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NOx emissions (part 2)

In the first part of my comment I showed that concerning mean annual NO2 concentration, Luxembourg is among the better of the EU28 countries, whereas Germany is the worst.

This second part will be on emissions from petrol (gasoline) and diesel engines, and the efficiency of the various Euro norms. I rely for a good part on an excellent **report** by the Kings College of London, the University of Leeds and the AEA (Agricultural Engineers Association), published in 2011 for DEFRA (Department for Environment, Food and Rural Affairs).

1. Emissions of NOx from petrol and diesel engines.

Diesel engines are the workhorses in heavy machinery, as they have an efficiency of about 35% compared to 25% of conventional petrol engines; this higher efficiency was one of the main reasons to introduce Diesel engines in ordinary vehicles, as the fuel consumption for a given power output is lower (and the price of Diesel fuel less taxed in many countries). In Diesel engines, the vaporized injected fuel burns lean, with an excess of oxygen and at high pressure, and some spots in the cylinder can reach temperatures over 1500 °C. The excess of oxygen favors the formation of NOx. Conventional petrol engines burn a very equilibrated air/fuel mixture (which is created in the carburetor or in the injection system), without any oxygen or fuel excess; the result is a combustion with lower levels of NOx which can easily be removed by a 3-way catalyst. Gasoline direct injection (DI) engines have a better fuel efficiency and torque at low rpm's, but suffer from higher NOx emissions, similar to the Diesel engines. The gasoline DI engines become more and more fashionable, and some of their NOx problems are solved by special catalytic converters and ECR (exhaust gas re-circulation); you may read this report from DEUPHI which shows testing of an engine releasing not more than 0.2g NOx/kWh (the US Federal limit for heavy trucks is 0.26 g NOx/kWh). Nevertheless one should bear in mind that the switch from conventional to DI gasoline engines will increase the NOx problems of gasoline driven vehicles.

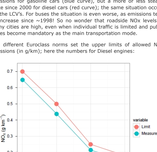
2. Main findings of the report "Trends in NOx and NO2 emissions in the UK and ambient measurements"

This report is interesting because it relies heavily on remote sensing detectors (RSD) to **measure** the NOx/NO2 levels under urban traffic conditions (mostly low speeds of 36 km/h). The report finds big differences between published factors and the measurements for light vehicles, and that certain catalytic techniques used in heavy goods vehicles (trucks) are inefficient in urban conditions.

The following figure shows how NOx emissions (here expressed as the ratio NOx/CO2*1000) changed during the years for 4 classes of vehicles: passenger cars, HGV (heavy goods vehicles = trucks), LGV (light good vehicles = small transporters) and buses:

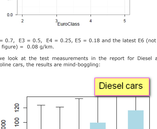
The CAR pattern clearly show a rather dramatic decrease of NOx emissions for gasoline cars (blue curve), but a more or less steady state since 2000 for diesel cars (red curve); the same situation occurs for the LCV's. For buses the situation is even worse, as emissions tend to increase since ~1998! So no wonder that roadside NOx levels at many cities are high, even when individual vehicle tested and public buses become mandatory as the main transportation mode.

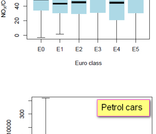
The different Euroclass norms set the upper limits of allowed NOx emissions (in g/km); here the numbers for Diesel engines:



E2 = 0.7, E3 = 0.5, E4 = 0.25, E5 = 0.18 and the latest E6 (not on this figure) = 0.08 g/km.

If we look at the test measurements in the report for Diesel and gasoline cars, the results are mind-boggling:





These 2 figures represent box-and -whiskers graphs: the black line corresponds to the median of the sample (50% of the sample are below, 50% higher), the blue rectangular boxes the 25-75% percentiles (i.e. 50% of the samples lie inside the box), and the full extend of the whiskers (the black lines) represent 99% of the sample size.

For petrol cars, the efficiency of the increasing stringent norms is clearly visible, **even if there seems to be a stand-still from E3 on**. Diesel engines do not show this: on the contrary the latest E norms do bring a worsening! This is a clear sign that the over-optimistic E norms are nearly impossible to fulfill for Diesel cars that must be fuel-efficient and powerful. No wonder that many manufacturers of Diesel cars (like Volkswagen) installed clever software to fool the compliance procedures.

Nobody should be astounded that real measurements give other results than the official numbers based on laboratory measurements and/or computer programs. The problem with measurements under real driving conditions is that these conditions are impossible to standardize (the state of the road, the weather etc. are changing parameters), whereas measurements in the lab can be made under well defined conditions. The next figure shows the difference between the higher road-side measurements (RSD) and the official factors:

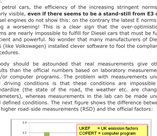


Figure 6.3: Emission factors for petrol cars.

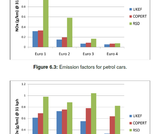
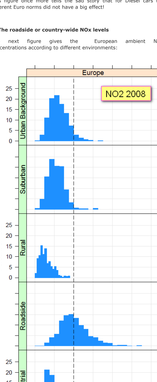


Figure 6.4: Emission factors for diesel cars.

This figure once more tells the sad story that for Diesel cars the different Euro norms did not have a big effect!

3. The roadside or country-wide NOx levels

The next figure gives the European ambient NO2 concentrations according to different environments:



The vertical line at 40 ug/m3 corresponds to the European limit for annual average concentrations; of the 5 different environments, the roadside remains the only problematic location. Even urban or suburban backgrounds lie well below the 40 ug/m3 limit!

Let us look how this roadside situation changed during the years for different countries:

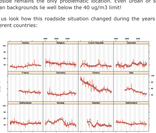


Figure 2.8: Monthly de-seasonalized trends o NO2 at roadside sites for select European Countries.

Except Greece and Italy, all countries show a more or less horizontal trend for the full period 1995 to 2009: **this means that the different Euro norms did not have a big effect at roadside locations.** One reason, as shown above, is that successive more modern Diesel engines were unable to drastically lower their NOx emissions, and the increasing number of these vehicles (especially in Diesel cars; an increase pushed by political decisions to lower fuel consumption (and supposed climate-hurting CO2 output) which made Diesel fuel less expensive than gasoline.

4. Conclusion

NO2 (or NOx) mitigation is a wicked problem, and only naive persons believe that impossible stringent norms will miraculously achieve results that are nearly impossible to obtain for physical and/or engineering reasons. Maybe we would be better off if the scare-mongering about the dangers of NO2 would cease, and solutions for lowering NO2 emissions were allowed more time for research, experimentation and development. Pierre Lutgen (who holds a PhD in chemistry and has been working for the French Environment on very low NO2 levels (read his French article on nitrites). But NO2 as a gas is an irritant for the lung linings, and may form very small particles when reacting with other substances; it also has a detrimental effect on plant-life (some put the allowed limit as low as 30 ug/m3). So high levels of NO2 clearly should be avoided. But as often in environmental policies, setting limits at impossible low values will not hasten the accordance, but favor clever proceedings to circumvent these limits.

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