On-Board Vehicle Emissions Measurements for hybrid buses and light duty vehicles in Hong Kong

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March 2016

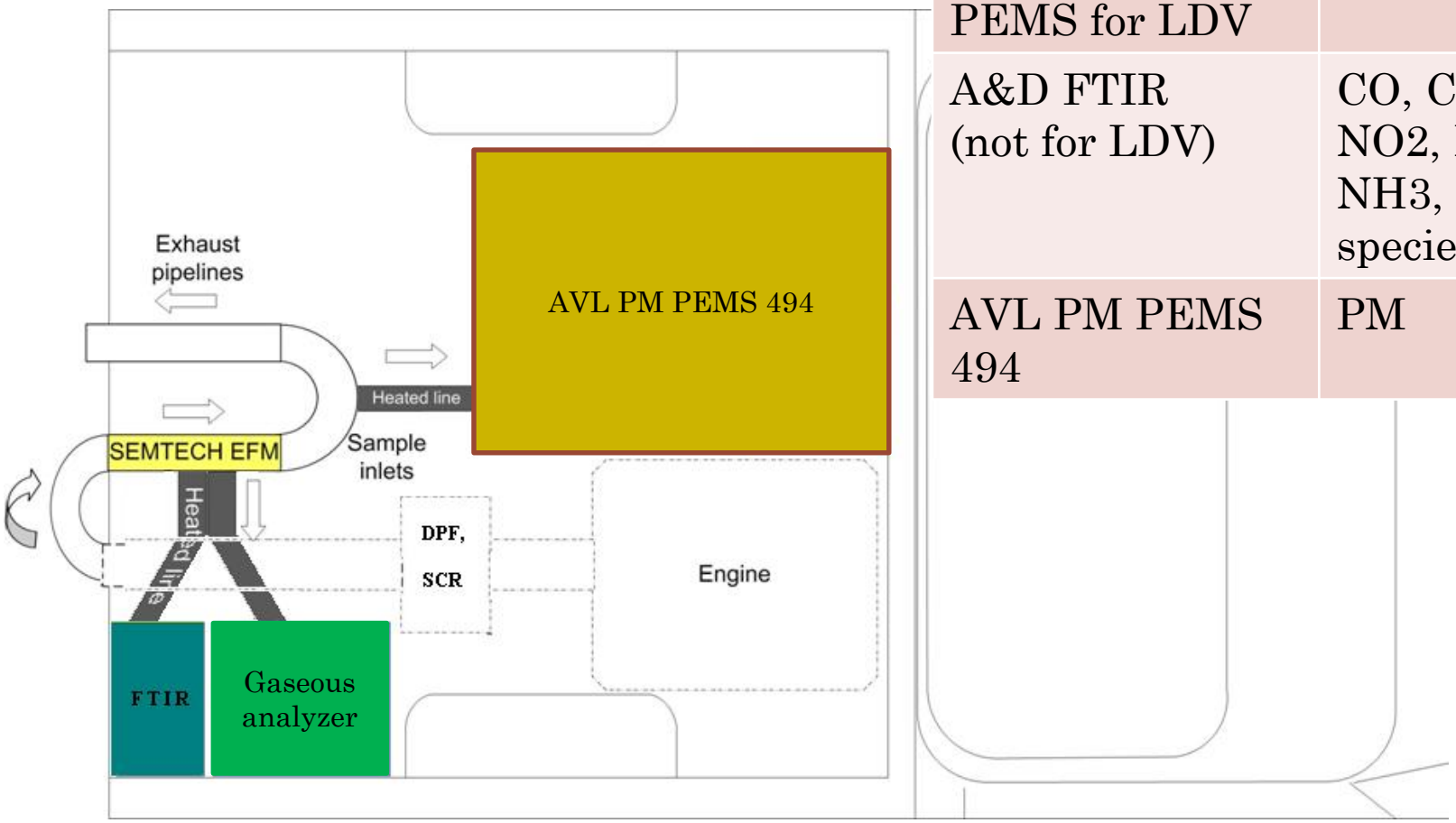
Outline

- Test Set Up and Protocols
- Real-world Emission Measurements from Hybrid Buses and Results
- Real-world Emission Measurements from VW Light Duty Trucks and Results
- Conclusion & Way Forward

Test Protocol

- Follow most stringent testing requirements:
  - PEMS requirements in Euro VI for gaseous pollutants/ISO16183 for PM
  - CFR 1065 Subpart J
- Zero every hour, audit every three hours & calibrate/ span check the gas analyzers twice a day
- Analyze 2-3 fuel samples from the fuel tank of each test vehicle
- Use professional drivers
- Drive on a fix route or follow a vehicle of the same class
- Capture traffic by video camera mounted in front of the test vehicle

Test Schematics

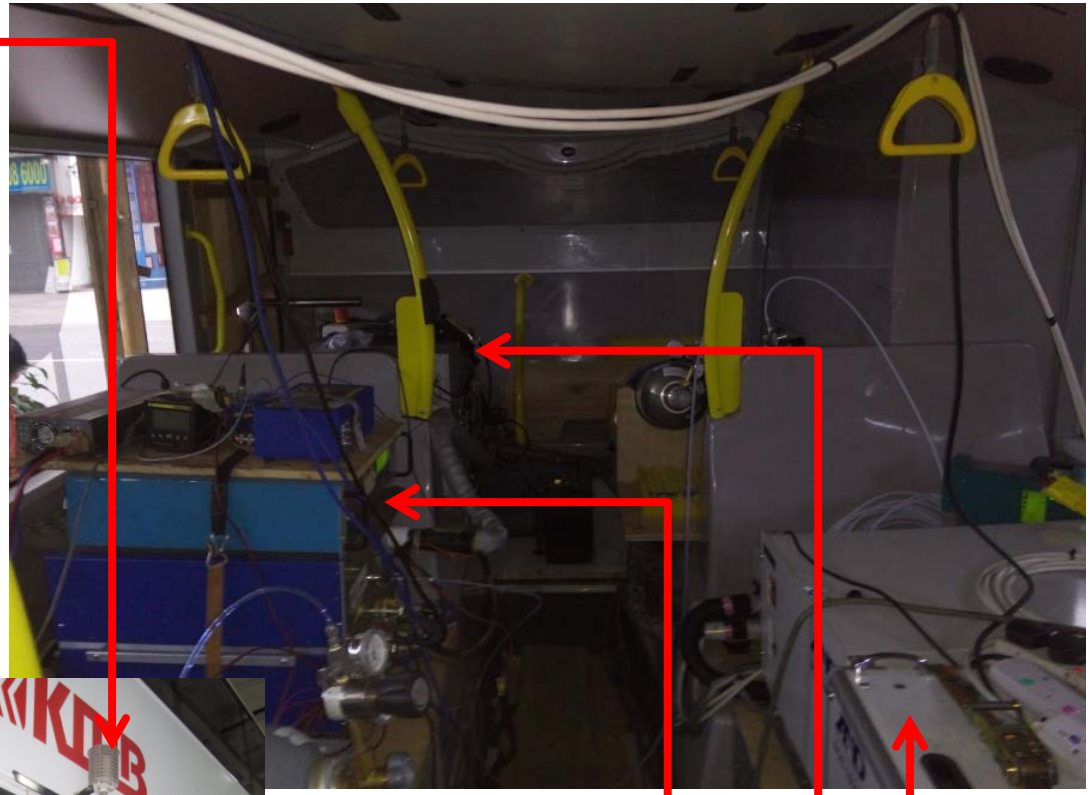


PEMS used	Pollutants
Gaseous analyzer a) SEMTECH-DS for bus b) AVL GAS PEMS for LDV	CO, CO2, NO, NO2, THC
A&D FTIR (not for LDV)	CO, CO2, NO, NO2, N2O, NH3, HC species
AVL PM PEMS 494	PM

Vehicle Installation

Weather probe

Speedometer



SEMTECH DS

FTIR

AVL PM

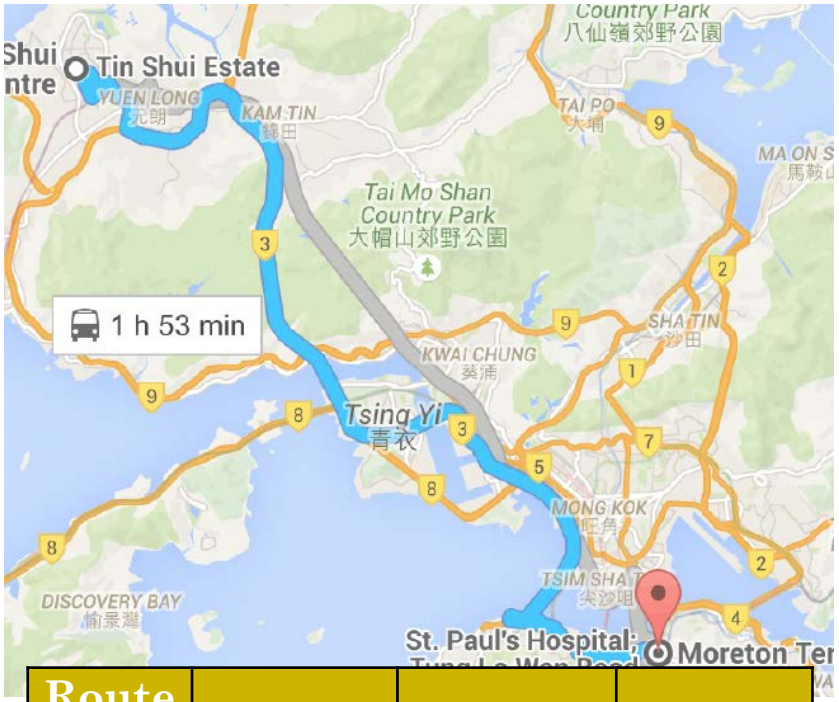
VEHICLE INFORMATION

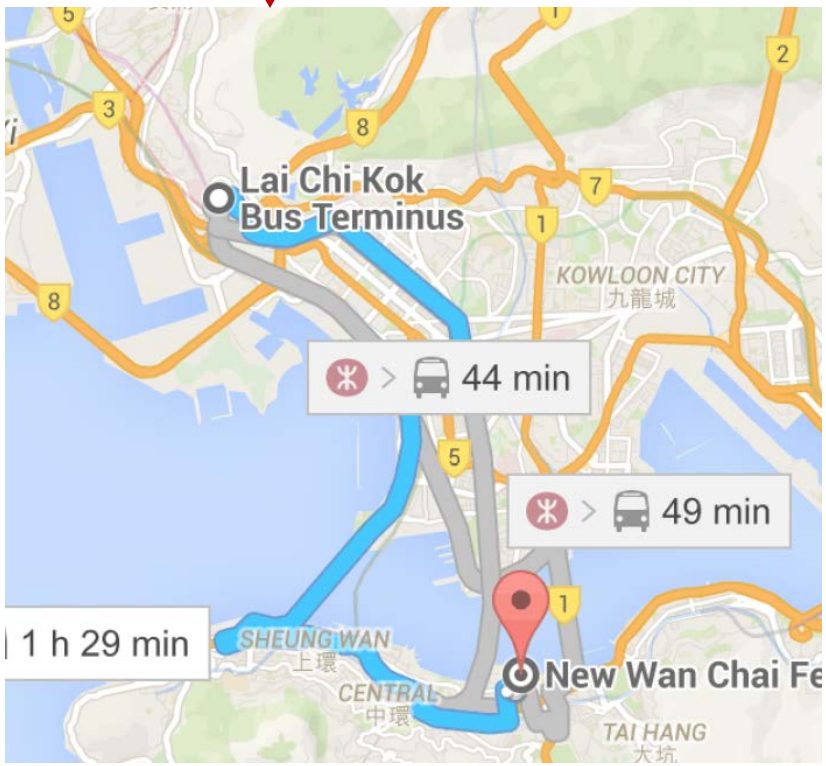
Description	Control double deck bus	Hybrid double deck bus	Heavy heavy duty truck
Make	Alexander Dennis		Scania
Eng Model	Enviro 500 Turbo	Enviro 500H Hybrid	DC1306360 XPI
Eng Capacity	8.9 litre	6.7 litre	9.3 litre
Emis Std	Euro V	Euro VI	
Engine rated power	326bhp@ 2100RPM	274bhp@ 2100RPM	355bhp@ 1900RPM
Engine rated torque	1500Nm@ 1200-1400RPM	1100Nm@ 1200-1600RPM	1850Nm@ 1000-1300RPM
Gross vehicle weight	26.4 ton		
After treat. device	SCR	EGR, DPF, SCR	DOC,DPF, SCR

Route

969 (mainly highway)

905 (Mainly urban)





Route No.	Area	Control	Hybrid
969	Mainly highway	Apr-15	Apr-15
619	Mainly urban	Jan-15	Feb-15
905	Mainly urban	Feb-15	Mar-15
8	Mainly urban	May-15	May-15
1A	Urban	Jan-15	Jan-15
5B	Urban	Mar-15	May-15

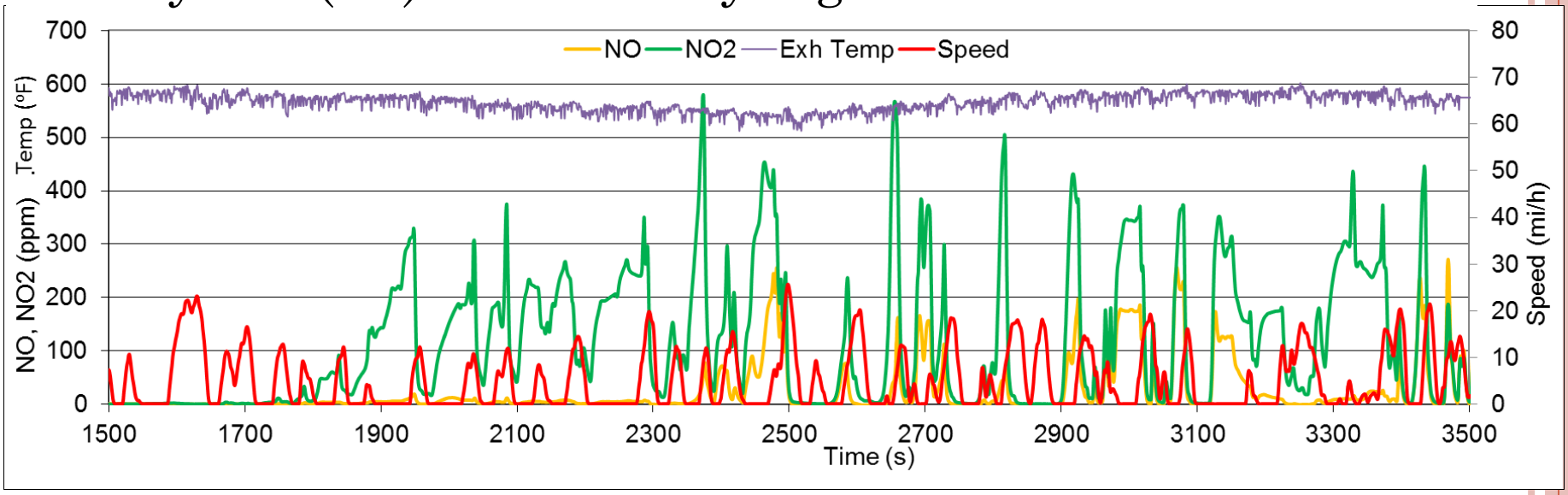
Slide show of PEMS testing for hybrid double deck (DD) buses

969 (mainly highways)

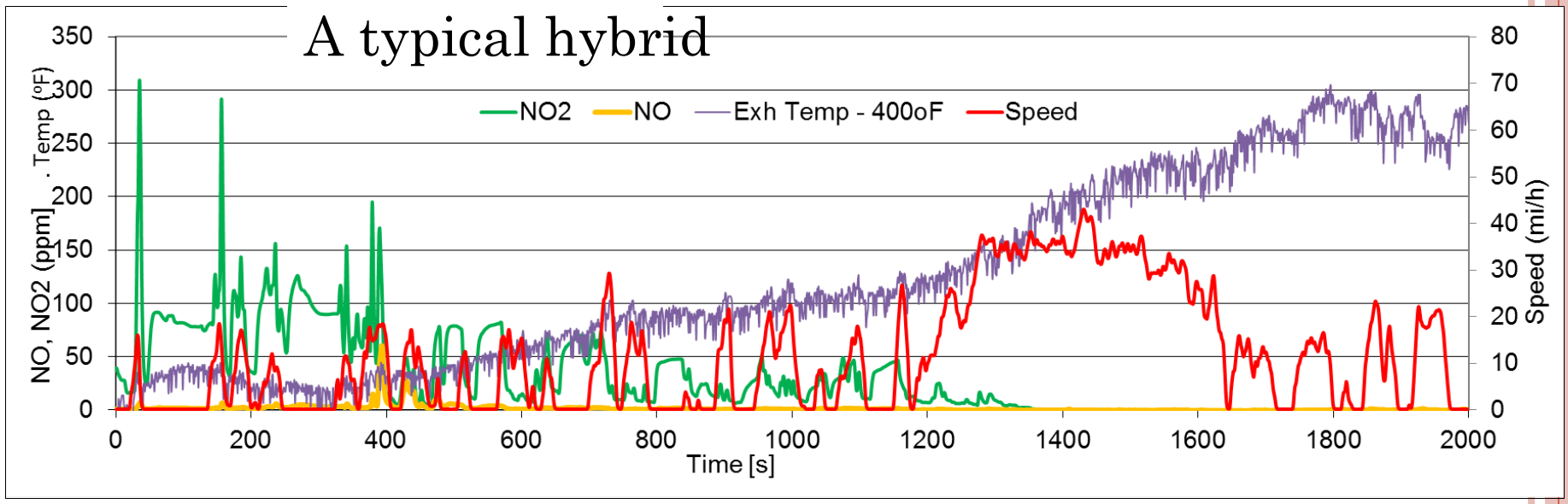
905 (mainly urban)

REAL-TIME EMISSION: NO, NO2

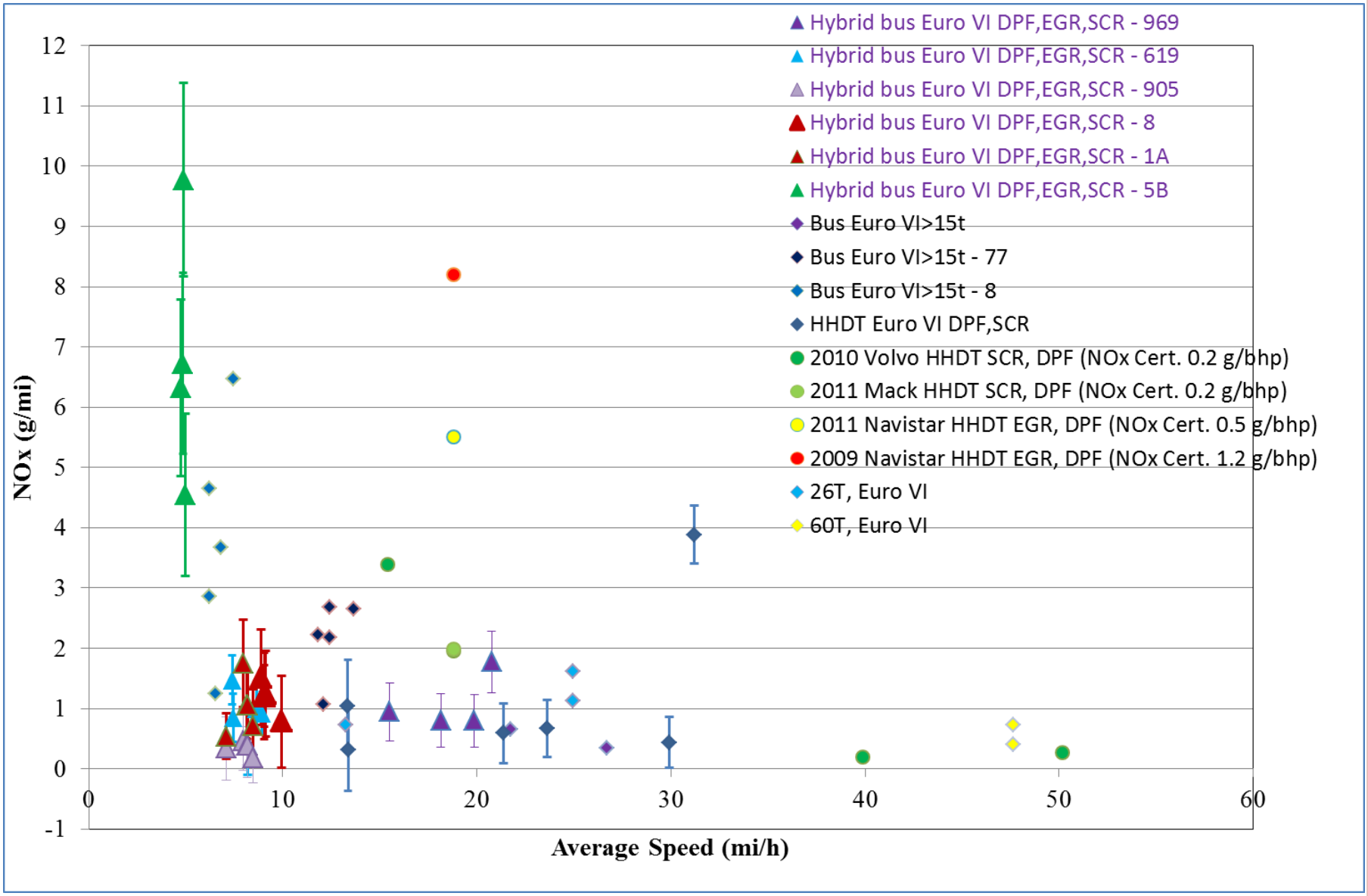
The hybrid (5B): Abnormally high NO2 conc. observed



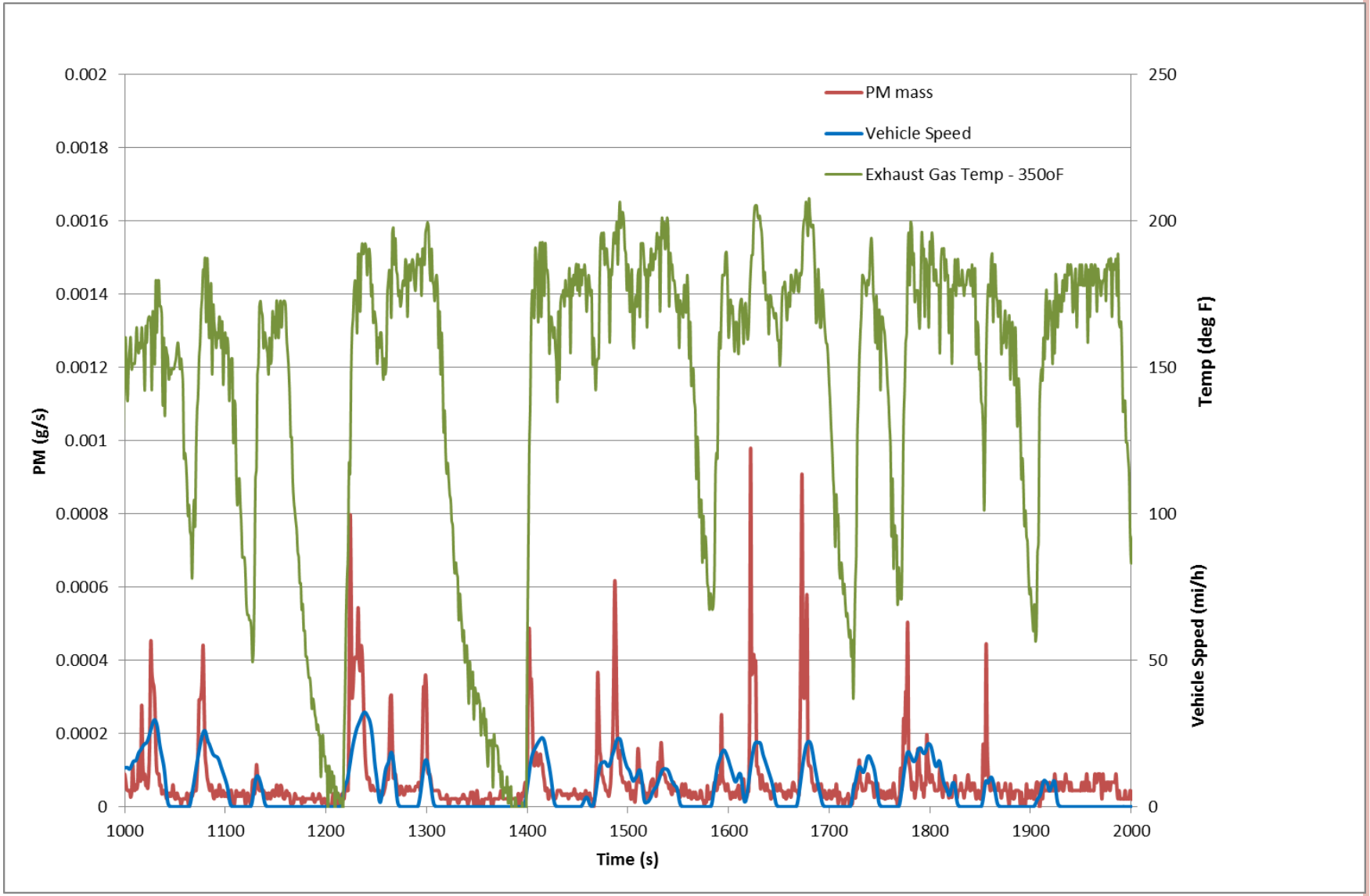
A typical hybrid



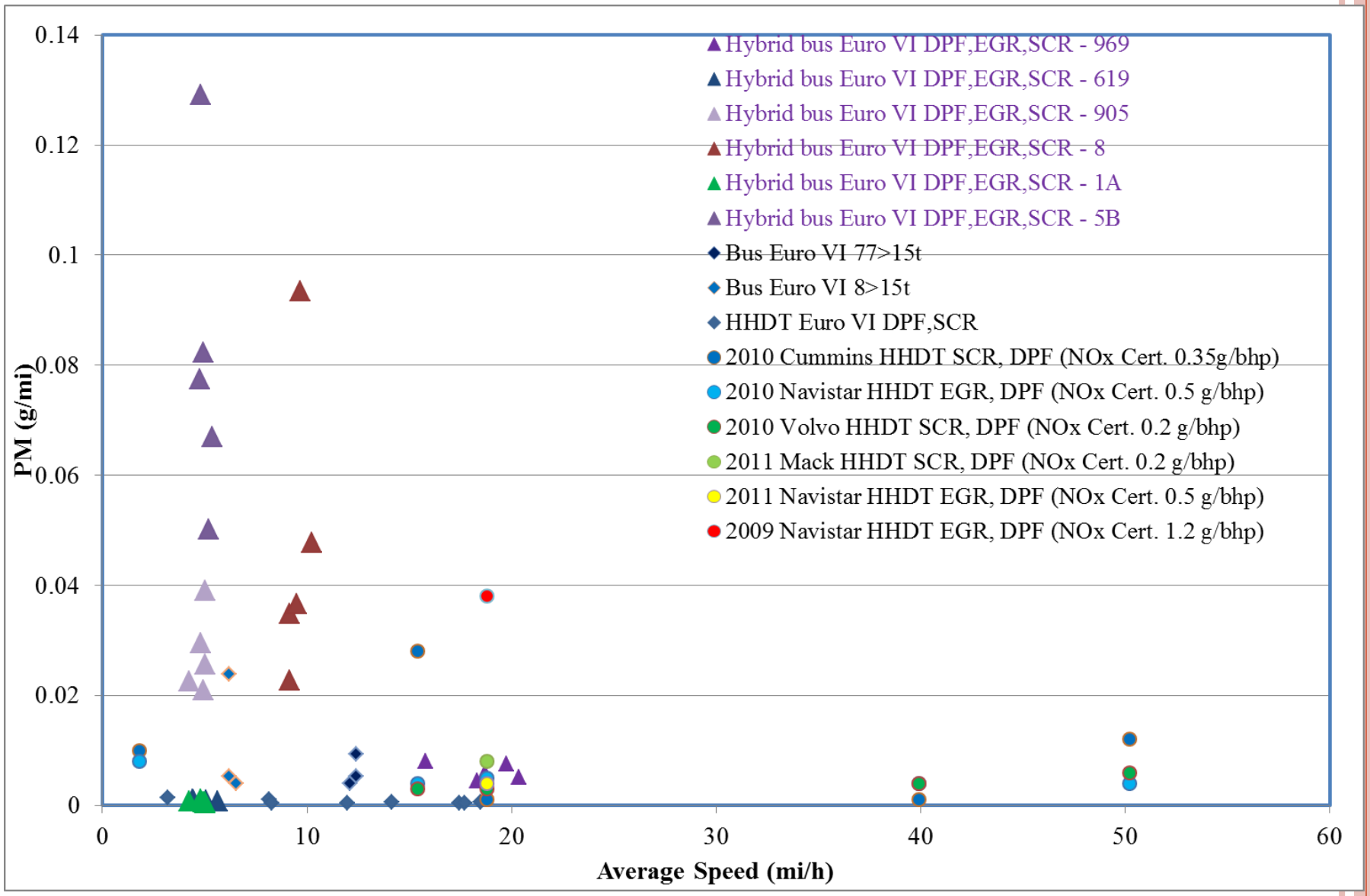
Comparison of NOx emissions from hybrid DD buses with the other Euro VI vehicles



Real-time emission: PM



Comparison of PM emissions from hybrid DD buses with the others



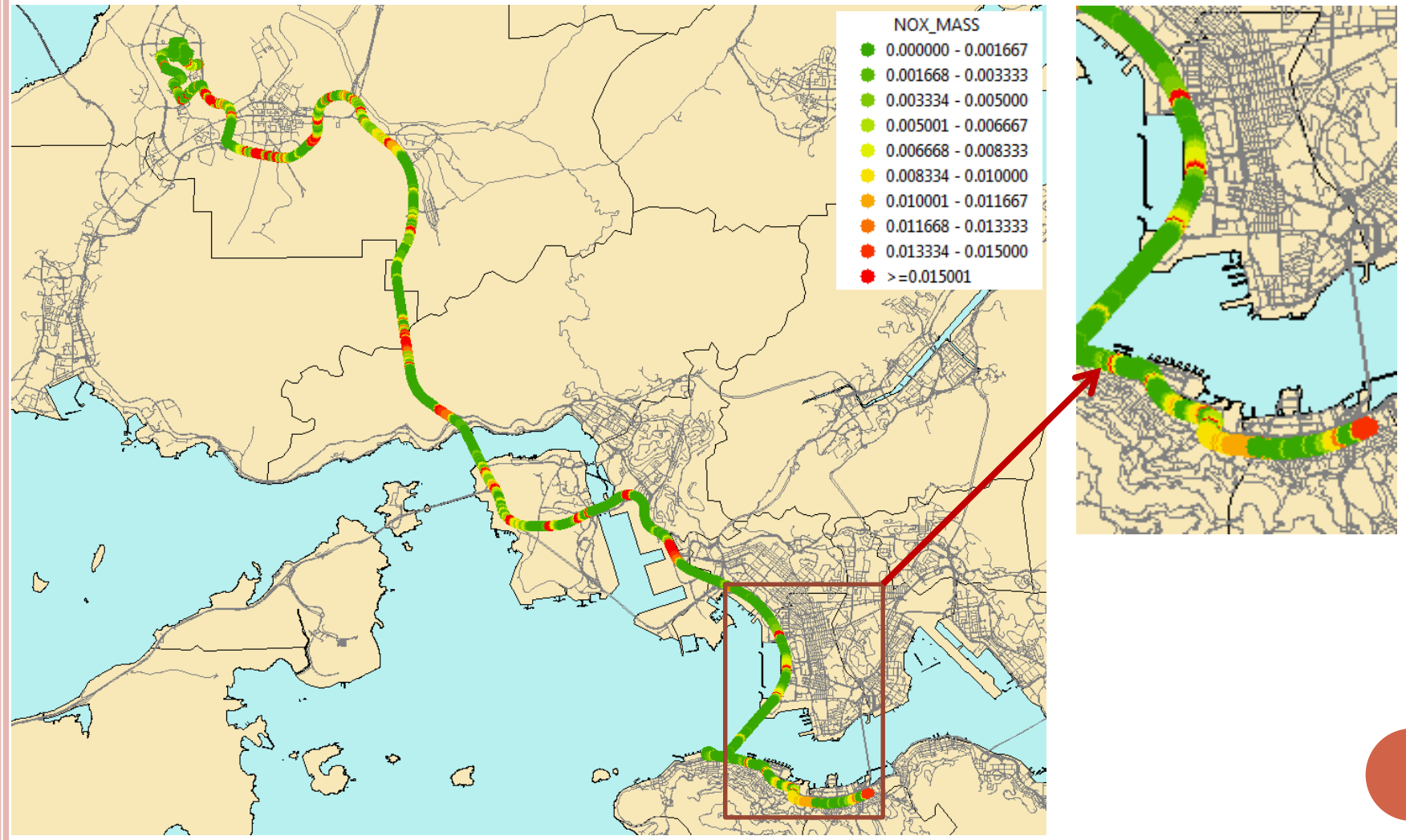
CO2 EMISSION: EFFECT OF A/C

Emission Tests conducted in summer

Reduction %	Average Ambient Temp (°F)		% diff of CO_2 of hybrid bus over control bus
	(Euro VI Hybrid)	(Euro V Control)	
969 – mainly highways	80	83	-7%
619 – mainly urban	65	67	-12%
905 – mainly urban	66	71	-21%
8 - mainly urban	90	90	26%
1A - urban	69	63	-12%
5B - urban	89	80	20%

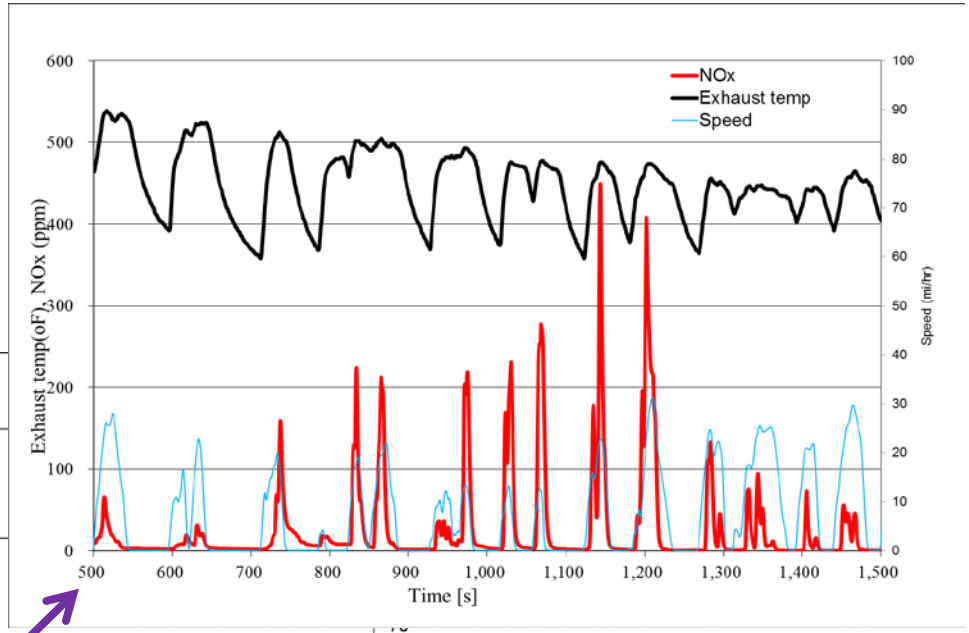
Urban-Highway

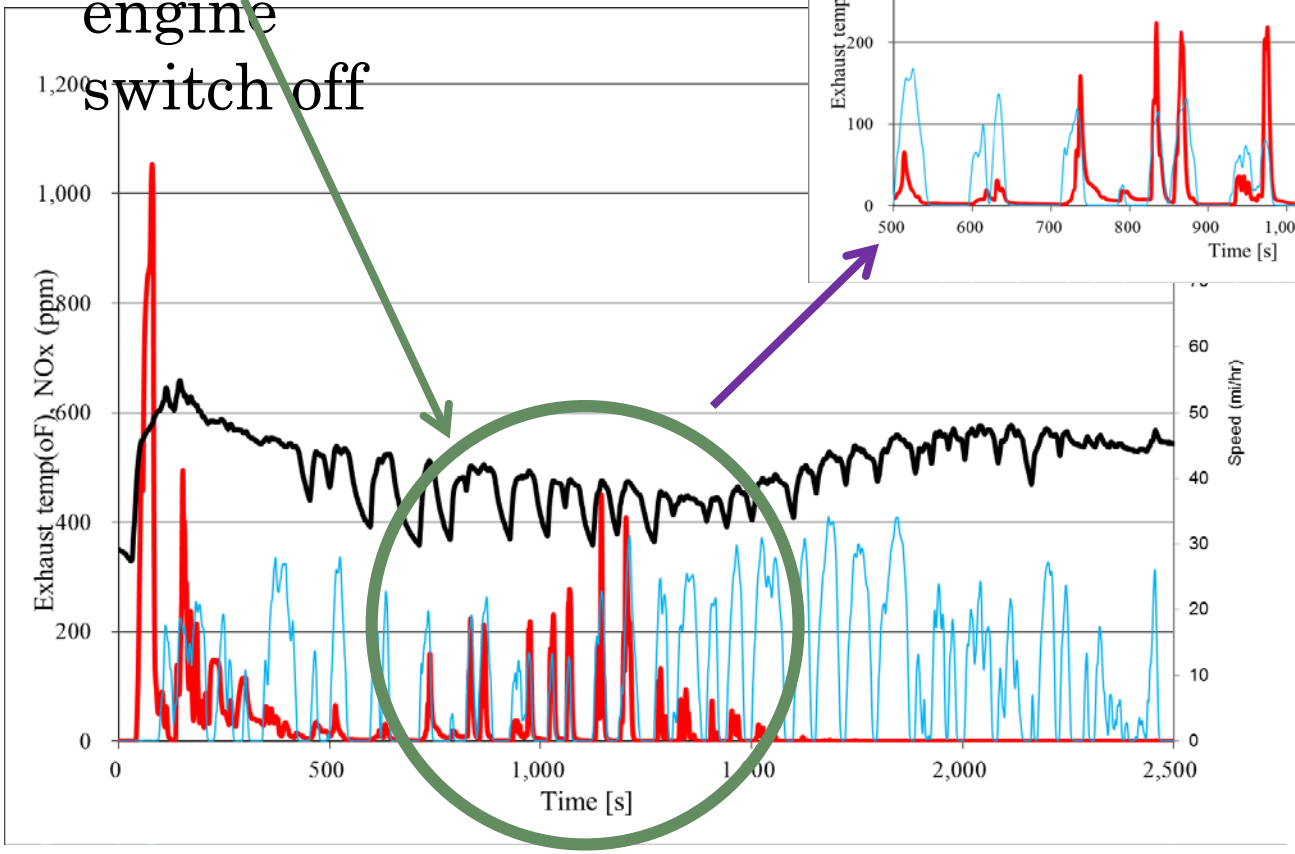
NOx EMISSION IN URBAN AND HIGHWAY



NOx emission: Effect of urban driving

Emission spikes during engine switch off





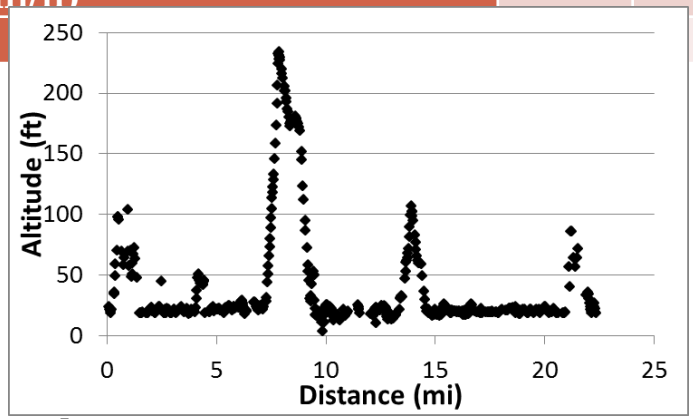
NH3 & N2O emissions (Euro VI hybrid vs. Euro V control)

TITLE	Bus	NH3		N2O	
		Median (ppm)	95th per. (ppm)	Median (ppm)	95th per. (ppm)
1A - urban	Control	0.5	2	0.8	14.2
	Hybrid	0	0.2	17.5	59.7
619 – mainly urban	Control	0.2	0.5	0.9	25
	Hybrid	0.2	0.7	13.9	43.7
905 – mainly urban	Control	0	0.4	1	19.6
	Hybrid	0	1.1	9.2	29.8
969 – mainly highways	Control	0	0.1	0.8	8
	Hybrid	0.1	0.4	10.9	63.6
5B - mainly urban	Control	0	0.1	0.7	3
	Hybrid	0	0	20.2	58
8 - mainly urban	Control	0	0.3	0.6	12.5
	Hybrid	0	0.2	12.3	65.6

VW Diesel Light Duty Trucks

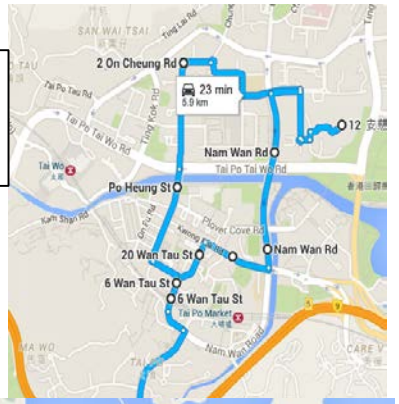
- Fix route test

Parameter	NEDC	Fix route
Duration (sec)	1180	3494
Distance (mi)	7	19
Average speed (mi/h)	21	19
Max speed (mi/h)	75	63
Ave. RPA (m/s^2)	0.145	0.267
Share %		
idling (<1.2 mi/h)	25	23
low speed (1.2-31 mi/h)	54	48
medium speed (31-56 mi/h)	14	23
		6



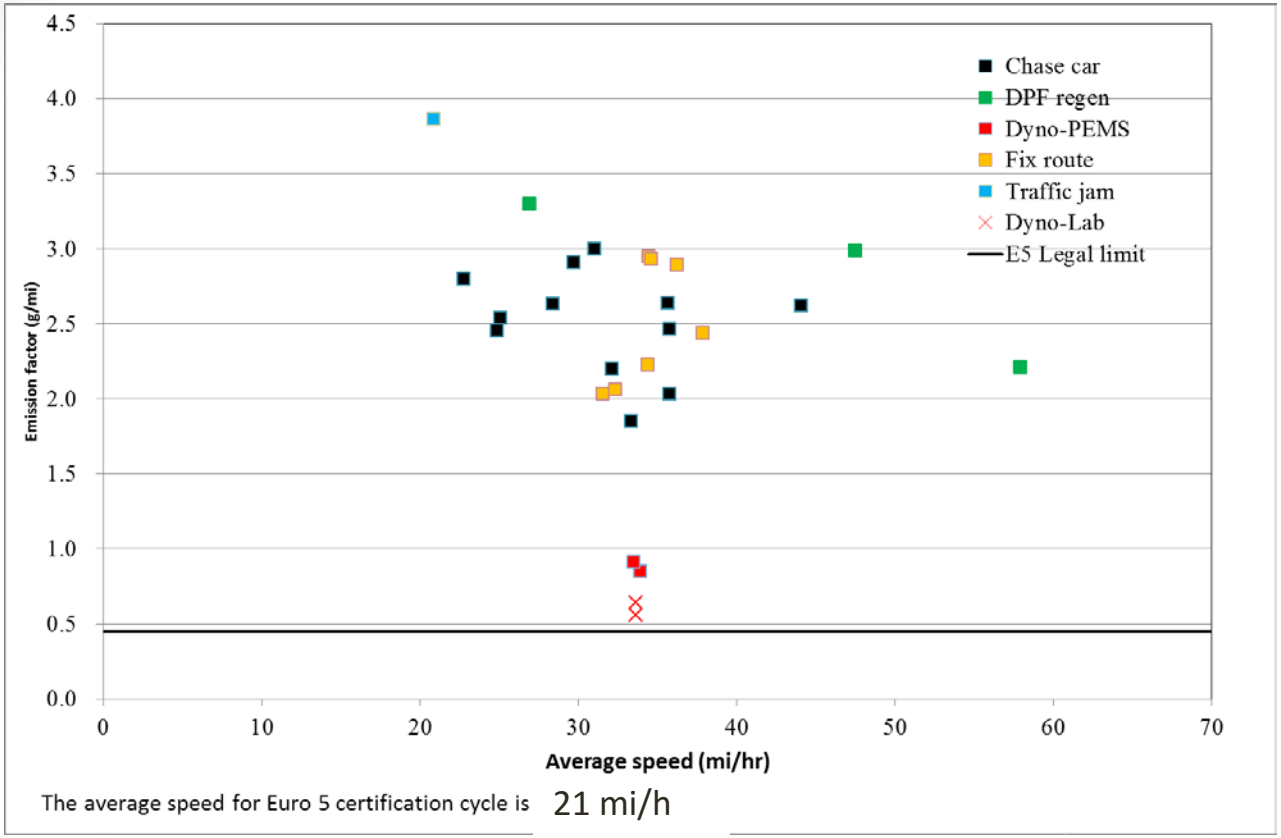
- Chase car
- Dyno

Travelled around suburban area



Started at suburban area

VW Transporter 5: NOx

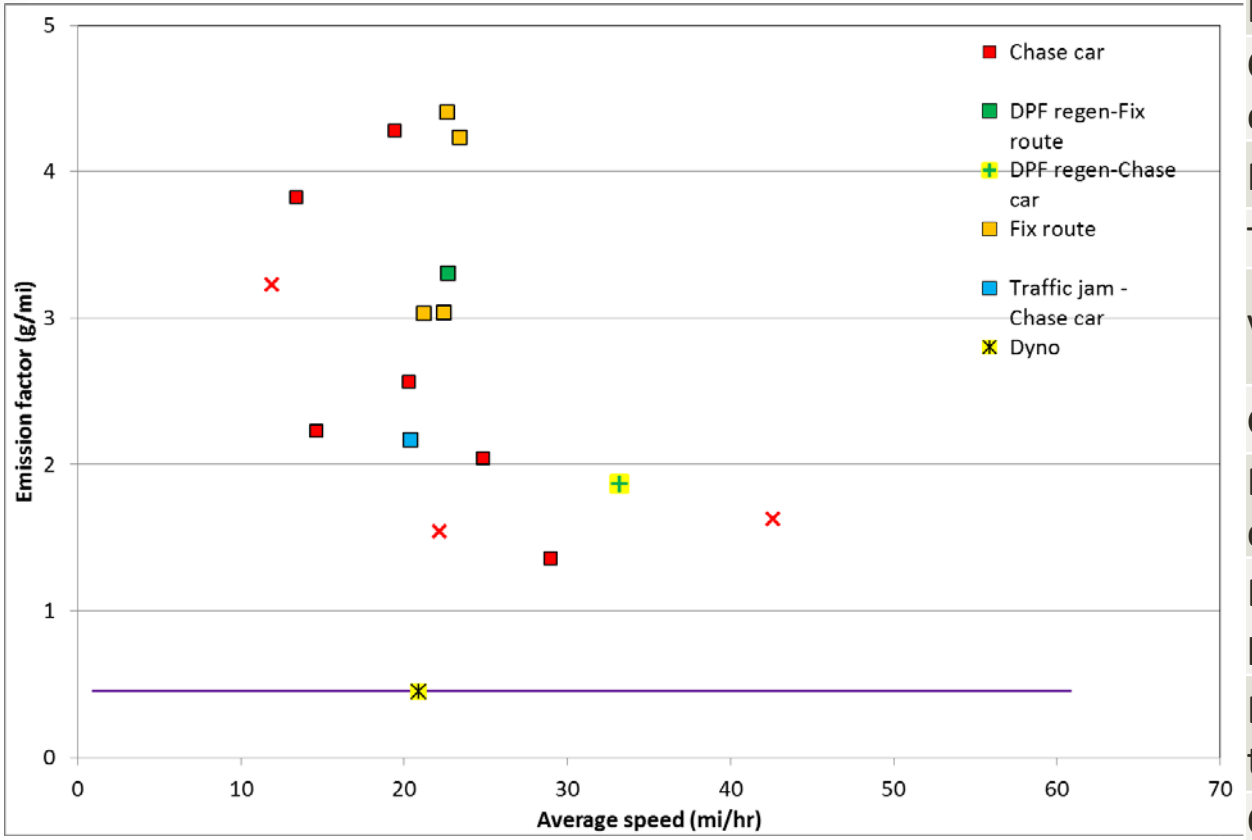


Dyno testing: Vehicle weight including PEMS but no cold start.

All PEMS testing are hot running.

Fuel Type	Diesel
Euro Std	Euro 5
Control devices	DPF,EGR
Model year	2015
Test age	1
Vehicle model	Transporter
GVW	3.1 ton
Engine displacement	2 litre
Engine rated power	138bhp@ 3500rpm
Engine peak torque	340Nm@1750 -2500rpm
Odometer reading	52 miles
Wt. before install.	2.3 ton
Wt. After Install.	2.8 ton

VW Amarok: NOx



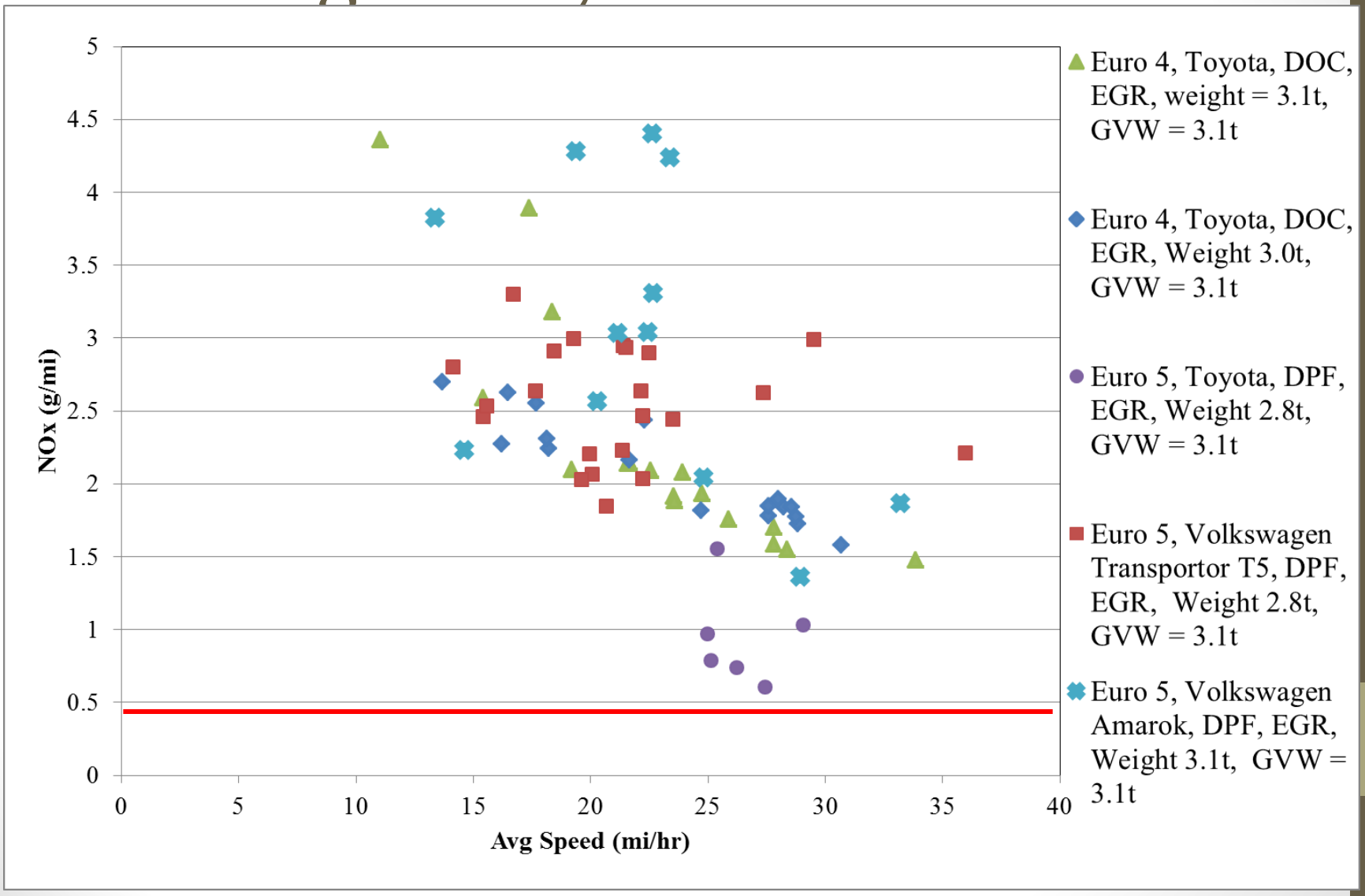
Invalid result: Drift correction > 4% for NO2 (based on CFR1065.650)

Dyno testing complies with Euro 5 certification requirements and with cold start.

All PEMS testing are hot running.

Fuel Type	Diesel
Euro Std	Euro 5
Control devices	DPF,EGR
Model year	2014
Test age	1
Vehicle model	Amarok 2.0 TDI
GVW	3.1 ton
Engine displacement	2 litre
Engine rated power	177 bhp @ 4000 RPM
Engine peak torque	420 Nm @ 1750 RPM
Odometer reading	537 miles
Wt. before install.	2.4 ton
Wt. After Install.	3.1 ton

Comparison of VW Trucks with Other Light Duty Diesel Trucks



Conclusion & Way Forward

- The NOx and PM emissions from the Euro VI hybrid double deck buses are similar to the Euro VI HHDT
- The CO2 emissions of hybrid Euro VI double deck buses are similar to diesel Euro V buses, but higher than the Euro VI HHDT
- For high loading of air conditioning occurred often in HK summer, the CO2 emissions of hybrid double deck buses are higher than diesel Euro V buses
- Spikes appear in NOx emissions from hybrid double deck buses in urban area because the engines will switch off often. Hence, exhaust temp. will be dropped rapidly and SCR may not fully function

Conclusion & Way Forward

- Tested two Euro 5 VW light duty diesel trucks. The emissions are comparable to Euro 4 vehicles of the same class. The emissions are higher in PEMS testing than on dyno.
- Will conduct on-board testing using PEMS on diesel Euro VI double deck buses for comparison this summer.
- Will conduct PEMS and dyno testing on Euro 6 VW Caddy

Thank you.