

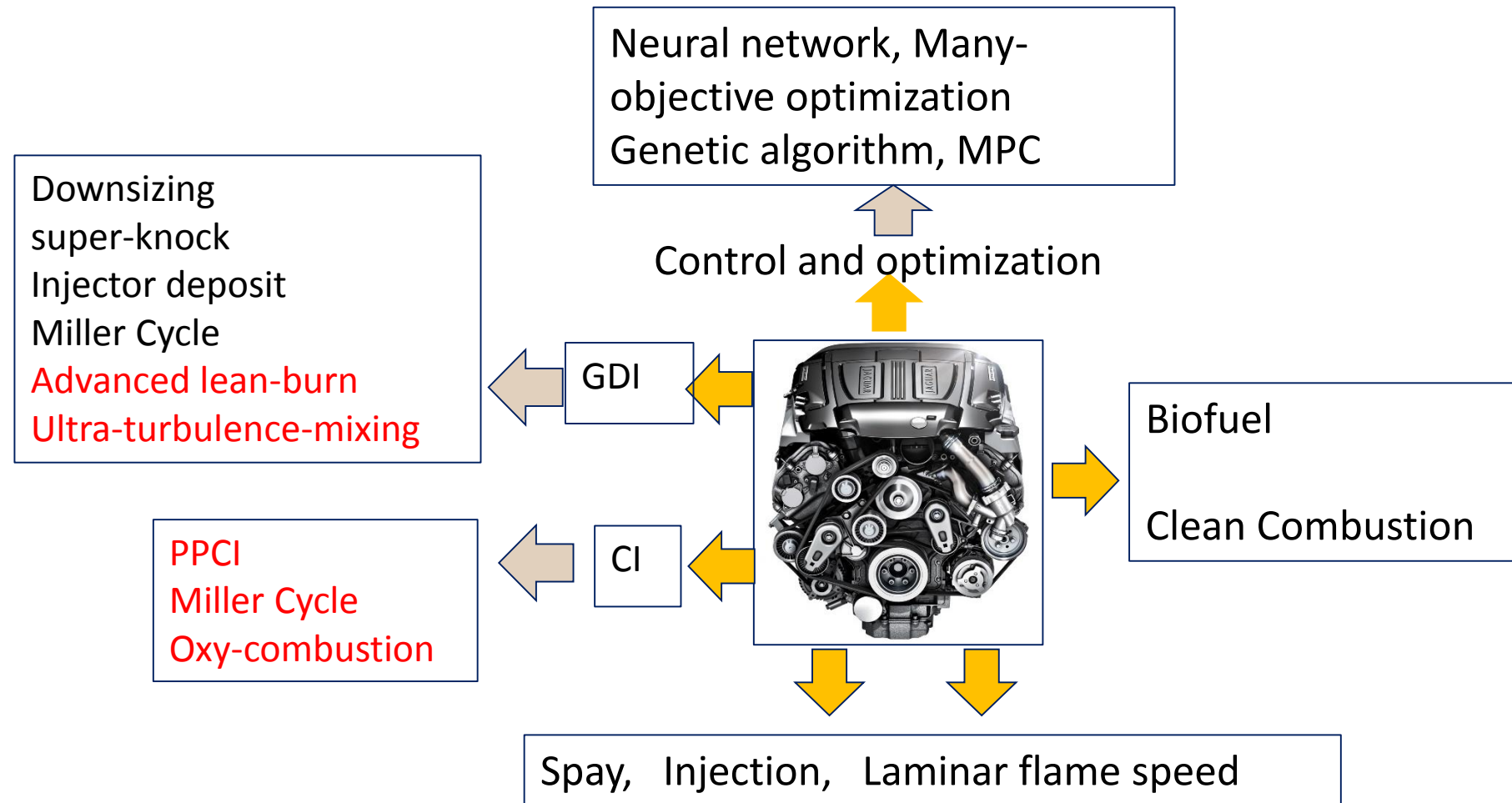
Minimization of diesel emissions via hybridization and advanced exhaust after-treatment system



2018-present : Coventry University ; C-ALPS; Lecturer

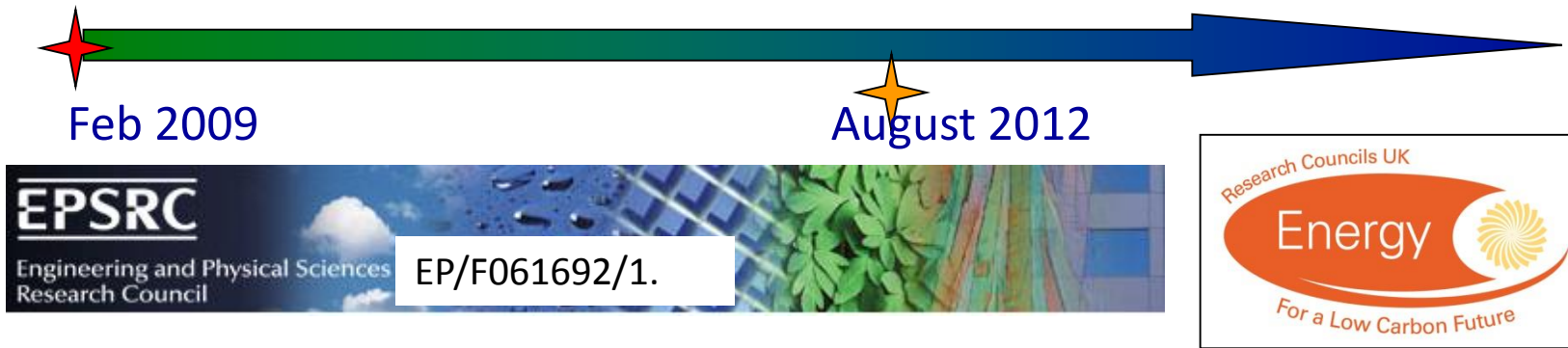
2015-2017 : Shell Global Solutions (DE) ; Marie Curie Fellow; GLT, bioethanol, octane booster

2010-2014 : University of Birmingham; Mechanical Engineering ; PhD; 2, 5-dimethylfuran





Impact of 2, 5-dimethylfuran on Engine Performance and Emissions as New Generation of Sustainable Bio-fuels



To study the characteristics of combustion and emissions of newly proposed generation of Bio-fuels for gasoline (SI) engines with bench-marking to gasoline and ethanol, involving modelling and experimental study of fuel spray, direct injection mixture preparation, and combustion and emissions (regulated and unregulated).



Centre for Advanced Low-Carbon Propulsion Systems Research Topics

Hybridisation

Development of virtual vehicle powertrain platform
Hybrid system optimization (EM, eBooster, ESA, e-CAT)
Safety of electrified powertrains
Development of validation methods for electrified powertrains

ICE related

Dedicated high efficiency ICEs for HEV
Alternative and synthetic fuels
Exhaust After-treatment concepts

Hydrogen

Hydrogen fuel cells
Air path and function development for hydrogen fuel cells

Collaboration with FEV

C-ALPS engine test lab

- Four transient powertrain test cells
- Full emission analysis capability
- FEV IS 3.0 fast data acquisition
- Battery emulator up to 60 kW
- FEV Morphee 24/7 full automation



C-ALPS and FEV collaboration

- Mutual fund for the C-ALPS engine test building
- Access to industry standard calibrated GT-Power models
- Access to proprietary FEV Software - SimEx & Virtual Engine
- Access to facilities and knowledge from FEV and Aachen Uni.

China moves towards banning the internal combustion engine

Its government is developing a plan to phase out vehicles powered by fossil fuels

California Considers Following China With Combustion-Engine Car Ban

Charge: India in ambitious drive for all cars to be electric by 2030

🏠 > News

Diesel and petrol car ban: Plan for 2040 unravels as 10 new power stations needed to cope with electric revolution

Paris Wants to Ban the Combustion Engine by 2030

News > Business > Business News

German court to rule on whether cities can ban heavily polluting vehicles in pivotal moment for country's car makers

Dienstag, 27. Februar 2018, 12.00 Uhr

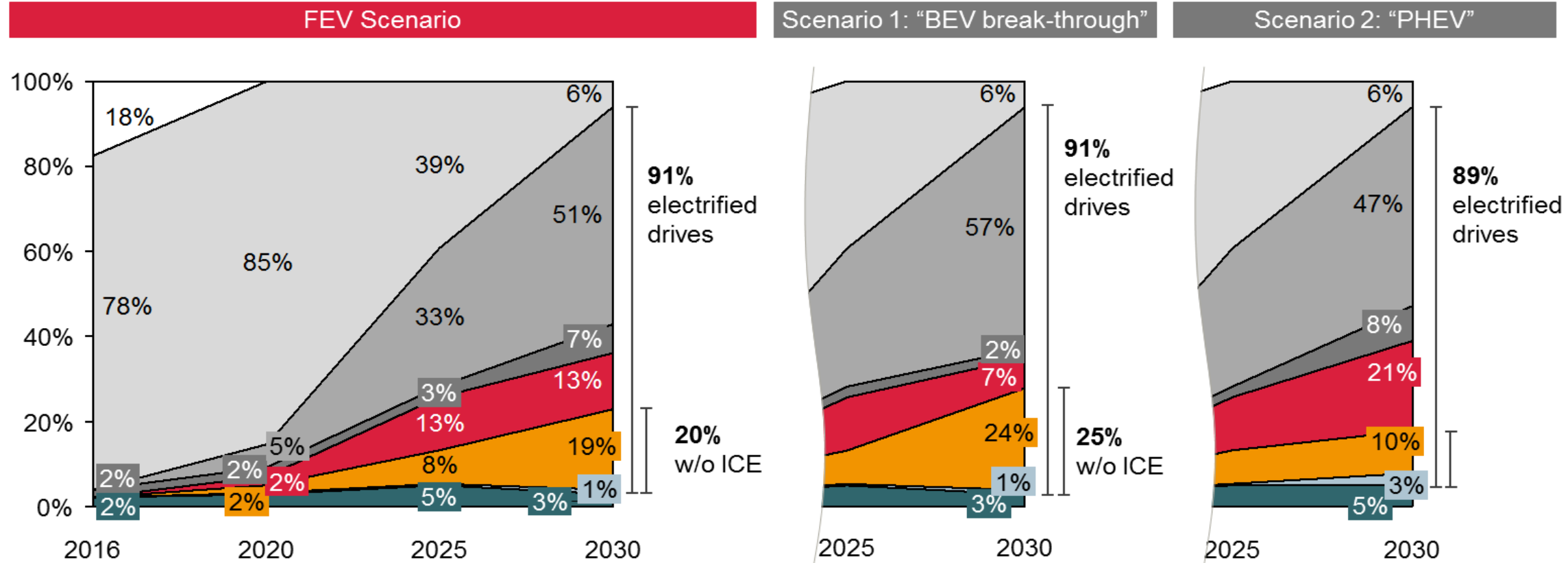
Leipziger Bundesverwaltungsgericht urteilt: Weg für Diesel-Fahrverbote ist frei

Four of world's biggest cities to ban diesel cars from their centres

News > London

Petrol and diesel cars set to be banned in parts of east London with £130 fines for motorists who flout rules

Passenger car in 2030 in Europe: FEV



CO₂ fleet emission:

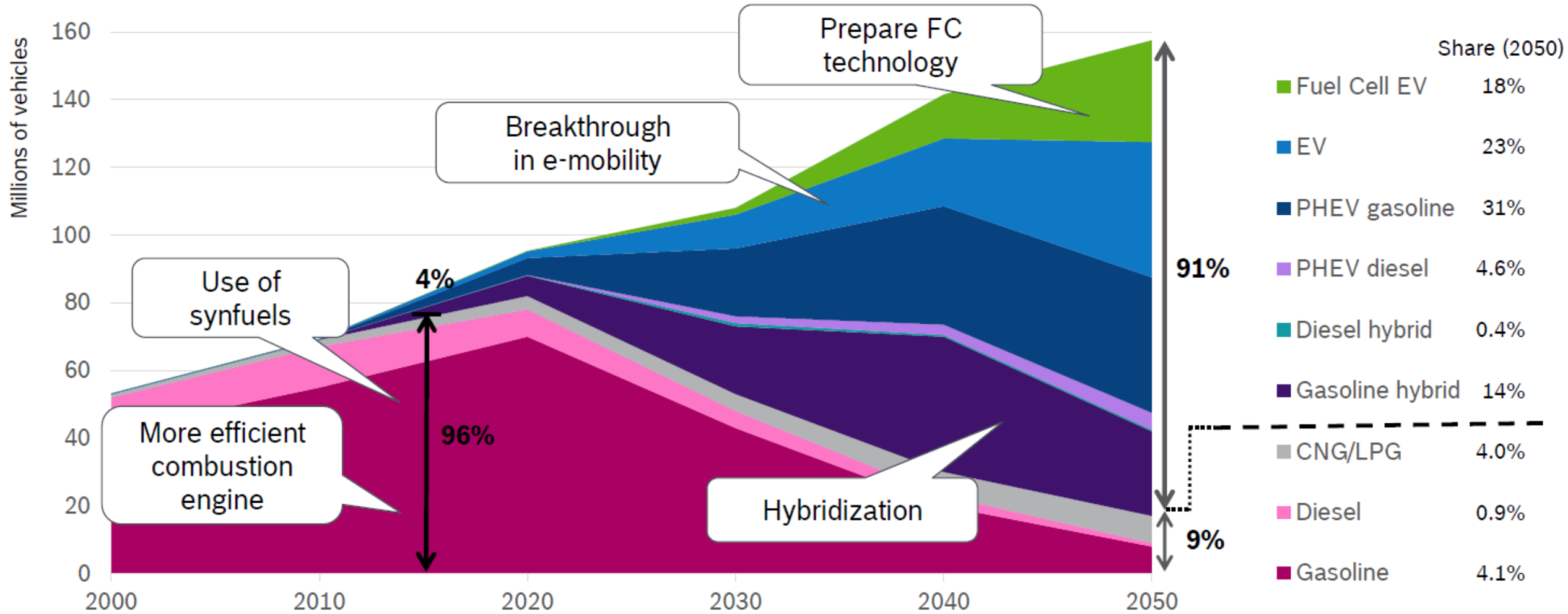
<95 g/km* <75 g/km* <65 g/km* <65 g/km* <65 g/km*

*: normalized to NEDC

Source: FEV  ICE only  Stop-Start & 12V Energy Mgmt  Mild Hybrid  Full Hybrid  Plug-In Hybrid  Battery Electric  Fuel Cell  Others

Until 2030, 69%-76% of passenger cars will be hybrid

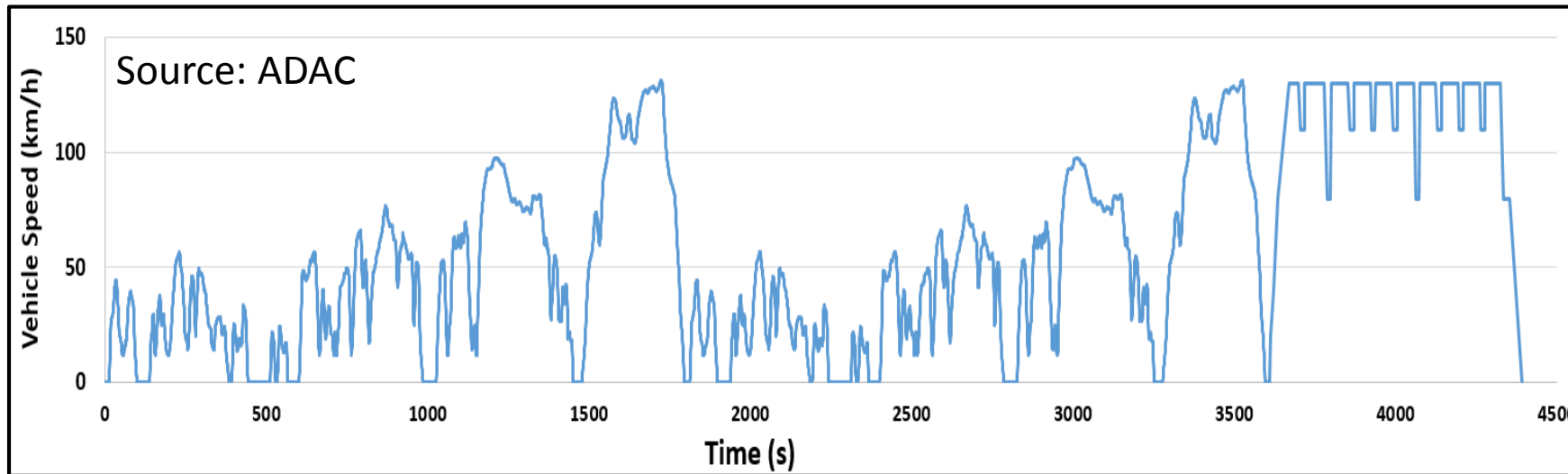
Global passenger cars in 2050: IEA



Until 2050, 49% of passenger cars will be hybrid

- Which emissions are issues faced by current CI/SI vehicles?
- 66+74 European cars were tested in ADAC EcoTest cycle for the assessment of their gaseous and particulate emissions.
- ADAC EcoTest cycle consists of one cold WTLC +warm WTLC + ADAC highway cycle.

Audi	Hyundai
BMW	Mazda
Mercedes	Renault
Ford	SEAT
VW	Skoda
Citroen	Nissan
Fiat	Opel
Jaguar	Peugeot
Land Rover	Subaru
Kia	Alfa Romeo

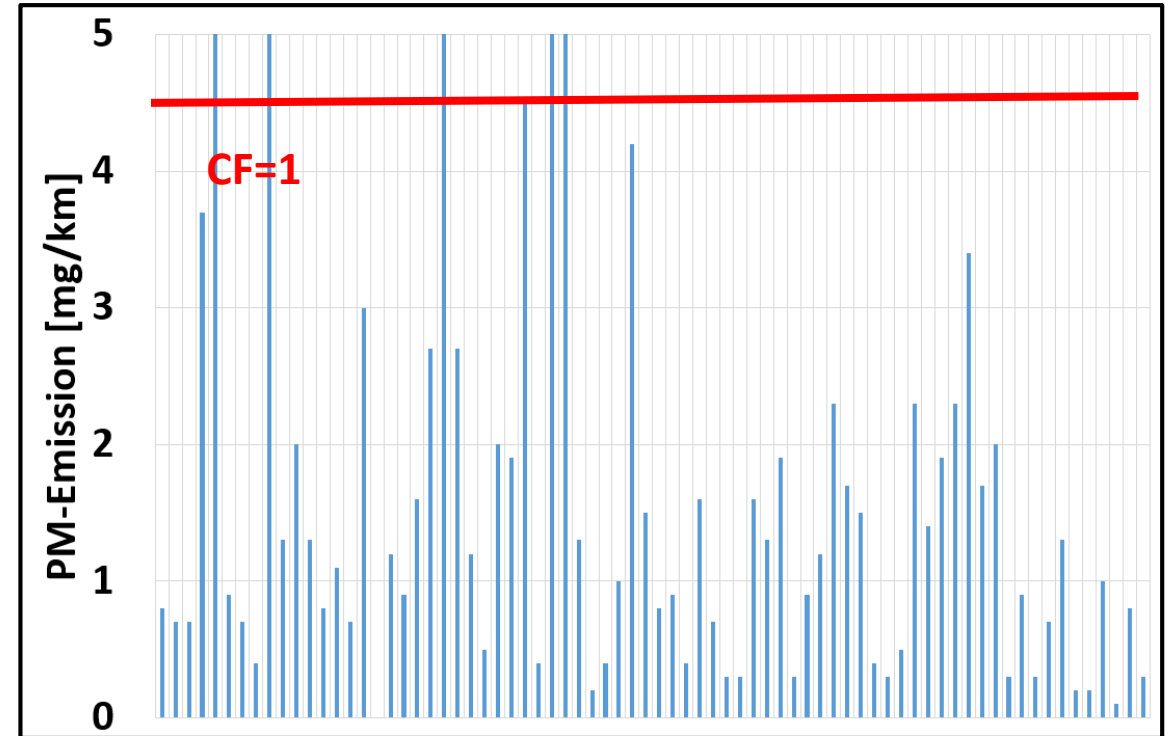
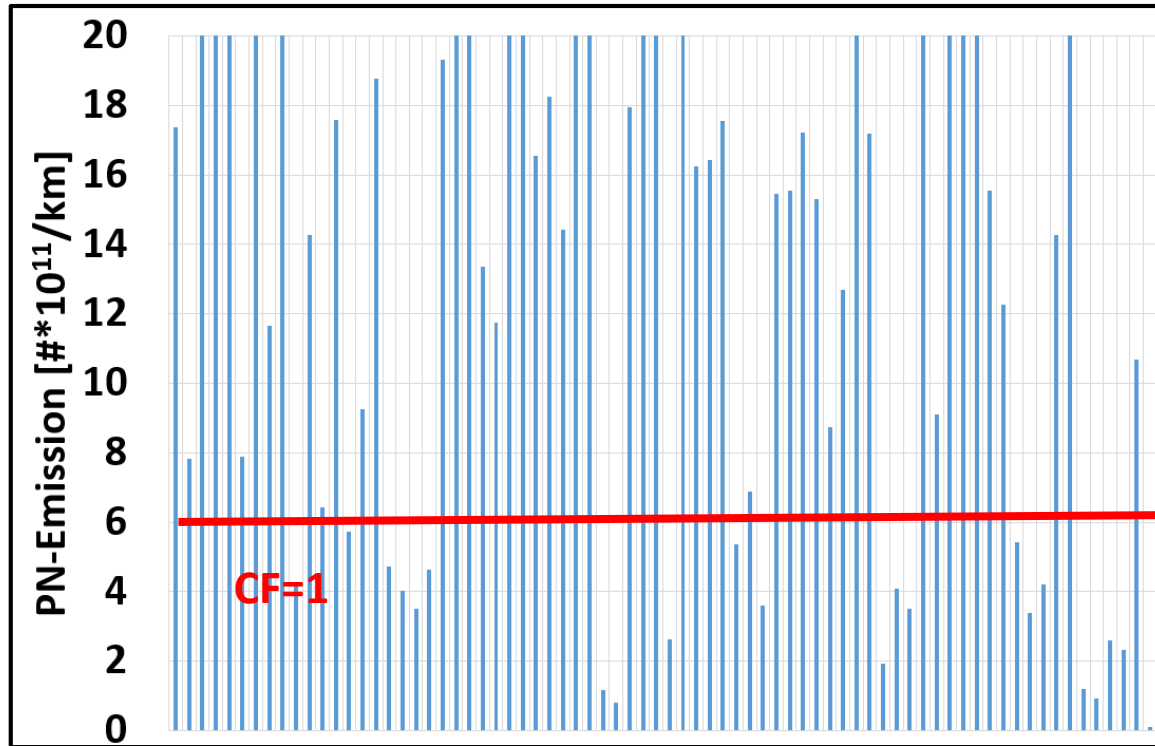


ADAC EcoTest cycle

Gasoline emission challenge

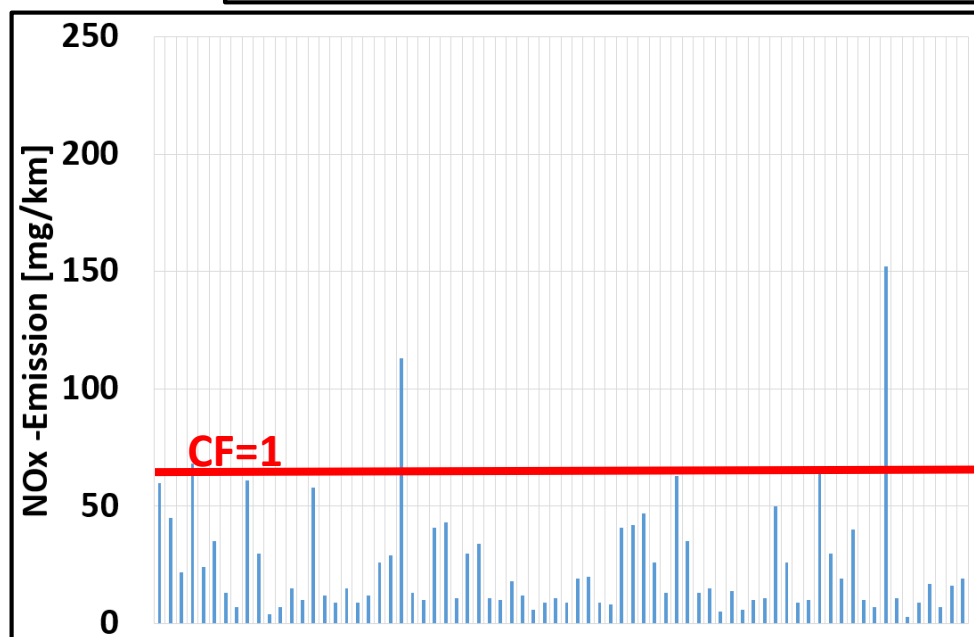
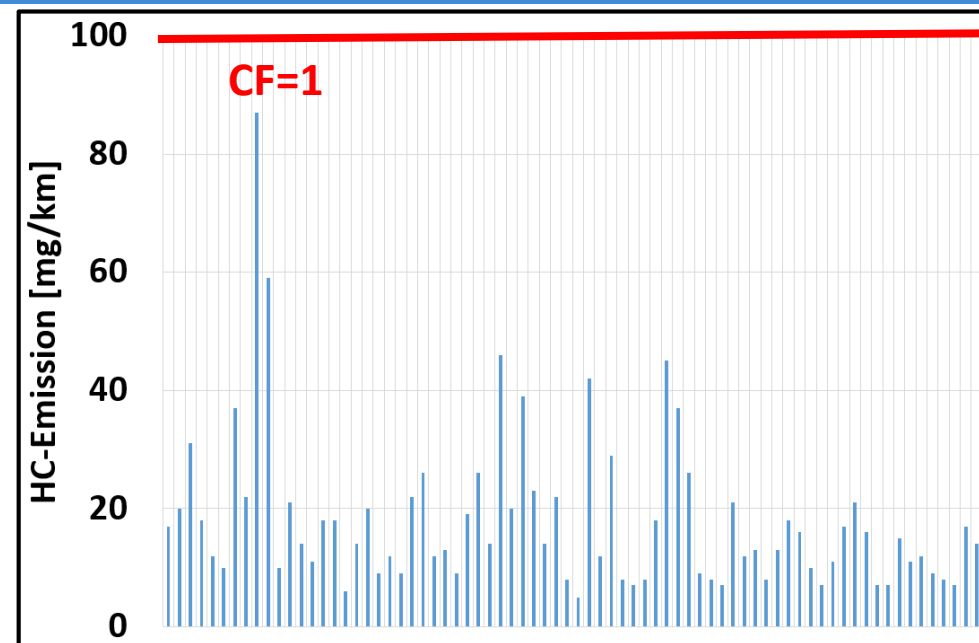
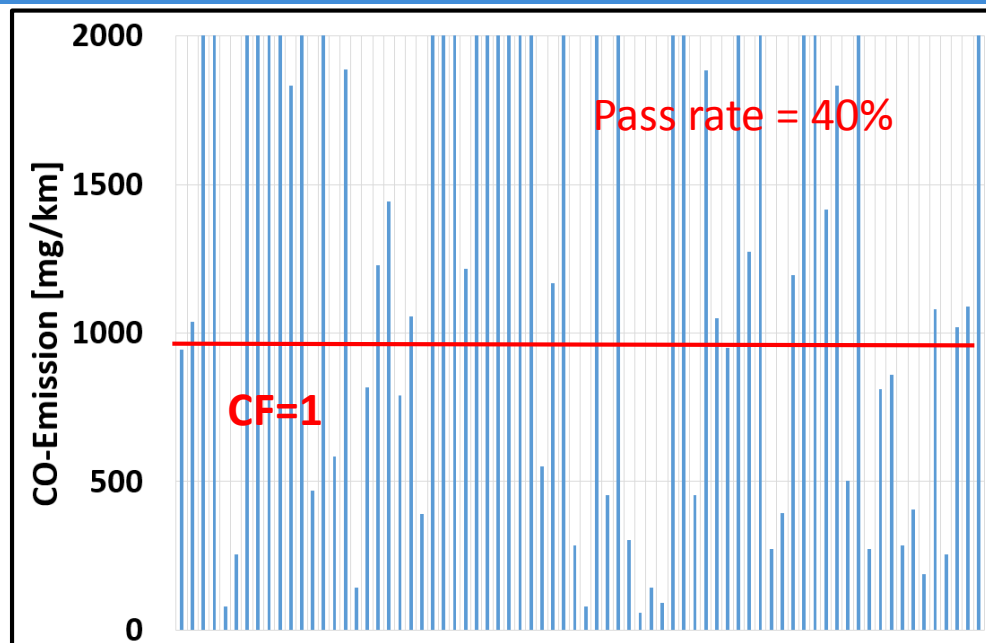
Euro 6d temp: CF=2.1

Euro 6d : CF=1.5



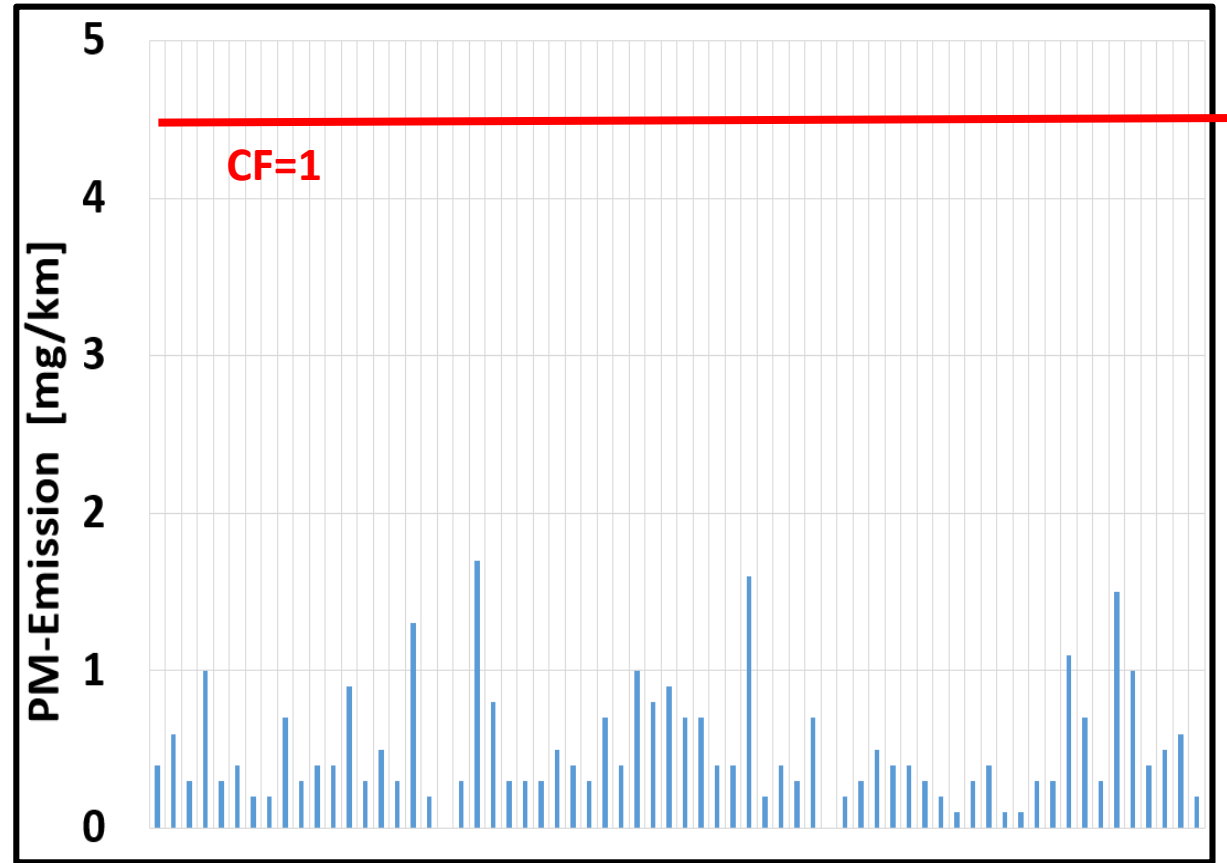
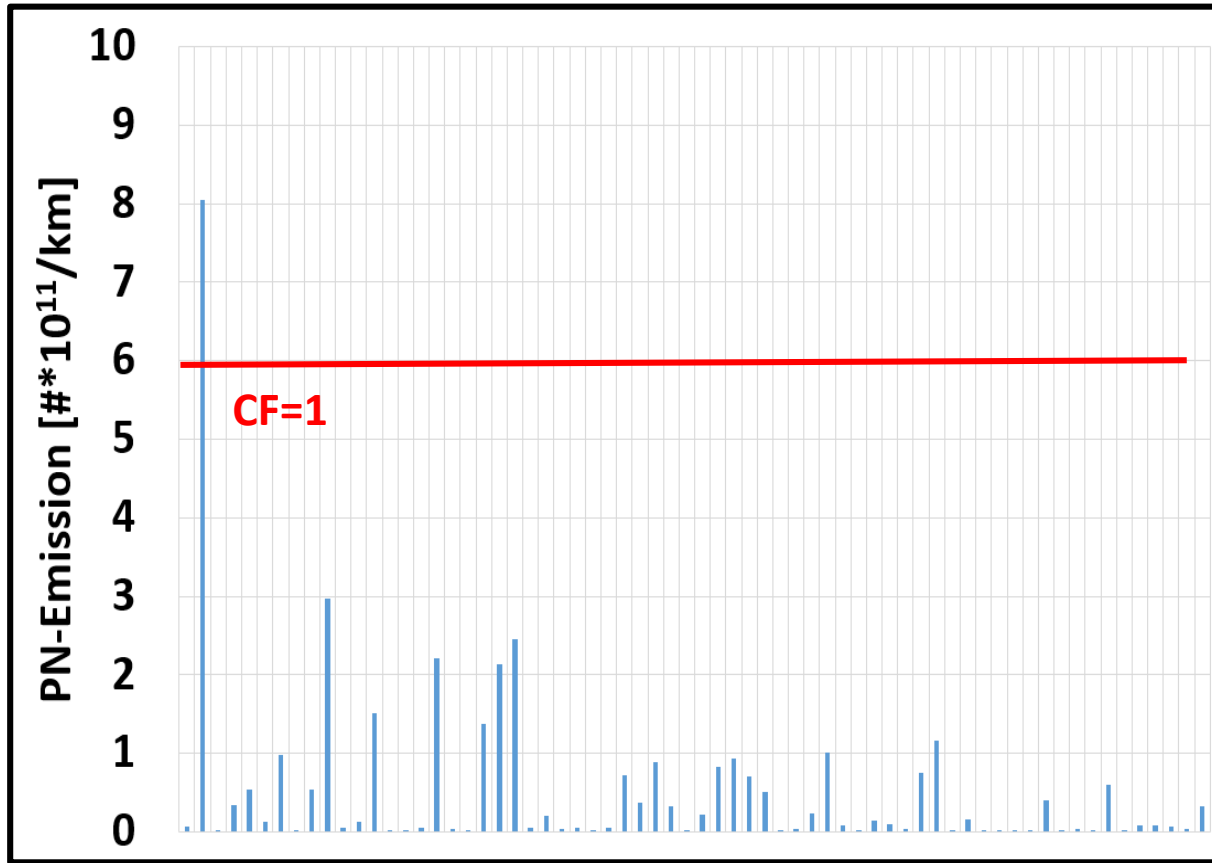
- 仅仅30%的被测量汽油车通过在ADAC EcoTest cycle中通过了PN测试.
- 几乎所有的被测量汽油车通过PM测试.
- 仅仅两辆车安装有GPF.

Gasoline emission challenge



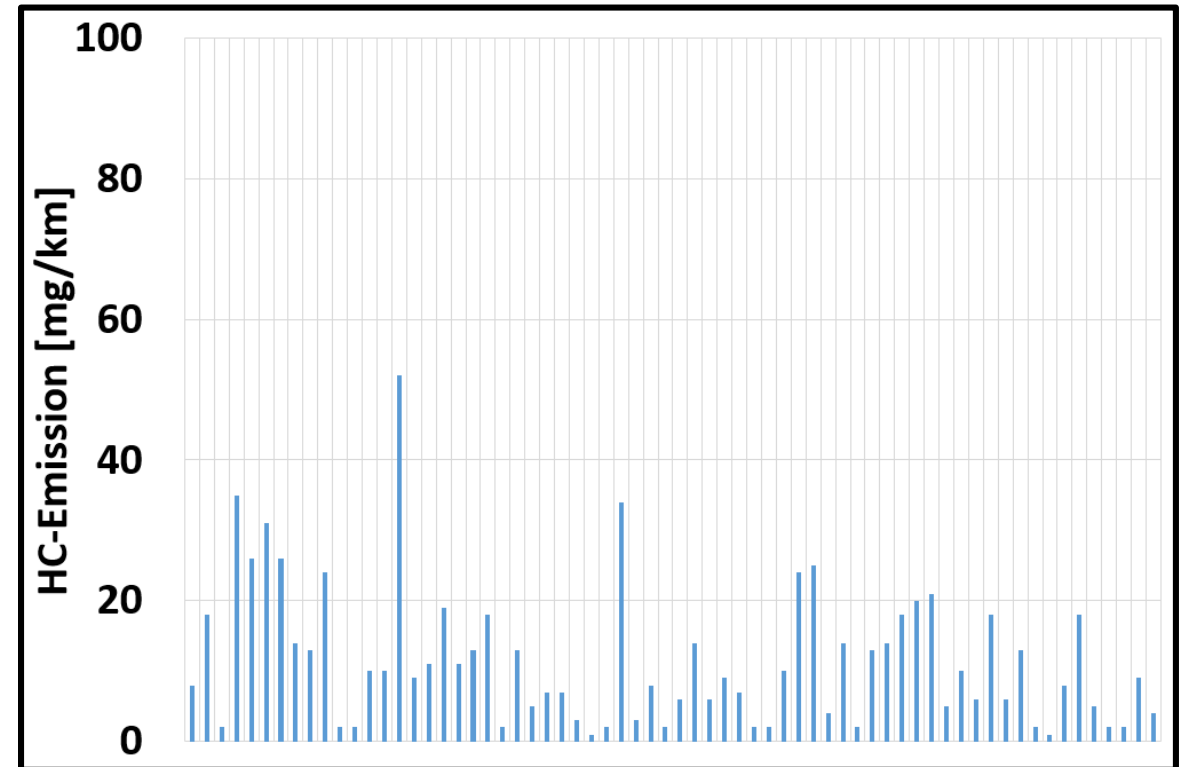
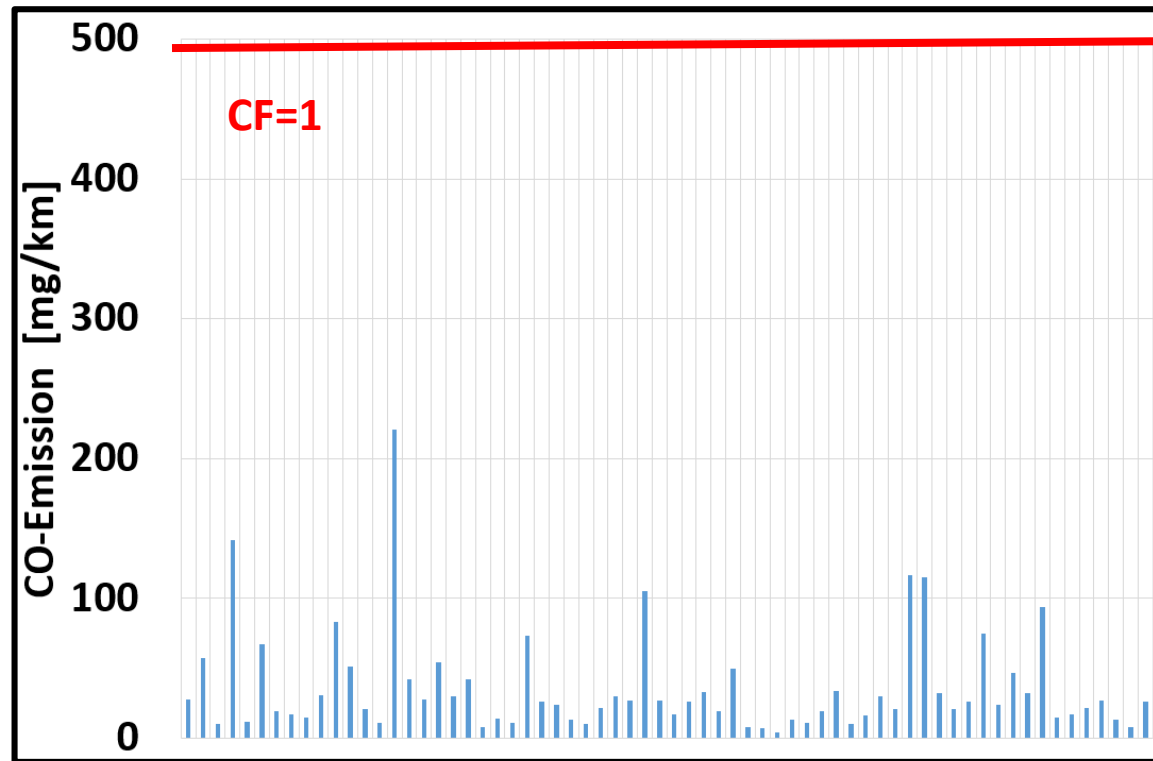
- 高CO排放与高升功率发动机的 $\lambda < 1$ 的高工况运行直接有关
- **NO_x和HC几乎100%通过**

Diesel emission challenge



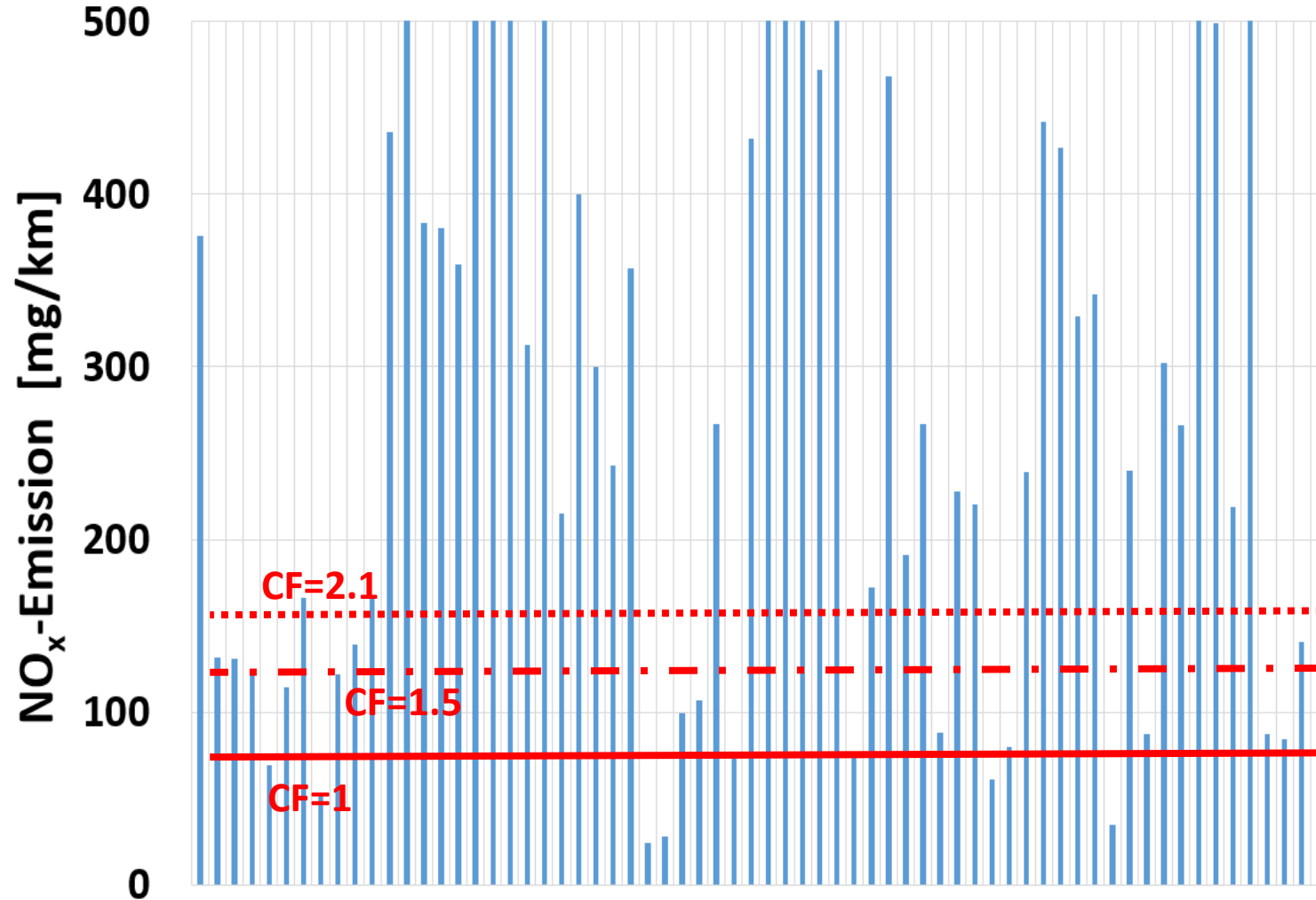
- **Almost 100% of the vehicles pass the PN and PM emissions regulation requirement.**
- **All the EU5 diesel vehicles are equipped with DPF.**

Diesel emission challenge



Tailpipe CO compliance at real world driving is not an issue for diesel passenger cars.

Diesel emission challenge



Pass rates:

12% @ CF=1

26% @ CF=1.5

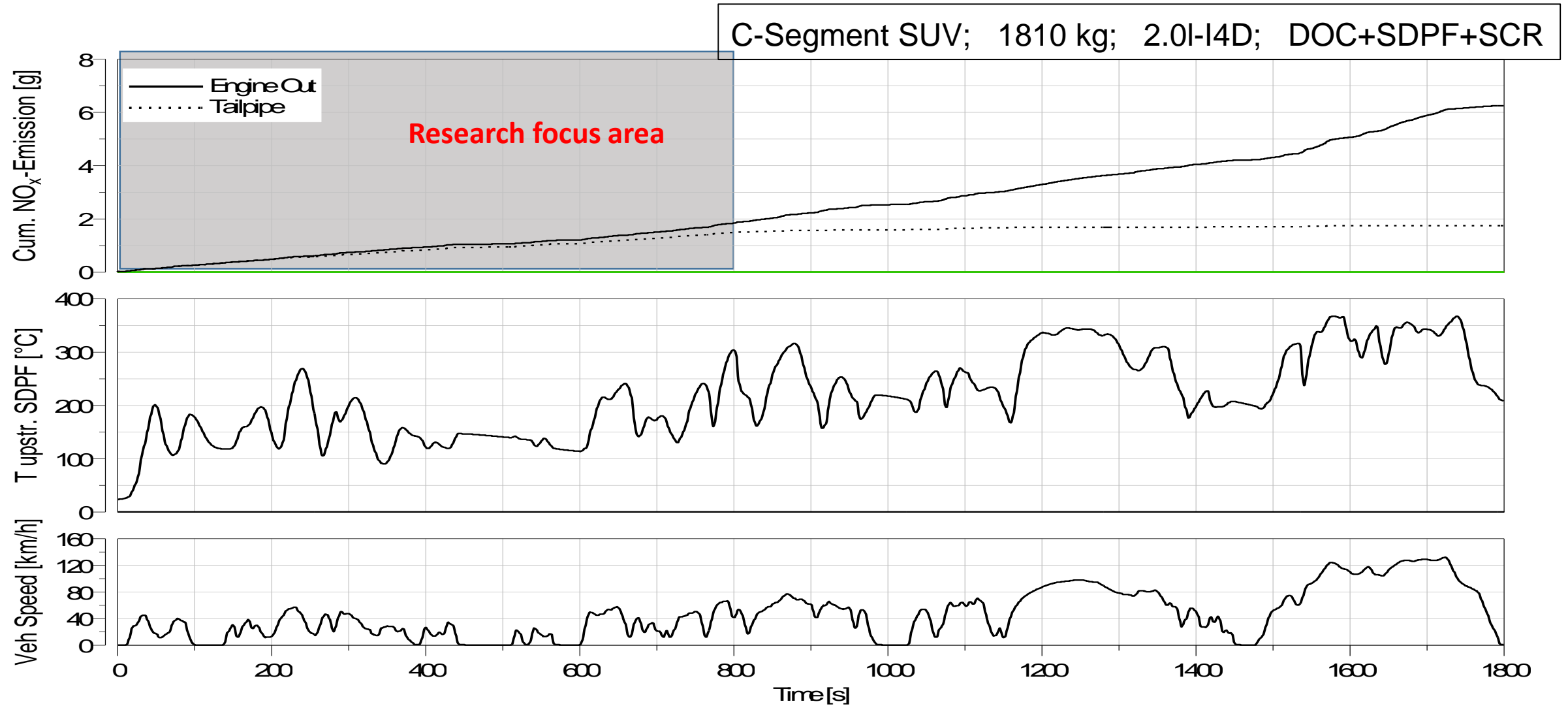
35% @ CF=2.1

Average NO_x emissions: 318 mg/km

Median NO_x emission: 240 mg/km

- **NO_x compliance at real world driving is a challenge for diesel passenger cars.**
- **In the future, diesel vehicles require both in- and out-cylinder NO_x treatment.**

Diesel emission challenge



Solutions for diesel NOx emission challenge

Engine Out Emissions



Advanced FIE
雾化



Hybridization



eBooster®

Thermal Management



VVT



Low Thermal
Inertia
components



Rapid Heating
modes



Turbine
By-Pass
减小尾气温度损失

Exhaust After-treatment



LNT+SCR
冷启动NOX



Two stage SCR
systems



Electrically
heated
catalysts

直接加热尾气

Solutions for diesel NOx emission challenge

Two examples:

1. Hybridization + advanced after-treatment system
2. Smart air path and electrically heated catalyst (eCAT)

Solutions for diesel NOx emission challenge

Engine Out Emissions



Advanced FIE
雾化



Hybridization
动力辅助



eBooster®
间接提高发动机尾气温度

Thermal Management



VVT



Low Thermal Inertia components



Rapid Heating modes



Turbine By-Pass
减小尾气温度损失

Exhaust After-treatment



LNT+SCR
冷启动NOx






Two stage SCR systems

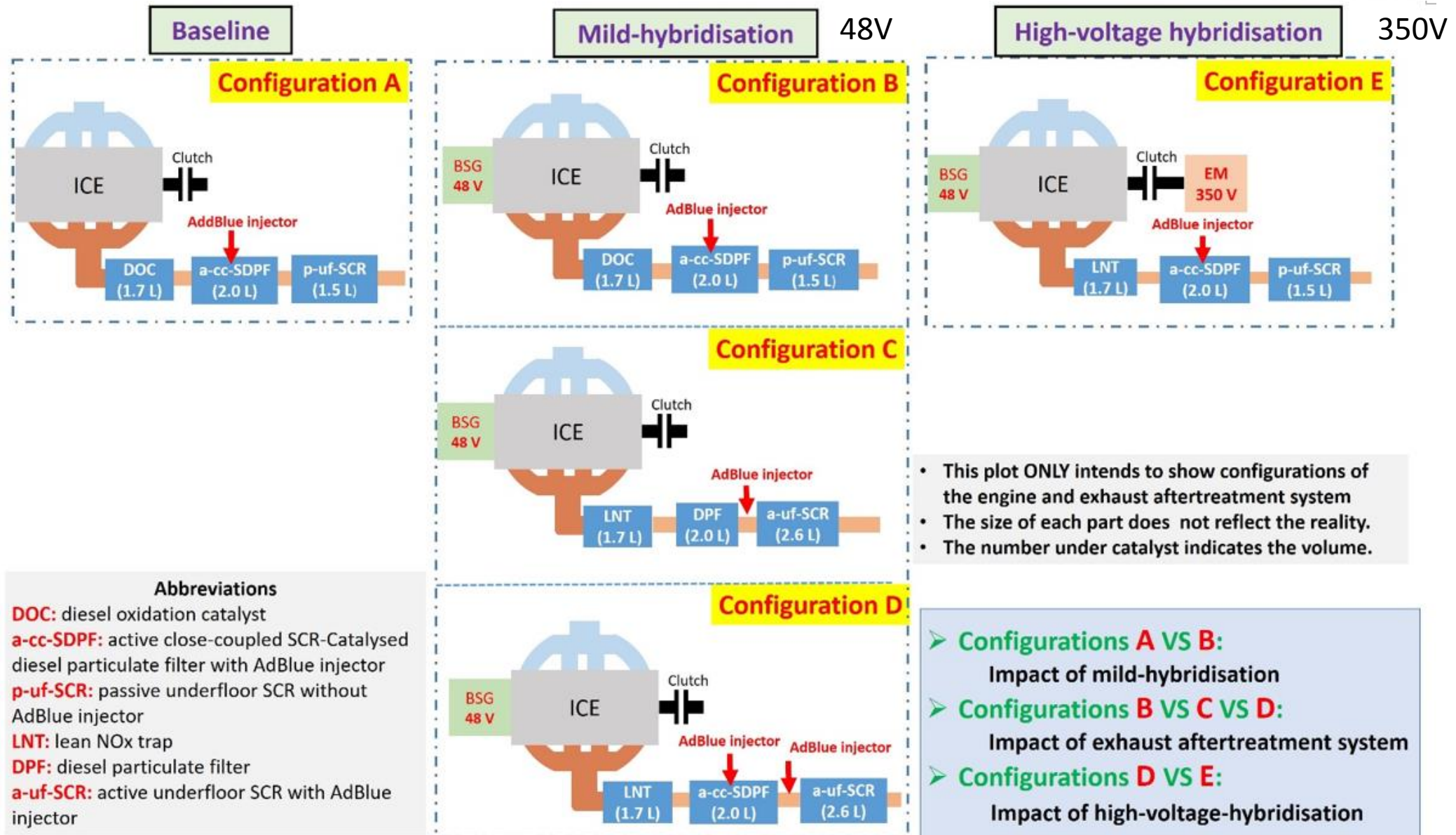


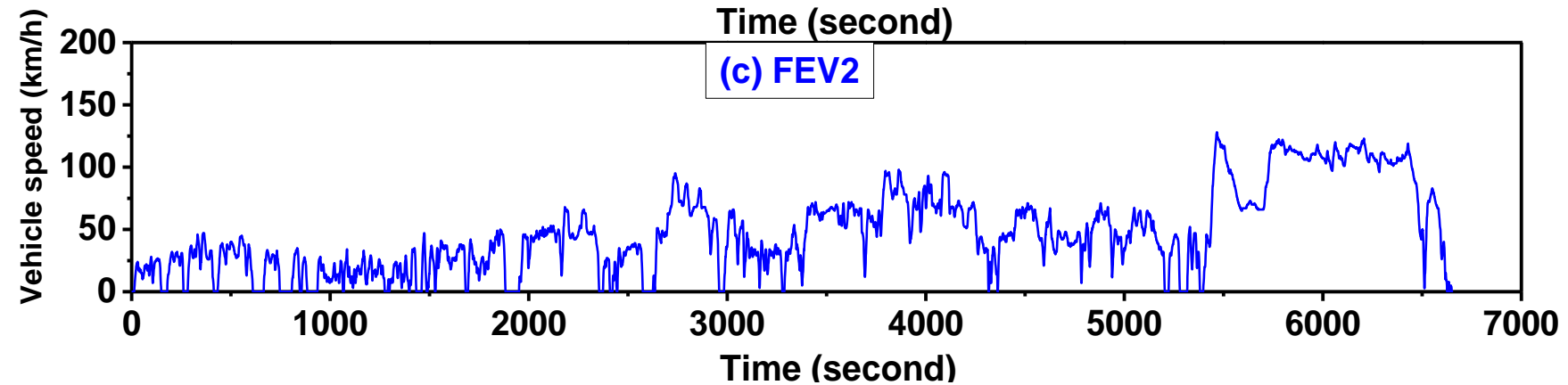
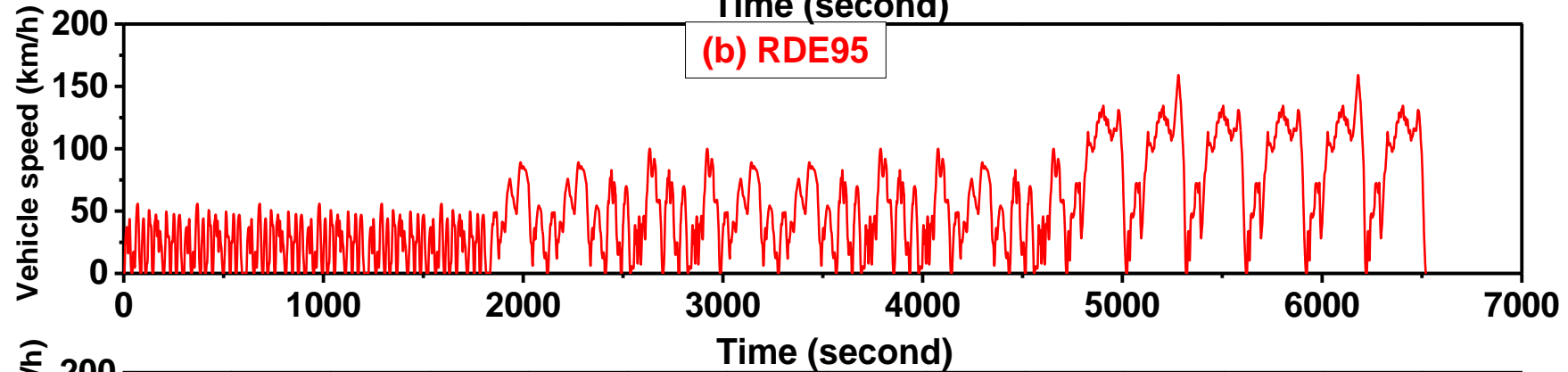
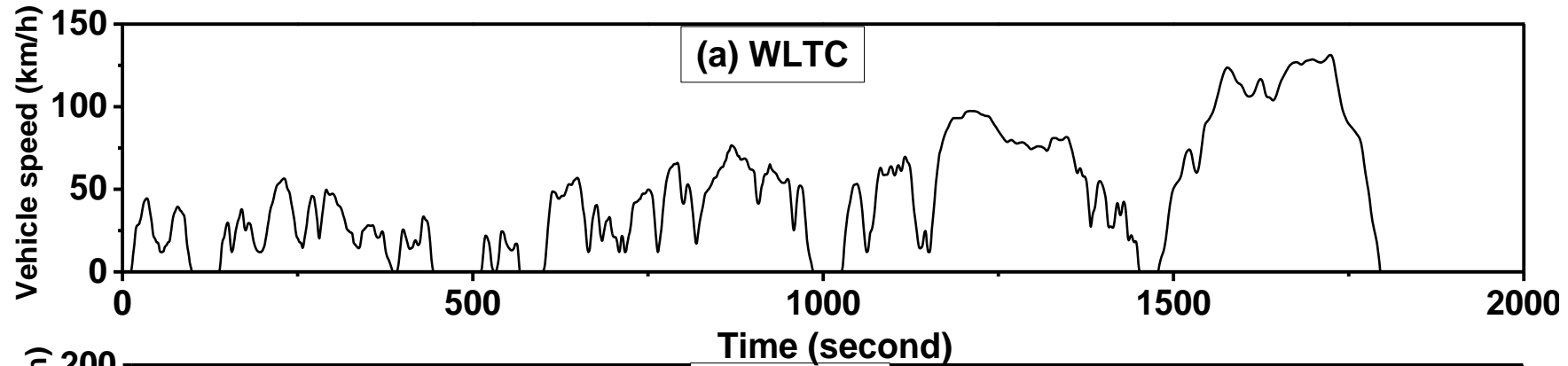
Electrically heated catalysts
直接加热尾气

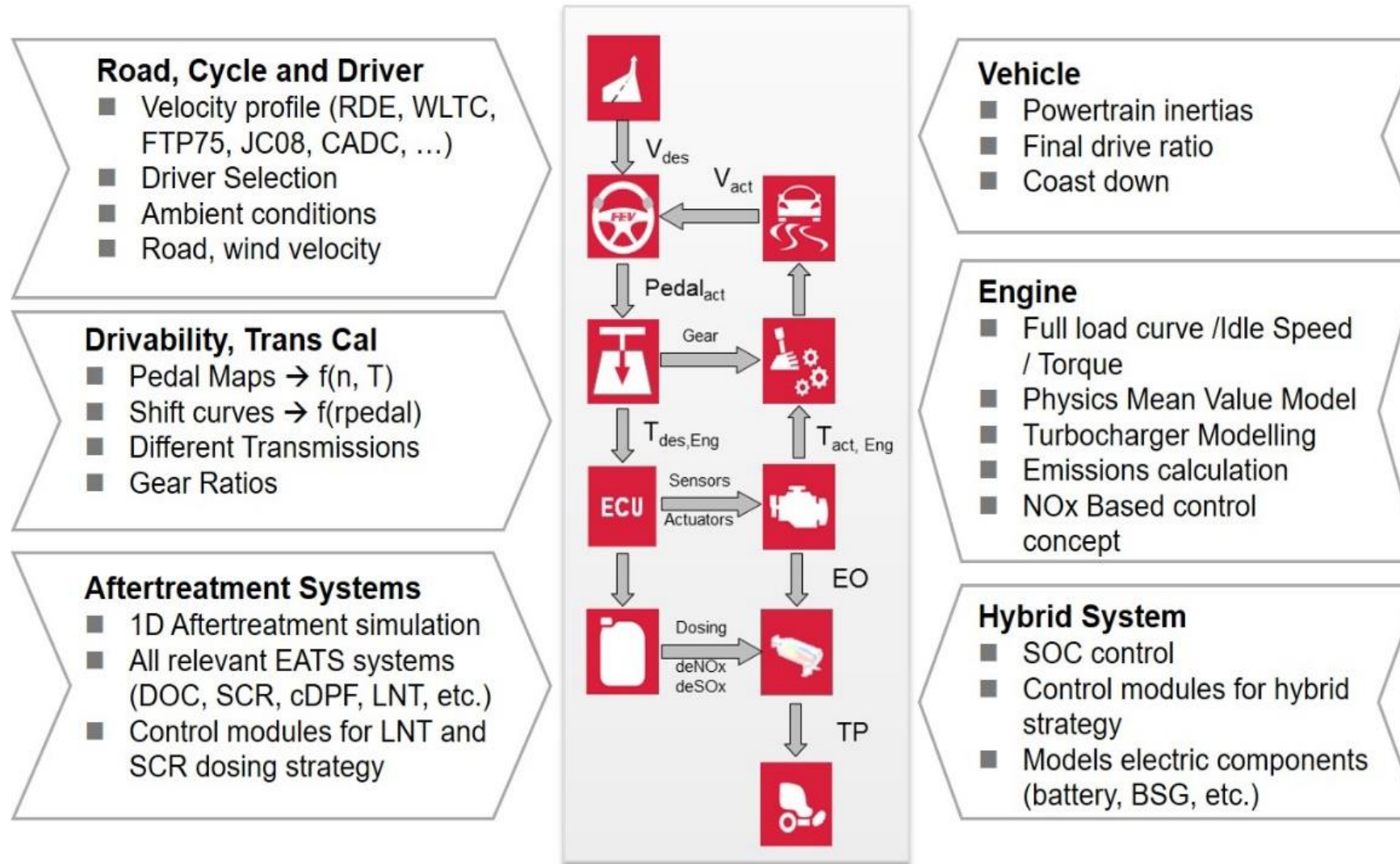
Base A Vehicle	Type	C-segment SUV
	Mass	WLTC: 1700 kg
		RDE: 2100 kg
Engine (front-engine, rear-drive)	Displacement	1.998 L
	Max. Power	140 kW
	Max. Torque	400 Nm
	EGR system	uncooled high-pressure + cooled low-pressure EGR
Transmission	Type	DCT-7
EAS	Layout/capacity	DOC (1.7 L) / a-cc-SDPF (2.0 L) / p-uf-SCR (1.5 L)

Config. Code	Engine	Battery** capacity (kWh)	EAS	
			Layout	Capacity (L)
A	Base engine	0	DOC/a-cc-SDPF /p-uf-SCR	1.7/ 2.0/1.5
B	 Base engine	1		
C	48V BSG (12 kW, 25 kg*)		LNT/DPF/a-uf-SCR	1.7/2.0/2.6
D	 48V BSG (12 kW, 25 kg*)		LNT/a-cc-SDPF /a-uf-SCR	1.7/2.0/ 2.6
E	 350V EM (50 kW, 100 kg*)	2	LNT/a-cc-SDPF/p-uf-SCR	1.7/2.0/1.5

Configuration B VS A: Impact of mild-hybridisation (without engine start-stop strategy)
 Configuration B VS C VS D: Impact of EAS (with engine start-stop strategy)
 Configuration E VS D: Impact of high-voltage-hybridisation (with engine start-stop strategy)

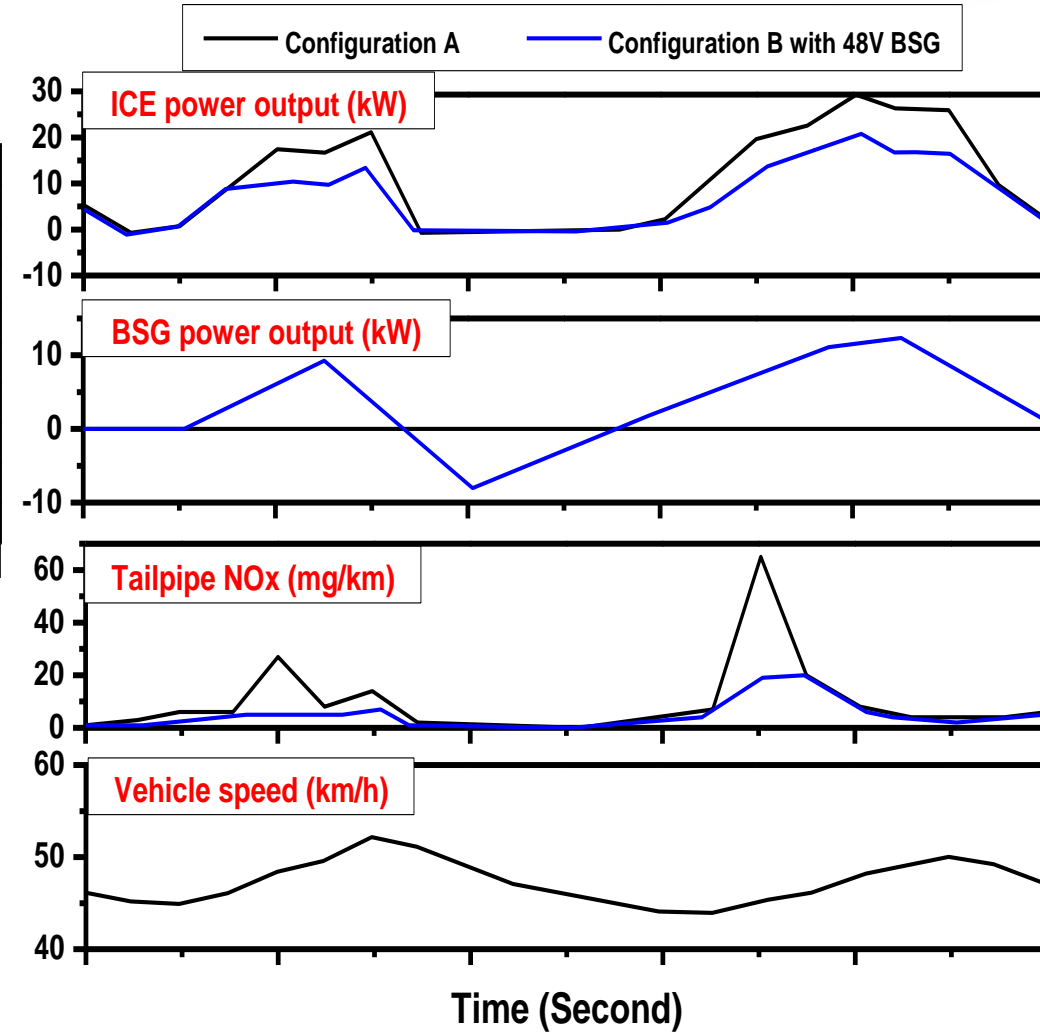
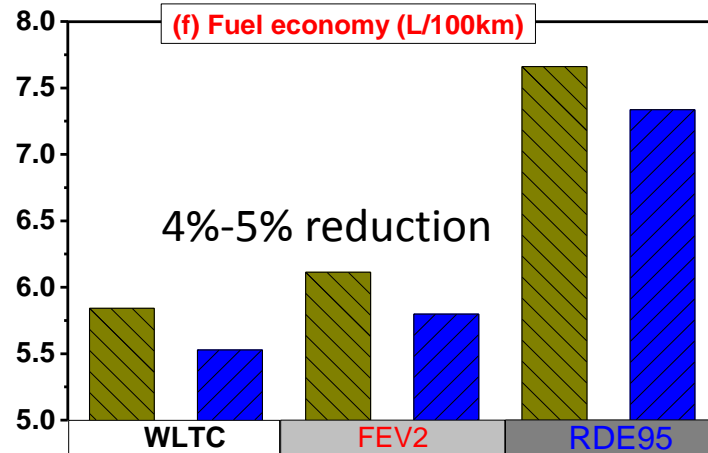
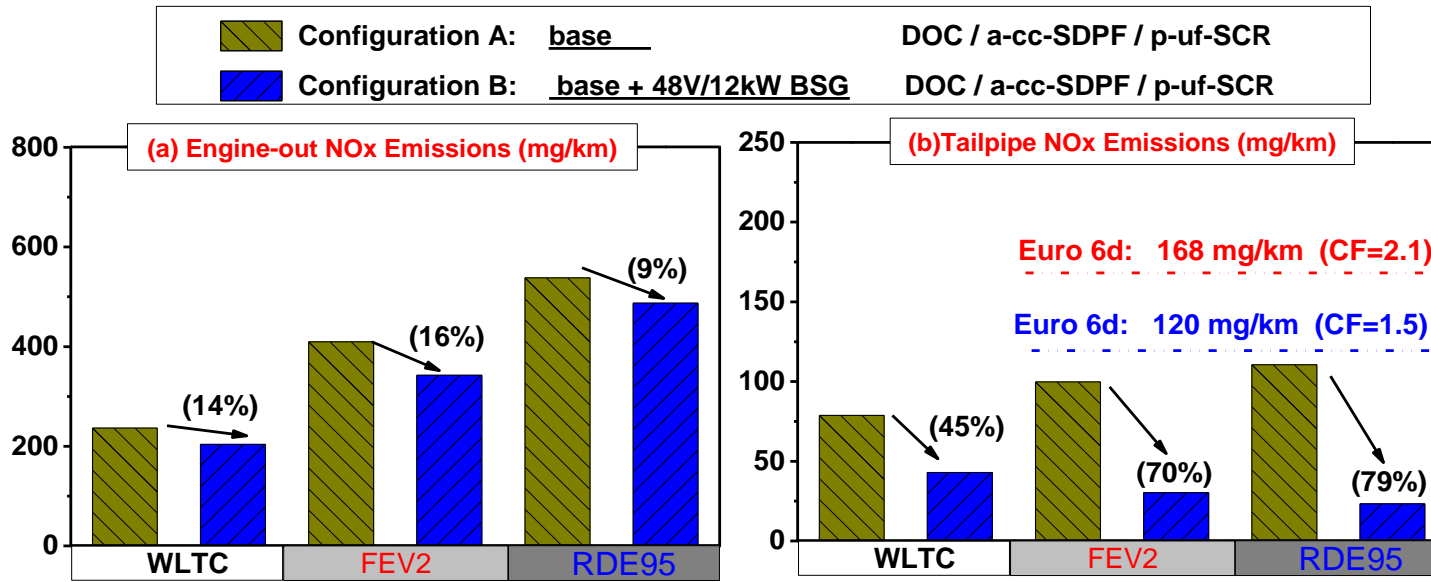






FEV SimEx, a dedicated in-house Simulink-based modelling package, is used for simulation.

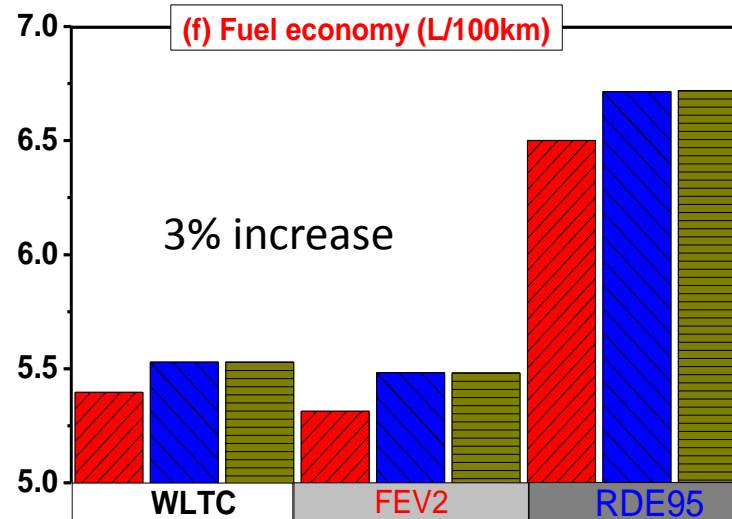
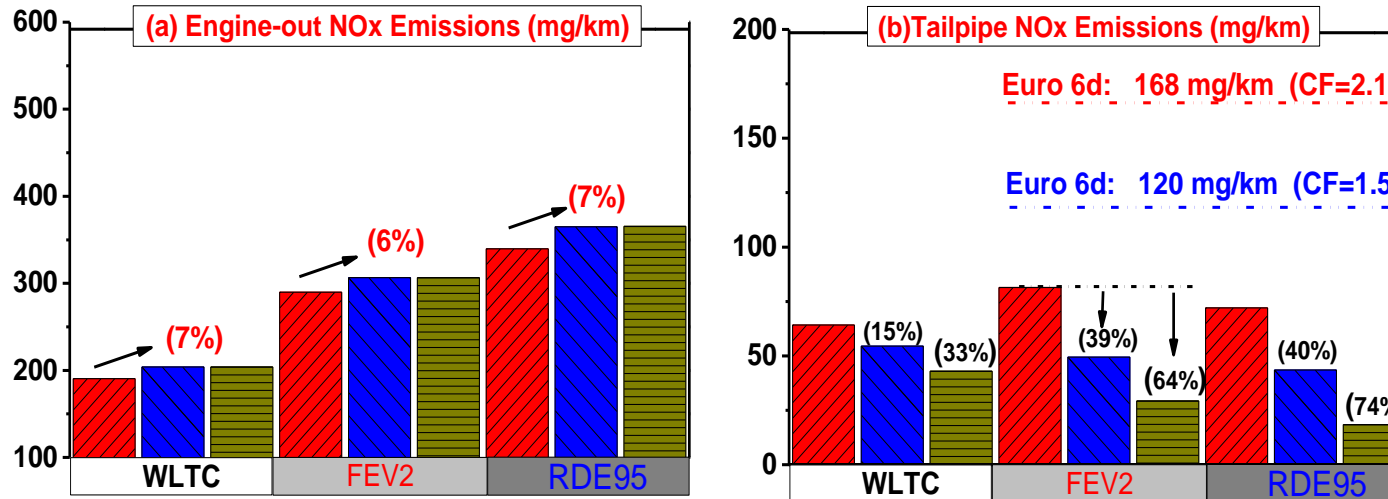
Results: Impact of 48V hybridization



* Engine start and stop function was not used

Results : Impact of EAS

	Configuration B: base + 48V/12kW BSG	<u>DOC / a-cc-SDPF / p-uf-SCR</u>
	Configuration C: base + 48V/12kW BSG	<u>LNT / DPF / a-uf-SCR</u>
	Configuration D: base + 48V/12kW BSG	<u>LNT / a-cc-SDPF / a-uf-SCR</u>

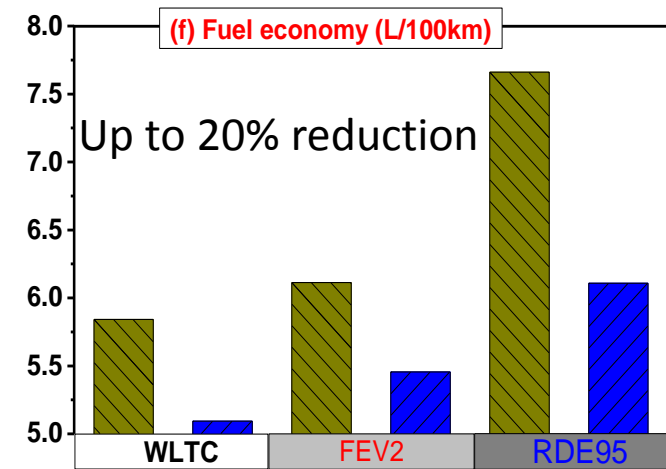
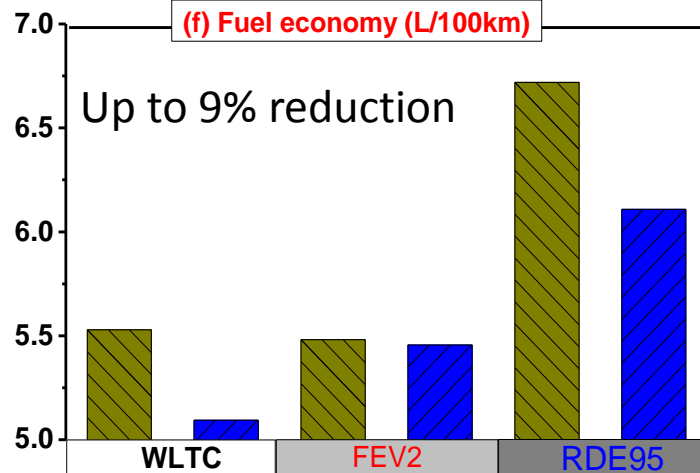
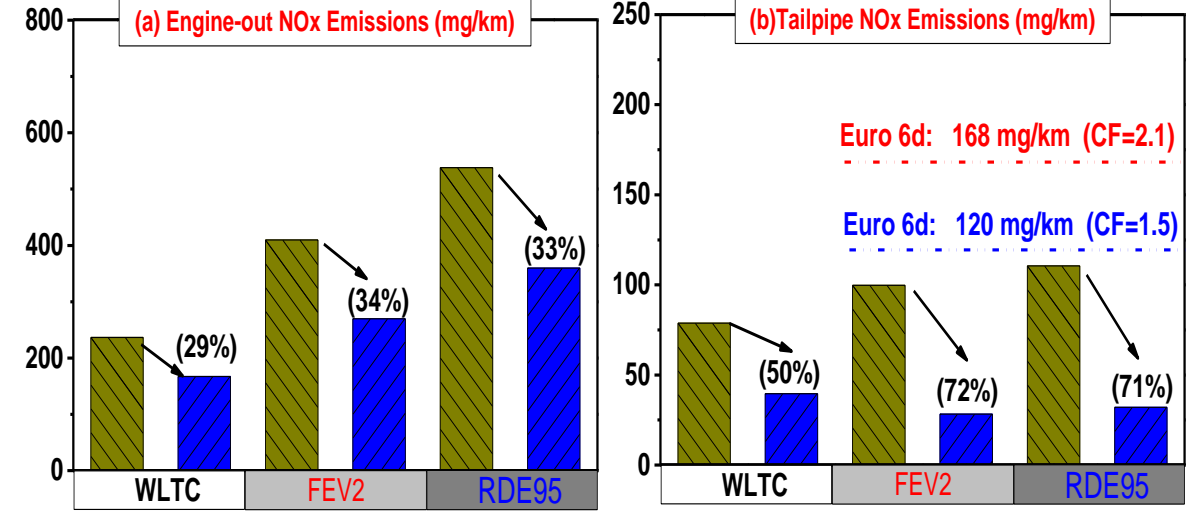
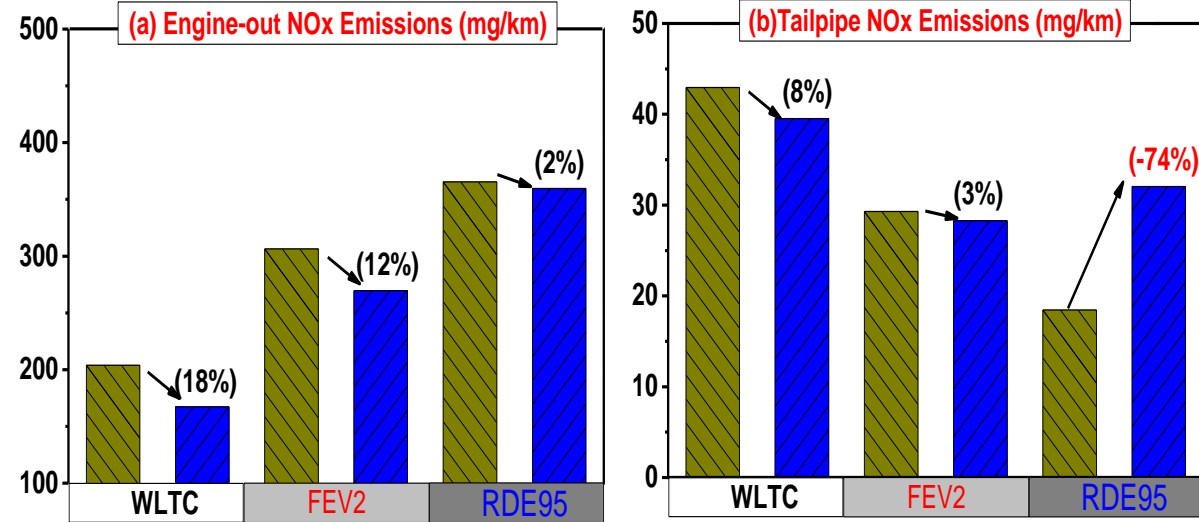


* Engine start and stop function was used





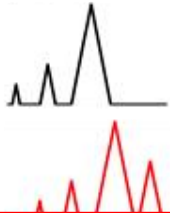





Results: Impact of 350V hybridization

■ Configuration D: base + 48V/12kW BSG LNT / a-cc-SDPF / a-uf-SCR
■ Configuration E: base + 48V/12kW BSG + 350V/50kW EM LNT / a-cc-SDPF / p-uf-SCR

■ Configuration A: base DOC / a-cc-SDPF / p-uf-SCR
■ Configuration E: base + 48V/12kW BSG + 350V/50kW EM LNT / a-cc-SDPF / p-uf-SCR



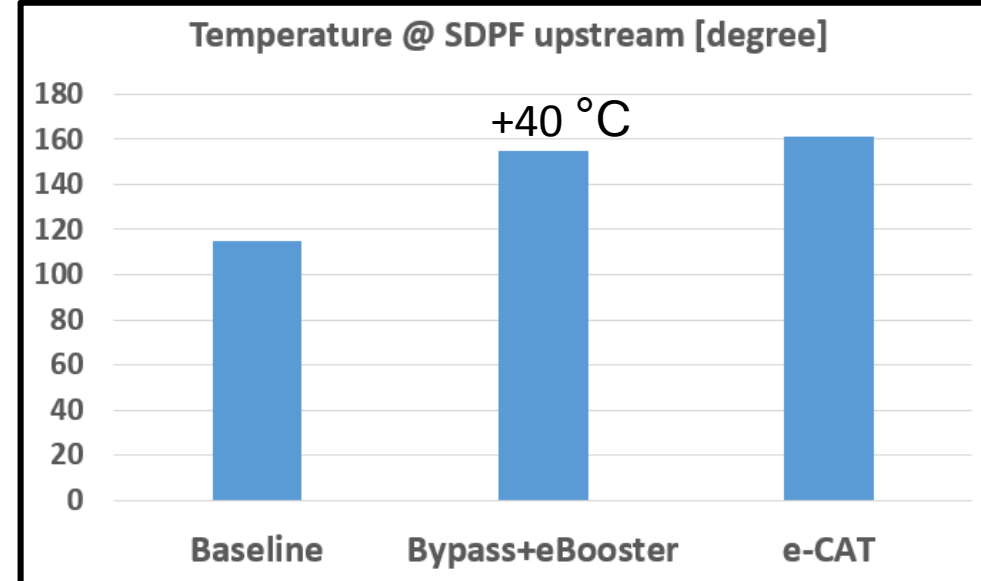
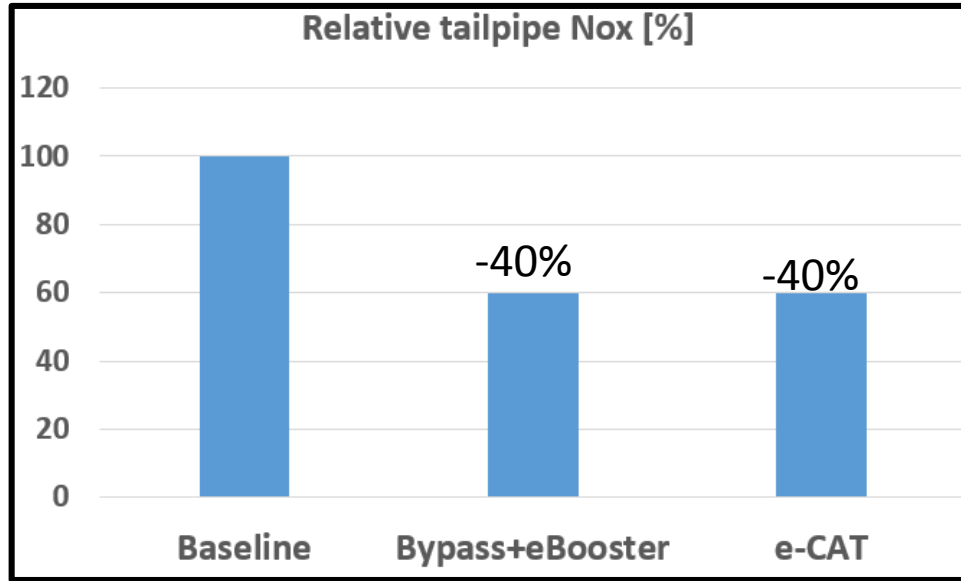
Smart air path vs eCAT

Engine Out Emissions	Thermal Management	Exhaust After-treatment
 <p>Advanced FIE 雾化</p>  <p>Hybridization 动力辅助</p>	 <p>VVT</p>  <p>Low Thermal Inertia components</p>  <p>Rapid Heating modes</p>	 <p>LNT+SCR 冷启动NOX</p>  <p>Two stage SCR systems</p>
 <p>eBooster®</p>	 <p>Turbine By-Pass 减小尾气温度损失</p>	 <p>Electrically heated catalysts</p>

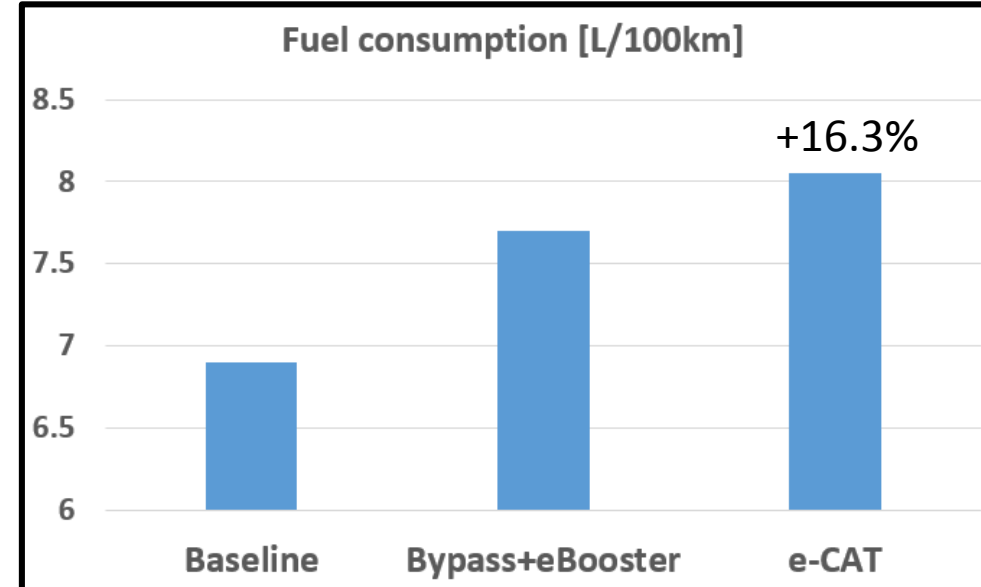
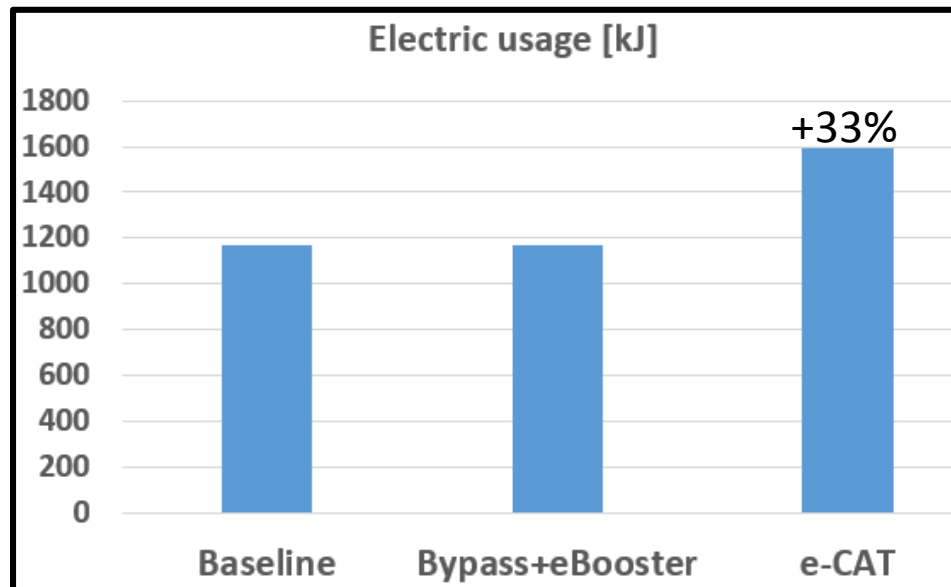
Smart air path

eCAT

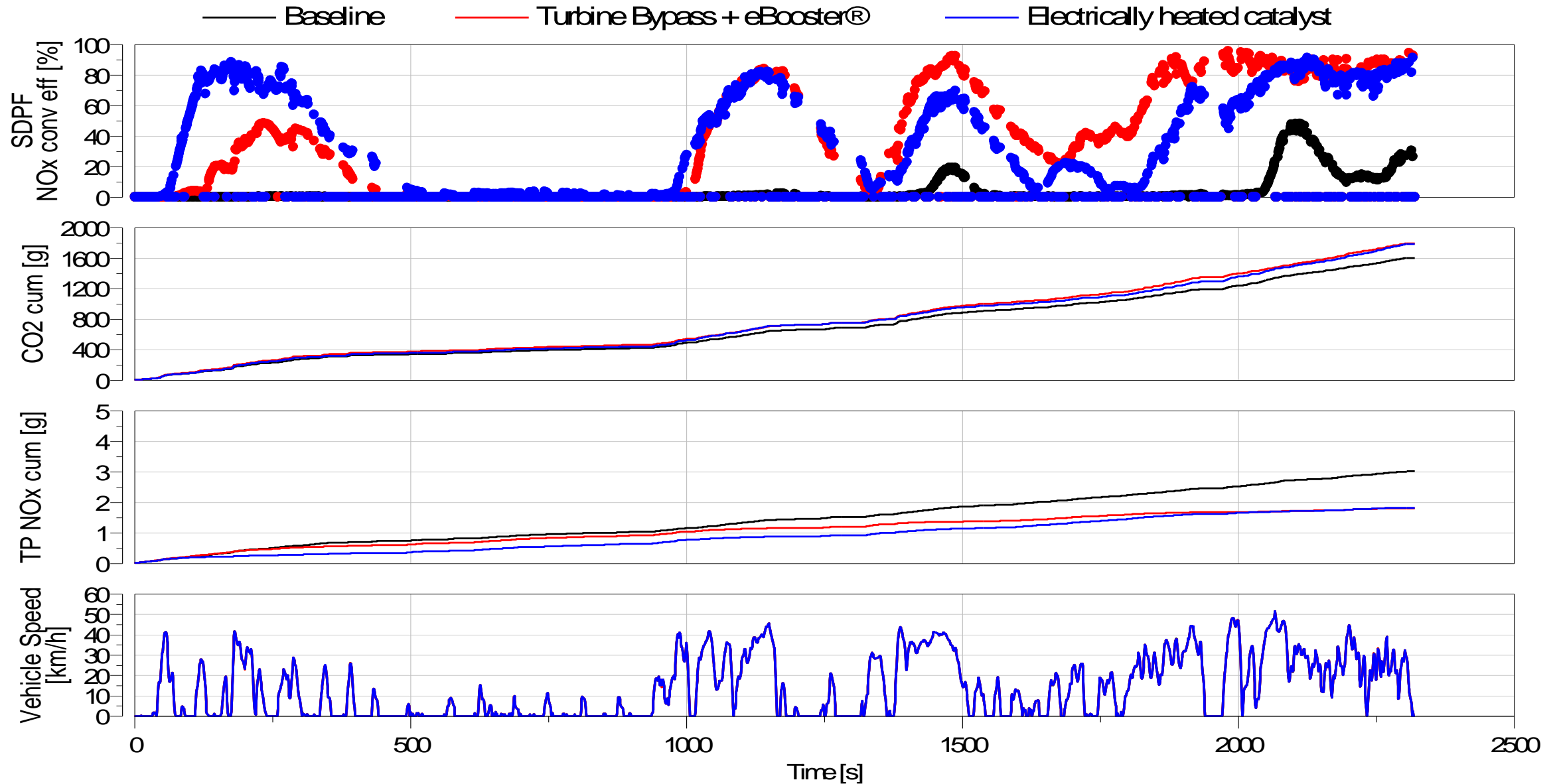
Smart air path VS e-CAT



e-CAT:
2.5 kW




































































Smart air path VS e-CAT



- In diesel-based passenger vehicles, PM and PN emissions are not issue since the introduction of Euro 5 emission regulation. NO_x emission is still a concern, especially at engine becomes more efficient.
- Hybridization, especially 380 V high voltage application, and advanced exhaust after-treatment system provide a pathway for the clean diesel powertrain solution.
- Virtual vehicle simulation platform, for example, FEV SimEx, becomes more important as diesel powertrain becomes more and more complicated.

Future mobility – Fuels and lubricant

Mobility Modes		Liquid Fuels	LPG	CNG	LNG	H ₂	Electricity
City Car 	Compatibility	++	+	+	∅	+	+
	Lubes	 	 	 	∅	 	 
Long Distance Car 	Compatibility	++	+	+	∅	+	○
	Lubes	 	 	 	∅	 	 
Light Truck 	Compatibility	++	+	+	∅	+	○
	Lubes	 	 	 	∅	 	 
Heavy Truck 	Compatibility	++	∅	○	+	∅	∅
	Lubes	 	∅	 	 	 	
Rail 	Compatibility	++	∅	○	+	∅	++
	Lubes	 	∅	 	 		 
Ship 	Compatibility	++	∅	○	+	∅	∅
	Lubes	 	∅	 	 		
Aircraft 	Compatibility	++	∅	∅	∅	∅	∅
	Lubes	 	∅	∅	∅	∅	∅

++ (Fully) compatible
 + With minor restrictions
 ○ With major restrictions
 ∅ No option
  Engine Oil
  Gearbox/Diff Oil