

Expected Light Duty Vehicle Emissions from Final Stages of Euro 6



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Contents

- What is Euro 6 and what are the stages of its introduction?
- What are the challenges of complying with Euro 6 including Real Driving Emissions?
- What actual tailpipe emissions do we expect?

Euro 6 diesel emissions limits are (nearly) comparable to gasoline for key emissions

Selected Euro 6 Emissions Limits (Passenger Car)

Emissions		Gasoline (Positive Ignition)	Diesel (Compression Ignition)
Oxides of Nitrogen	NO _x (mg/km)	60	80
Particulate Mass	PM (mg/km)	4.5 [GDI only]	4.5
Particle Number	PN (#/km)	6 x 10 ¹¹	6 x 10 ¹¹

Euro 6 legislation aims to reduce the difference between legislated emissions levels and real world levels

- Euro 6 tailpipe emissions legislation is being introduced in stages to 2021

Implementation Dates for Passenger Cars

Emission Standard	Test Cycle	Real Driving Emissions	Today																																																																																			
			2015			2016			2017			2018			2019			2020			2021																																																																	
			J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Euro 6b	NEDC	Voluntary Monitoring	[Grey shading]																																																																																			
			[Blue shading]																																																																																			
Euro 6c	WLTC	Voluntary Monitoring	[Grey shading]																																																																																			
			[Blue shading]																																																																																			
Euro 6d-temp	WLTC	Temporary CF = 2.1 (1.5 for PN)	[Grey shading]																																																																																			
			[Blue shading]																																																																																			
Euro 6d	WLTC	Final CF ≤1.5	[Grey shading]																																																																																			
			[Blue shading]																																																																																			

Key:

Type Approval

New Vehicles

NEDC : New European Driving Cycle;

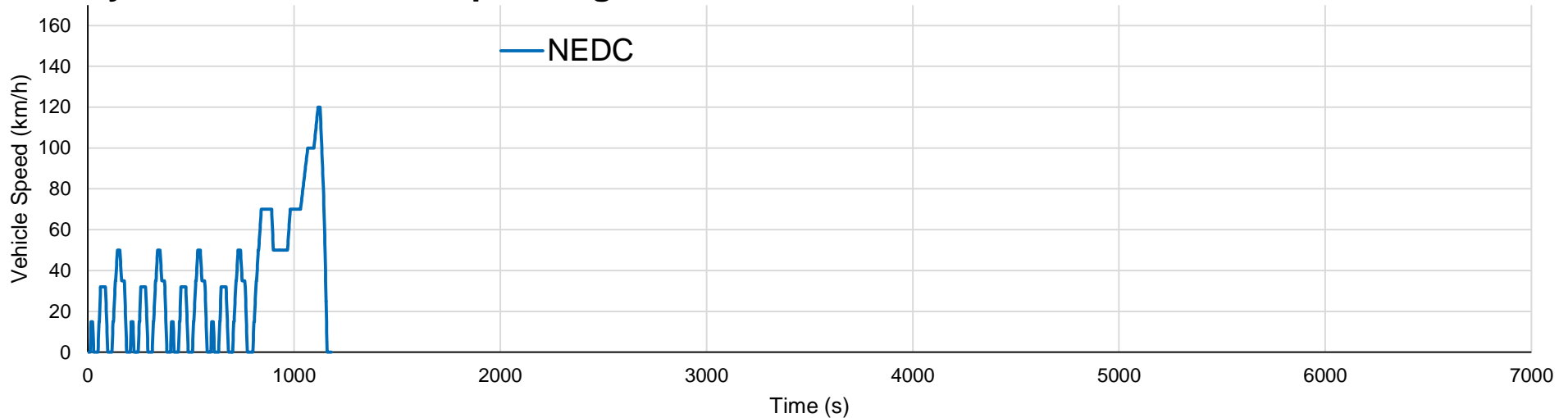
WLTC : Worldwide harmonized Light vehicles Test Cycle

Conformity Factor : The maximum ratio between the legislated emissions limit under laboratory testing and those measured in real driving conditions



The New European Drive Cycle (NEDC), used since the 1990s, requires relatively light load and low speed engine operating conditions

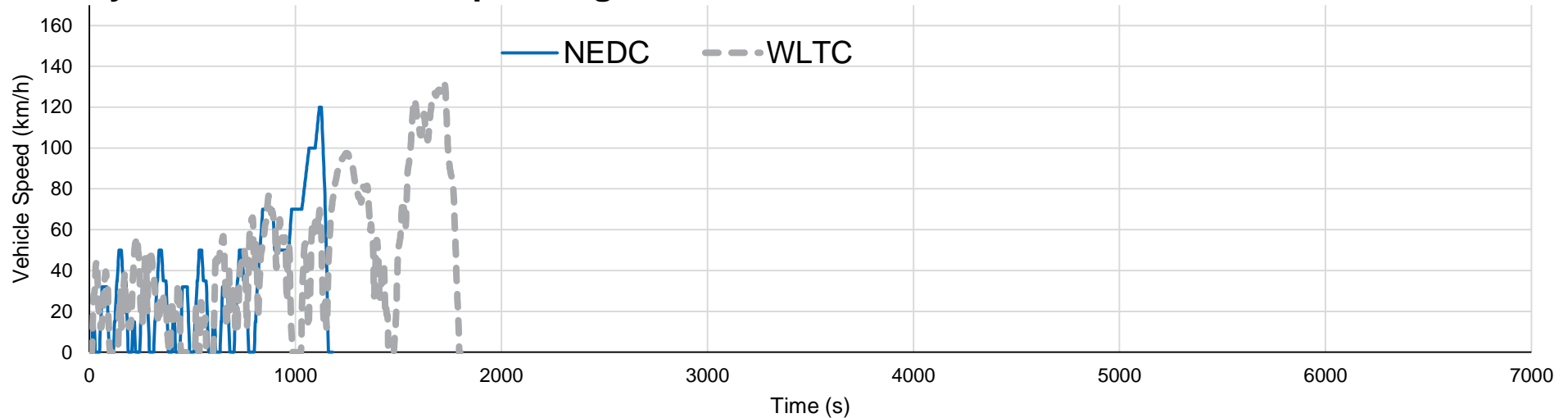
Drive cycles used for Euro 6 passenger cars



Drive Cycle	Duration (s)	Average Speed (km/h)	Maximum Speed (km/h)	Maximum Acceleration (m/s ²)
NEDC	1180	33.3	120.0	1.04

The Worldwide harmonized Light vehicles Test Cycle (WLTC) is more representative of real world driving conditions than NEDC

Drive cycles used for Euro 6 passenger cars

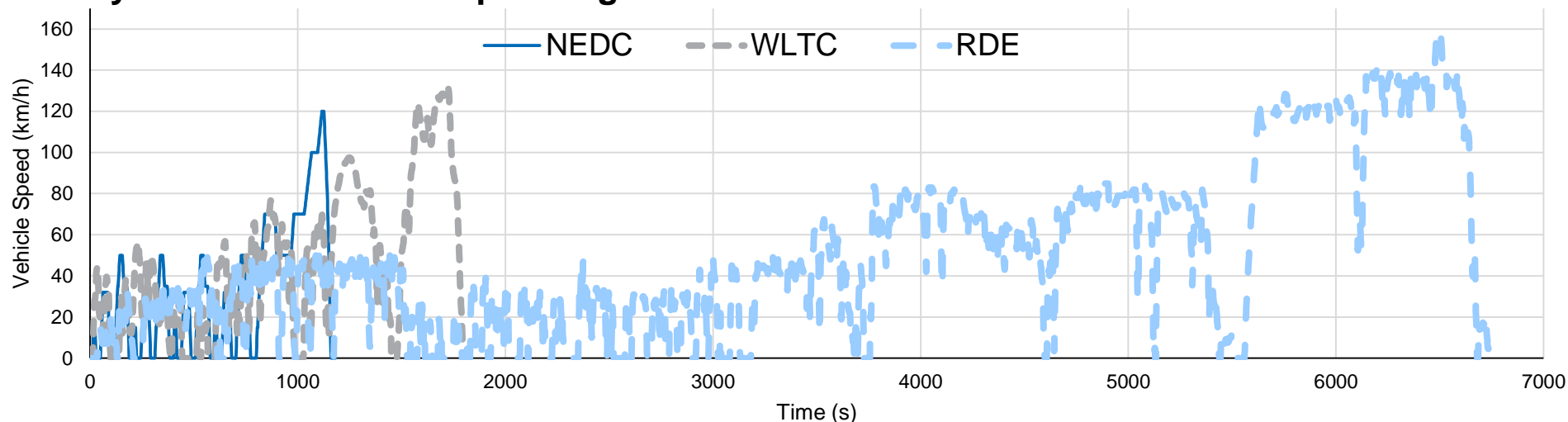


Drive Cycle	Duration (s)	Average Speed (km/h)	Maximum Speed (km/h)	Maximum Acceleration (m/s ²)
NEDC	1180	33.3	120.0	1.04
WLTC	1800	46.5	131.3	1.67

- RDE and WLTC have
 - Increased number & magnitude of accelerations
 - Higher maximum speeds

An RDE cycle is complementary to the WLTC, testing vehicles on real roads under realistic driving conditions

Drive cycles used for Euro 6 passenger cars



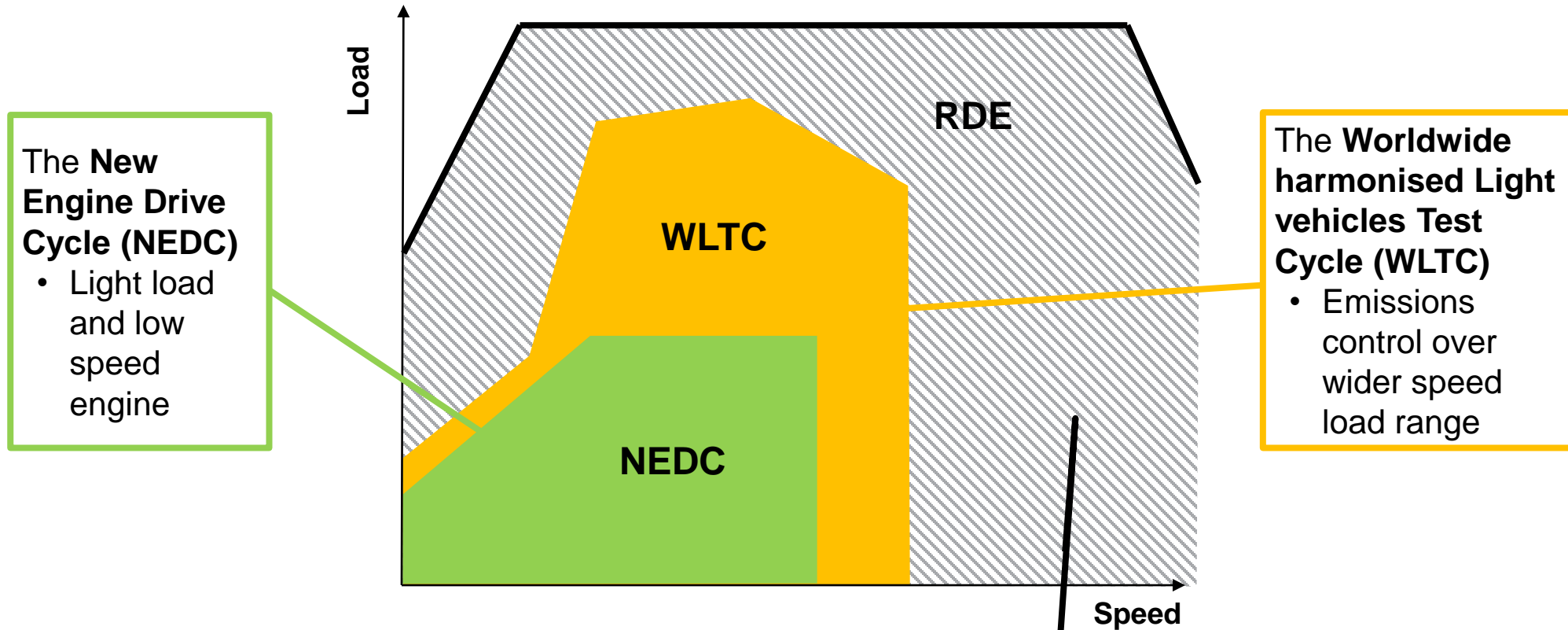
Drive Cycle	Duration (s)	Average Speed (km/h)	Maximum Speed (km/h)	Maximum Acceleration (m/s ²)
NEDC	1180	33.3	120.0	1.04
WLTC	1800	46.5	131.3	1.67
RDE	6769	49.7	159.6	4.17

- RDE and WLTC have
 - Increased number & magnitude of accelerations
 - Higher maximum speeds

- Environmental conditions
 - “Moderate RDE” :
0°C to 30°C, 0 to 700m altitude
Representative of most normal driving
 - “Extended RDE” :
-7°C to 35°C and 1300m altitude

Ricardo's RDE cycle is an example of a valid high speed and high dynamic RDE test

The implementation of WLTC and RDE from 2017 will extend the engine speed and load conditions at which emissions are regulated



The New Engine Drive Cycle (NEDC)

- Light load and low speed engine

The Worldwide harmonised Light vehicles Test Cycle (WLTC)

- Emissions control over wider speed load range

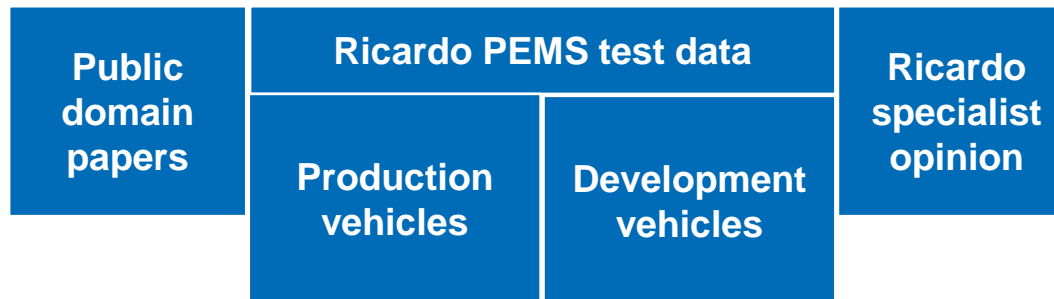


Real Driving Emissions (RDE)

- Measured on-road using Portable Emissions Measurement System (PEMS)
- In real road and traffic conditions

Real world emissions data from public domain sources have been combined with Ricardo test data from RDE compliant testing

- This study has considered emissions under real world driving conditions from a variety of sources



- Most published domain data refers to Euro 6b vehicles
- Ricardo has tested production vehicles certified to Euro 6b and 6c, or under development to Euro 6d, fitted with combinations of NOx aftertreatment control:
 - Exhaust Gas Recirculation (EGR)
 - Lean NOx Trap (LNT)
 - Selective Catalytic Reduction (SCR)

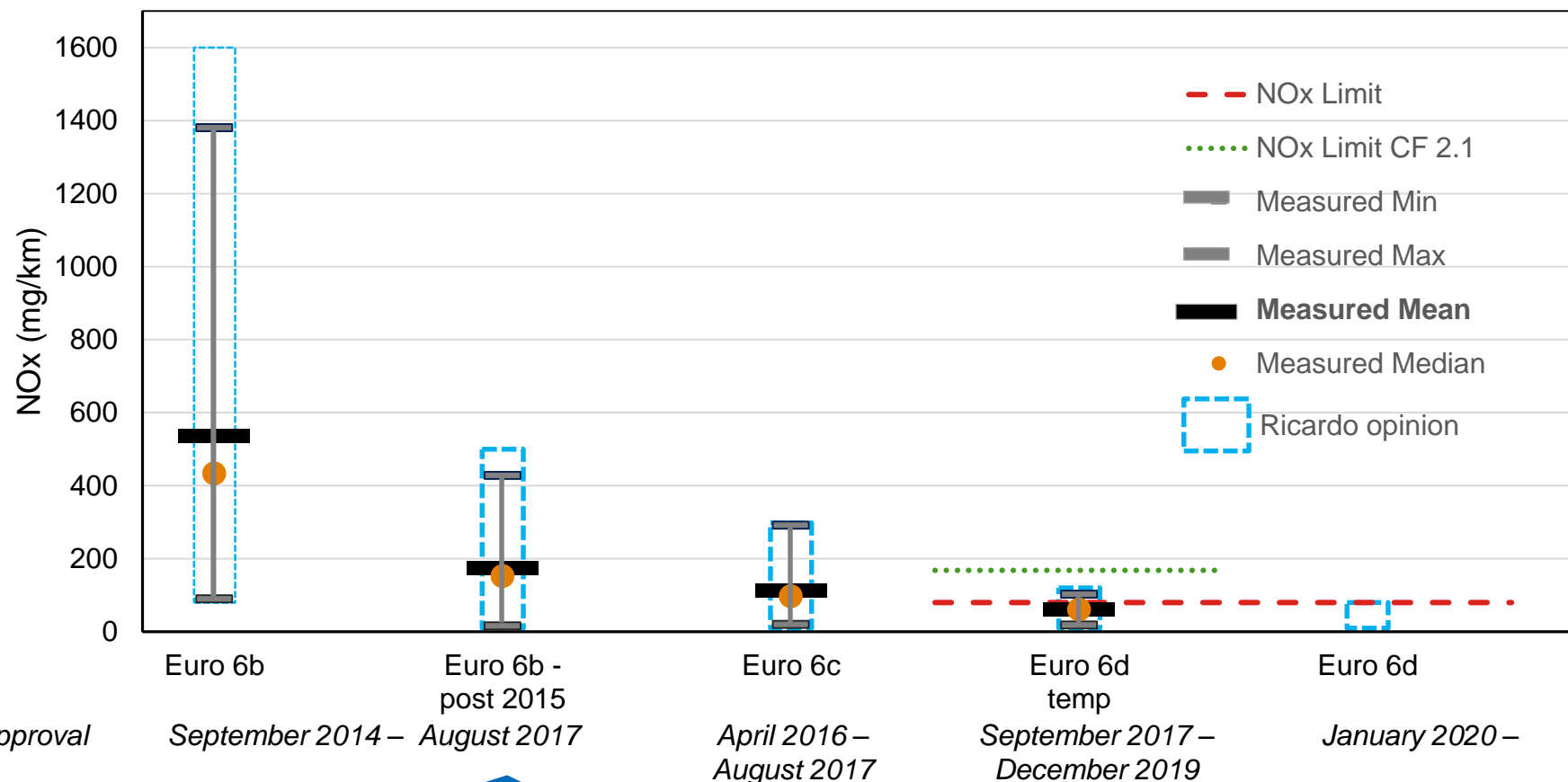


- Vehicles tested by Ricardo over a variety of RDE compliant cycles



The stages of Euro 6 introduction show a progressive reduction in real world driving diesel NOx emissions

Diesel NOx under real world test conditions

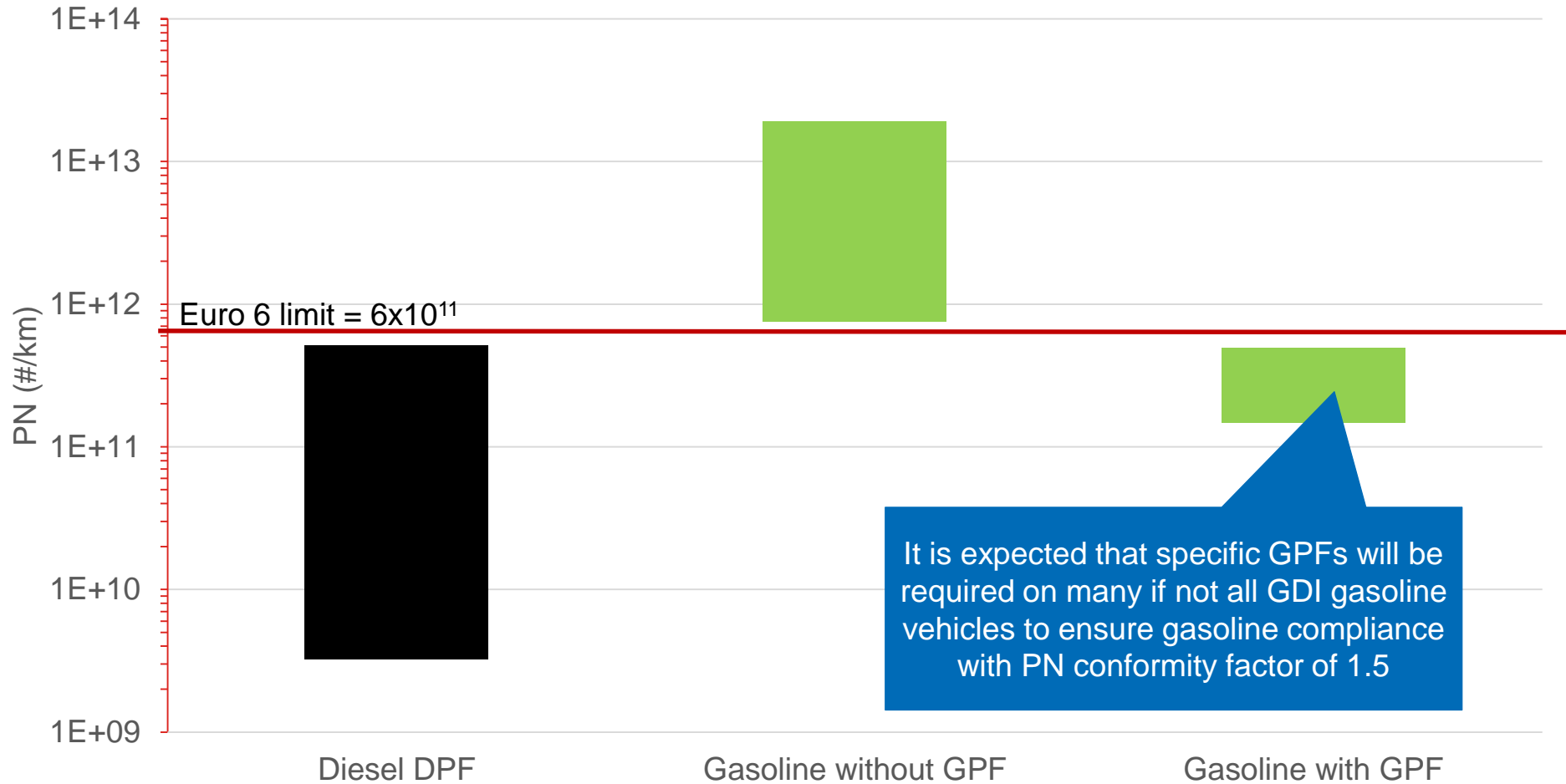


Post 2015 vehicles which meet Euro 6 NOx levels under at least one real driving test cycle



Diesel Particle Number complies comfortably with the limit value. Gasoline technologies also expected to require particle filters

Particle Number on RDE Compliant Cycle from Euro 6 Vehicles





Future Euro 6 regulations will deliver substantial reductions in real world NOx emissions for diesel vehicles – comparable to gasoline

- Although there are a limited number of Euro 6c and 6d-temp ready vehicles to date, the evidence suggests that the technical solutions applied to Euro 6d will achieve regulated conformity factors under real world driving and moderate RDE conditions
- The evidence indicates that vehicle averaged real world diesel NOx emissions are substantially reduced by successive levels of Euro 6 legislation, from Euro 6b to Euro 6d
- Specific and careful configuration and calibration of the emissions control systems is required for real world diesel NOx control
- Real world diesel PN data for Euro 6c and 6d vehicles are within the Euro 6 conformity factor limits
- A GPF is likely to be required for gasoline vehicles to meet Euro 6d PN emissions requirements on all RDE cycles