How clean are current diesel vehicles

Content

The debate about internal combustion engines, diesel engines in particular, is relentless. The stakes are high: from stricter emission limits under the future Euro 7 emissions standard to a prohibition of diesel engines altogether everything is on the table. But how clean are current diesel vehicles really? ADAC, the German automobile club, presents the results from the current Green New Car Assessment Programme (Green NCAP) and ADAC Ecotest.

Diesel models in the Green NCAP test

The Green NCAP test procedure consists of two elements: **exhaust gas testing in the lab** and **exhaust gas testing on the road** (real driving emissions or RDE).

The procedure is based on the current Worldwide Harmonized Light-Duty Test Procedure (WLTP) and its new Worldwide Harmonized Light-Duty Test Cycle (WLTC). The latter is designated WLTC+ in Green NCAP terminology. The '+' is meant to signify that the **tests are exceeding the legal requirements for vehicle type approval**. Unlike for type approval, the tests are conducted at lower ambient temperature (14°C vs. 23°C). In addition, the BAB130 motorway cycle adopted into the Green NCAP test procedure from the ADAC Ecotest and the full-throttle acceleration it includes is an extreme challenge for the vehicles' exhaust gas aftertreatment systems. Another special challenge is the WLTC cycle run at -7°C – one that only the really robust exhaust gas aftertreatment systems are equal to.

The RDE tests conducted with mobile test units (PEMS+) **also exceed the legal requirements.** The test portfolio includes test runs under high payload, dynamic driving, a lap run as efficiently as possible and a simulated ride in congested traffic with plenty of stop-go phases that is typical of congested urban traffic.

To make sure that the vehicles and their exhaust gas aftertreatment systems **are really running clean at any operating point** Green NCAP aims at covering as many load points of the engine map in its emission tests. To this end, the full-throttle curve of each drive unit is established.

For further information on Green NCAP, go to www.adac.de/greenncap. (in German)

Current lab test results

Within the framework of the EU-sponsored Green Vehicle Index (GVI) project, Green NCAP **analysed the exhaust gas performance of the 17 best-selling diesel models on the European market from various makers and vehicle segments in detail**. The **results** obtained **are representative for new vehicles approved for sale in Europe since 2018**.

The **tests showed average NOx emissions of 52mg/km across all diesel models tested**, all of them homologated to Euro 6d or Euro 6d-TEMP. Both in the cold and warm engine tests at 14°C and in the motorway cycle, the average NOx values (60mg/km) were below the current Euro 6 NOx limit of 80mg/km. **Only cold-starting at -7°C still results in values exceeding the limit.**

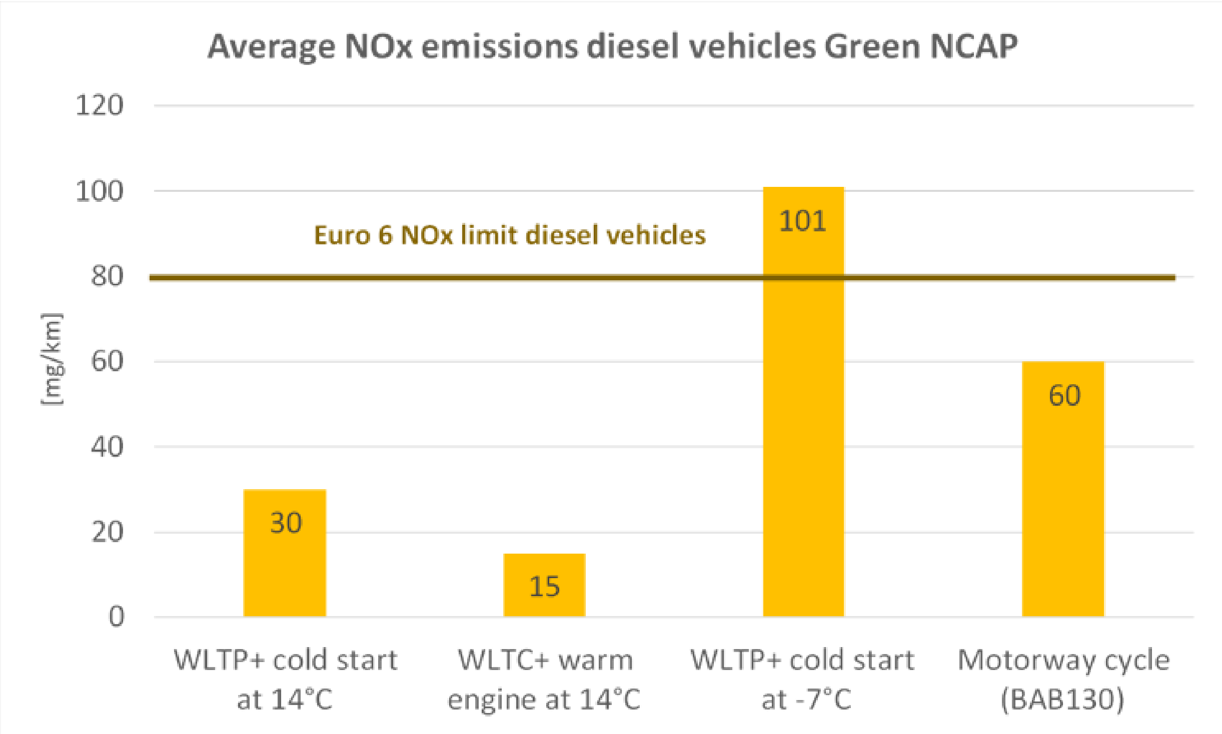

Figure 1: Avg. NOx emissions of Euro 6d-TEMP/Euro 6d diesel models in the Green NCAP lab test

As the results of the NOx measurements show, **low nitrogen oxide emission levels depend less on vehicle size or engine power than on the built-in emission control technology. SCR catalytic converters are the state of the art in diesel vehicles nowadays.** However, **an SCR catalytic converter per se is not sufficient** to effectively reduce NOx emissions in whatever driving conditions. Although simple SCR systems ensure low levels in the type approval cycles, they reach their limits at high exhaust gas flow rates, e.g. in the motorway cycle and/or at low temperatures. High exhaust gas flow rates require large SCR catalytic converters, low ambient temperatures as efficient a warm-up strategy as possible to make the SCR operational quickly. This can be achieved by mounting the catalytic converter close to the engine or using small-size units.

A **solution may be to use twin systems**, as e.g. in the BMW X1, which **combines an NOx trap catalytic converter (lean NOx trap, LNT) that can be employed directly at low temperatures and an SCR system for higher exhaust gas flows**. Alternatively, a **combination of two in-line SCR catalytic converters**, as e.g. in the Škoda Octavia 2.0 TDI, can be used: **an SCR catalytic converter close to the engine that heats up quickly and a larger one that handles higher exhaust gas flow rates.**

Models with notable NOx emission levels at low temperatures include the Peugeot 3008 1.5 BlueHDI 130, Ford Kuga 2.0 EcoBlue, Mercedes Benz A Class 180d (Euro6d-TEMP variant) and Kia Sportage 1.6 CRDi 136 AWD. It seems that in these models, the warm-up strategy for the catalytic converter is not optimised. This means that nitrogen oxides are not being reduced effectively during the first minutes after cold-starting at -7°C.

The models noted in the motorway cycle include the VW Passat 2.0 TDI and – again – the Peugeot 3008 1.5 BlueHDI 130. It appears that these exhaust treatment systems do not cope with the high exhaust gas flow rates generated when accelerating full throttle.

The **detailed results of all diesel models in the Green NCAP lab test** are shown in Table 1 (sorted by ascending average NOx emissions in the Green NCAP test).

Table 1: NOx emissions – detailed results of all diesel models in the Green NCAP lab test

Model	Exhaust and emission control system	Engine power (kW)	NOx Green NCAP (mg/km)	NOx WLTP+ cold start at 14°C (mg/km)	NOx WLTP+ warm at 14°C (mg/km)	NOx BAB motorway (mg/km)	NOx WLTC+ cold start at -7°C (mg/km)
BMW X1 18d xdrive Automatic	LNT + SCR	110	12	12	2	16	19
Mercedes Benz C Class 220d 9G-T	SCR	143	17	20	4	1	45
BMW 3 Series 320d	LNT + SCR	140	18	10	11	16	35
Volvo XC60 D4	SCR	145	20	22	4	5	48
Mercedes Benz V Class 250d 9G-T	SCR	140	21	24	5	13	41
Škoda Octavia 2.0 TDI Estate	Dual SCR	85	21	26	4	2	54
SEAT Leon 2.0 TDI	Dual SCR	110	27	18	14	29	45
Opel/Vauxhall Zafira Life S 2.0	SCR	130	40	28	4	63	63
Jeep Renegade 1.6 Multijet	SCR	88	46	49	39	7	91
Land Rover Discovery Sport D180	SCR	132	51	37	29	42	94
Dacia Duster Blue dCi 115 2WD	SCR	85	51	42	19	66	77
Ford Kuga 2.0 EcoBlue Hybrid	SCR	110	52	37	5	8	159
Volkswagen T6.1 Multivan 2.0 TDI	SCR	146	62	57	30	35	128
Volkswagen Passat 2.0 TDI DSG	SCR	140	76	26	15	156	105
Peugeot 3008 1.5 BlueHDI 130	SCR	96	92	44	24	148	152
Mercedes Benz A Class 180d	SCR	85	110	28	8	191	212
Kia Sportage 1.6 CRDi 136 AWD	LNT + SCR	100	160	33	32	225	352
	Average		**52**	**30**	**15**	**60**	**101**

Current road test results (RDE)

Tests conducted with mobile exhaust gas testing units (PEMS+) resulted in an average NOx value of 39mg/km across all tested Euro 6d-TEMP/Euro 6d diesel models. However, the **average NOx values in the individual test cycles are also below the current Euro 6 NOx limit of 80mg/km**. This is true not only of cold and warm start but also of higher loads, e.g. dynamic driving in the PEMS+ Sport cycle.

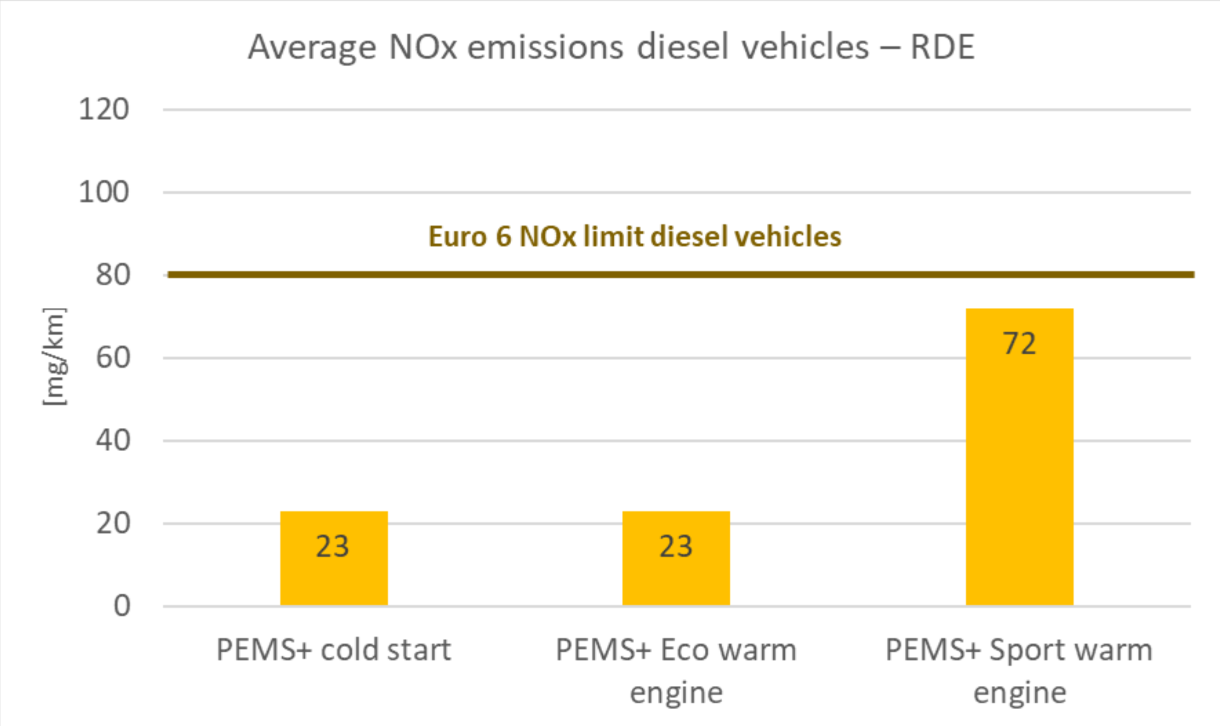

Figure 2: Avg. NOx emissions of Euro 6d-TEMP/Euro 6d diesel models in the Green NCAP road test

Models with increased NOx emission levels at higher loads (PEMS+ warm Sport) included the Dacia Duster Blue dCi 115 2WD, Jeep Renegade 1.6 Multijet, Kia Sportage 1.6 CRDi 136 AWD and Ford Kuga 2.0 EcoBlue Hybrid.

The **detailed results of all diesel models in the Green NCAP road test (RDE)** are shown in Table 2 (sorted by ascending average NOx emissions in the Green NCAP test).

Table 2: NOx emissions – detailed results of all diesel models in the Green NCAP (RDE)

Model	Engine power (kW)	NOx Green NCAP (mg/km)	NOx PEMS+ cold start (mg/km)	NOx PEMS+ warm Eco (mg/km)	NOx PEMS+ warm Sport (mg/km)
Volvo XC60 D4	145	9	9	3	15
Mercedes Benz V Class 250d 9G-T	140	10	13	5	12
BMW X1 18d xdrive Automatic	110	15	9	18	18
Škoda Octavia 2.0 TDI Estate	85	16	14	19	15
Mercedes Benz C Class 220d 9G-T	143	17	8	12	32
BMW 3 Series 320d	140	24	10	21	42
SEAT Leon 2.0 TDI	110	25	7	14	53
Opel/Vauxhall Zafira Life S 2.0	130	28	21	34	29
Mercedes Benz A Class 180d	85	28	29	16	39
Land Rover Discovery Sport D180	132	34	21	24	56
Volkswagen T6.1 Multivan 2.0 TDI	146	34	38	32	33
Peugeot 3008 1.5 BlueHDI 130	96	46	35	34	71
Volkswagen Passat 2.0 TDI DSG	140	48	31	18	94
Dacia Duster Blue dCi 115 2WD	85	65	44	38	112
Jeep Renegade 1.6 Multijet	88	67	38	47	117
Kia Sportage 1.6 CRDi 136 AWD	100	84	47	27	177
Ford Kuga 2.0 EcoBlue Hybrid	110	116	10	34	303
	Average	**39**	**23**	**23**	**72**

Diesel cars in the ADAC Ecotest

The ADAC Ecotest also **exceeds the vehicle type approval requirements**. The test measurements are taken in the new Worldwide Harmonized Light Vehicles Test Cycle (WLTC, Version 5.3) and the ADAC motorway cycle. The WLTC consists of a cold-start and a warm-start test. In all three test cycles, the day-time running lights (or low beams) and the air-conditioning are on and payload is 200kg.

Vehicles achieving **at least 4 Ecotest stars in the lab test, are also tested on the road (RDE)** to ensure that the emission levels remain as low under RDE conditions on the road as they were in the lab.

For further information on the ADAC Ecotest, go to www.adac.de/ecotest. (in German)

Current results

The ADAC Ecotest results confirm the Green NCAP test findings.

The current ADAC Ecotest statistics show **an average NOx value of 49mg/km across all Euro 6d-TEMP diesel models tested (85 vehicles) and 34mg/km across all Euro 6d diesel models tested (22 vehicles)**. **The transition to the Euro 6d emissions standard seems to have resulted in a further improvement of nitrogen oxide emissions values.** This is true not only of the average Ecotest value but also of the individual test cycles, i.e. WLTC cold start at 23°C, WLTC warm engine at 23°C and the ADAC motorway cycle. Notable improvement was seen in the **ADAC motorway cycle: the average value of 77mg/km is now below the current Euro 6 NOx limit** of 80 mg/km.

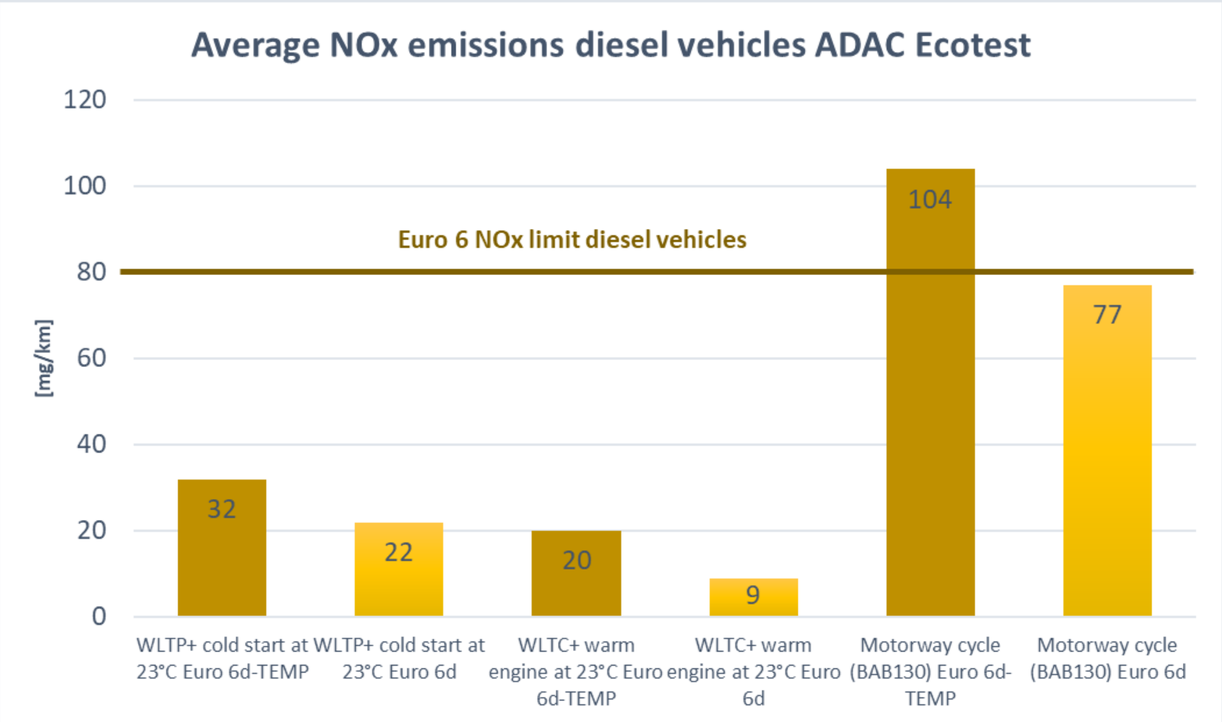

Figure 3: Avg. NOx emissions of Euro 6d-TEMP/Euro 6d diesel models in the ADAC Ecotest

Further reductions in NOx emissions in anticipation of the transition to the Euro 6d emissions standard are owed notably to improved – more responsive and effective – SCR systems, the combination of NOx trap catalytic converters and SCR systems and the new twin dosing technology (twin SCR cat). The VW group are using their new Twin-Dosing SCR system in most of their Euro 6d diesel models.

Among the ADAC Ecotest vehicles, only the Hyundai Santa Fe SEVEN 2.2 CRDi Signature 4WD DCT (139 mg/km) and the KIA Sorento 2.2 CRDi Platinum AWD DCT8 (148 mg/km) exceed the current Euro 6 NOx limit due to their high NOx emissions in the ADAC motorway cycle. The two vehicles are based on the same platform and use the same engine and transmission technology. The emission control technology used in these vehicles seems to be unable to cope with the increased exhaust gas flow rates generated in full-throttle acceleration, hence failing to reduce NOx emissions sufficiently.

The **detailed results of all 22 Euro 6d diesel models in the ADAC Ecotest** are shown in Table 3 (sorted by ascending average NOx emissions in the ADAC Ecotest). Since Euro 6d models were not available from all manufacturers, the up-to-date table shows only few manufacturers. Other models and manufacturers are routinely added and investigated in the framework of the Ecotest. Results are published at adac.de/ecotest (in German).

Table 3: NOx emissions – detailed results of all diesel models in ADAC Ecotest

Model	Emissions standard	Engine power (kW)	NOx Ecotest (mg/km)	NOx WLTP cold (mg/km)	NOx WLTC warm (mg/km)	NOx BAB motorway (mg/km)
Mercedes GLA 200 d Progressive 8-speed DCT	Euro 6d-ISC (WLTP)	110	6	15	2	1
Mercedes GLB 220 d AMG Line 4MATIC 8-speed DCT	Euro 6d-ISC (WLTP)	140	8	12	4	8
BMW X1 sDrive18d xLine Steptronic	Euro 6d-ISC-FCM (WLTP)	110	8	7	5	11
Mercedes B 220 d Progressive 8-speed DCT	Euro 6d (WLTP)	140	9	21	4	1
Mercedes GLC 220 d 4MATIC 9G-TRONIC	Euro 6d-ISC (WLTP)	143	9	17	7	1
Mercedes GLE Coupé 400 d AMG Line 4MATIC 9G-TRONIC	Euro 6d-ISC (WLTP)	243	9	17	6	2
Mercedes E 400 d T-Model Exclusive 4MATIC 9G-TRONIC	Euro 6d-ISC-FCM (WLTP)	243	9	18	5	3
Opel/Vauxhall Insignia Sports Tourer 2.0 Diesel Ultimate Automatic	Euro 6d-ISC-FCM (WLTP)	128	11	19	10	2
KIA Ceed 1.6 CRDi Spirit	Euro 6d (WLTP)	100	14	17	12	11
VW Golf Variant 2.0 TDI SCR R-Line DSG	Euro 6d-ISC-FCM (WLTP)	110	14	17	3	24
VW Tiguan 2.0 TDI SCR Elegance 4MOTION DSG	Euro 6d-ISC-FCM (WLTP)	110	14	19	2	23
Opel/Vauxhall Astra Sports Tourer 1.5 Diesel Elegance Automatic	Euro 6d-ISC (WLTP)	90	16	21	7	22
BMW 320d Touring Steptronic	Euro 6d-ISC-FCM (WLTP)	140	18	18	6	31
Peugeot 508 2.0 BlueHDi 160 Allure EAT8	Euro 6d (WLTP)	120	19	27	20	9
Peugeot 5008 2.0 BlueHDi 180 Allure Pack EAT8	Euro 6d-ISC (WLTP)	133	26	29	25	23
Peugeot 3008 1.5 BlueHDi 130 Allure Pack EAT8	Euro 6d-ISC-FCM (WLTP)	96	26	51	18	5
VW Golf GTD DSG	Euro 6d-ISC-FCM (WLTP)	147	30	17	4	75
VW Tiguan 2.0 TDI SCR R-Line 4MOTION DSG	Euro 6d-ISC-FCM (WLTP)	147	44	24	7	109
Hyundai Tucson 1.6 CRDi 48V Hybrid Prime AWD DCT (BAHV)	Euro 6d-ISC-FCM (WLTP)	100	47	21	3	129
KIA Sportage 2.0 CRDi 185 Eco-Dynamics+ GT-Line AWD Automatic	Euro 6d (WLTP)	136	58	25	23	138
Hyundai Santa Fe SEVEN 2.2 CRDi Signature 4WD DCT	Euro 6d-ISC-FCM (WLTP)	148	139	32	10	414
KIA Sorento 2.2 CRDi Platinum AWD DCT8	Euro 6d-ISC-FCM (WLTP)	148	212	29	25	643
	Average		**34**	**22**	**9**	**77**

Diesel models under 'extreme load'

The ADAC motorway cycle with its powerful acceleration element is a great challenge for the tested vehicles. This additional test developed by ADAC is designed to show whether the exhaust emission control system also performs well outside the legally prescribed test. The ADAC motorway cycle reflects the fact that in most European countries the motorway speed limit is 130kph. In addition, it also includes full-throttle acceleration. The ADAC motorway cycle consists of a short preconditioning phase, which will not be included in the measurement, and two identical test phases.

In the ADAC Ecotest, the motorway cycle is run with the engine at operating temperature, which is applicable to most real use cases. To test the effectiveness of state-of-the-art diesel exhaust gas control systems, **ADAC has submitted two current diesel models to the extreme test as exemplary cases**: what happens if you **drive onto a motorway at full throttle with a cold engine**? This scenario is **not very typical of the everyday usage patterns**. It could be imagined though after overnighting in a motorway service station. Since this is very stressful for the engine (full-throttle acceleration with a cold engine), we would recommend rather not to do this. The tests were conducted with a VW Golf 2.0 TDI and a Mercedes E 400d. Both are Euro 6 compliant and equipped with a twin SCR catalytic converter system.

The result is surprising: Both vehicles prove not to be big-time polluters, even in the extreme conditions of this test. In the first phase of the motorway cycle, the NOx emissions are somewhat elevated, however clearly below 200mg/km. This may sound like a lot but is a more than respectable value under the test conditions. In this test, the nitrogen oxide emissions of older diesel vehicles would have been exponentially higher. Quite remarkably, the SCR systems were fully effective in just a short time so that the emissions in the second phase of the motorway cycle were on the same level as in the warm engine test. **This shows how quickly state-of-the-art SCR systems respond and work effectively.**

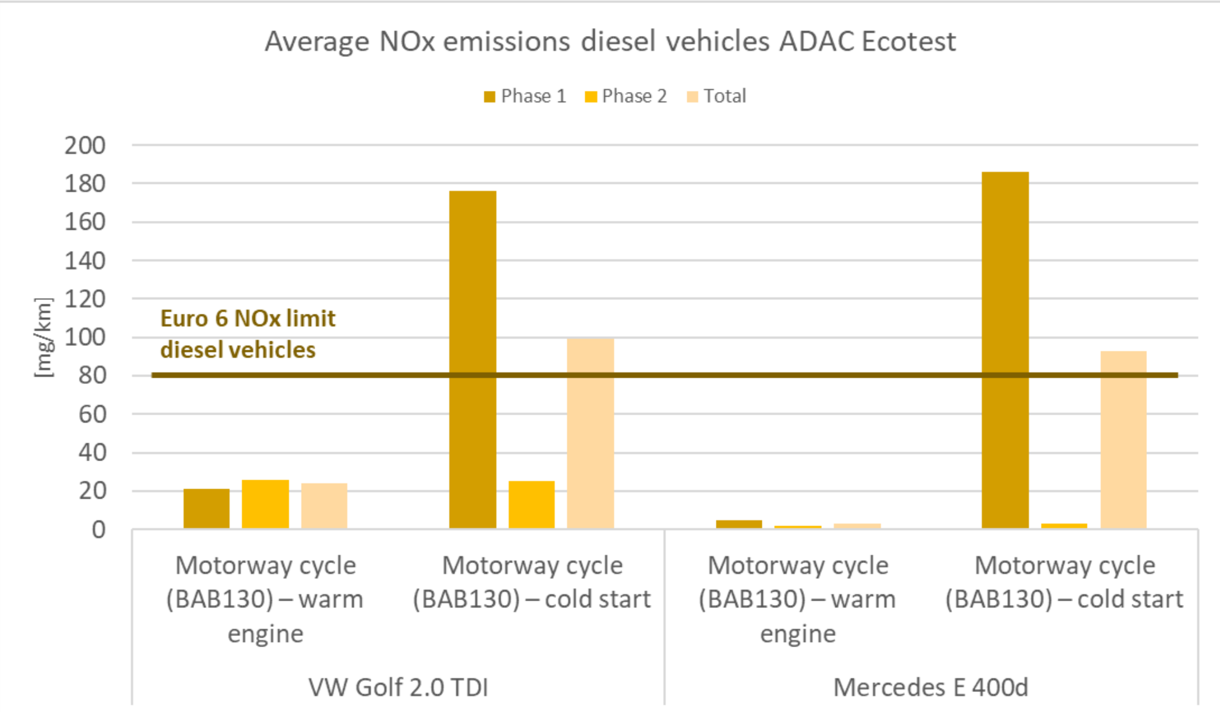

Figure 4: Avg. NOx emissions of two Euro 6d diesel models in the motorway cycle under cold-start conditions

Investigation of other pollutants

Regarding other limited pollutants such as carbon monoxide (CO), hydrocarbons (HC) and particulate matter (PM/PN), **the emissions of the tested vehicles are clearly below the limits**. **Even the particulate emissions of state-of-the-art diesel vehicles are extremely low**, unmatched even by petrol vehicles with particulate filters.

Furthermore, **state-of-the-art diesel vehicles hardly produce any ammonia emissions** – mandatory limits for which are under discussion – although the SCR emission control technology of injecting urea into the exhaust tract, used in virtually all of these vehicles, bears the potential risk of provoking an NH_3 breakdown by overdosing. **This shows just how sophisticated SCR emission control technology is nowadays.**

Bottom line

The current test results have shown that **diesel passenger cars equipped with state-of-the-art exhaust emission control technology may be enabled to generate very low amounts of NOx emissions across the whole operational range** and **are already clearly below the current Euro 6 NOx limit value** of 80mg/km. This includes improved – more responsive and effective – SCR systems, the combination of NOx trap catalytic converters and SCR systems and the new twin dosing technology (twin SCR cat).

ADAC is open to ideas for revising the regulations with a view to reducing pollutant emissions from road vehicles under Euro 7. **However, further development of the air quality (immissions) and exhaust gas standard (emissions) regulations must be coordinated better than was the case in the past** (negative example: low emission zones and driving bans). The **principle that regulations should focus on the desired effect rather than on certain technologies must prevail in the further development of vehicle emission limits**. The legislative process must not primarily aim at eliminating certain technologies such as the internal combustion engine. **There is nothing to be said against new challenging emission limits and making them even stricter within the existing margins but they must remain technologically feasible.**

However, instead of focusing on individual challenging load points likely to generate higher NOx emissions for a brief period of time, **the main aim should be on reducing fuel consumption and CO_2 emissions**. For ensuring further reductions of NOx emissions in certain load points that are brought into rarely and only for brief periods of time would require considerably more complex and costly technical measures that could also result in considerably higher fuel consumption.

The future Euro 7 standard should be set at a level with which most of the best engines today are compliant and further optimisation efforts should concentrate mainly on CO_2 reduction. This is where manufacturers should concentrate their efforts in the future. Clever hybrid drives still offer plenty of potential for increasing efficiency. The current ADAC statistics have shown that current diesel vehicles equipped with state-of-the-art drive technology are clean in RDE conditions and are not likely to cause excessive pollution even under extreme test conditions.

It is now time to deploy such technology in all types of vehicles. The legislator should facilitate this deployment by amending the type approval requirements. The available options include reasonable and practical emission limits as well as further adjustments to the relevant testing procedures.

ADAC has shown that further reductions in fuel consumption and pollutant emissions are feasible. The issue is to **further develop internal combustion engines with a view to achieving climate-neutrality**, which requires **adequate incentives**. **In the future, e-fuels will allow new vehicles equipped with internal combustion engines to be climate-neutral.** Since reducing CO_2 emissions in the passenger car population is a pressing necessity to begin with, investments in the production of alternative carbon-neutral fuels are also required. **There is no need today to reject technology options based on internal combustion engines altogether. Climate-neutral mobility is not a question of the type of drive but of the type of fuel or energy used to propel vehicles.**

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ADAC e.V.
Test & Technical Services
81360 Munich/Germany
E-mail tet@adac.de
www.adac.de