Particulate matter emissions: Otto-cycle engines have potential for improvement

Content

The debate about internal combustion engines 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 **Otto-cycle** and diesel vehicles really in relation to their **particulate emissions**? ADAC, the German automobile club, presents the results from the current Green New Car Assessment Programme (Green NCAP) and ADAC Ecotest.

Test procedures: Green NCAP and ADAC Ecotest

Green NCAP

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). Another element, the BAB130 motorway cycle adopted into the Green NCAP test procedure from ADAC Ecotest and the full-throttle acceleration it includes are 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.** Also part of the test portfolio are test runs under high payload, dynamic driving and a lap run as efficiently as possible. Furthermore, 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 system **are really running clean at any operating point** Green NCAP aims at covering as many load points of the engine map as possible 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)

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 daytime 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)

Comparative study of diesel and Otto-cycle engine particulate emissions

Within the framework of the EU-sponsored Green Vehicle Index (GVI) project, Green NCAP **analysed the exhaust gas performance of Europe's 25 best-selling Otto-cycle engine (including 2 CNG) models and 17 diesel vehicles from various makers and vehicle segments**, all type-approved to the current Euro 6d TEMP emissions standard. The **results** obtained **are representative for new vehicles approved for sale in Europe since 2018**.

The **tests revealed that the average particle number (PN) for all Otto-cycle engine models** both in the cold and warm engine tests at 14°C and under cold-start conditions at -7° as well as in the motorway cycle, **were well below the current Euro 6 PN limit of 6.0 x 10^{11} 1/km with road tests confirming these results**.

Also the ADAC Ecotest validates these results with measurements covering a total of 136 Otto-cycle engine (including 2 CNG) models and 106 diesel vehicles approved to Euro 6d or Euro 6d TEMP.

It becomes clear, however, that **in all tests particle numbers measured in Otto-cycle engine models were much higher on average than the average particle numbers of diesel vehicles (with particulate filter), while emissions of Otto-cycle engine vehicles were generally lower than those of earlier diesel vehicles without particulate filter**.

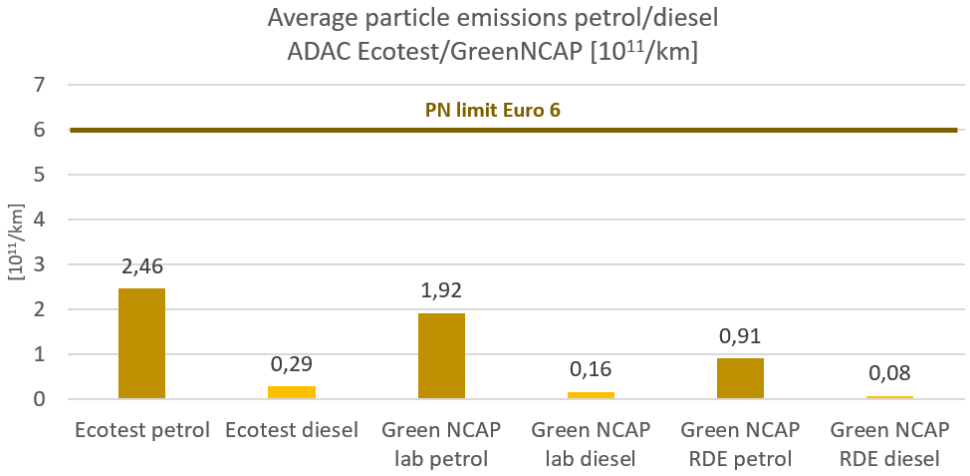

Figure 1: Average particle numbers emitted from diesel and Otto-cycle engines (source: ADAC Ecotest, Green NCAP)

Comparison of PN emissions from direct and indirect injection Otto-cycle engines

Current passenger car emission legislation mandates particulate matter (PM) and particle number (PN) emission limits for diesel engines and direct injection Otto-cycle engines only. **These limits do not apply to indirect injection Otto-cycle engines**.

Time and again, the ADAC Ecotest shows that vehicle models powered by this type of engine have clearly increased particle emissions.

The average particle number (PN) measured in a total of 136 Otto-cycle engine models (including two CNG vehicles) approved to the Euro 6d and Euro 6d TEMP standards shows that particulate emissions from direct-injection Otto-cycle engines (120 models) were clearly lower than those of indirect injection vehicles (16 models). **Direct injection Otto-cycle engines with particulate filter (107) had the best results**.

It becomes clear, however, that **particle numbers measured in Otto-cycle engine models were much higher on average than the average particle numbers of diesel vehicles**. All of the diesel vehicles tested exhibited low PN emission levels throughout, which did not increase excessively even under challenging conditions.

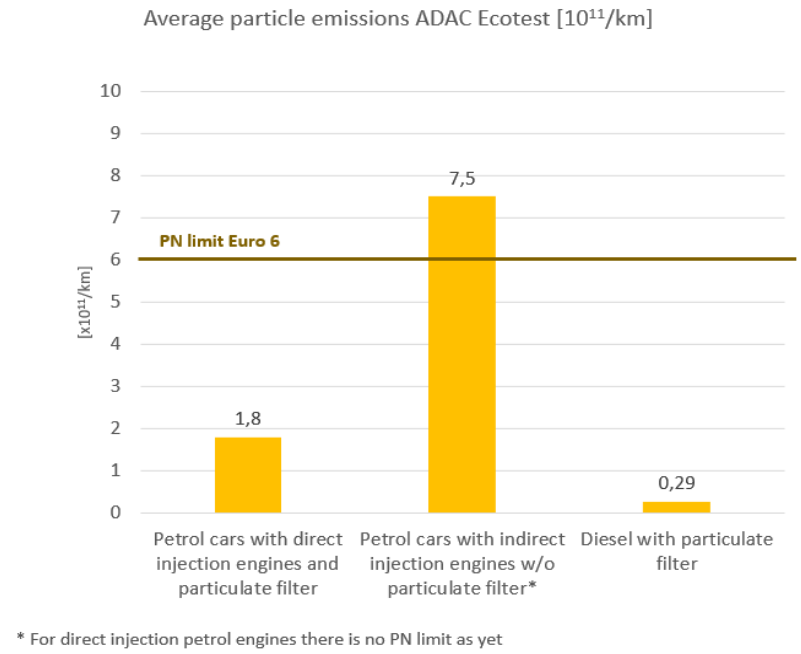

Figure 2: Average PN emissions – direct injection Otto-cycle engines with particulate filter, indirect injection engines without particulate filter and diesel engines (source: ADAC Ecotest)

The detailed results of all indirect injection petrol engines without particulate filter (15 models) are shown in Figure 3.

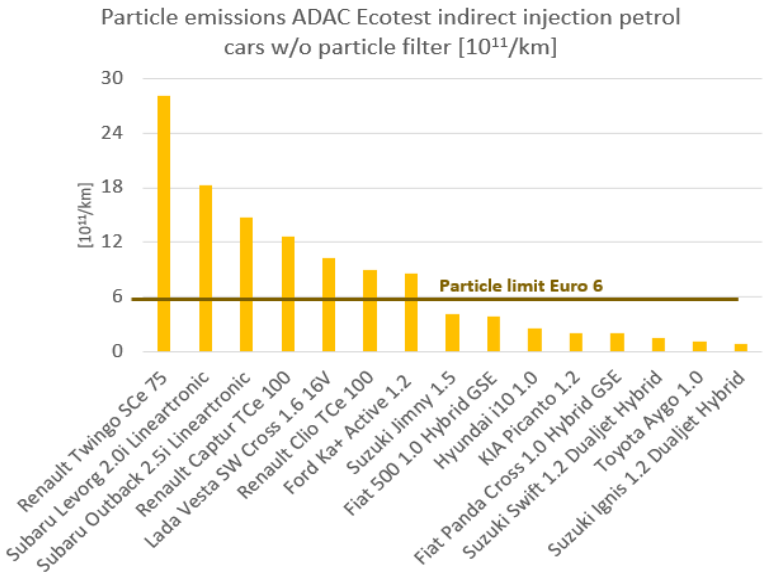

Figure 3: Average PN emissions – indirect injection engines without particulate filter (source: ADAC Ecotest)

The values measured for Renault (Twingo SCe 75, Captur TCe 100, Clio TCe 100), Subaru (Levorg 2.0i, Outback 2.5i), Lada (Vesta 1.6) und Ford (Ka+ 1.2) stood out.

Ultrafine particles of less than 23nm

The size of soot particles that form in a combustion engine ranges between less than 10nm and several hundred nm. **The current passenger car emissions legislation refers to ultrafine particles larger than 23nm**.

Green NCAP **measurements of ultrafine particles of 10nm and more** were performed for 12 vehicle models: 2 diesel cars, 2 CNG models and 4 petrol engines each with and without particulate filters.

The results show that all engine variants have higher particulate emissions if ultrafine particles of 10nm and more were considered. **Especially the values for petrol engines without particulate filter were conspicuous.**

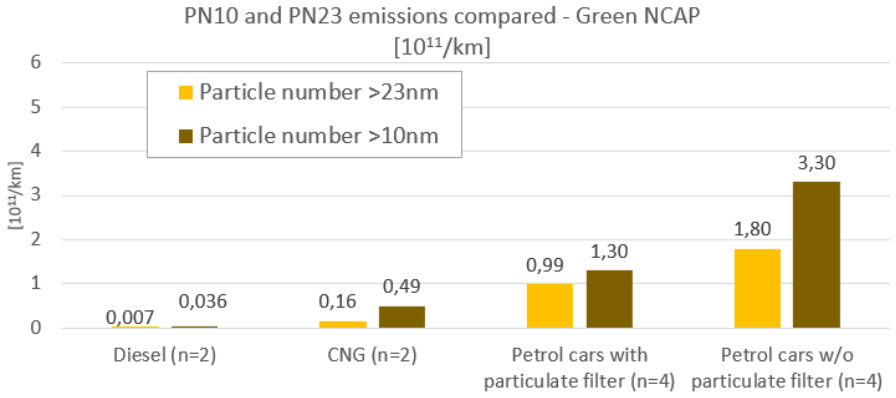

Figure 4: Comparison of average PN10 and PN23 emissions (source: Green NCAP)

Bottom line

The current test results have shown that **diesel passenger cars equipped with state-of-the-art exhaust emission control technology may generate very low amounts of particulate emissions across the whole operational range** and **are already clearly below the current Euro 6 particulate emissions limit value**.

Otto-cycle engines, and indirect injection models in particular, have quite some potential for improvement.

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.**

Identical limits for both Otto-cycle and diesel **across technologies** have been fundamental ADAC demands for decades. In this context, ADAC specifically recommends **the application of the particulate matter (PM) and particle number (PN) limits be extended to indirect injection Otto-cycle engines**.

Also, the PN limit should cover as wide a range of particle sizes emitted by an engine as possible.
The size of soot particles that form in a combustion engine ranges between less than 10nm and several hundred nm. The current passenger car emissions legislation refers to ultrafine particles larger than 23nm.

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