverage of
average operating
conditions only**



**Stringent not-to-
exceed limits**



PEMS: data analysis



Robustness and practicality of the PEMS data evaluation methods [JRC standpoint]:

- Availability, reliability, and traceability of test data
- Consistency with current emissions regulation (e.g., data averaging)
- Ability to assess the RDE performance of vehicles
- Sensitivity to identify high emitters (not only average) under specific conditions (e.g., urban driving)
- Ability to evaluate *a posteriori* test conditions and judge validity of (parts of) a realized test
- Data coverage and robustness against uncertainties of data acquisition
- Technologically neutral and future prove
- Practical and applicable by independent organizations



PEMS: time line



- **Building structured data base of PEMS tests from 10/2013**
- **One data evaluation method selected by end 2013/early 2014**
- **Fine tuning and vehicle testing until mid 2014**
- **Procedure drafting (testing + data evaluation) until mid 2014**
- **Implementation end 2014**
- **Binding RDE requirements from Euro 6c onwards in 2017**



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