Evolution of Advanced Emissions Control System to meet NOx and Particulates Regulations

Cécile Favre

Integer Emissions Summit Europe • Brussels • 27 June 2018

AECC
ASSOCIATION FOR EMISSIONS CONTROL BY CATALYST

Association for Emissions Control by Catalyst (AECC AISBL)

AECC members : European Emissions Control companies

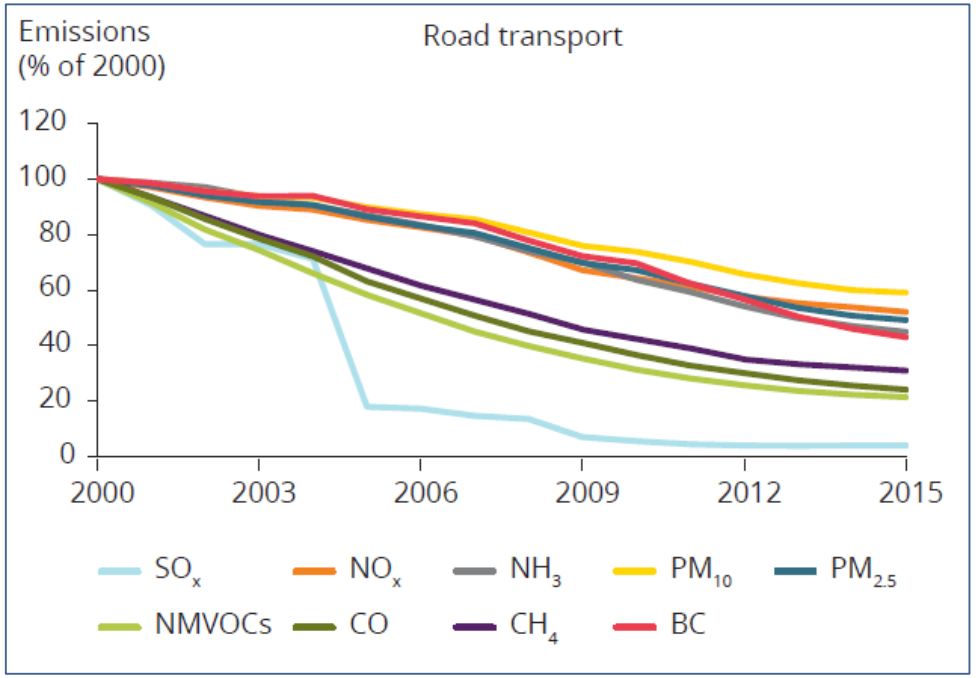
- Exhaust emissions control technologies for original equipment, retrofit and aftermarket for all new cars, commercial vehicles, motorcycles, and non-road mobile machinery

Content

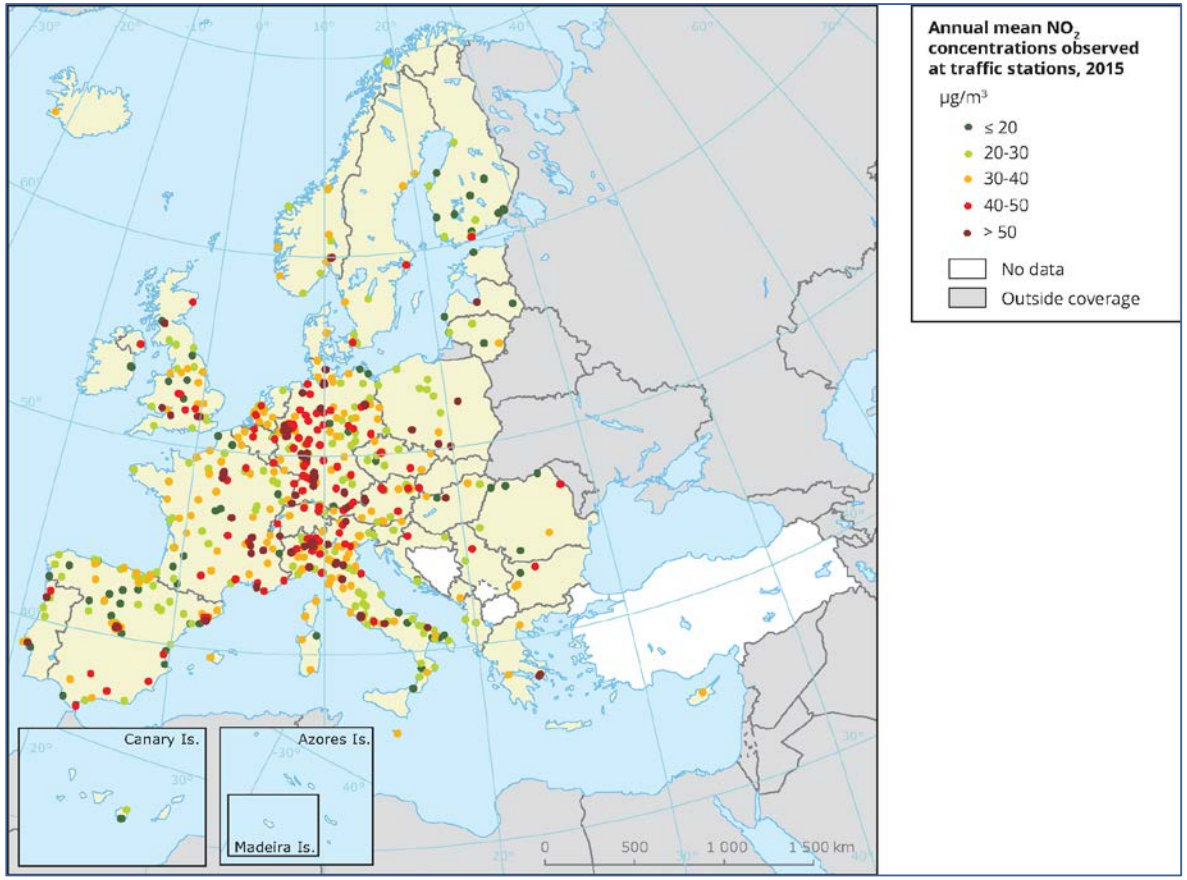
- Context
- Overview of emission control technologies
- Plug-In Hybrid vehicle emissions towards the boundaries of RDE

EU Air Quality has improved over the years

But further efforts are needed

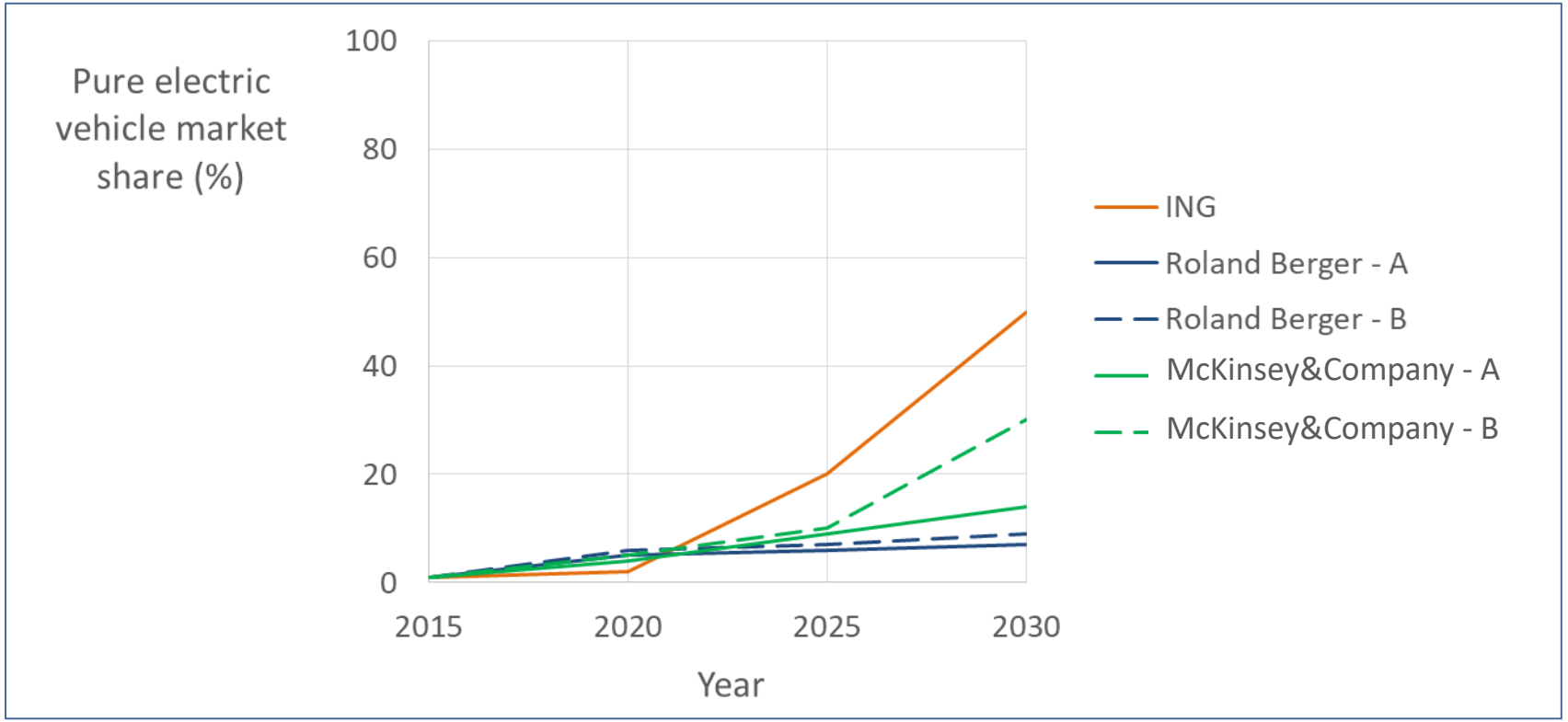


Source: European Environment Agency (EEA)



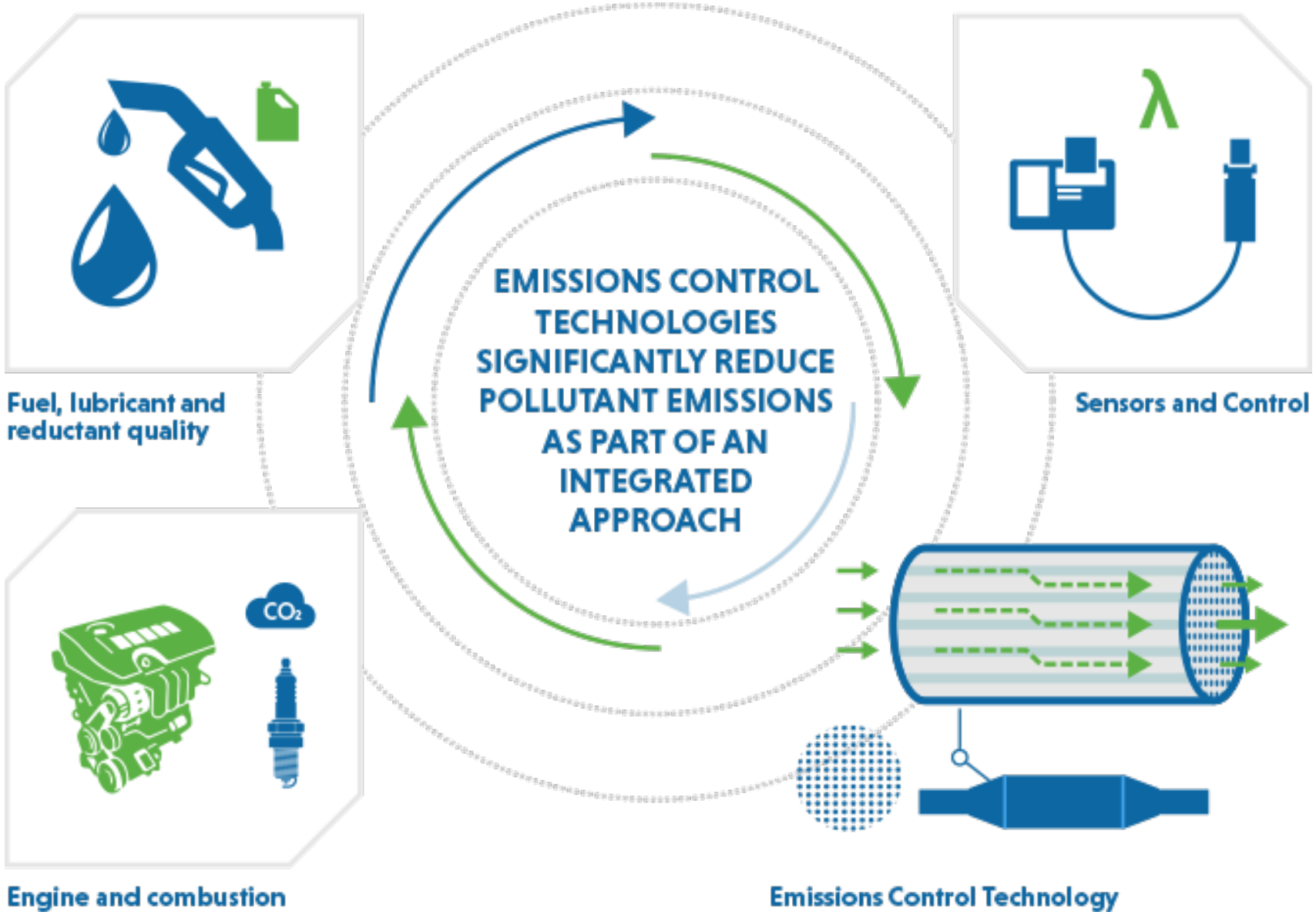
50-70% of powertrains still expected to include an ICE in 2030

Predictions of pure electric vehicles market share by 2030



Sources:
ING – Breakthrough of electric vehicle threatens European car industry, July 2017
Roland Berger – Fuels and vehicles roadmap 2030+, April 2016
McKinsey&Company – Boost! Powertrain KIP, January 2011

ICE: Internal Combustion Engine


EMISSIONS CONTROL TECHNOLOGIES SIGNIFICANTLY REDUCE POLLUTANT EMISSIONS AS PART OF AN INTEGRATED APPROACH
Fuel, lubricant and reductant quality
Sensors and Control
Engine and combustion
Emissions Control Technology
CO2

Content

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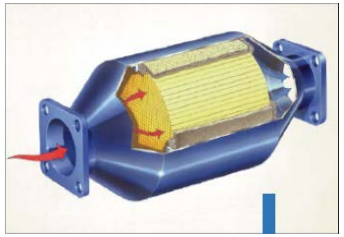
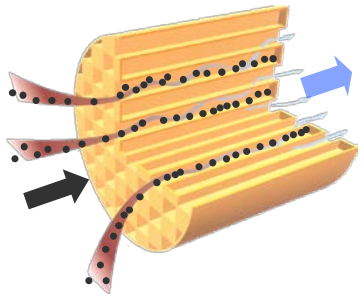
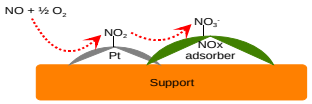
Core emissions control technologies





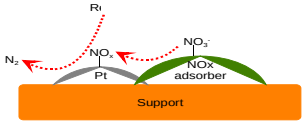
Technology		Light-duty		Heavy-duty		NRMM	Motorcycle & Moped
	Acronym	Petrol	Diesel	Diesel	Gas, Petrol	Mostly diesel	Mostly petrol
Oxidation catalyst	OC	●					●
Diesel Oxidation Catalyst	DOC		●	●		●	
3-Way Catalyst	TWC	●			●		●
Diesel Particulate Filter	DPF		●	●		●	
NOx Adsorber	LNT	●	●				
Selective Catalytic Reduction	SCR		●	●		●	
Gasoline Particulate Filter	GPF	●					

Lean

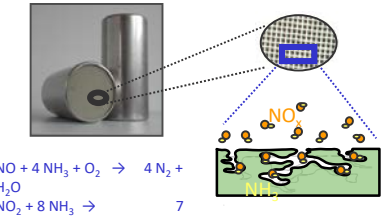


NO_x Adsorption

Rich



NO_x Reduction

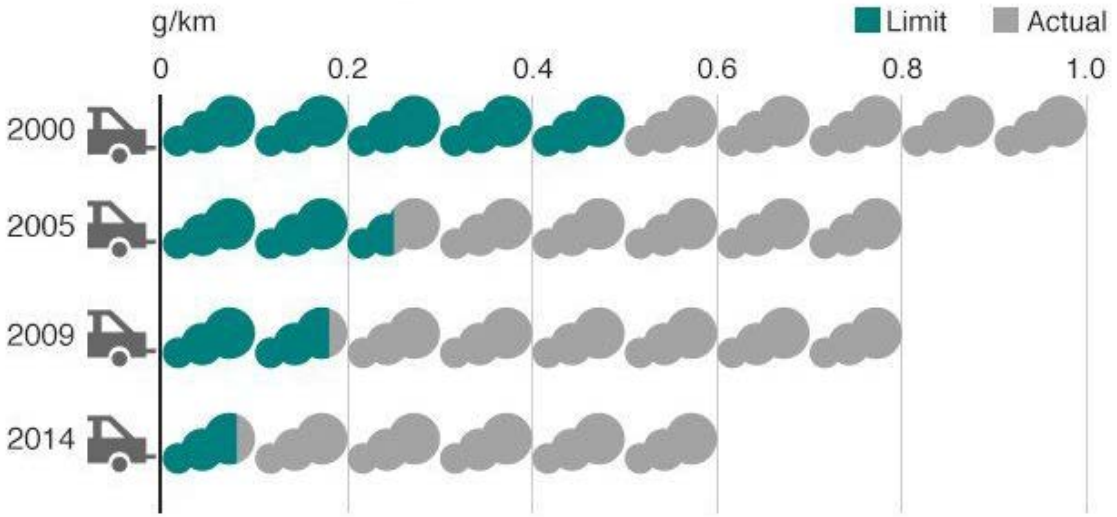


$4\,NO + 4\,NH_3 + O_2 \rightarrow 4\,N_2 + 6\,H_2O$

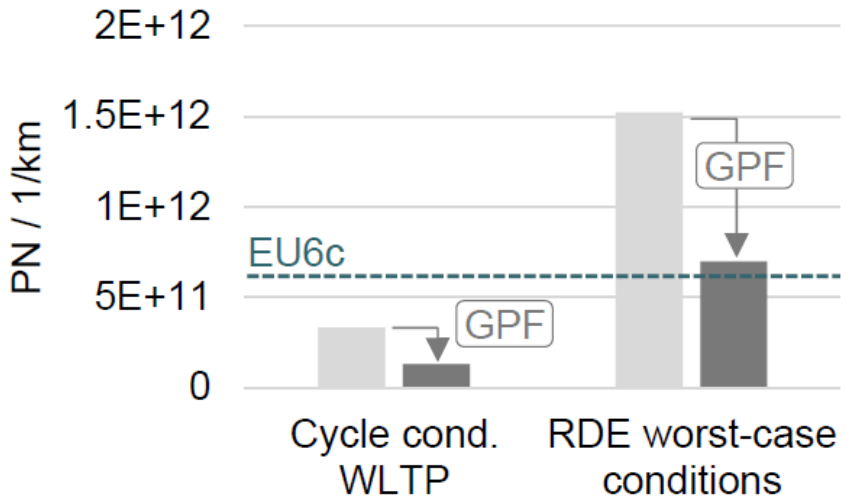
$6\,NO_2 + 8\,NH_3 \rightarrow 7\,N_2 + 12\,H_2O$

EU RDE legislation

Aims to close the emissions gap between lab and real-world



Source: average on-road diesel NOx emissions, the ICCT



Source: Gasoline Particulate Filters Market and Technology Trends and their Impact on Calibration, FEV, SIA powertrain 2017

PEMS equipment used to measure emissions on the road

Low NOx emission diesel cars: a reality

Bosch demonstrated urban NOx Real-Driving Emission (RDE) consistently below 80 mg/km

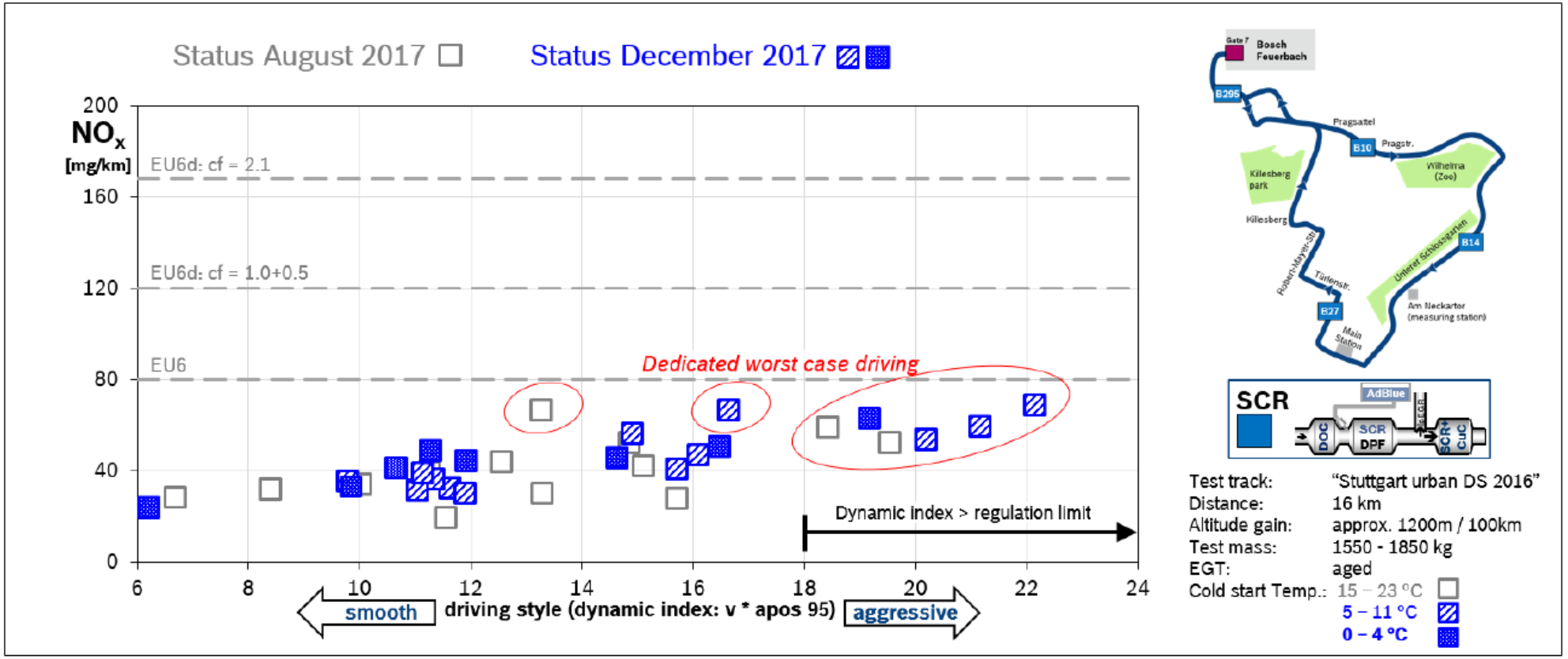
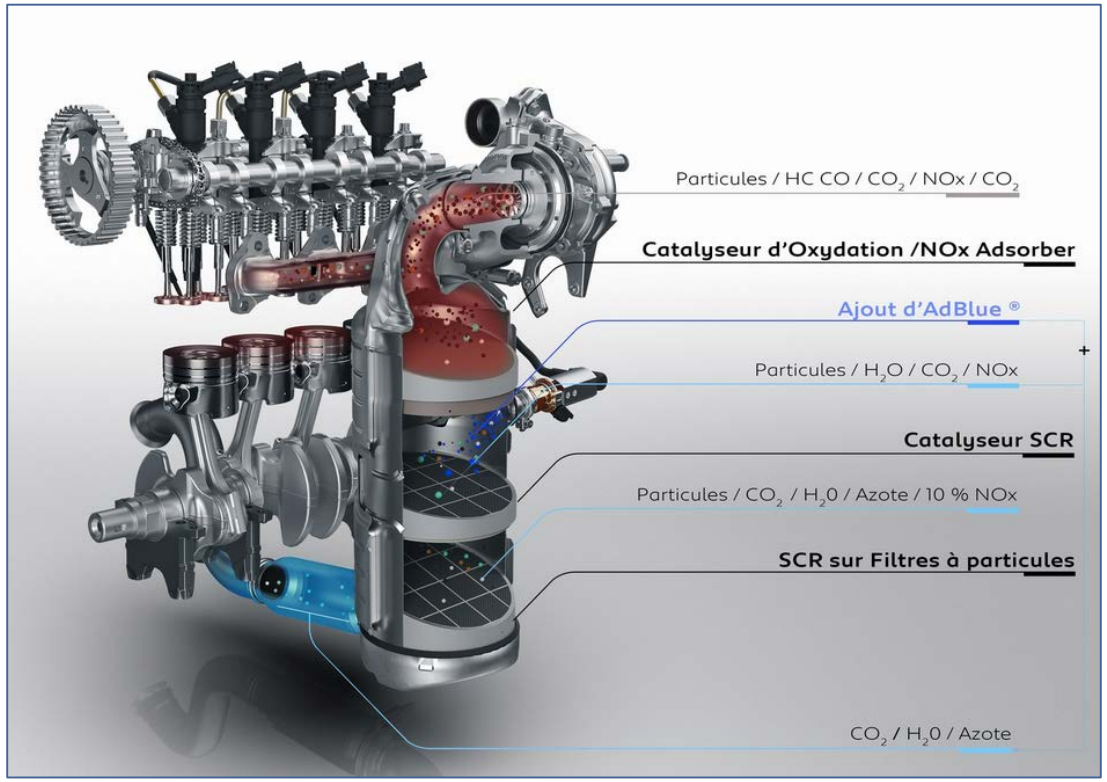


Figure 9: On-road measurements "Stuttgart – urban"

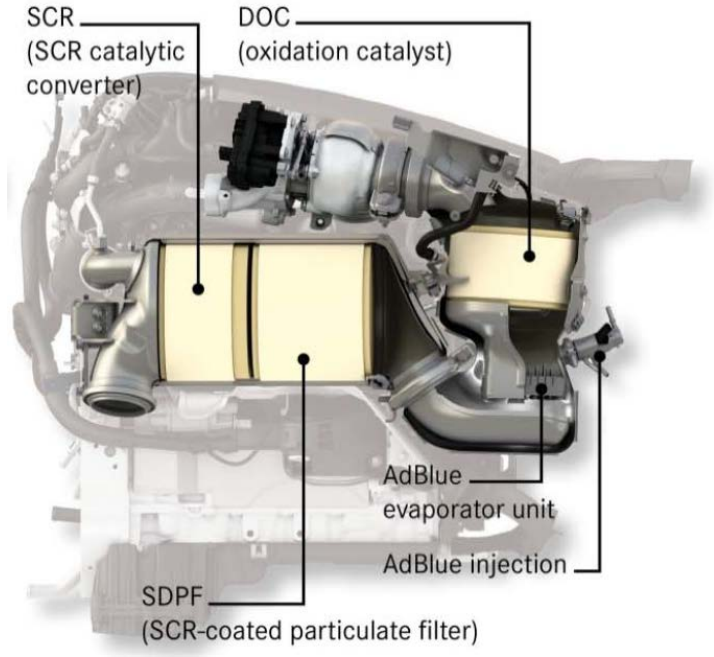
Source: Kufferath (Bosch), the path to a negligible NO_2 immission contribution from the diesel powertrain, Vienna Motor Symposium, April 2018

Light-duty diesel emissions control technology evolution

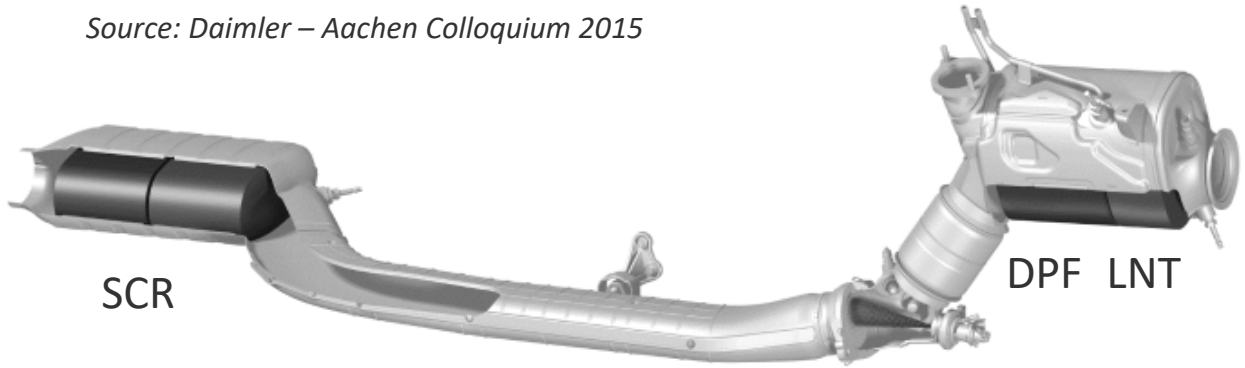
Towards combination of technologies in a compact design for RDE compliance



Source: Peugeot – 308 press release 2017



Source: Daimler – Aachen Colloquium 2015

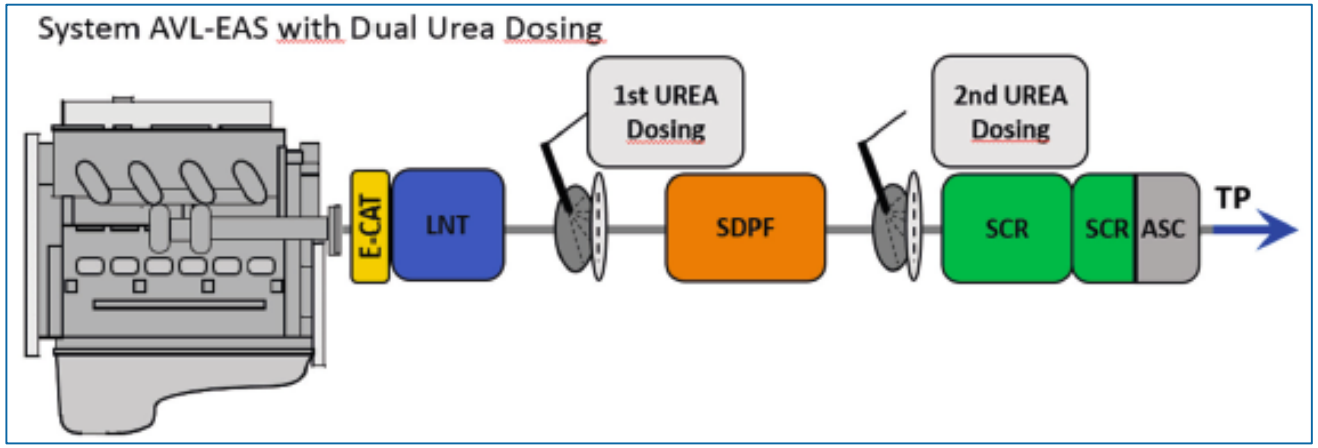


Source: BMW – Aachen Colloquium 2015

Light-duty diesel emissions control technology evolution

Potential for future improvements to cover a wide range of driving conditions

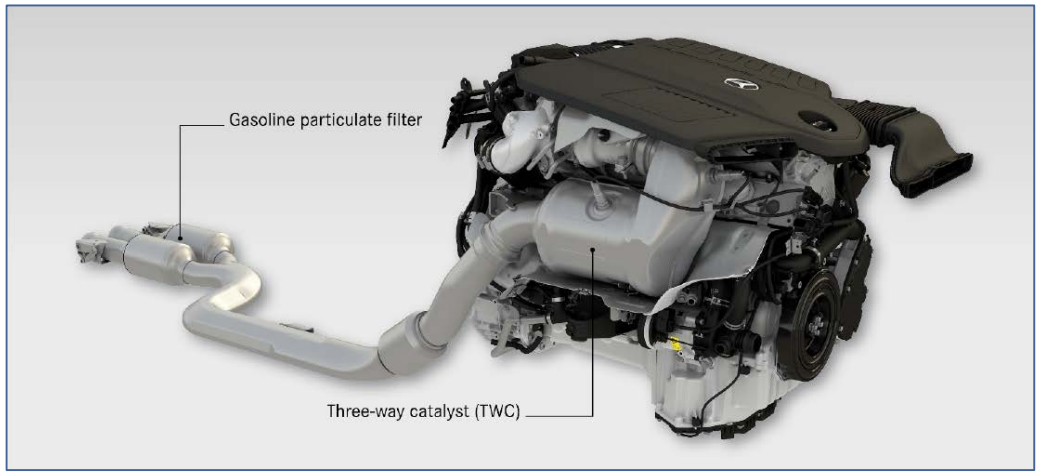
- SCR in different locations to cover urban and motorway driving
- Dual urea injection to provide more flexible dosing
- Optimising thermal management for urban driving



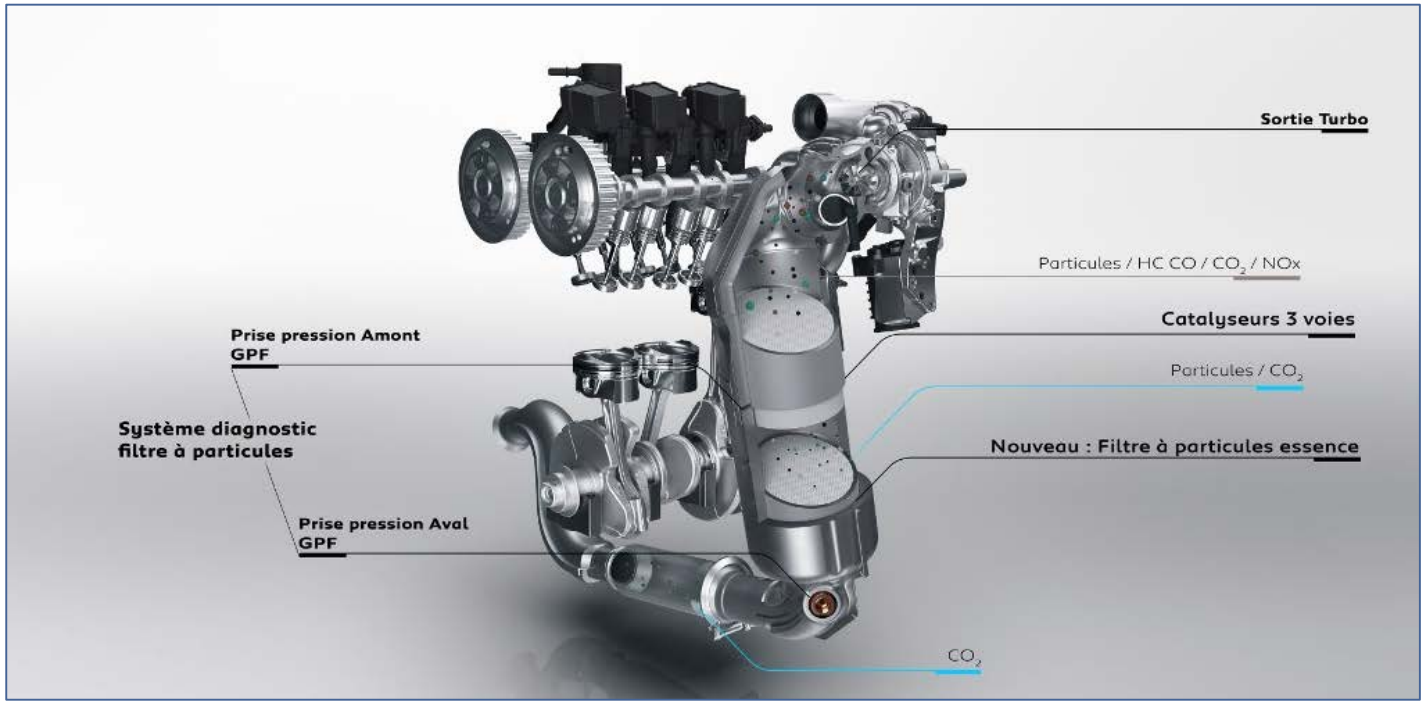
Source: AVL – Highly Efficient Exhaust Gas Aftertreatment for Future Diesel Applications – 10th International Exhaust Gas and Particulate Emissions Forum February 2018

Light-duty gasoline emissions control technology evolution

Introduction of particulate filters on cars with direct injection for RDE compliance



Source: Daimler – Vienna Motorensymposium 2017



Source: Peugeot – 308 press release 2017

RDE-compliant cars (Euro 6d-TEMP) are available on the market

- List at www.adac.de/infotestrat/umwelt-und-innovation/abgas/modelle_mit_euro_6d_temp/default.aspx
- 569 models (on 12.06.18)
  - Incl. 224 diesel models

ADAC

Marke	Modell	Motorart	Hubraum in ccm	Leistung in kW	Abgasnorm	Markt-einführung ab
Audi	A6 50 TDI	Diesel	2967	210	Euro6d-TEMP	Jun. 18
Audi	A7 Sportback 50 TDI	Diesel	2967	210	Euro6d-TEMP	Feb. 18
BMW	i3 (94Ah) (inkl. REX)	Elektro	647	125	Euro6d-TEMP	Apr. 18
BMW	i3s (94Ah) (inkl. REX)	Elektro	647	135	Euro6d-TEMP	Apr. 18
BMW	216i Active Tourer	Otto	1499	80	Euro6d-TEMP	Mrz. 18
BMW	218i Active Tourer	Otto	1499	103	Euro6d-TEMP	Mrz. 18
BMW	225xe iPerformance Active Tourer	Hybrid	1499	165	Euro6d-TEMP	Mrz. 18
BMW	216d Active Tourer	Diesel	1496	85	Euro6d-TEMP	Mrz. 18
BMW	218d Active Tourer	Diesel	1995	110	Euro6d-TEMP	Mrz. 18
BMW	220d Active Tourer	Diesel	1995	140	Euro6d-TEMP	Mrz. 18
BMW	216i Gran Tourer	Otto	1499	80	Euro6d-TEMP	Mrz. 18
BMW	218i Gran Tourer	Otto	1499	103	Euro6d-TEMP	Mrz. 18
BMW	216d GranTourer	Diesel	1496	85	Euro6d-TEMP	Mrz. 18
BMW	218d GranTourer	Diesel	1995	110	Euro6d-TEMP	Mrz. 18
BMW	220d Gran Tourer	Diesel	1995	140	Euro6d-TEMP	Mrz. 18
BMW	420i Coupé	Otto	1998	135	Euro6d-TEMP	Mrz. 18
BMW	430i Coupé	Otto	1998	185	Euro6d-TEMP	Mrz. 18
BMW	i8 Coupé	Hybrid	1499	275	Euro6d-TEMP	Mai. 18
BMW	i8 Roadster	Hybrid	1499	275	Euro6d-TEMP	Mai. 18
BMW	X1 sDrive18i	Otto	1499	103	Euro6d-TEMP	Mrz. 18
BMW	X1 sDrive18d	Diesel	1995	110	Euro6d-TEMP	Mrz. 18
BMW	X1 xDrive18d	Diesel	1995	110	Euro6d-TEMP	Mrz. 18
BMW	X1 xDrive20d	Diesel	1995	140	Euro6d-TEMP	Mrz. 18
BMW	X2 sDrive18i	Otto	1499	103	Euro6d-TEMP	Mrz. 18
BMW	X2 sDrive18d	Diesel	1995	110	Euro6d-TEMP	Mrz. 18
BMW	X2 xDrive18d	Diesel	1995	110	Euro6d-TEMP	Mrz. 18
BMW	X2 xDrive20d	Diesel	1995	140	Euro6d-TEMP	Mrz. 18
BMW	X3 xDrive20i	Otto	1998	135	Euro6d-TEMP	Dez. 17
BMW	X3 xDrive30i	Otto	1998	185	Euro6d-TEMP	Dez. 17
BMW	X4 xDrive20i	Otto	1998	135	Euro6d-TEMP	Apr. 18
BMW	X4 xDrive30i	Otto	1998	185	Euro6d-TEMP	Apr. 18
Citroen	C3 PureTech 68	Otto	1199	50	Euro6d-TEMP	Mai 18
Citroen	C3 PureTech 82	Otto	1199	61	Euro6d-TEMP	Mai 18
Citroen	C3 PureTech 110	Otto	1199	81	Euro6d-TEMP	Mai 18
Citroen	C3 BlueHDi 100	Diesel	1997	75	Euro6d-TEMP	Mai 18
Citroen	C4 Spacetourer BlueHDi 160	Diesel	1997	120	Euro6d-TEMP	Mai 18
Volvo	V60 D3	Diesel	1969	110	Euro6d-TEMP	Jul. 18
Volvo	V60 D4	Diesel	1969	140	Euro6d-TEMP	Jul. 18
Volvo	S90 T4	Otto	1969	140	Euro6d-TEMP	Mrz. 18
Volvo	S90 T5	Otto	1969	184	Euro6d-TEMP	Mrz. 18
Volvo	S90 T6	Otto	1969	228	Euro6d-TEMP	Mrz. 18
Volvo	S90 T8 Twin Engine	Hybrid	1969	288	Euro6d-TEMP	Mrz. 18
Volvo	S90 D3	Diesel	1969	110	Euro6d-TEMP	Mrz. 18
Volvo	S90 D4	Diesel	1969	140	Euro6d-TEMP	Mrz. 18
Volvo	S90 D5	Diesel	1969	173	Euro6d-TEMP	Mrz. 18
Volvo	V90 T4	Otto	1969	140	Euro6d-TEMP	Mrz. 18
Volvo	V90 T5	Otto	1969	184	Euro6d-TEMP	Mrz. 18
Volvo	V90 T6	Otto	1969	228	Euro6d-TEMP	Mrz. 18
Volvo	V90 T8 Twin Engine	Hybrid	1969	288	Euro6d-TEMP	Mrz. 18
Volvo	V90 D3	Diesel	1969	110	Euro6d-TEMP	Mrz. 18
Volvo	V90 D4	Diesel	1969	140	Euro6d-TEMP	Mrz. 18
Volvo	V90 D5	Diesel	1969	173	Euro6d-TEMP	Mrz. 18
Volvo	V90 Cross Country T5	Otto	1969	184	Euro6d-TEMP	Mrz. 18
Volvo	V90 Cross Country T6	Otto	1969	228	Euro6d-TEMP	Mrz. 18
Volvo	V90 Cross Country D4	Diesel	1969	140	Euro6d-TEMP	Mrz. 18
Volvo	V90 Cross Country D5	Diesel	1969	173	Euro6d-TEMP	Mrz. 18
Volvo	XC40 T3	Otto	1498	114	Euro6d-TEMP	Feb. 18
Volvo	XC40 T4	Otto	1969	140	Euro6d-TEMP	Feb. 18
Volvo	XC40 T5	Otto	1969	182	Euro6d-TEMP	Feb. 18
Volvo	XC40 D3	Diesel	1969	110	Euro6d-TEMP	Feb. 18
Volvo	XC40 D4	Diesel	1969	140	Euro6d-TEMP	Feb. 18
Volvo	XC60 T5	Otto	1969	184	Euro6d-TEMP	Feb. 18
Volvo	XC60 T6	Otto	1969	228	Euro6d-TEMP	Feb. 18
Volvo	XC60 T8 Twin Engine	Hybrid	1969	288	Euro6d-TEMP	Feb. 18
Volvo	XC60 D3	Diesel	1969	110	Euro6d-TEMP	Feb. 18
Volvo	XC60 D4	Diesel	1969	140	Euro6d-TEMP	Nov. 17
Volvo	XC60 D5	Diesel	1969	173	Euro6d-TEMP	Nov. 17
Volvo	XC90 T5	Otto	1969	184	Euro6d-TEMP	Mrz. 18
Volvo	XC90 T6	Otto	1969	228	Euro6d-TEMP	Mrz. 18
Volvo	XC90 T8 Twin Engine	Hybrid	1969	288	Euro6d-TEMP	Mrz. 18
Volvo	XC90 D5	Diesel	1969	173	Euro6d-TEMP	Nov. 17
VW	up! GTI	Otto	999	85	Euro6d-TEMP	Jan. 18
VW	Touareg 3.0 V6 TDI SCR	Diesel	2967	210	Euro6d-TEMP	Jul. 18

and many more …

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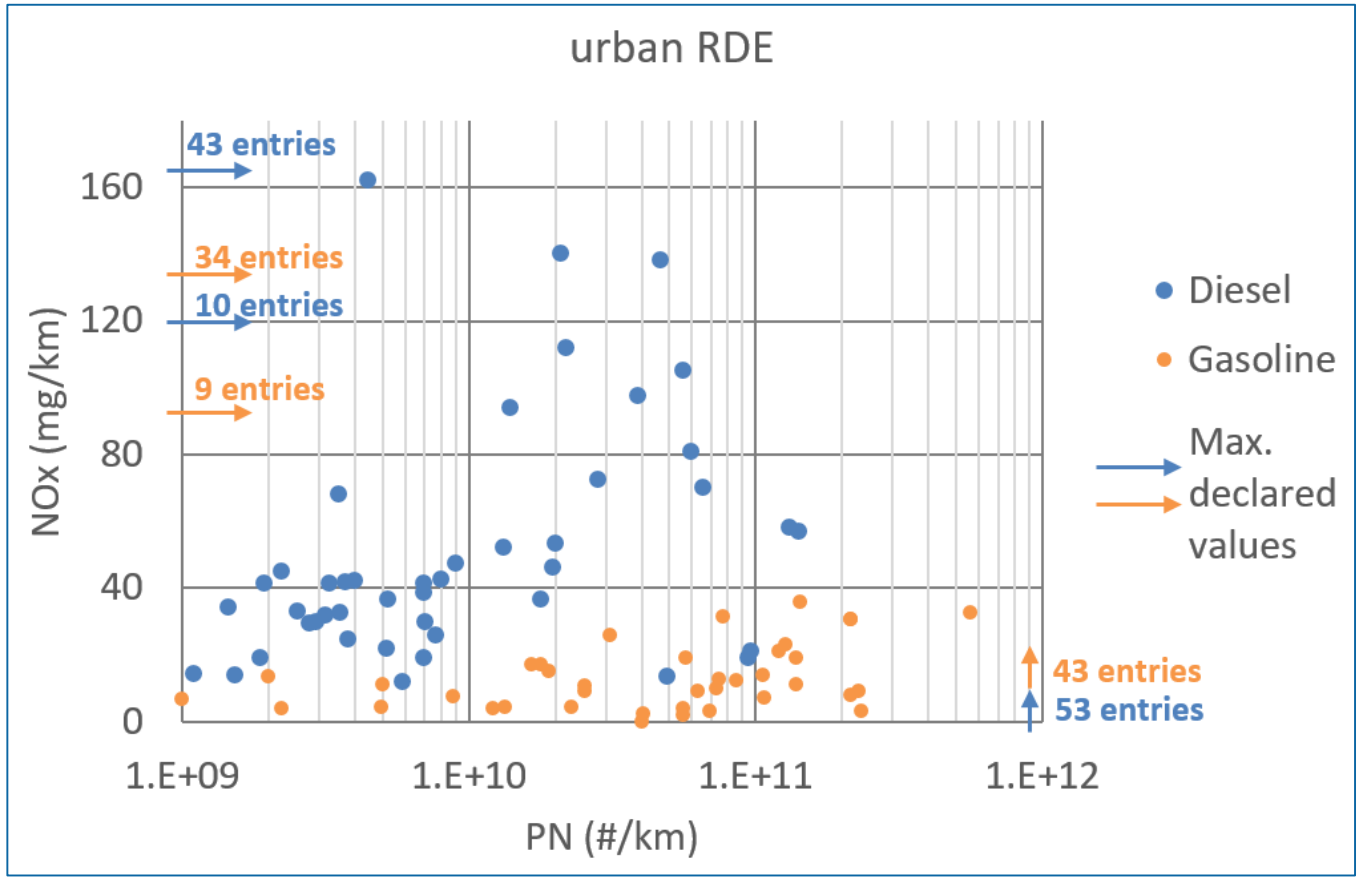
Emissions performance of latest diesel and gasoline vehicles

Declared values of Euro 6d-Temp vehicles well within standards



Source: PEMS results and maximum declared values from ACEA RDE database consulted on 26 April 2018

Content

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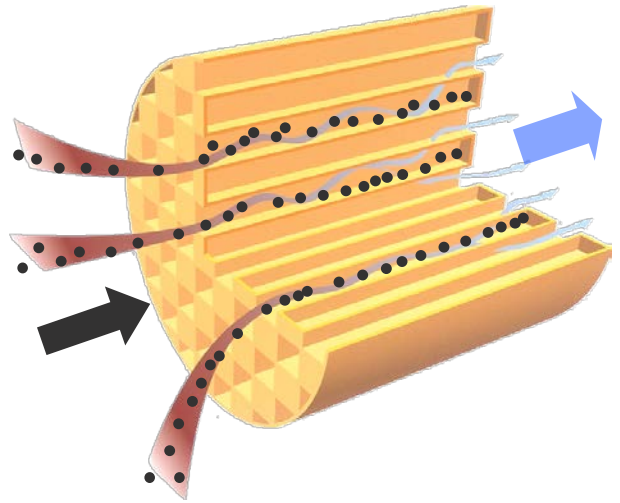
- Overview of emission control technologies
- Plug-In Hybrid vehicle emissions towards the boundaries of RDE

2017 PHEV test programme set-up

- Objective: measure the real-world behaviour of a market-representative Plug-in Hybrid Electric Vehicle (PHEV)
- Vehicle: C-segment, 1.5l class GDI engine, Euro 6b, E5 market fuel
- Test Matrix
  - All 4 driving modes: Electric, Hybrid, Charge and Sport
  - Variation in initial battery State of Charge (SOC)
  - RDE on-road and on the chassis dyno
  - 2 tests repeated with a coated Gasoline Particulate Filter (GPF) replacing the second (underfloor) Three-Way Catalyst (TWC)



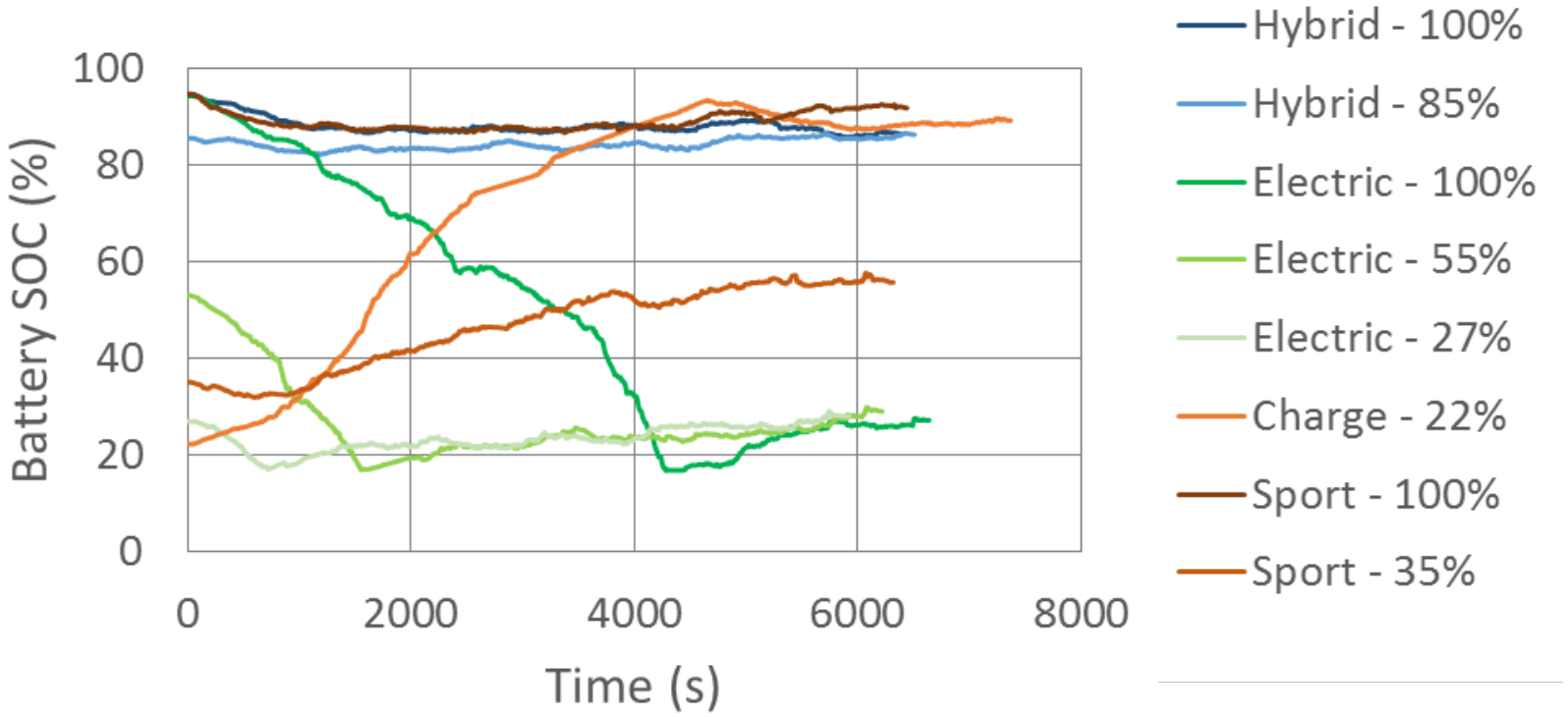
- Emissions are compared to similar GDI vehicle tested in 2016 AECC test programme*

* Real-World Emissions Measurements of a GDI Vehicle without and with a GPF, Demuynck, et al., SAE 2017-01-0985

8 combinations of mode and initial battery SOC tested

Change in battery SOC (State of Charge) during on-road RDE tests

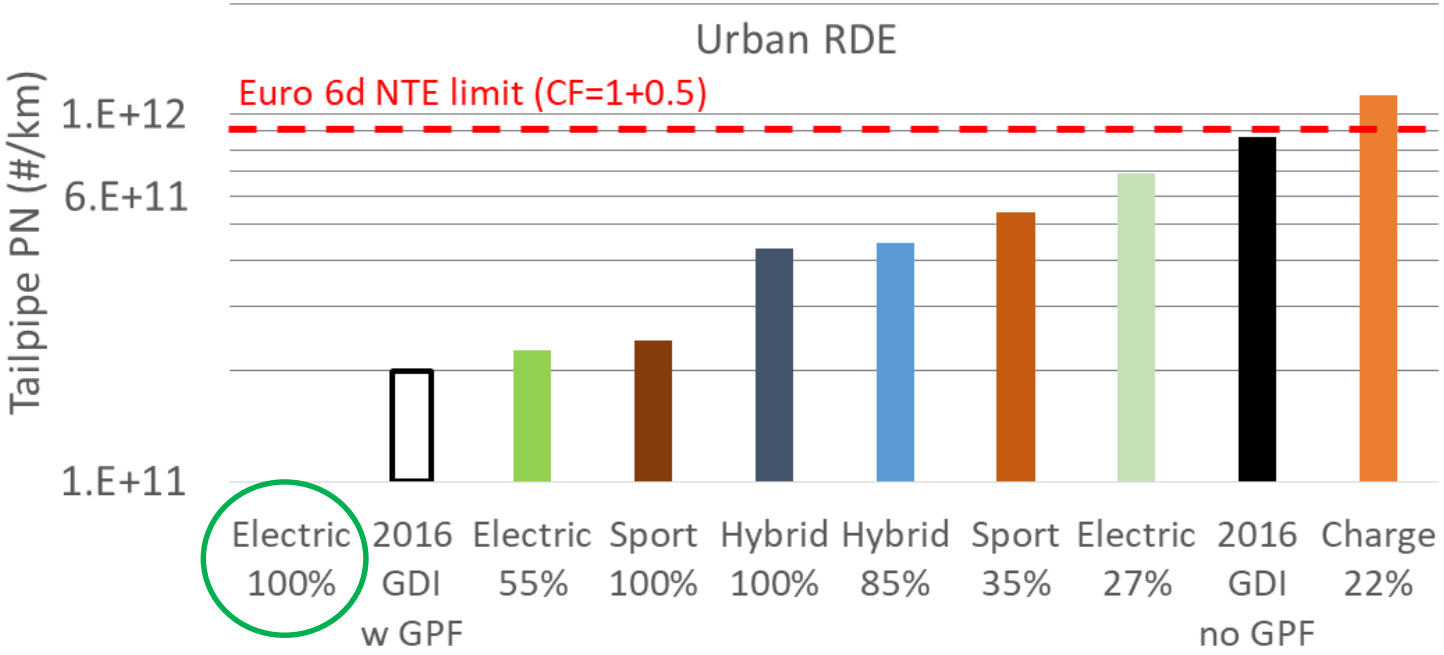
SOC	Electric	Hybrid	Charge	Sport
100%	1x	1x	-	1x
85%		1x		
55%	1x			
25%	1x		1x	1x



- Comparison to WLTP definitions
  - Charge depleting: Electric – 100%
  - Charge sustaining: Hybrid – 85% and Electric – 25%

Most urban PN emissions higher than GDI with GPF

Results presented at Integer Emissions Summit 2017 (Dresden)



- Electric mode – full battery: urban part entirely run electric → zero urban tailpipe PN emissions
- Charge mode – empty battery: high power demand on ICE → highest PN emissions

ICE: Internal Combustion Engine

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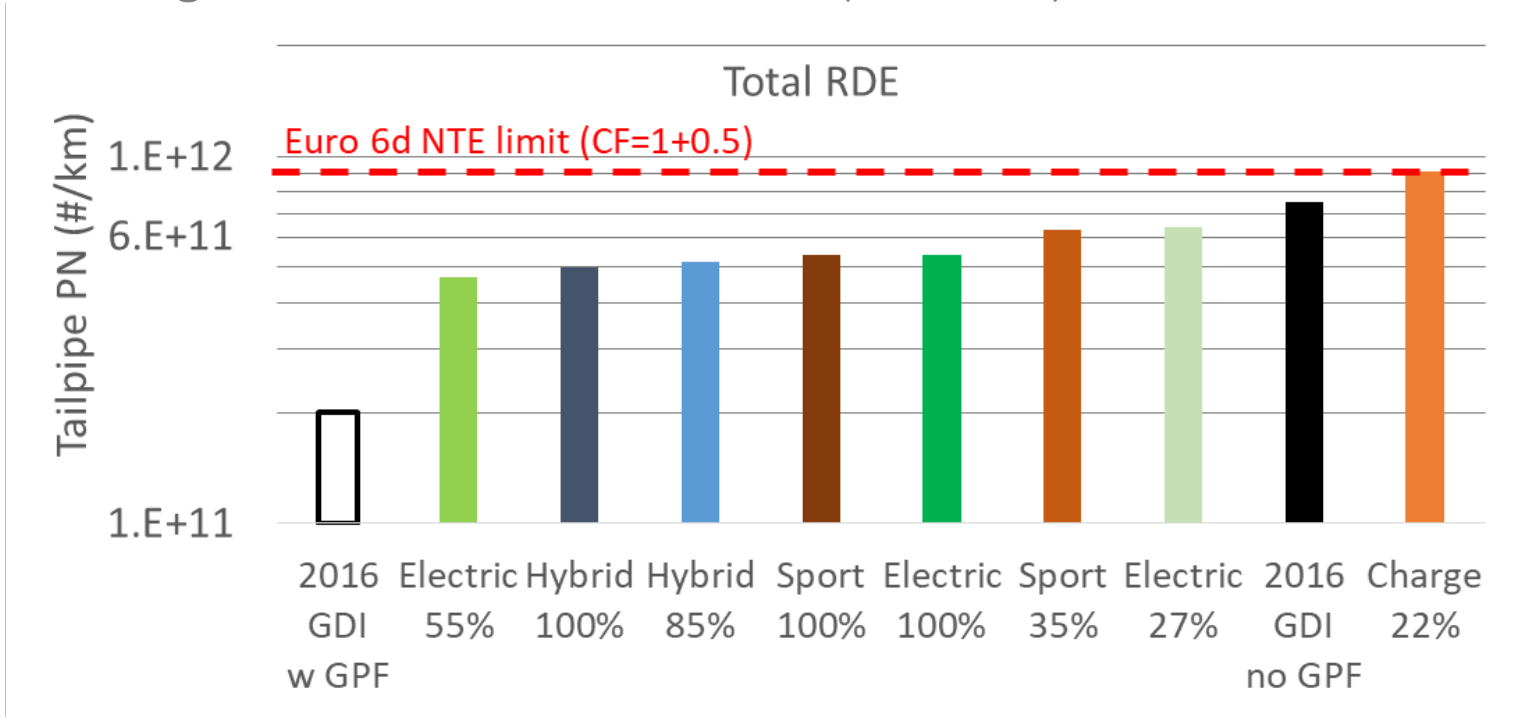
All total RDE PN emissions higher than GDI with GPF

Results presented at Integer Emissions Summit 2017 (Dresden)



- Electric mode – full battery: ICE operates for 2/3 of trip, but PN emissions as high as other modes
- Charge mode – empty battery: high power demand on ICE → highest PN emissions

ICE: Internal Combustion Engine

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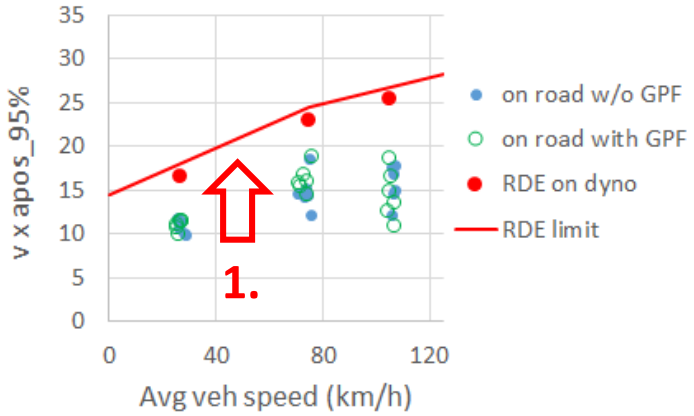
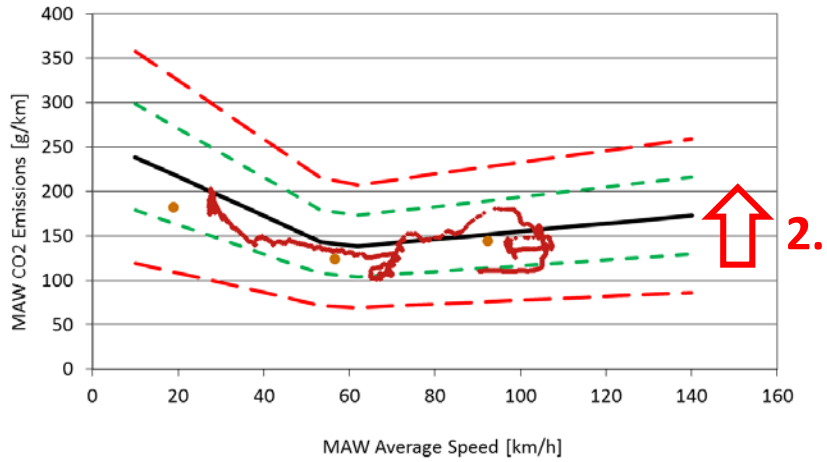
Investigate going to the boundaries of RDE

Severitized RDE (SRDE) methodology developed on chassis dyno

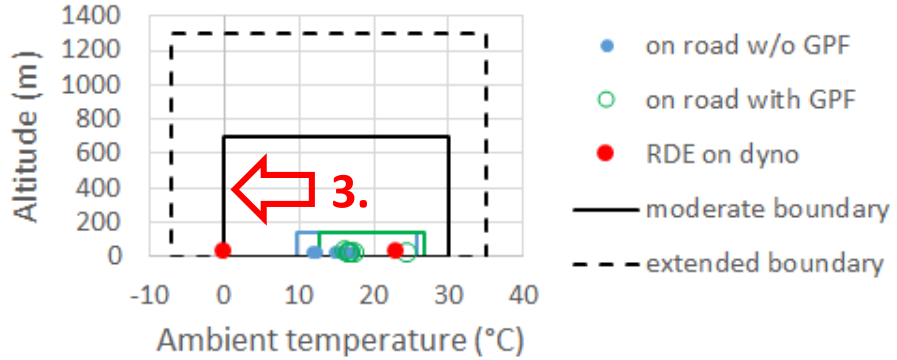
1. Change accelerations



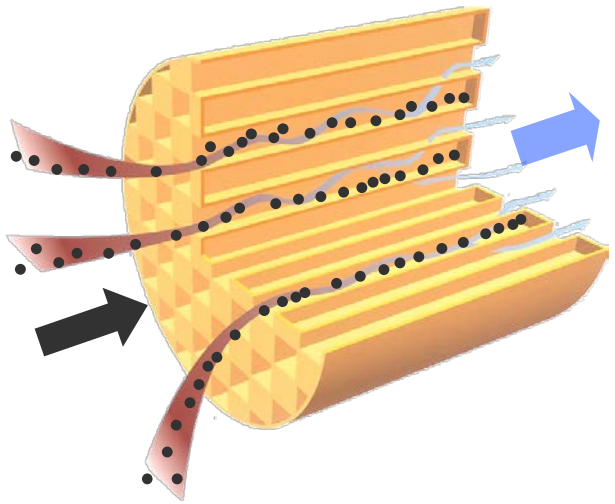
2. Change dyno load

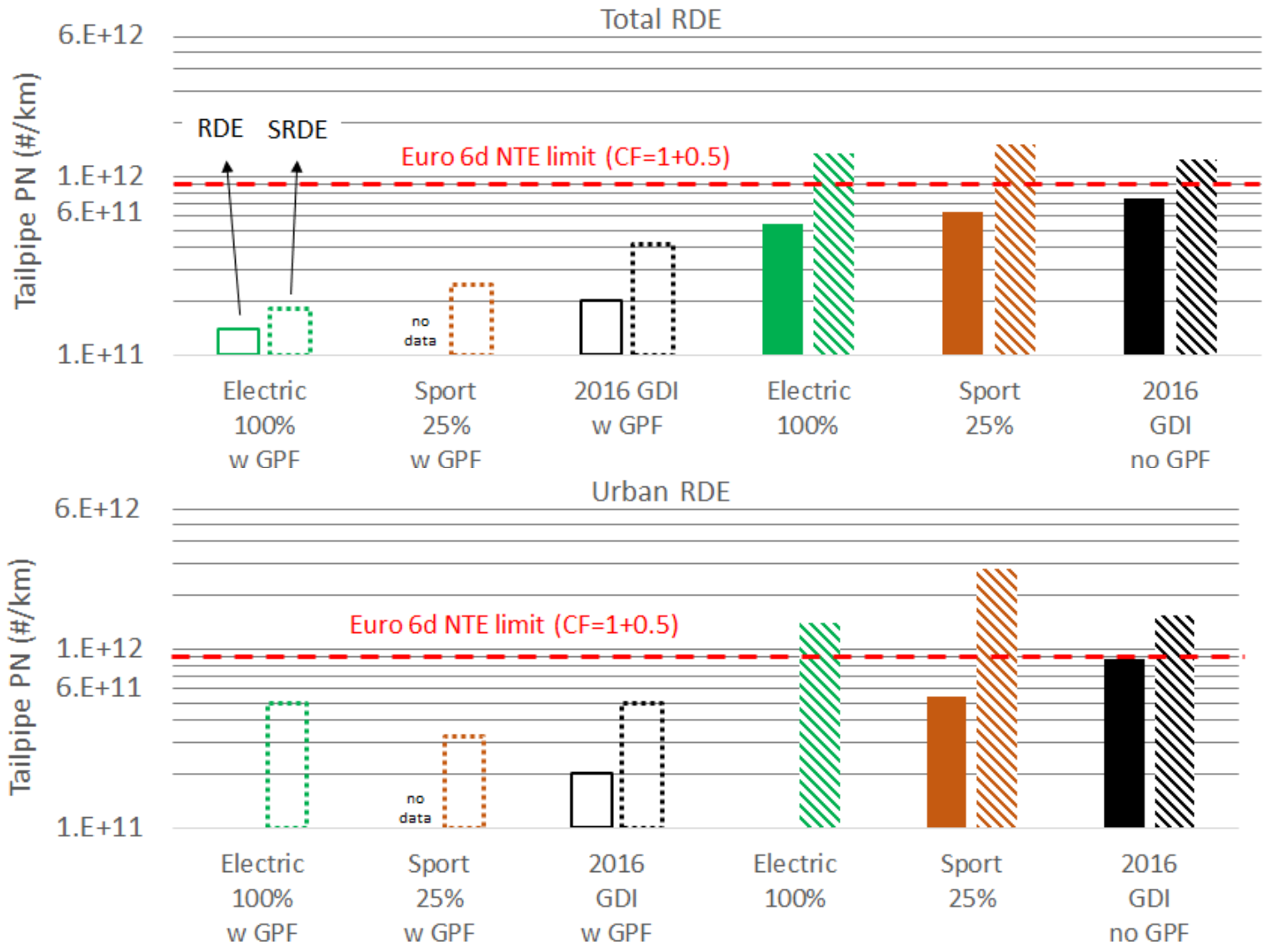


3. Change ambient temperature



Severitized RDE (SRDE) shows need for GPF to meet NTE PN limit





Note: 1.6 factor for extended ambient temperature included where applicable

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Conclusions

- A new era for vehicle emissions control started 1/9/2017 with RDE and WLTP introduction.
- Emissions control technologies evolved for RDE compliance up to boundary conditions.
- On-road emissions performance of latest diesel and gasoline vehicles are well within standards.

THANK YOU!

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