



L'Observatoire de l'air en Île-de-France

Real Driving Emission Campaign for the Paris Public Transport

Adrian Arfire, PhD, Metrology Engineer | 23-01-2018

1 | Airparif



Monitoring, explaining and informing

► According to the French air Act (1996), air pollution is monitored :

- by **independent regional organizations**
- gathering **the stakeholders in their administration board**
1/4 State – 1/4 local authorities – 1/4 industries – 1/4 experts and NGOs
(environmental and consumer protection)

► **Airparif is:**

- **An independent expert**
- The observatory of Air Pollution in the Paris region (Ile-de-France):
- Set up in **1979**
- **Accredited** by the French Ministry in charge of the Environment



ASSESSING and HELPING the authorities with their mitigation plans

- Before their implementation
- Impact assessment afterwards
- Supporting dialogue with the stakeholders

UNDERSTANDING and ANALYSING

- Air pollution phenomena
- Links with climate change
- People exposure

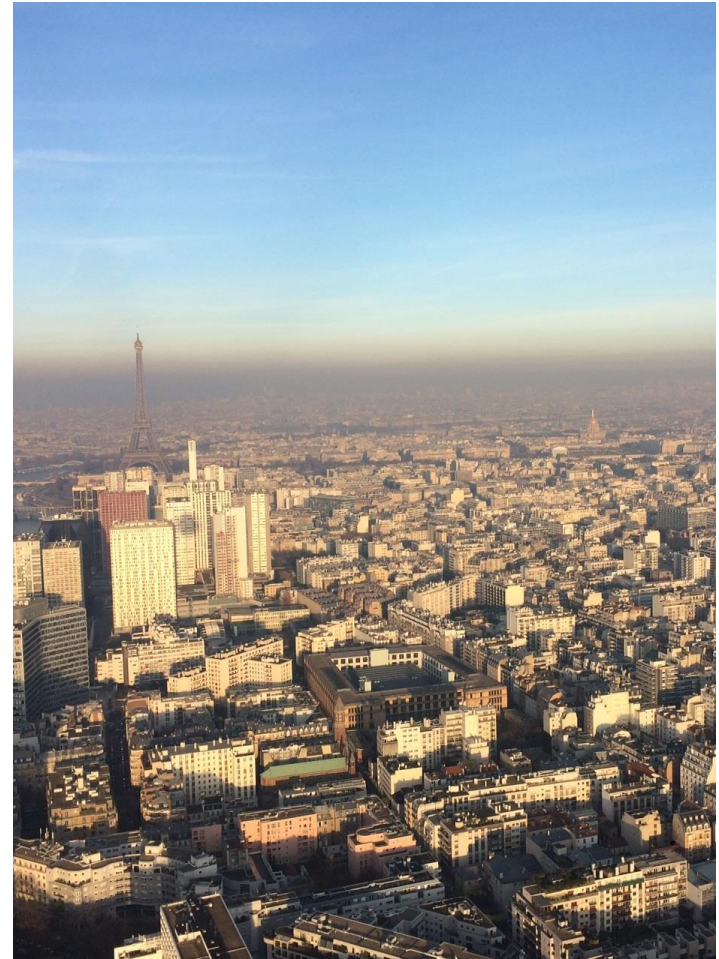
MONITORING air pollution

FORECASTING and DISPLAYING

- Daily air pollution levels
- Pollution episodes

INFORMING

- Citizens, medias
- Authorities and decision makers



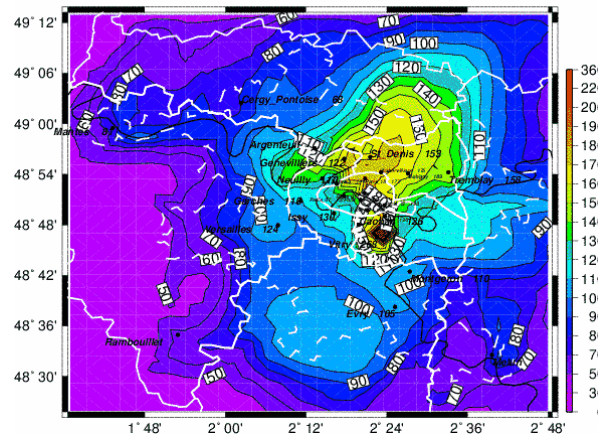
Credit : Generali Balloon

A combined use of 3 complementary monitoring tools

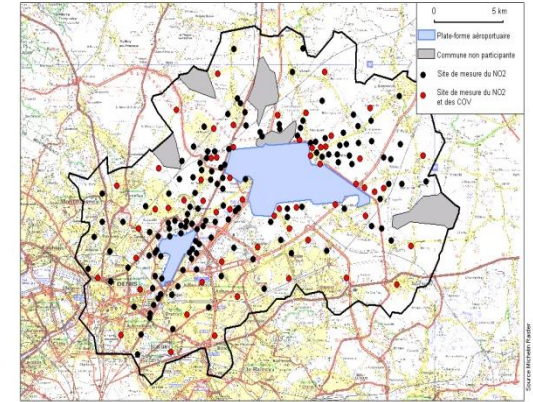


Fixed monitoring stations

Concentration max (assimilee) en NO2 le 10/02/2004

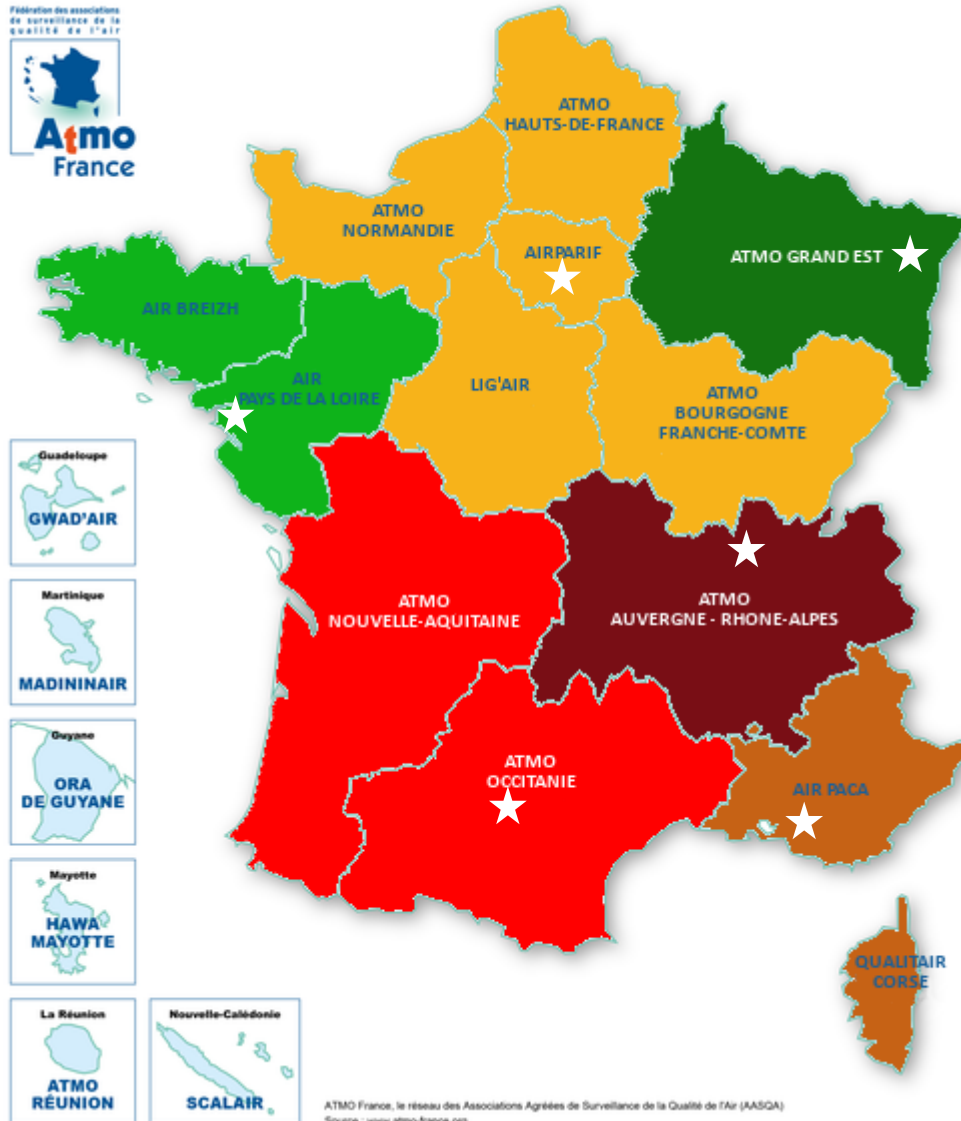


Modeling tools
Emission inventories



Monitoring campaign





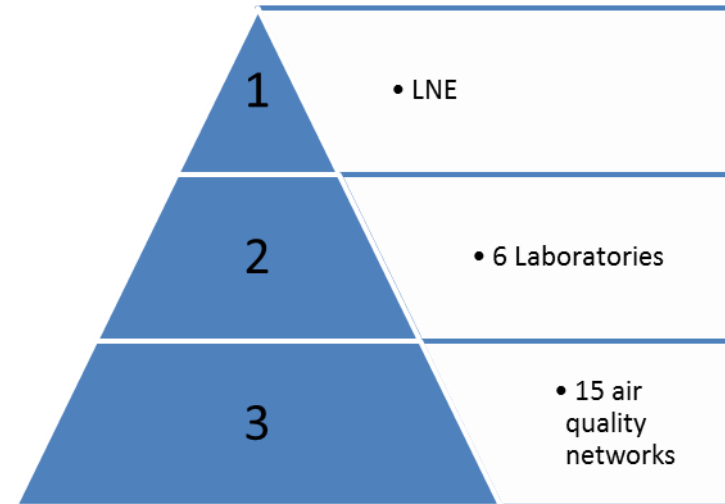
ATMO France, le réseau des Associations Agréées de Surveillance de la Qualité de l'Air (AASQA)
 Source : www.atmo-france.org

Metrology lab



Credit : JB Gurliat

Ministry of the Environment



2 | Real Driving Emission Campaign



EU Emission Standards for Heavy-Duty Diesel Engines: Steady-State Testing

Stage	Date	Test	CO	HC	NOx	PM	PN	Smoke	
			g/kWh				1/kWh	1/m	
Euro I	1992, ≤ 85 kW	ECE R-49	4.5	1.1	8.0	0.612			
	1992, > 85 kW		4.5	1.1	8.0	0.36			
Euro II	1996.10		4.0	1.1	7.0	0.25			
	1998.10		4.0	1.1	7.0	0.15			
Euro III	1999.10 EEV only		ESC & ELR	1.5	0.25	2.0	0.02		0.15
	2000.10			2.1	0.66	5.0	0.10 ^a		0.8
Euro IV	2005.10	1.5		0.46	3.5	0.02		0.5	
Euro V	2008.10	1.5		0.46	2.0	0.02		0.5	
Euro VI	2013.01	WHSC	1.5	0.13	0.40	0.01	8.0×10 ¹¹		

a - PM = 0.13 g/kWh for engines < 0.75 dm³ swept volume per cylinder and a rated power speed > 3000 min⁻¹

EU Emission Standards for Heavy-Duty Diesel and Gas Engines: Transient Testing

Stage	Date	Test	CO	NMHC	CH ₄ ^a	NOx	PM ^b	PN ^e
			g/kWh				1/kWh	
Euro III	1999.10 EEV only	ETC	3.0	0.40	0.65	2.0	0.02	
	2000.10		5.45	0.78	1.6	5.0	0.16 ^c	
Euro IV	2005.10		4.0	0.55	1.1	3.5	0.03	
Euro V	2008.10		4.0	0.55	1.1	2.0	0.03	
Euro VI	2013.01	WHTC	4.0	0.16 ^d	0.5	0.46	0.01	6.0×10 ¹¹

a - for gas engines only (Euro III-V: NG only; Euro VI: NG + LPG)

b - not applicable for gas fueled engines at the Euro III-IV stages

c - PM = 0.21 g/kWh for engines < 0.75 dm³ swept volume per cylinder and a rated power speed > 3000 min⁻¹

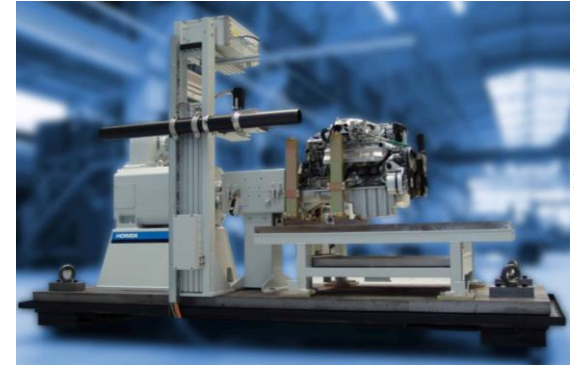
d - THC for diesel engines

e - for diesel engines; PN limit for positive ignition engines TBD

- ▶ Engine test stands
 - Typical for heavy-duty vehicle engines

- ▶ Chassis dynamometer
 - Rare for heavy-duty vehicles

- ▶ Portable Emission Measurement System (PEMS)
 - Rapidly increasing in popularity
 - Conformity tests for heavy-duty vehicles since 2007 in U.S. and since 2009 in Europe (on Euro V and Euro IV vehicles)



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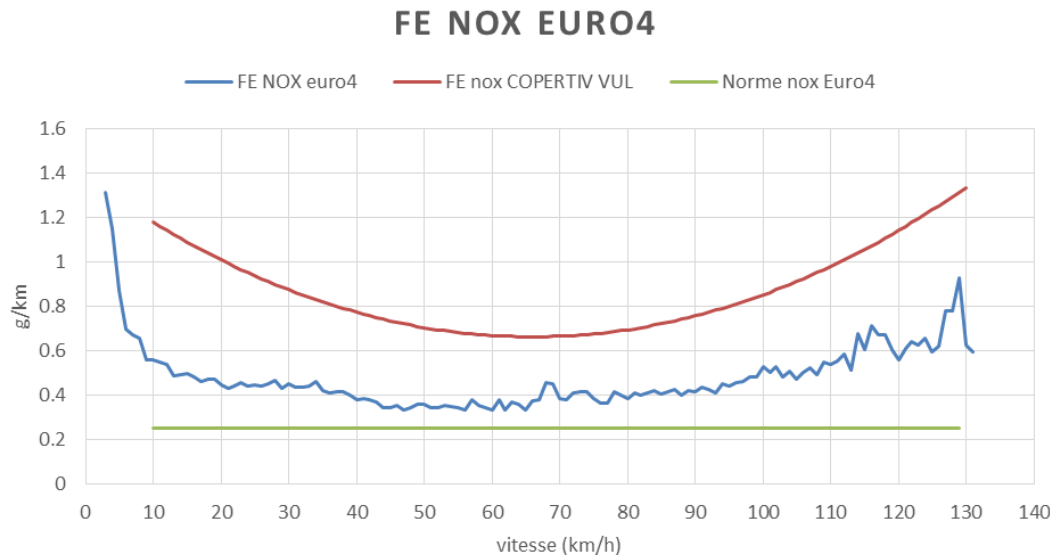
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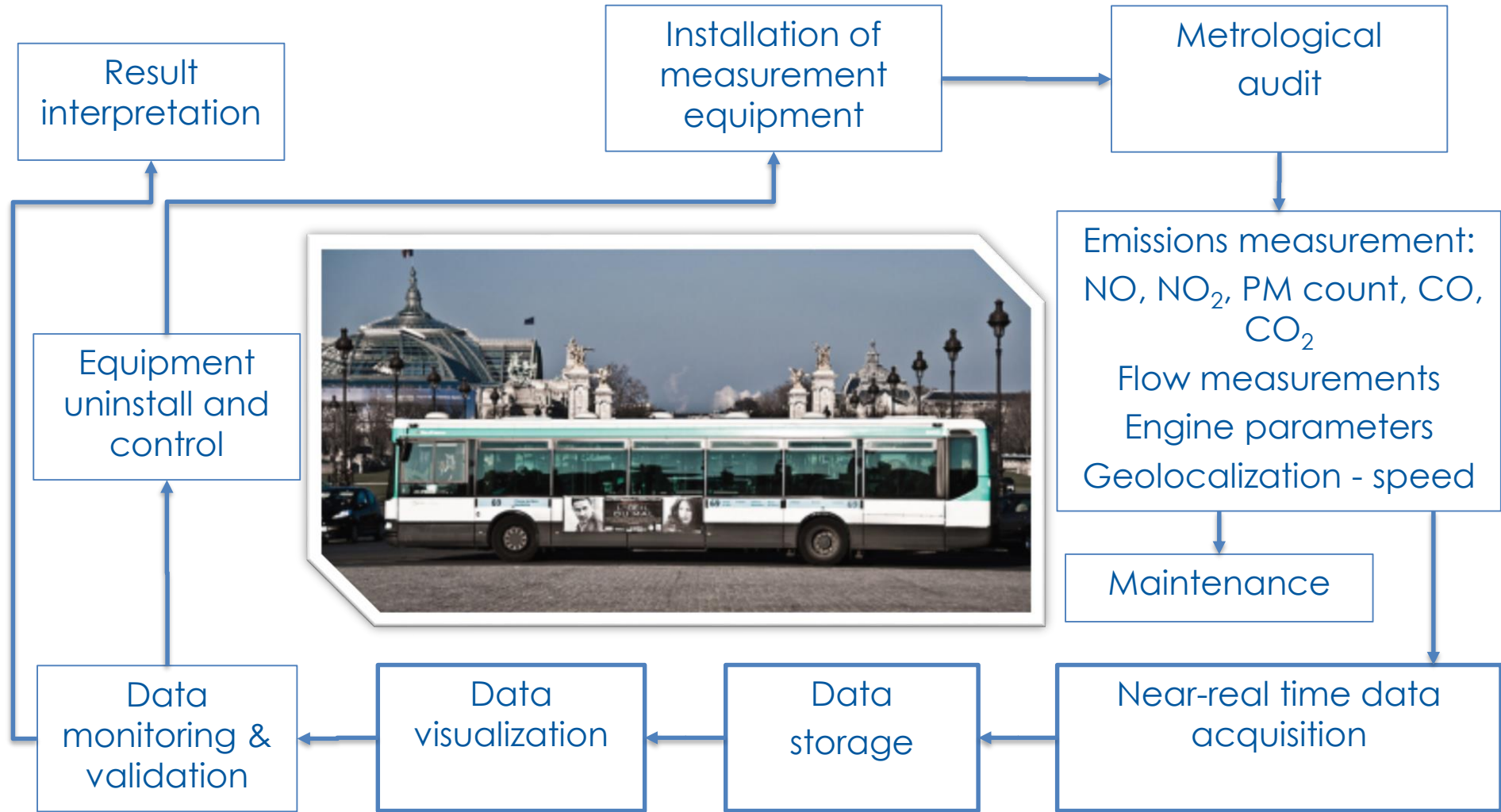
Objectives :

- Comparison of emissions in real-world conditions for “Euro 4”, “Euro 6”, and “Hybrid Euro 6” buses;
- Comparison with emission models currently used at the European level;



- Determine the influence factors according to different parameters, such as traffic conditions or season.

- ▶ Large-scale & long-term
 - ▶ During normal bus operation
 - ▶ 11 types of buses from 3 different operators in the Parisian region
 - ▶ For each type of bus, 2 different buses will be equipped
 - ▶ 2 to 3 buses in parallel, during **2 weeks of acquisition**
 - ▶ Seasonal campaigns (summer/winter)
- **In total: 26 acquisition rounds**



3 | Equipment & Vehicle Deployment



► **Collaboration with Austrian manufacturer AVL**

AVL M.O.V.E. Gas-PEMS iS

- NO/NO₂ – non dispersive ultra violet analyzer
- CO/CO₂ – non dispersive infrared analyzer
- O₂ – electrochemical sensor



AVL M.O.V.E. PN-PEMS

- PN – advanced diffusion charger sensor coupled with volatile particle remover

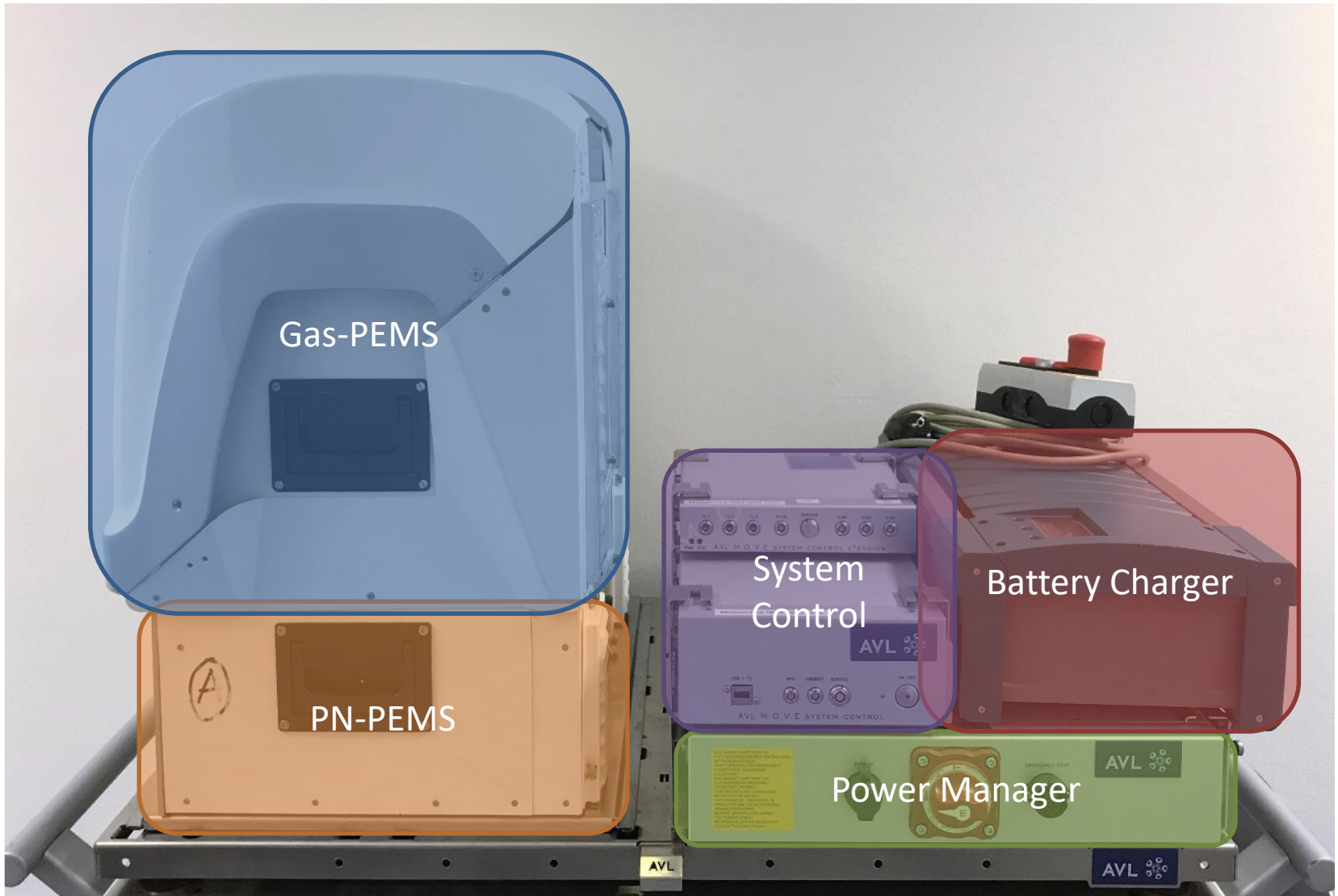
AVL M.O.V.E. Exhaust Flow Meter

- Robust Pitot probe flow measurement



Additional sensors

- Ambient parameters (temperature, relative humidity, pressure)
- GPS localization



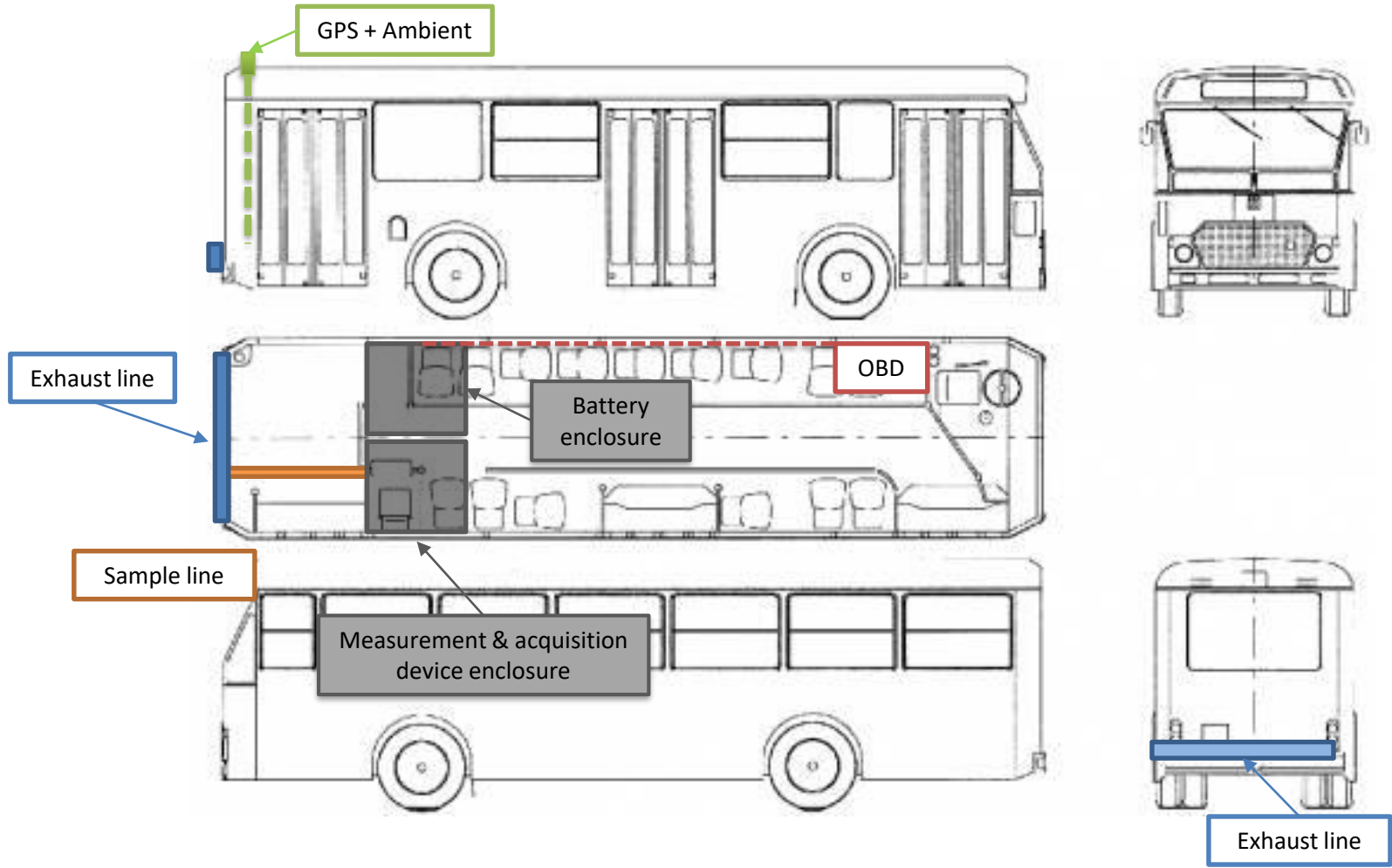
Autonomy

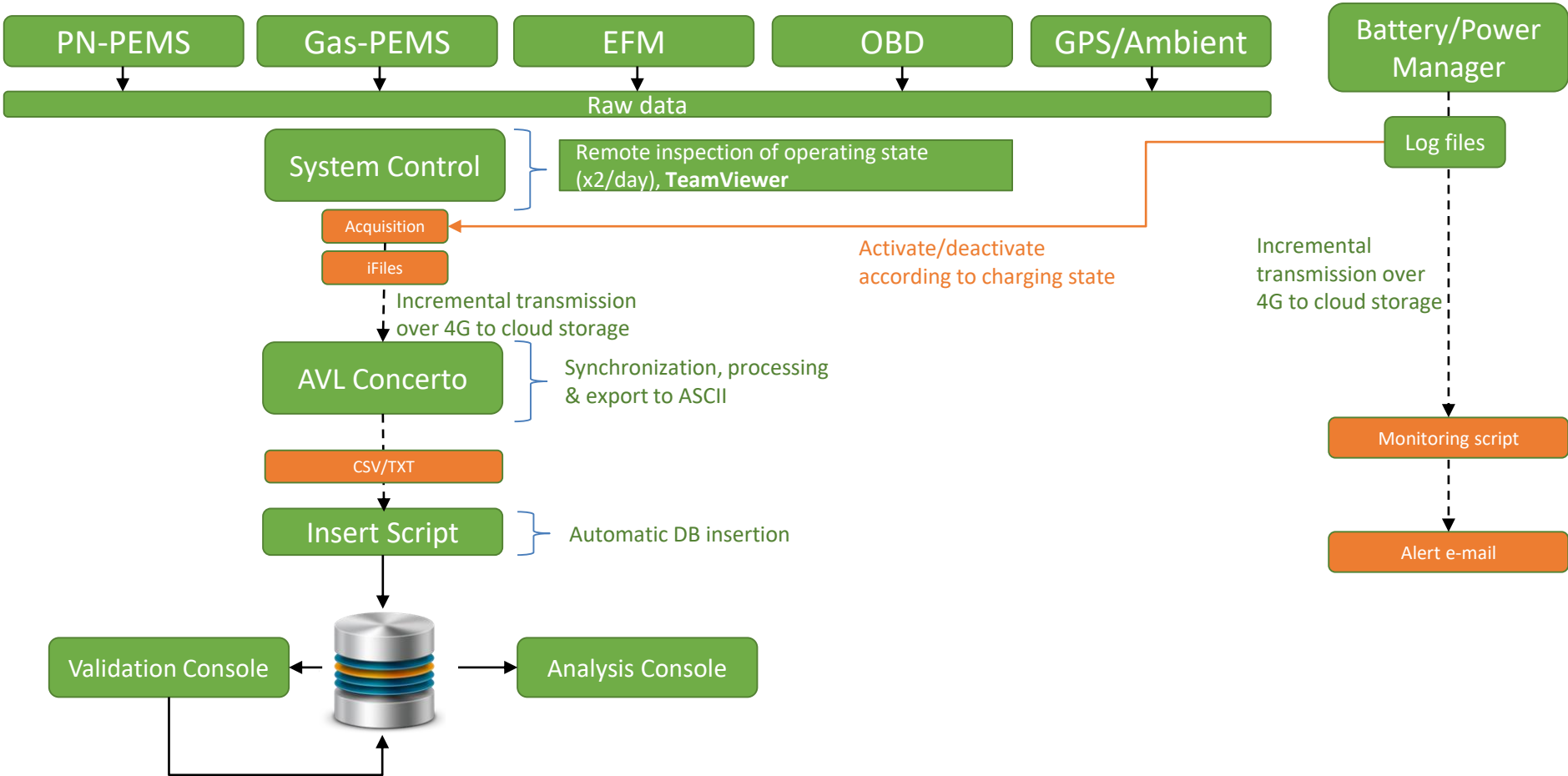
- 8 hours acquisition & transmission
- 8x absorbent glass mat batteries (~40 kg / piece)



Communication

- 4G data link for measurement data transfer and remote device inspection





4 | Data Analysis



	Exhaust temperature	Engine load	Driving style	Slope	Aging
Euro IV					
Euro VI					
Hybrid Euro VI					

	Exhaust temperature	Engine load	Driving style	Slope	Aging
Euro IV	2 nd order				
Euro VI	1 st order				
Hybrid Euro VI	1 st order				

Exhaust temperature

- plays a critical role on the activation of the Selective Catalytic Reduction (SCR) system
- No SCR on Euro IV

	Exhaust temperature	Engine load	Driving style	Slope	Aging
Euro IV	2 nd order	1 st order			
Euro VI	1 st order	1 st order			
Hybrid Euro VI	1 st order	1 st order			

Engine load

- Should increase emissions for Euro IV
- Should be compensated by faster activation of SCRs and Diesel Particulate Filters (DFPs) on Euro VI

	Exhaust temperature	Engine load	Driving style	Slope	Aging
Euro IV	2 nd order	1 st order	2 nd order		
Euro VI	1 st order	1 st order	2 nd order		
Hybrid Euro VI	1 st order	1 st order	2 nd order		

Driving style

- Aggressive driving could have a negative affect on emission control systems
- Previous UK study showed negligible effect

Ricardo, 2017, Real World Emissions and Control: Use of PEMS on Heavy Duty Vehicles to Assess the Impact of Technology and Driving Conditions on Air Quality in Urban Areas, IAPSC 2017 Conference proceedings, Telford, www.iapsc.org.uk/assets/document/0517_J_Andersson2017.pdf

	Exhaust temperature	Engine load	Driving style	Slope	Aging
Euro IV	2 nd order	1 st order	2 nd order	2 nd order	
Euro VI	1 st order	1 st order	2 nd order	2 nd order	
Hybrid Euro VI	1 st order	1 st order	2 nd order	1 st order	

Slope

- Same UK study [Ricardo, 2017] showed sensibility particularly for hybrid vehicles
- Engine of hybrid vehicles usually off during descent → engine cool down?

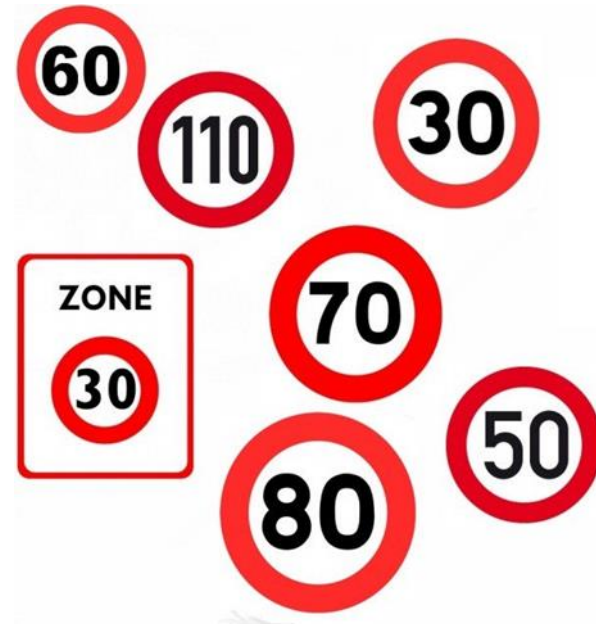
	Exhaust temperature	Engine load	Driving style	Slope	Aging
Euro IV	2 nd order	1 st order	2 nd order	2 nd order	2 nd order
Euro VI	1 st order	1 st order	2 nd order	2 nd order	2 nd order
Hybrid Euro VI	1 st order	1 st order	2 nd order	1 st order	2 nd order

Aging

- A 2016 Dutch study showed no clear relationship

TNO, 2016, Netherlands In-Service Emissions Testing Programme For Trucks And Buses, https://www.tno.nl/media/8585/06_tno_vonk_1130-1200_in-service_emissions_testing_programme_for_trucks_and_buses.pdf

- Ambient temperature at cold start
- Average speed
- Traffic conditions
- Type of infrastructure (e.g. bus lane, speed limits)





L'Observatoire au service de la Santé
et de l'Action

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