

Summary:

NO₂ emission from the fleet of vehicles in major Norwegian cities

Challenges and possibilities towards 2025

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Whereas particle emissions have decreased, the emissions of NO₂ in major Norwegian cities has increased, mainly due to the increasing number of diesel vehicles and an unwanted side-effect of particulate filters and oxidizing catalysts. The increased emissions, the national requirements for air quality and NO₂ are violated. Emission factors from HBEFA's emission model together with calculations made by NILU indicate that emissions of NO₂ in major Norwegian cities will continue to increase towards 2015 but thereafter decrease towards 2025. Even if the NO₂ concentrations in the air should satisfy the yearly limit by 2025, there will be periods with short term exceedances. This means that the authorities need to consider measures to reduce the real life emissions. Our calculations include uncertainties, especially related to "real life" emissions from the Euro 6/VI diesel vehicles. The uncertainties will have to be investigated and reduced by further emission tests of new and future diesel light vehicles as well as heavy duty vehicles in "real life" settings.

Air quality and NO_x

Exhaust emissions from vehicles is a problem in major cities, and nitrogen oxides (NO_x), together with particulate matter (PM), are the dominant harmful components in exhaust gases. Nitrogen oxides consist of NO and NO₂. NO₂ is the most important with respect to its adverse health effects at ambient levels in urban settings.

NO_x from vehicles are mainly formed in combustion engines at temperatures over 1700°C. The chemical processes of formation, transformation and decomposition of NO_x are complex and complicated.

Concentrations of NO₂ in the air have increased in the past 10 years in some of the major cities in Norway, particularly in Oslo and Bergen, where limit values for acceptable air quality were exceeded several times in 2010.

Unlike modern petrol engines, diesel engines are not fitted with efficient systems for removing NO_x emissions. The lack of effective systems for reducing NO_x-emissions, has led to high ambient concentrations of NO₂ in major Norwegian cities, especially during times of congestion, cold clear weather without wind and inversion. Inversion is when the air is colder and heavier at the ground than higher up.

NO_x emissions from diesel engines

Modern vehicles with diesel engines emit more NO_x than equivalent petrol engine vehicles. In dense urban traffic, new cars with diesel engines may emit 0.5 to 1.5 grams of NO_x per kilometer, which is 20 to 40 times more than a similarly sized petrol engine car. New heavy-duty vehicles with diesel engines emit 4 to 10 grams of NO_x per kilometer in dense city traffic which is 160 to 400 times higher than a petrol passenger car.

NO_x emissions from new vehicles with diesel engines have not been reduced as much as one might have expected from stringent EU requirements. New diesel engines meet stringent EU requirements for exhaust emissions when tested in the laboratory with today's type approval tests. However, real life emissions have been shown to be significantly higher under congested traffic conditions with driving patterns that vary more than when driving at more steady speeds. The results from type approval tests thus fail to be representative of the emissions that diesel vehicles emit in "typical" real life urban driving situations.

To meet the stricter Euro5 standard introduced in 2009, new effective particulate traps that burn the particles became necessary for passenger cars with diesel engines. These devices have proved effective in removing particles, but a side-effect of this and the the oxidizing catalysts is a significant increase in NO₂-emissions (see figure S.1). The proportion of NO₂ of the total emissions of NO_x is difficult to measure, but appears to be up to 50% of the total emissions of NO_x. For new passenger cars with petrol engine, the NO₂ proportion of NO_x emissions is approximately 5-10%.

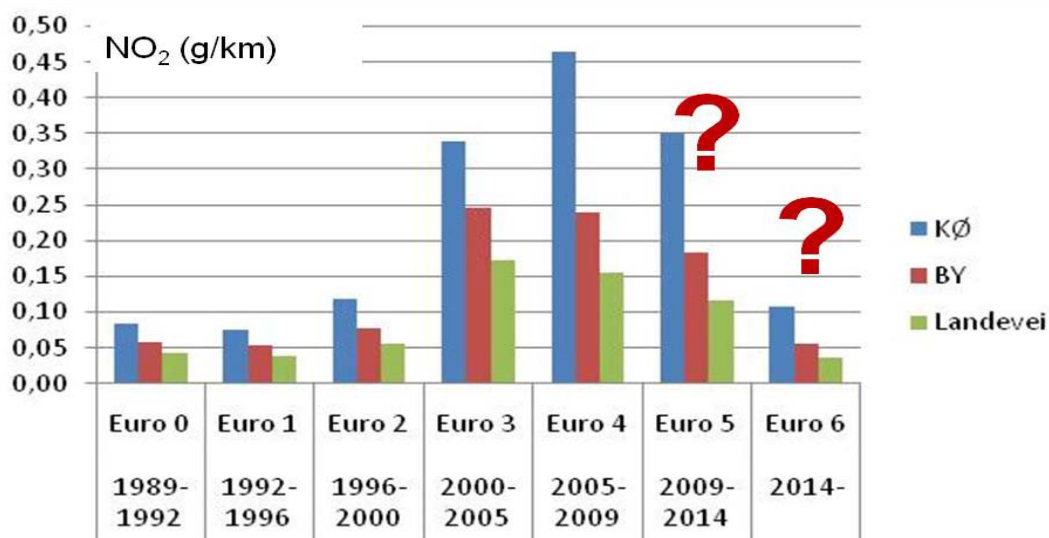


Figure S.1: Historic data and forecast of NO₂- emissions from new passenger cars with diesel engines under congested (blue), urban (red) and highway driving (green) conditions. Source: HBEFA and TØI.

Emission factors and air quality

We have used an emission model for calculating the emissions from Norwegian vehicles in different typical driving conditions (see example in figure S.1). The HBEFA model calculates that NO_x emissions from Euro 5 cars as compared to

Euro 4 cars are reduced with about 30%, and that emissions from Euro 6 cars (from 2014) are expected to be reduced by approximately 70% as compared to the emissions of Euro 4 cars.

Our HBEFA emission factors and calculations based on the expected change of the vehicle fleet show that the concentration of NO₂ will increase until 2015 and is then expected to decrease slightly (see figure S.2). The calculations show that without dedicated actions, exceedances of the air quality limit values for NO₂ can be expected for several years to come. Air quality in major cities is however heavily dependent on weather conditions, and with cold temperatures and temperature inversions that puts a lid on the pollutants near ground, it is likely that the limit values for NO₂ occasionally also will be exceeded in 2025.

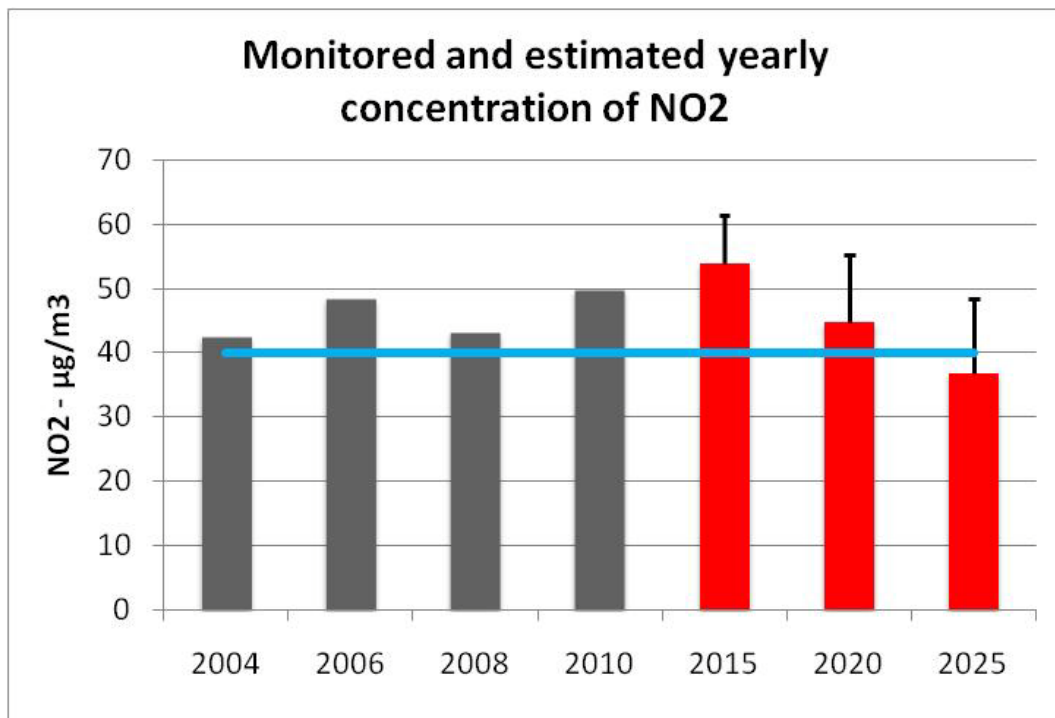


Figure S.2: Development of the annual NO₂ mean in Oslo. Historical concentrations are shown in grey and expected development in red. The blue line indicates the Pollution Act limit.

In contrast to the NO₂-emissions, the emissions of PM are expected to be reduced throughout the period up to 2025.

In the calculations of future emissions undertaken by the Norwegian Institute of Air Research (NILU), the introduction of electric and hybrid cars in the future is not taken into account, and only traditional diesel-powered buses are included. An increase in the proportion of full or partial electric drive vehicles and more environmentally friendly buses would improve air quality compared with the expected development given in figure S.2. However the expected emission of NO₂ in actual traffic from Euro 6/VI vehicles is assessed optimistically. The optimistic approach may be due to uncertainty given somewhat high reductions in emissions for the period 2015-2025.

New and more stringent emission requirements will be implemented by the EU from 2014. The question is what the new vehicles, which will meet the new Euro 6/VI requirements, will actually emit in real urban traffic.

Vehicle manufacturers, the European Union and the authorities are perfectly aware that the system for type approval of cars has not worked as planned in regard to reducing NO_x emissions from vehicles with diesel engines. The German motor organization ADAC has carried out emission tests of some Euro 6 diesel cars, and these show that vehicles can have high emissions of NO_x in real traffic even if they comply with the type approval limits. ADAC takes a serious view of this and is demanding that new Euro 6 vehicles with diesel engines have emissions of NO_x that under all driving conditions are at least 70% lower than for Euro 4 diesel vehicles.

Technology for cleaning diesel engine exhaust

The restructuring in 2007 of Norwegian vehicle tax encourages the purchase of diesel cars, and has led to a reduction in CO₂ emissions from new cars. It is desirable that this positive development of CO₂-emissions continues. However, it then becomes necessary also to reduce the emissions of NO₂ to avoid and reduce the health impacts. The technology for reducing and removing NO_x exists, but it is a challenge to get it to work effectively in real traffic. Fuel injection timing, exhaust gas recirculation (EGR) and selective chemical reduction (SCR) of NO_x to nitrogen gas can help reduce or completely eliminate emissions of NO_x.

Measures, restrictions and taxes

Emissions of NO_x and NO₂ can be reduced or eliminated by diesel-engine vehicles being replaced by vehicles that have different propulsion systems. Examples are petrol-powered cars and vehicles with gas engines or with full or partial electric propulsion. The disadvantages with these alternatives to diesel engines is that they are either less energy efficient or more expensive.

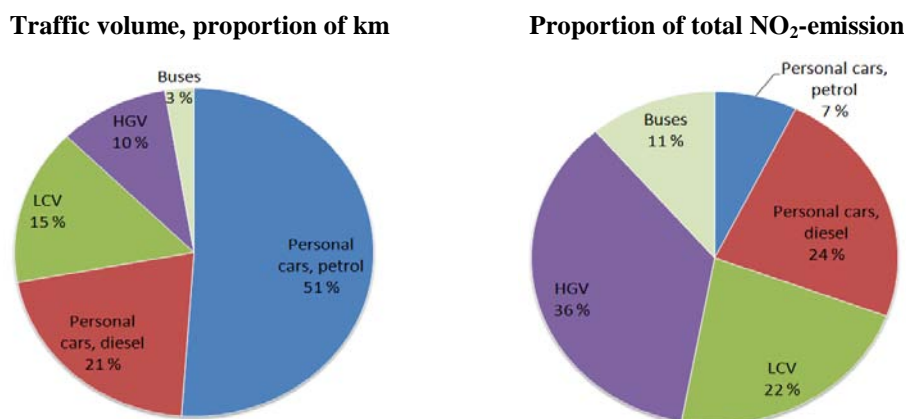


Figure S.3: The left chart shows the percentage of road work (percentage of all kilometres driven) for different vehicle classes in Oslo, while the chart on the right gives the percentage of total NO₂ emissions each vehicle class emits - 2010 values.

Figure S.3 shows the distribution of traffic volumes by type of vehicles and their share of NO₂ emissions in Oslo. When evaluating appropriate measures, it is an advantage to take into account the extent to which the various vehicle categories contribute to the emissions. If the share of new light diesel vehicles contribution to traffic volumes is larger than we estimate their share of the emissions might be even higher than calculated.

Emissions of NO₂ is mainly a problem in urban areas. To accommodate both global and local targets it will be desirable with vehicles that have low emissions of all exhaust components like NO₂, PM and CO₂. At the same time you have to solve local problems locally and global challenges globally. Local authorities will have to be given the power to implement local initiatives to solve the local challenges.

Today's diesel vehicles satisfying Euro 3, Euro 4 and Euro 5 type approval emission limits have very high emissions of NO₂. It may be appropriate to limit the use of these diesel vehicles on days and in cities where NO₂ concentrations are highest. People who are dependent on driving in the city every day might then choose to buy a low NO_x-emitting car rather than a high emitting diesel car. Most will probably still choose a car with diesel engine, with low CO₂-emissions, because a possible driving restrictions will occur relatively rarely and only in the larger cities.

Introducing a high NO_x component in the tax when buying a new car is disputable since the knowledge about emissions and reduction systems at the moment is inadequate. The NO_x tax component based on the current emission values from the type approval is not totally fair, and may be misleading because the currently used type-approval test inadequately represent "real life" urban traffic.

Need for more knowledge

Expertise on engine technology, exhaust emissions and dispersion of exhaust gases is required to introduce appropriate measures to implement new tax systems, to reduce global warming and to improve air quality locally.

Norway has not had its own laboratory for testing emissions from vehicles since 2002. Access to facilities for testing vehicles in real traffic and under Nordic climatic conditions is important since we want to reduce and predict future emissions from vehicles in Norway.