



# PEMS: From vehicle emission measurement to emissions modelling

EMISIA WORKSHOP, Zurich, 2017-11-17

# Background

- PEMS measurements are currently required by legislation for vehicle type approval
- For research purposes, PEMS offer a unique source of emission information that can be used for
  - Technology assessment
  - Emission factor development
  - Input to air quality modelling
- Data handling, processing and QA/QC can be overwhelming
- We can help in all stages of PEMS measurement and data handling
  - Following slides show tools and methods developed by Emisia and implemented by the Environmental Protection Department of Hong Kong

# PEMS systems available by EMISIA

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



NO, NO<sub>2</sub> : UV  
CO, CO<sub>2</sub>: NDIR  
O<sub>2</sub>: Elec-Chemical  
P: 220 W, 2 h on batteries

5.2017

GPS and ambient sensors, roof installed



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



PN: Diffusion Charger

6.2017

OBD data recorder



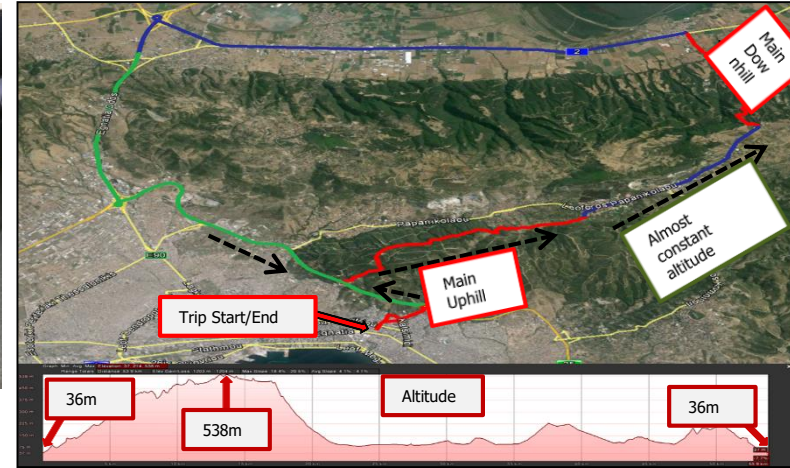
## OBS-ONE GS PN HDV Type



CO, CO<sub>2</sub>:  
NO, NO<sub>x</sub>: Dual CLD  
THC: FID  
PN: CPC  
P: 450 W, 4 h on batteries

9.2017

# Extensive experience with Light Duty Vehicles testing



PEMS equipment consists of several units installed on the vehicle:

- Gas analyzer connected with heated line to tailpipe
- OBD (CAN) data reader device
- GPS unit
- Several ambient condition sensors
- Exhaust gas temperature
- Exhaust flowmeter pending
- System control unit, which ensures simultaneous recording for all signals

# Technical Advisors to Hong Kong PEMS testing of buses



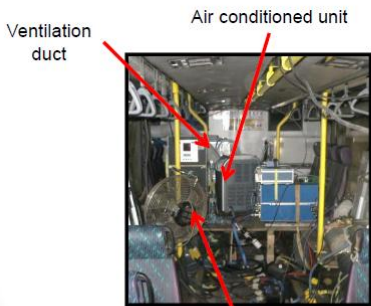
Back-up batteries

Generators



FID fuels

N2



Ventilation duct

Air conditioned unit

Fan

## Other supporting system for the testing

- 3 portable generators & each with 3,000 W were used
- Gas cylinders used
  - 2 FID fuels
  - 2 N2 for zeroing and purging of the FTIR, and
  - 1 Zero air for zeroing of the A&D THC analyzer
- Extra ventilation is required
  - Localized heat generated from the PEMS

Heated sampling line to PM filter system

Heated



Exhaust flow direction

Exhaust Flow Meter

# Why PEMS measurements can become a headache

- ▶ Instrument diversity (various PEMS devices, exhaust flowmeter, GPS, barometer, speedometer, OBD reader...)
  - ▶ Format, syncing, ...
- ▶ Data volume
  - ▶ Single 1-h trip easily creates 20Mb of data
- ▶ Processing methods
  - ▶ Regulatory or other methods to come up with g/s or g/km data

# PEMS data handling

## PEMS data handling & IT infrastructure

Collection and Organization

Storage and Indexing

IT interface (web, other)

System Update & Maintenance

## Data analysis

Grouping

Corrections

Processing (regulatory or other)

Analysis

Assessment

## Emission Modelling

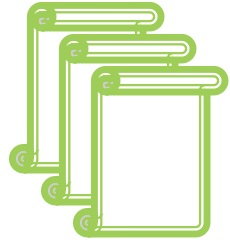
New emission model development (various scales)

Enhancing existing models (e.g. COPERT, etc.)

# PEMS data flow



PEMS Measurement



Output files



Processed data storage



Raw data file server



A dashboard showing three types of data visualizations: a line graph, a bar chart, and a histogram.

Visualisation

Emission factors

Statistics

# QA/QC procedures

## Phase 0: Data pre-processing

1. Sub-trip  
disaggregation

2. Speed  
smoothing

## Phase 1: Overall test verification

1. Operation  
feasibility

2. Speed and  
pollutant trace  
statistics

3. Visual  
inspection  
(speed trace)

## Phase 2: Individual trace verification

1. Visual  
inspection  
(pollutant trace)

2. COV/  
PTM  
analysis

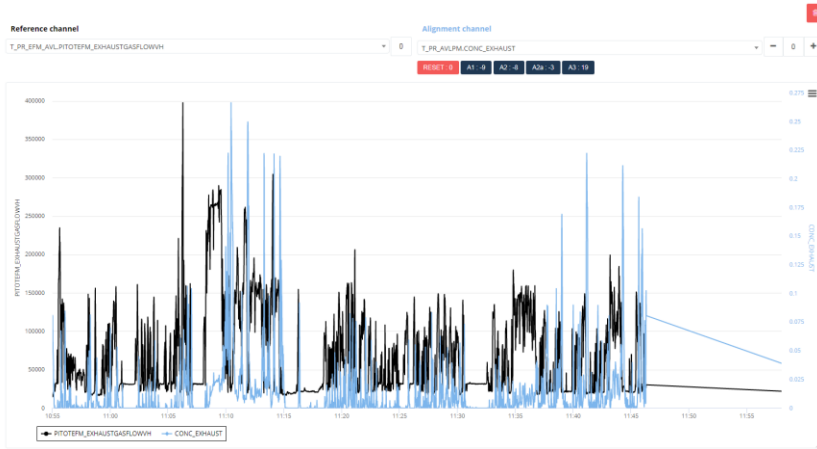
3. Clipping  
detection

4. Baseline  
drift  
detection

5. Outlier  
detection



# Time Alignment



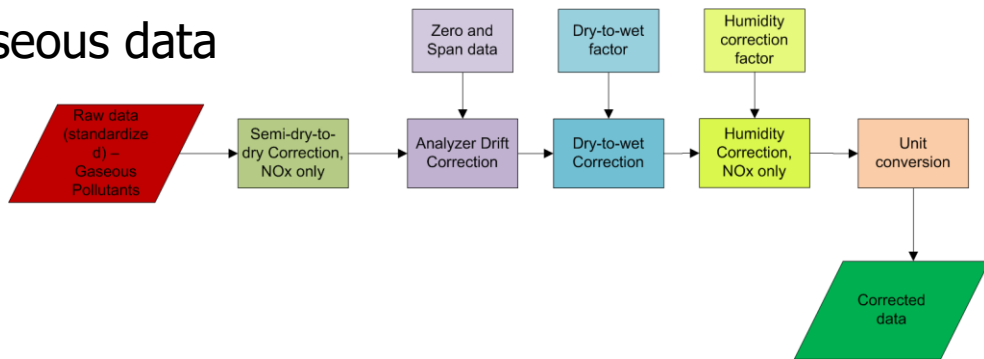
The charts are fully interactive – the target series can be ‘dragged’ to all directions and zoomed in/out.

The user can opt to find the optimal time shift automatically (e.g. correlation) or enter an offset manually

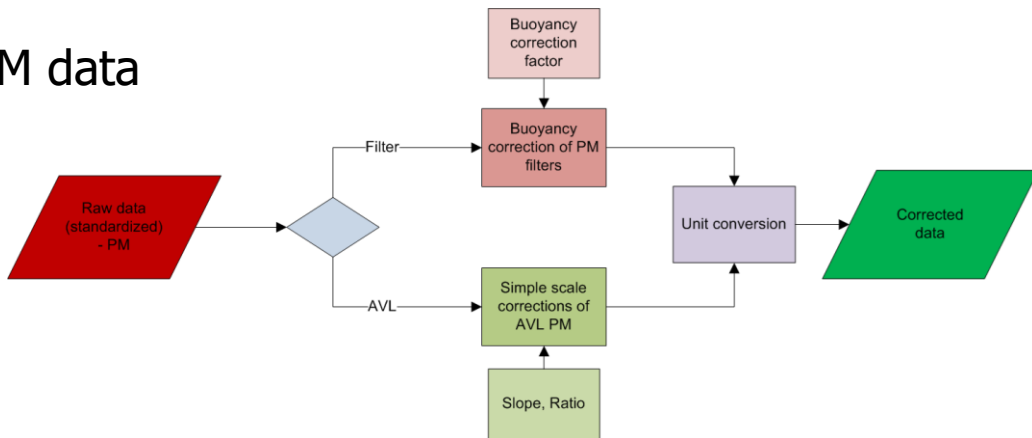


# Examples of PEMS data calculation algorithms

## Gaseous data



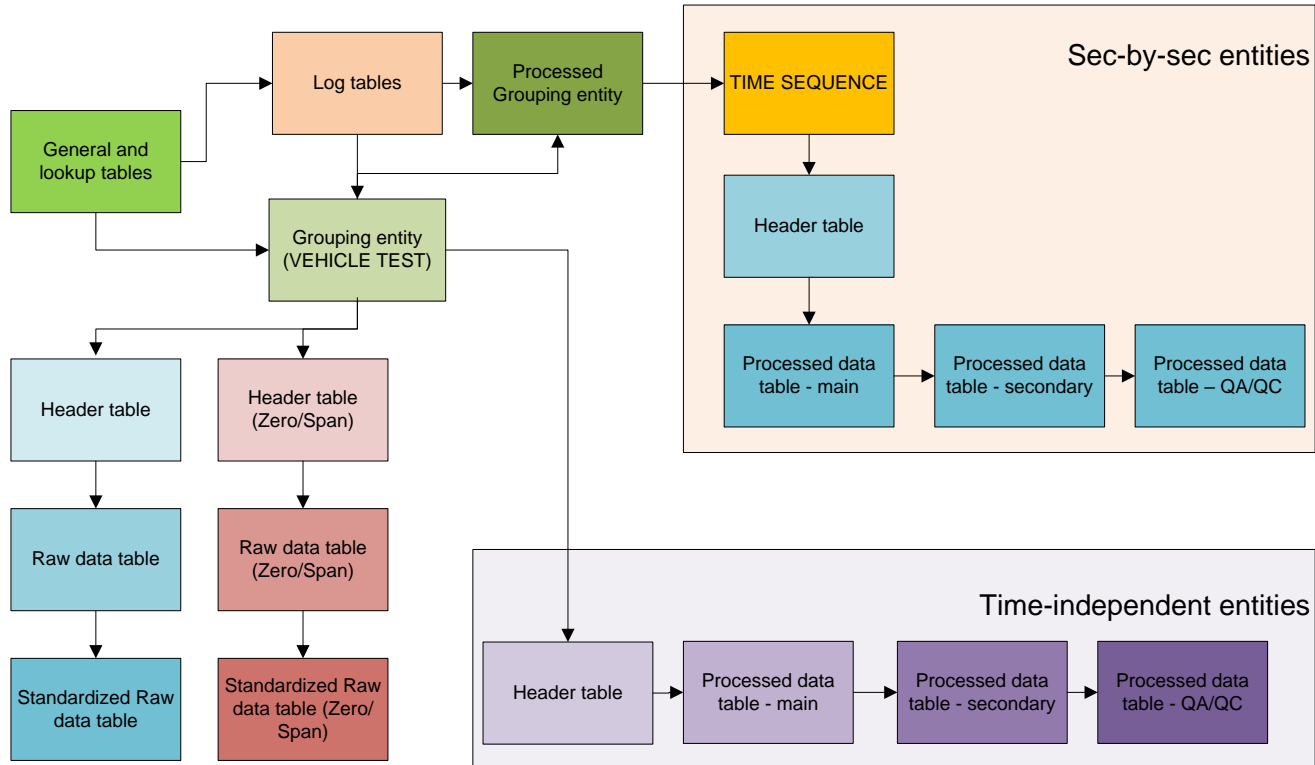
## PM data



The screenshot shows a software interface with a dark sidebar on the left containing navigation options: Files, Tests, Trips, Process, Time align trips, Process test, Charts realtime, Charts per trip, Charts per vehicle, Chart statistics, and Account. The main area is titled 'Selected test details' and shows 'TEST ID : 20160628001', 'Test date : 28 Jun 2016', and 'Fuel : DIESEL'. Below this, there is a section 'Available procedures for this test' with a list of checkboxes for various correction procedures: Speed correction, Semi-dry-to-dry, Drift correction, Dry-to-wet, NOx humidity, PM correction, Remove Negative, and Concentration to mass. At the bottom of this list are 'Check all' and 'Uncheck all' buttons.

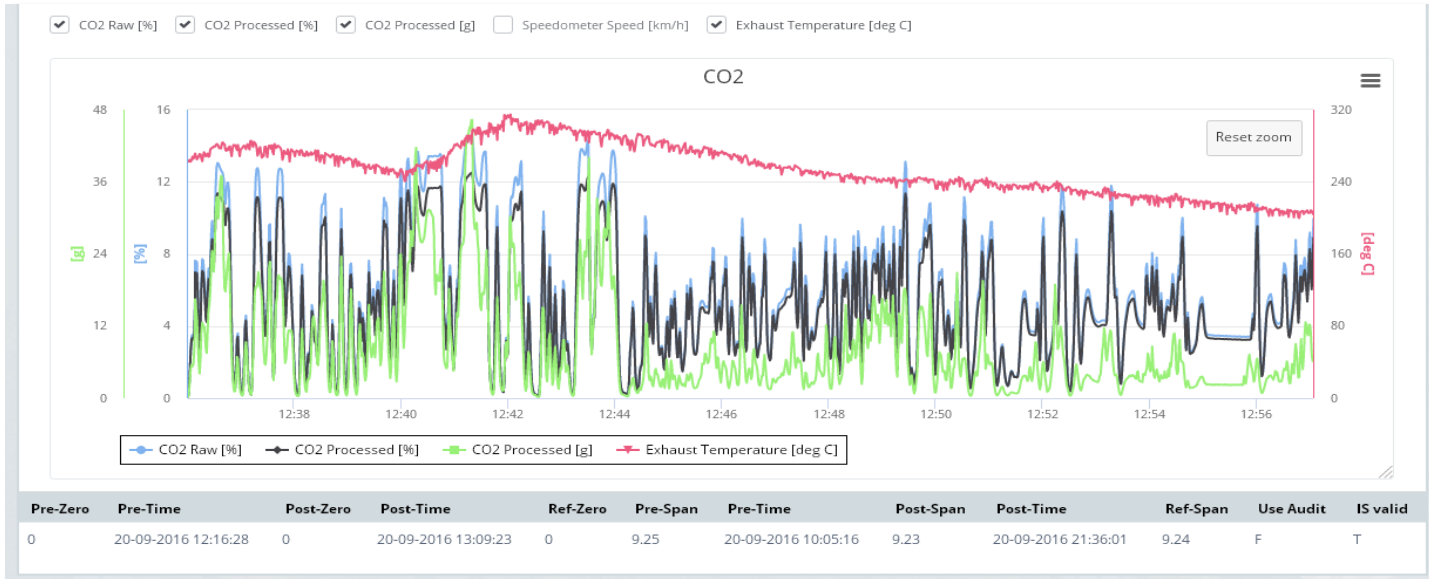


# IT infrastructure

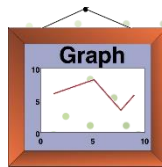


# CO<sub>2</sub> rate and exhaust temperature

## Example of graph

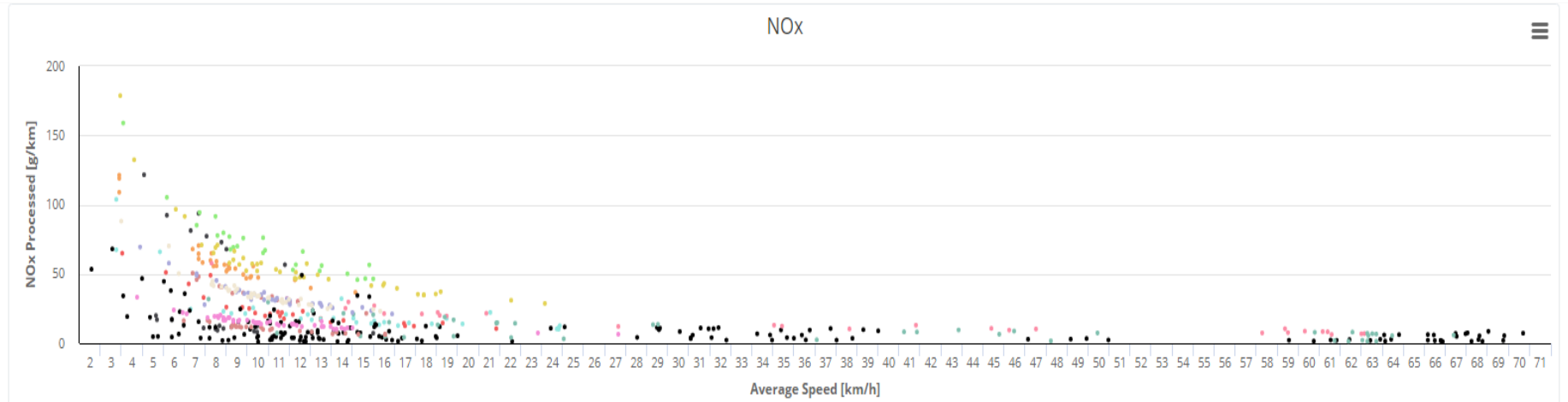


Snapshots of emission performance by combining different signals

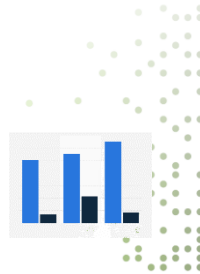


# NOx as a function of Euro standard

## Example of emission factor



500-m integrations of emission rates as a function of mean speed

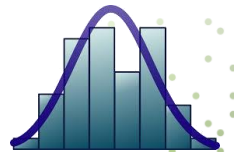


# CO<sub>2</sub> emissions variability per speed class

## Example of statistics

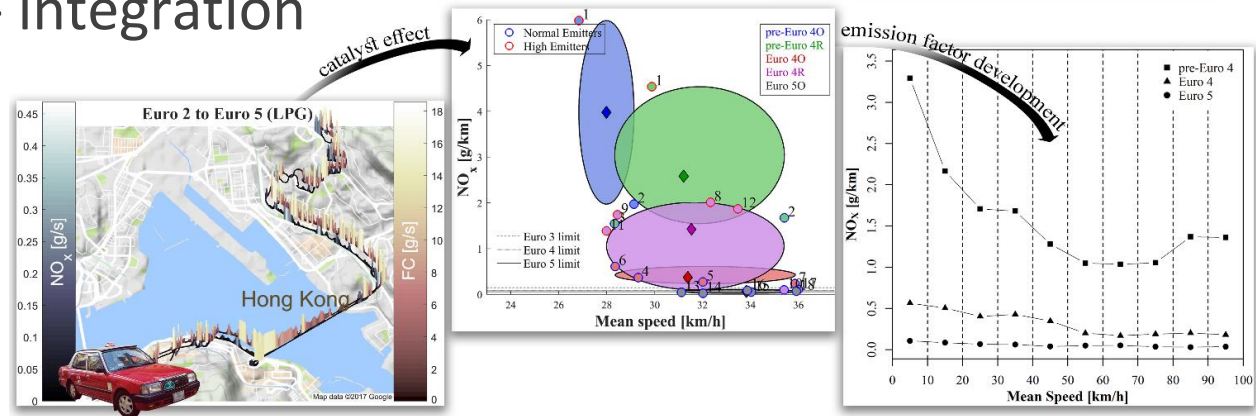


Distribution of 1 Hz CO<sub>2</sub> emission rate as a function of speed class.  
Box-plots and outliers shown



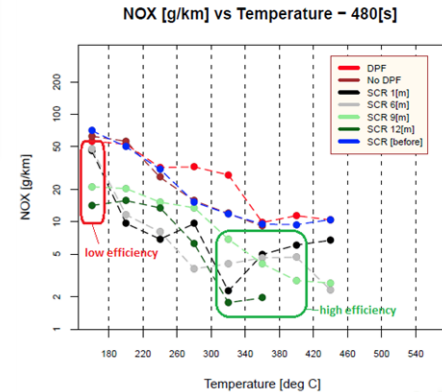
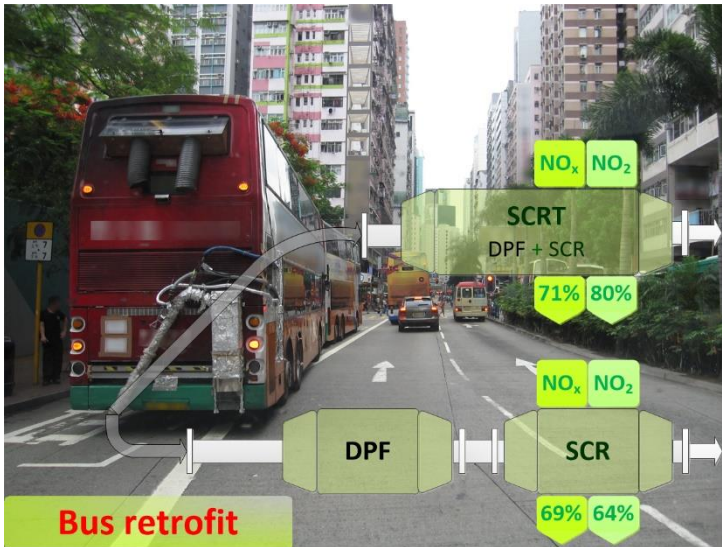
# Environmental Assessment of LPG Taxi Fleet

- 18 LPG taxis
- 370 hours of field data
- Euro 2 to Euro 5 technology
- Impact of TWC and lambda sensor replacement
- Time- and distance- integration
- Vehicle speed and road slope impact on emission levels



# SCR and DPF diesel bus retrofits

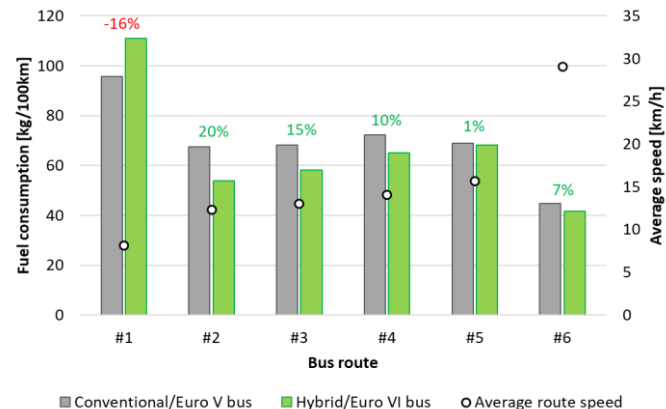
- 6 double-deck diesel buses
- DPF and SCR; SCRT retrofit



- Emission levels
- Effect of DPF technology
- Impact of SCR on criteria pollutants
- Impact of operation conditions

# Assessment of urban hybrid buses performance

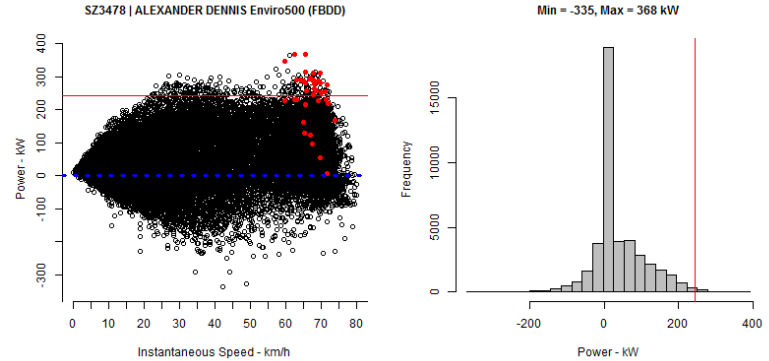
- ➔ 6 Euro V diesel and 6 Euro VI hybrid-diesel double-deck buses
- ➔ SCR (all); DPF and SCR (hybrids)



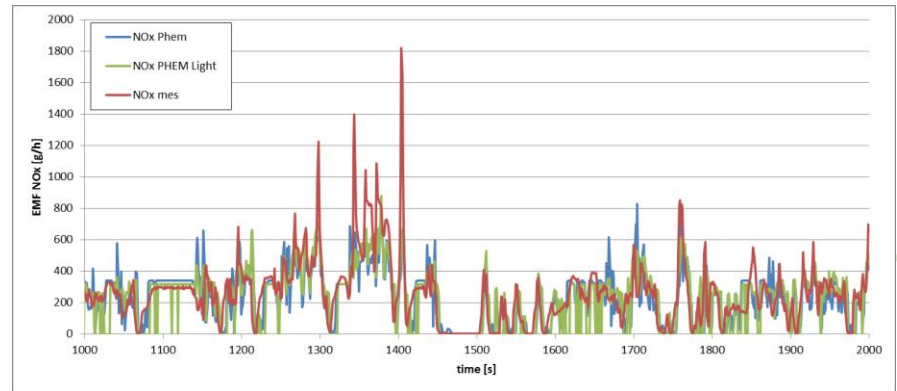
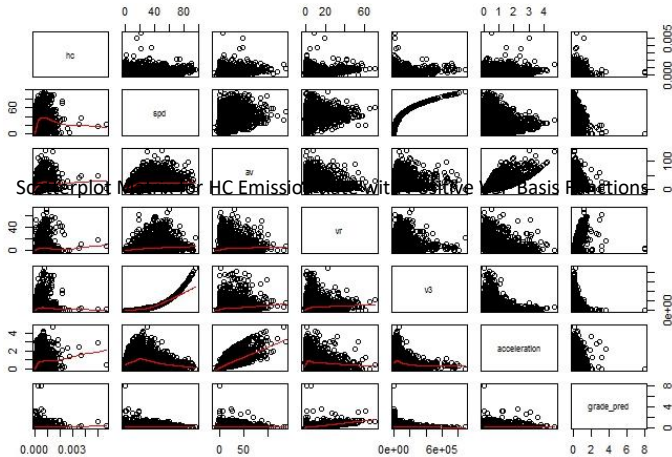
- ➔ FC benefits of hybrids
- ➔ Benefits of combining hybrid and Euro VI technologies
- ➔ Distance-based and energy-based EFs
- ➔ Effects of driving, ambient, operational conditions on EF and FC

# Emissions modelling based on PEMS data

- Meso-scale emission modelling
- Micro-scale emission modelling



Velocity-power plot and power histogram

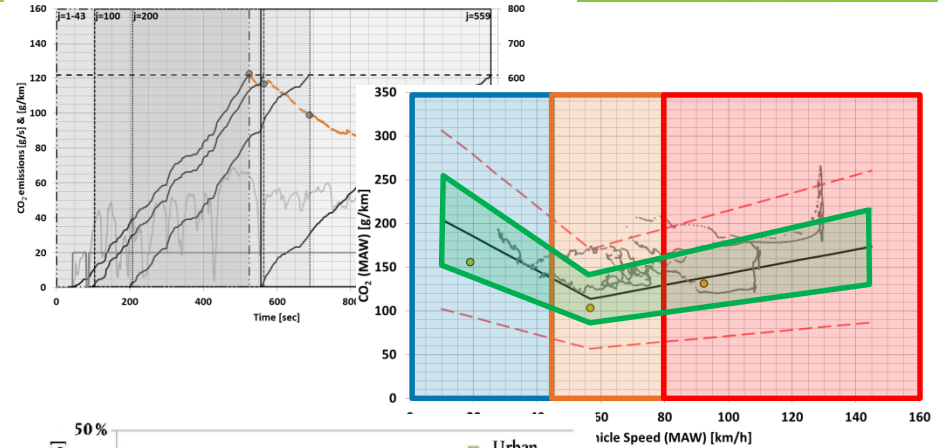


NOx emissions – measurement compared to simulation

# Regulatory evaluation and visualization

## ➤ Moving Average Window (MAW) interface (EMROAD method)

- Checks compliance criteria
- Produces CO<sub>2</sub> MAW chart



## ➤ Vehicle Specific Power (VSP) interface (power binning method)

- Input: rolling resistance, vehicle mass, the road gradient
- Produces a chart of the VSP bins for three speed classes

