The invisible killer on Europe's roads

Methodological note

January 2024

1. Introduction

The European Commission defines nitrogen oxides (NO_x) and fine particulate matter ($PM_{2.5}$) as the key air pollutants from road transport.[1] T&E analysed the extent to which different policy scenarios could reduce these pollutants between present day and 2050. The study also includes ammonia (NH_3), which is a result of exhaust after-treatment and NO_x reaction with sunlight rather than direct fuel combustion. While it is emitted in much lower quantities due to its toxicity, it still has a significant environmental and health impact. Numbers are estimated and reported for the EU's 27 member states. On the policy side, two levers were analysed: climate regulation (the heavy-duty vehicle, or HDV CO_2 standards) and air pollution regulation (emission standards).

Three scenarios were examined for the CO_2 standards: current policies (BAU), the new Commission proposal from February 2023 (COM) and T&E's recommendations to improve that proposal (T&E).[2] In addition, we looked at both a case where Euro VI is the highest air pollution standard, and where the more ambitious Euro 7 is implemented from 2027.[3]

Section 2 describes the calculation steps we followed to get the levels of air pollution in Europe. Section 3 transforms those emissions into costs for society. Comparison with existing studies is performed in Section 4, before discussing some issues concerning Euro 7.

2. Air pollution

Air pollutant levels are calculated based on T&E's European Union Transport Roadmap Model (EUTRM), which forecasts the transport sector dynamics under different policy scenarios. The model follows an activity-based approach: A country's emissions are calculated from its diesel trucks' yearly activity

[1] European Commission. (2022). *Proposal for a regulation of the European Parliament and of the Council on type-approval of motor vehicles and engines and of systems, components and separate technical units intended for such vehicles, with respect to their emissions and battery durability (Euro 7) and repealing Regulations (EC) No 715/2007 and (EC) No 595/2009 (p.7)*. Link.

[2] A recent briefing by T&E explains the three scenarios and their climate consequences in detail.

[3] Until Euro 6, the nomenclature was differentiated between vehicle categories (Arabic numbers for cars, Roman for trucks). With Euro 7, the Arabic notation is used for both. This is why we used different nomenclature in this sentence and throughout this document.

multiplied by a composite emission factor that accounts for the fleet distribution within each Euro emission class. Emission factors in grams of pollutant per kilometre for classes Euro I to Euro IV are taken from the European Environmental Agency (EEA) repository[4] of measurements in real-world driving conditions. Factors for Euro V and Euro VI come from the European Commission Impact Assessment[5] of the Euro 7 standards. This choice was made to be able to replicate historical emissions, as they would be too low in case we used EEA factors.[6]

The partial unreliability of the latter values is given by the difficulty of replicating trucks' real-world driving conditions, especially in urban areas. Euro 7 factors come from the Impact Assessment as well. Among the scenarios analysed, we opted for PO3a, which the Commission defines as "the most effective in achieving the identified objectives, while also being cost-efficient by bringing the highest health and environmental benefits for citizens at low regulatory costs for industry".[7] However, we decided to use the emission limits, which are higher than the average emission factors. This is justified by the empirical evidence of real-world emissions being significantly higher than the target values declared in the regulation.[8][9]

Once the factors are chosen, we take their average weighting by the above-mentioned share of activity within each Euro class. This allows us to obtain a composite emission factor expressing the overall fleet emissions in grams of pollutant per kilometre. Emissions are then obtained by applying the formula:

$$Emissions_{prys} = CEF_{prys} * activity_{rys}$$

Where:

- $Emissions$ = total emissions in tonnes of pollutant
- CEF = composite emission factor in grams of pollutant per kilometre
- $activity$ = diesel vehicles mileage in kilometres
- p = pollutant ∈ {NO_X, $PM_{2.5}$, NH_3}
- r = region ∈ {EU27 countries}
- y = year ∈ [2024, 2050]
- s = scenario ∈ {BAU, COM, T&E}

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[4] EMEP/EEA air pollutant emission inventory guidebook 2019. Link.

[5] European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Ntziachristos, L., Papadopoulos, G., Samos, Z. (2022). *Euro 7 impact assessment study.* Link.

[6] The unreliability of the EEA measurements is given by the difficulty of replicating the exact real-world driving conditions, especially in urban areas.

[7] European Commission. (2022). *Proposal for a regulation of the European Parliament and of the Council on type-approval of motor vehicles and engines and of systems, components and separate technical units intended for such vehicles, with respect to their emissions and battery durability (Euro 7) and repealing Regulations (EC) No 715/2007 and (EC) No 595/2009 (p.11)*. Link.

[8] Carslaw D., Rhys-Thaler G.(2013). *New insights from comprehensive on-road measurements of NOx, NO2 and NH3 from vehicle emission remote sensing in London, UK.* Link.

[9] Mulholland E., Miller J., Bernard Y., Lee K., Rodriguez F. (2022). *The role of NOx emission reductions in Euro 7/VII vehicle emission standards to reduce adverse health impacts in the EU27 through 2050.* Link.

Note that we are only looking at the overall emissions of air pollutants, not their concentration in the atmosphere. The following section addresses this potential issue and its solution in more detail.

3. Costs

The main reference for our economic assessment is the CE Delft study on the external costs of transport.[10] They identify four channels through which air pollution impacts society:

- **Health effects**: inhalation of pollutants leads to the risk of respiratory (asthma, bronchitis, pneumonia) and cardiovascular (coronary syndromes, arrhythmia, stroke) diseases, medical treatment, production loss and death. This is the main component of air pollution costs;
- **Crop losses**: ozone as a secondary air pollutant (from VOC and NO_X) and NO_X itself lead to lower crop yields;
- **Material and building**: on surfaces, pollution (PM) and corrosion (NO_X and SO_2);
- **Biodiversity loss**: NO_X causes acidification of soil, rainfalls and water. Together with NH_3, it is also responsible for the eutrophication of water masses. These phenomena create adverse living conditions for animals and plants, causing a decrease in ecosystem biodiversity.

Health issues translate into an economic cost for society through working days lost due to illness, hospital admissions, medication, years of life lost (YOLL) and increased mortality. Losses due to the degradation of the environment and the repairing costs of buildings are then added on top.

The resulting environmental prices - in €/kg of pollutant - express the social marginal value of preventing emissions, i.e. the loss of welfare due to one additional unit of pollutant being emitted into the environment. The cost estimates are based on the concentration of pollutants in the atmosphere, which in turn depends on where tailpipe emissions - hence, truck and bus activity - are located. As we use the same activity projections as the Commission and CE Delft themselves, we can assume the relationship between tailpipe emissions and atmospheric concentration to be the same.[11] This allows us to apply the CE Delft's cost factors to the air pollutants' mass resulting from our previous calculations. Though this is a simplifying assumption, it is the best approximation where a full assessment of air pollution concentration is not possible.

Since 2019, the year when the CE Delft study was published, there is evidence that costs per unit of pollutant have increased.[12] This is mainly driven by an observed increased mortality due to prolonged exposure to $PM_{2.5}$.[13] However, since there is no complete quantification of the increase yet, we did not

[10] CE Delft (2019). *Handbook on the external costs of transport.* Link.

[11] Assume, for example, that 1 kg of tailpipe NO_X emissions is distributed as 0.8 kg in an urban area and 0.2 kg in a rural area. Our assumption implies that if we have 2 kg of tailpipe NO_X in the same region and from the same source (trucks and buses), this will result in 1.6 kg in the urban area and 0.4 kg in the rural one. Hence, the concentration is proportional to tailpipe emissions.

[12] World Health Organisation. (2021). *WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide.* Link.

[13] Ricardo Energy & Environment for Defra. (2023). *Air Quality damage cost update 2023.* Link.

modify the CE Delft values, conscious that the study will underestimate the economic savings from tighter emission standards. On the other hand, as prices are expressed in € at the 2016 price level, indexation to 2022 has been performed. The overall Health Consumer Price Index (HCPI), which reflects consumer goods and energy prices that have been severely hit by the war in Ukraine, is not adequate for the purpose. By contrast, being health the main component of air pollution costs, we opted for the Health HCPI,[14][15] whose average increase across the EU27 countries is 8% - against 18% of the all-items HCPI.

Air pollution costs are generally higher in urban than in rural areas, and even more in metropolitan areas. For this reason, CE Delft differentiates NO_x and $PM_{2.5}$ pollution costs between rural, urban and metropolitan areas. These are then grouped into one single value by weighting for the share of activity trucks and buses perform in each area in each country.[16]

Yearly future savings are calculated as the difference between air pollution costs between two scenarios. The resulting cash flows are actualised to present value using the discounted cash flow (DCF) methodology. The purpose of DCF is to estimate the money a country would save from the implementation of higher standards, adjusted for the time value of money. Hence, total savings result from

$$\Delta\text{€}_{tot} = \sum_{y=2024}^{2050} \Delta\text{€}_{y} * (1 + r)^{-(y-2023)}$$

Where:
$\Delta\text{€}_{y}$ = cost difference between scenarios in year y
r = country-specific risk-free rate.[17]

When analysing government cash flows, the risk-free rate is used as a baseline because it captures the time value of money without factoring in any credit or default risk. It represents the return from investing in a risk-free asset (i.e. an investment that will return a defined amount of money in the future without uncertainty). Moreover, as it is calculated from government bonds or treasury bills yields, it reflects the different macroeconomic conditions across European countries. Lastly, the data for government expenditure in different functions come from Eurostat.[18]

4. Data check

Before looking at the results, it is imperative to assess the findings of our study in relation to existing research. We will focus on NO_x emissions only for two reasons: first because it is the main pollutant (95%

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[14] The index reflects the price level of medical products, appliances and equipment, outpatient services and hospital services as expressed in the ECOICOP notation. Link.
[15] All HCPIs are available on Eurostat. Link.
[16] Such values are calculated using the share of the population living in urban and metropolitan areas as a proxy.
[17] Source: Statista.
[18] General government expenditure by function (COFOG). Link. More details on the government function classification can be found in the manual of COFOG statistics. Link.

of HDVs emissions' total mass), and second because it is the only pollutant whose future trajectory is available in the Commission Impact Assessment. The baseline scenarios in the Impact Assessment and the EUTRM assume the HDV fleet evolves according to the current CO_2 emission standards: -15% CO_2 in 2025 and -30% for heavy trucks' new sales.

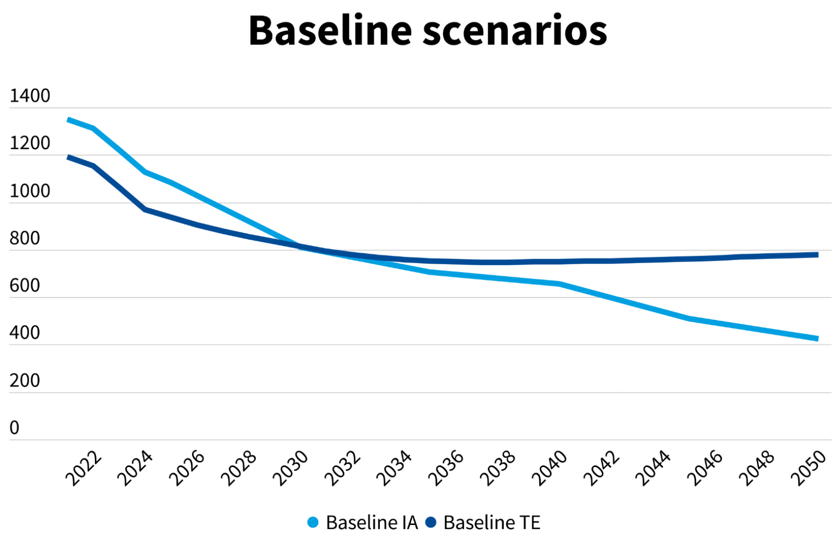

Figure 1: NO_x emissions in the baseline scenarios.

Despite the similarity of the inputs, the two models give different results for both historical and future emissions. The European Commission does not disclose emission factors for Euro classes I to IV, which likely caused the observed discrepancy from 2021 to 2027.[19] As the Commission factors for Euro V and VI are higher than those in the EEA database, it is reasonable to assume that this relationship will also hold for the other classes. As most of the fleet is either Euro V or Euro VI in the 2024-2050 period and we are using the same emission factors, the second discrepancy can be explained by the lower mileage diesel trucks have in the Commission study compared to ours. This is given by the higher share of zero-emission vehicles forecasted by the COPERT and SIBYL[20] models compared to the EUTRM, which assumes instead that truck manufacturers will keep a constant share of zero-emission sales in the future, just limiting themselves to comply with the regulation.

ZEV share of new sales	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Commission	5%	11%	25%	47%	60%	61%
T&E	6%	13%	13%	13%	13%	13%

[19] This is the most likely cause of discrepancy since both activity and CO_2 emissions between the two models are aligned.
[20] The two models used to assess air pollution in the Commission Impact Assessment.

When accounting for Euro 7, the results are much more aligned. Thanks to its emission factor being around 10 times lower than the one for Euro VI, Euro 7 drastically reduces NO_X emissions below 10% of the 2021 level. The above-mentioned difference in zero-emission sales is still responsible for NO_X in the Commission study being slightly lower (-98% compared to the 2021 level) than that in the T&E model (-93%), as shown by the steeper curve.

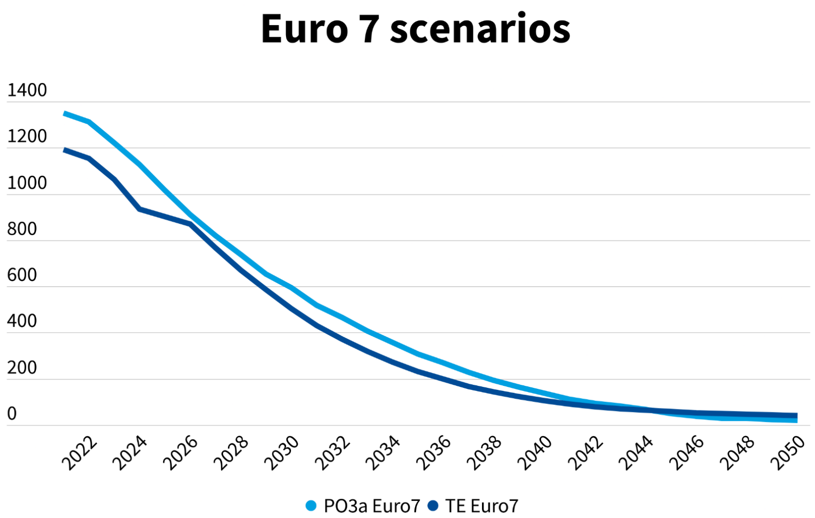

Figure 2: NO_X emissions in the Euro 7 scenarios.

5. Additional comments and Euro 7

The study does not include substances - like sulphur dioxide and non-volatile organic compounds - playing a role in air pollution. This is essentially due to a lack of data either on the emission factors or the costs side. However, the trucks' contribution to these compounds' overall emissions is rather limited - in the order of 1% of the total mass.[21]

Despite the overall analysis including the Euro 7 regulation, the values reported in the article only account for Euro classes until Euro VI. This choice is given by the uncertainty around the emission factors reported in the Commission Impact Assessment: they are supposed to reduce both NO_X and $PM_{2.5}$ emissions tenfold compared to Euro VI. As we have never observed such a reduction between subsequent Euro classes, it is reasonable to be prudent and not overestimate the impact of the new standards. Hence, the results in the article are based on a scenario where Euro 7 is not implemented. For the sake of the example, the theoretical NO_X emission limits under Euro VI were 0.46 g/km, while the Commission itself is using a more realistic factor of 2 g/km in the newest Impact Assessment.

Of course, once adding Euro 7 to the analysis, it is responsible alone for most of the pollution reduction - and associated costs - as this is what it is made for. Under the new scenario, the role of CO_2 emission

[21] Check the Impact Assessment (footnote 1) for more detail.

standards in curbing air pollution is limited. The following section reports the output of our analysis for both cases.

6. Further references contained in the text

The number of deaths from nitrogen dioxide and $PM_{2.5}$ reported in the article are figures from the European Environment Agency 2022 report.[22] The report mentions two different estimates: deaths due to exposure to air pollution above the 2021 World Health Organisation guideline levels, and deaths including exposure to lower concentrations of pollutants. The choice of using the latter figures is to fully account for the dangerous effects of the two pollutants. There is no quantification of the health effects of exposure to ammonia as this is mostly impacting costs through crop damage and biodiversity loss.

While the EUTRM estimates country-level air pollution levels from 2024 on, the numbers for the EU 2021 are obtained from the Commission's Impact Assessment and the European Environment Agency.

Lastly, the comparison between the health impact of air pollution with bad diet and tobacco is quoted from the WHO 2021 air quality guidelines.[23]

Further information

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[22] European Environment Agency (2022). *Health impacts of air pollution in Europe, 2022*. Link.
[23] World Health Organisation (2021). *Air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*. Link.