A comparison of the impacts of Euro 6 diesel passenger cars and zero-emission vehicles on urban air quality compliance

Introduction

A Concawe study aims to determine how real-driving emissions from the latest Euro 6 diesel passenger cars will impact ambient air quality compliance under different scenarios, and compares the results with a scenario where all new passenger cars are replaced with zero-emission vehicles.

Emission reduction measures have resulted in significant improvements in overall air quality in Europe. However, air quality continues to be a challenge in many urban areas, and non-compliance with air quality limit values (AQLVs) remains an issue, especially for nitrogen dioxide (NO_2) and particulate matter (PM).

In many cities, road transport has been the primary focus for emission reduction measures, and diesel passenger cars in particular are often assumed to be one of the main causes of non-compliance with AQLVs. However, technology to reduce emissions from diesel vehicles has made significant advances in recent years. To ensure that measured reductions in vehicle emissions more accurately reflect improvements in real-world driving emissions, a new real-driving emissions (RDE) test procedure that measures vehicle emissions under more realistic real-world conditions, and therefore provides more accurate information on the emissions generated in urban environments, has been introduced. [1]

Concawe commissioned two studies in 2017 to determine the expected emissions from the latest Euro 6 diesel passenger cars (including Euro 6d vehicles certified since September 2017) under the new testing methodology, and to understand how the emissions from Euro 6 diesel cars would impact ambient air quality compliance when compared with zero-emission vehicles (ZEVs). The first study, completed by Ricardo,[2] focused on determining the actual and expected real-driving emissions for multiple classes of Euro 6 vehicles (Euro 6b, Euro 6c, Euro 6d temp, Euro 6d). The study evaluated data obtained from literature as well as from Ricardo's own tests on a number of diesel passenger cars run using the newly developed on-road RDE test procedure and other real-world driving cycles. A prediction of how different Euro 6 vehicles, including the most advanced (Euro 6d) vehicles, would perform was provided. The study concluded, from existing data, that real-world NO_x emissions from diesel passenger cars are significantly reduced by successive improvements in Euro 6 legislation. It further concluded that when technical solutions currently being introduced are applied to Euro 6d cars, these vehicles are expected to meet the EU NO_x emission standard for Euro 6 passenger cars of 80 mg/km under RDE test conditions.

A second Concawe study carried out with Aeris Europe incorporated the data from the Ricardo study and used a state-of-the-art model to explore the impact of diesel passenger cars on NO_2 and PM compliance, and on population exposure under different scenarios, including a scenario where all new passenger cars are replaced with zero-emission vehicles. This study is an extension to the Concawe Urban Air Quality Study[3] which explored how urban air quality is affected by the emissions from vehicles and domestic combustion. The 2017 Aeris study extends the original study to focus on urban air quality in every major town and city in the EU that has an air quality monitoring station. It covers nearly 2,500 European air quality monitoring stations and includes a detailed analysis of air quality compliance and population exposure within 10 selected European cities. The approach and the key findings of this study are highlighted in this article. Additional detailed information can be found in Concawe Report 8/18.[4]

Modelling approach—compliance scenarios

The Aeris study used AQUIReS+, a suite of modelling tools developed in house by Aeris, to investigate the impact that fleet turnover to the latest Euro 6 diesel passenger cars would have on NO_2 and PM compliance during the period 2020–2030 throughout the EU-28. A detailed analysis was also performed for the following 10 European cities: Antwerp, Berlin, Bratislava, Brussels, London, Madrid, Munich, Paris, Vienna and Warsaw.

A Base Case emissions scenario was used as a starting point for all diesel passenger car scenarios in the modelling. This Base Case scenario is based on the January 2015 TSAP16 WPE (Working Party on Environment of the European Council) Current Legislation Baseline Scenario,[5,6] associated with the EU Air Policy Review process[7] as generated by the IIASA GAINS model.

The results of the Ricardo study were used to derive conformity factors[1] which were used to generate the different emission scenarios for AQUIReS+. Among the multiple emissions scenarios examined, the following two were used as key scenarios to illustrate the predicted results for NO_x:

- Ricardo Median Scenario: All Euro 6 diesel passenger cars introduced in a specific year are assumed to conform to the median level of the Ricardo results. This scenario assumes that all new diesel passenger car registrations from 2020 onwards are Euro 6d.
- ZEV Scenario: All new diesel passenger car registrations from 2020 onwards are replaced by zero tailpipe-emissions vehicles undertaking the same number of kilometres driven.

Details of the two scenarios are given in the following tables:

Table 1: Ricardo Median Scenario

SCENARIO	DESCRIPTION	YEARS	CF
Ricardo Median Scenario	Euro 6b pre-2015	Pre-2015	5.41
	Euro 6b post-2015	2015–2016	1.90
	Euro 6c	2017–2019	1.21
	Euro 6d temp	2020+	1

Table 2: ZEV Scenario

SCENARIO	DESCRIPTION	YEARS	CF
ZEV Scenario	Euro 6b pre-2015	Pre-2015	5.41
	Euro 6b post-2015	2015–2016	1.90
	Euro 6c	2017–2019	1.21
	Zero-exhaust vehicles	2020+	0

[1] A conformity factor (CF) is a simple coefficient of the legislated limit value (LLV) of 80 mg/km. For example, a conformity factor of 1.5 is one and a half times the LLV. This was introduced in Commission Regulation (EU) 2016/427 of 10 March 2016.

These scenarios have been chosen for detailed analysis, as they illustrate the effect that the largest reduction in emissions would have compared with an average emissions scenario. Additional results from all the scenarios examined can be found in Concawe Report 8/18.[4]

For particulate matter, two emission scenarios were considered. The first used the Base Case emissions and the second modelled the elimination of all diesel exhaust emissions for new passenger cars registered from 2020. PM emissions associated with tyre and brake wear and road abrasion remained unchanged between the scenarios.

Nitrogen oxide emissions

Figure 1 shows the Base Case NO_x emissions in Germany from all diesel passenger cars, broken down by Euro standard. Every country in the study possesses a unique vehicle fleet composition and subsequent emissions profile, each of which shows a similar evolution of emissions. Germany has been chosen as a representative example to illustrate these trends.

Figure 1: Diesel passenger car NO_x emissions in Germany—Base Case

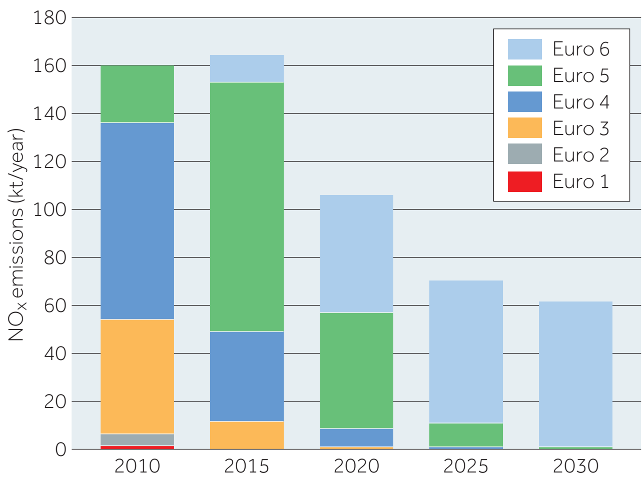


Figure 2 on page 7 shows the diesel passenger car NO_x emissions in Germany for the Ricardo Median Scenario. A reduction in Euro 6 diesel passenger car emissions from 2015 onwards is shown, with a nearly two-thirds reduction by 2030 as a result of improved emissions from diesel car technologies. The diesel passenger car NO_x emissions in Germany for the ZEV Scenario are shown in Figure 3.

Figure 2: NO_x emissions from diesel passenger cars in Germany—Ricardo Median Scenario

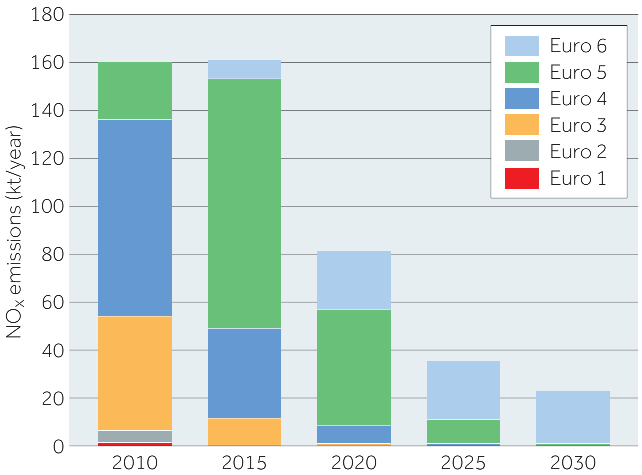
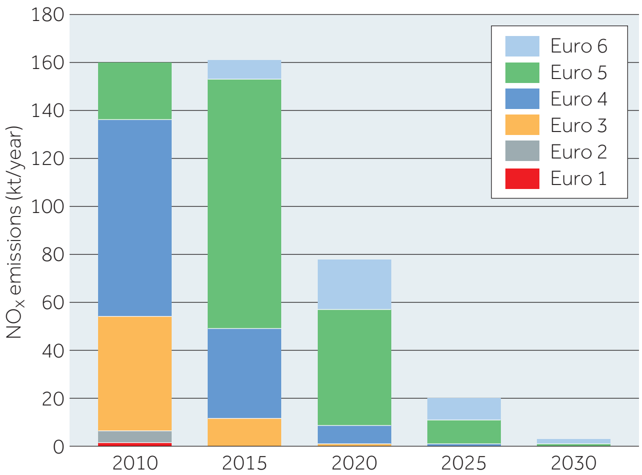


Figure 3: NO_x emissions from diesel passenger cars in Germany—ZEV Scenario



Particulate matter emissions

Figure 4 shows the Base Case emissions of $PM_{2.5}$ from all diesel passenger cars broken down by Euro standard over time in Germany, while Figure 5 shows the $PM_{2.5}$ emissions based on the ZEV Scenario. Successful implementation of exhaust treatment systems removes nearly all PM exhaust emissions. The remainder of the PM emissions are abrasive emissions from road, brake and tyre wear. As the non-exhaust component is produced independently of the vehicle powertrain, a switch to zero-emission vehicles will not affect this aspect and may actually increase this number as a function of increased vehicle mass.[8] In this study, no attempt was made to modify emissions in the ZEV Scenario to take into account vehicle mass.

Figure 4: Primary $PM_{2.5}$ emissions from diesel passenger cars in Germany—Base Case

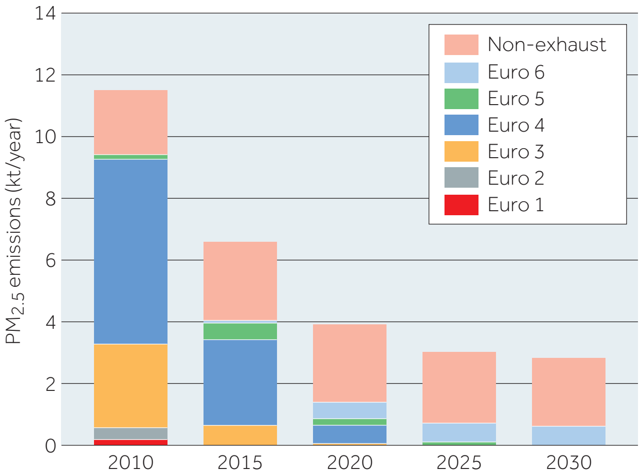
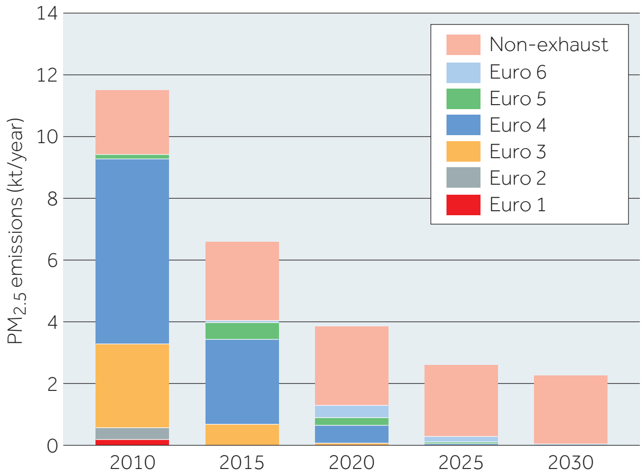


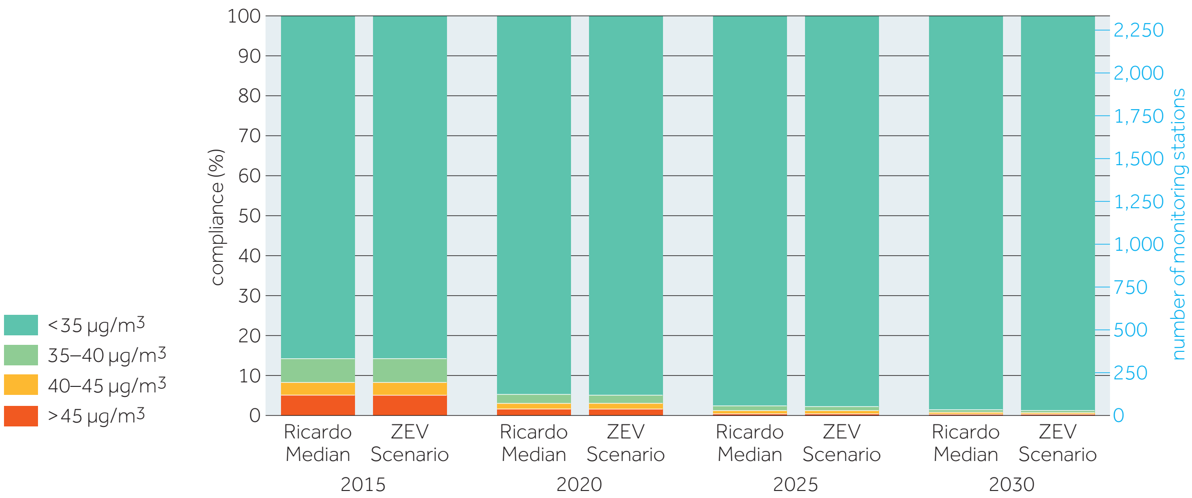
Figure 5: Primary $PM_{2.5}$ emissions from diesel passenger cars in Germany—ZEV Scenario



Results — nitrogen dioxide

Figure 6 shows the modelled compliance of NO_2 monitoring stations across the EU-28 for the Ricardo Median and ZEV Scenarios. The results show that, by 2020, roughly 2% of stations are predicted to be non-compliant, with a further 1.5% predicted to be possibly non-compliant. This is observed in both the Ricardo Median and the ZEV Scenarios which both exhibit a similar evolution of compliance over time. The difference in the overall number of stations achieving compliance between the two scenarios is just above 0% in 2020, less than 0.1% in 2025 and 0.2% in 2030. This strongly suggests that the progressive replacement of older diesel passenger cars by Euro 6d diesel cars will show a similar improvement in urban air quality compliance compared to a replacement with zero-emission vehicles.

Figure 6: NO_2 station compliance across the EU-28 for the Ricardo Median and ZEV Scenarios

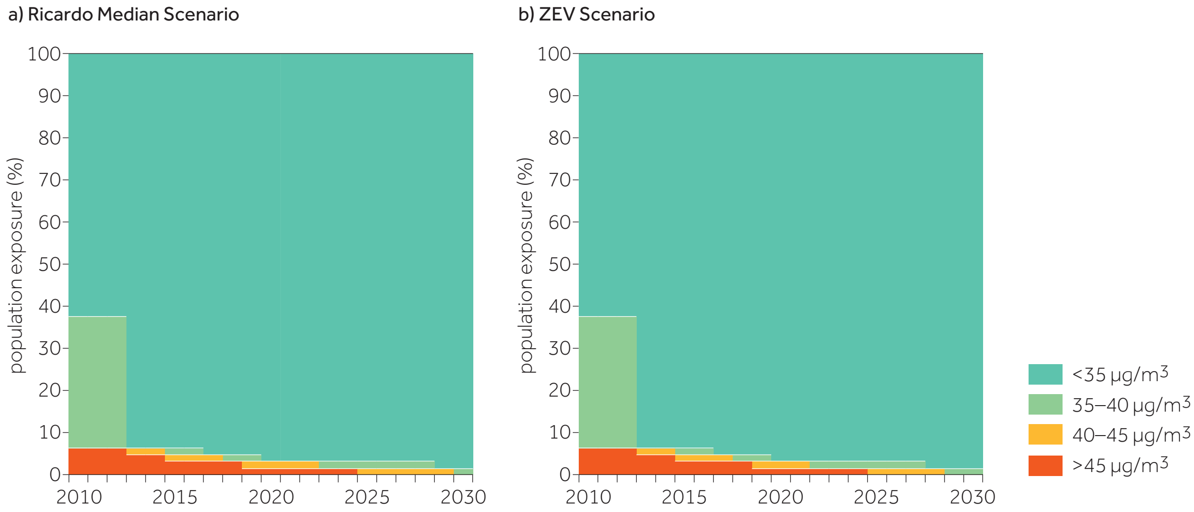


In terms of population exposure, the Aeris modelling[2] at city level shows that there is almost no difference between the Ricardo Median and ZEV Scenarios. Figure 7 on page 9 shows the exposure of the population of Munich[3] according to the two scenarios. No difference is seen between the two scenarios until 2022 and even then, the only difference is the shift of a single year forward in the ZEV Scenario. Ultimately both scenarios result in the same level of population exposure in 2025 and 2030. The same overall conclusion is true of other cities evaluated.

[2] The model uses the population exposure methodology described in the EEA paper, *Exceedance of air quality limit values in urban areas*.[9]

[3] Munich was chosen as a representative city; relevant findings were predicted for other cities.

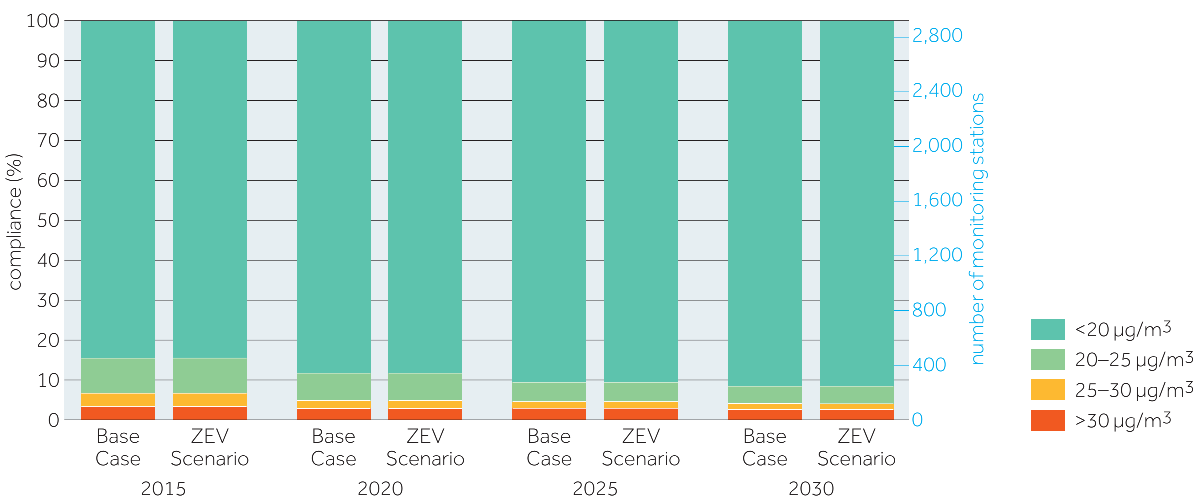
Figure 7: Population exposure to NO_2 in Munich—Ricardo Median and ZEV Scenarios



Results—particulate matter

Given the similar particulate emissions from Euro 6 diesel passenger cars and zero-emission vehicles it is not expected that there will be any change in air quality in terms of PM compliance. This is confirmed in Figure 8 which shows the modelled compliance of $PM_{2.5}$ monitoring stations across the EU-28 for the Base Case and the ZEV Scenario. The results show that by 2020 roughly 3% of stations are predicted to be non-compliant with a further 2% predicted to be possibly non-compliant. This is observed in both the Base Case and ZEV Scenarios which exhibit a similar evolution of compliance over time. This strongly suggests that non-compliance across the EU-28 is unrelated to Euro 6d diesel passenger cars, given that their substitution with zero-emission equivalents has no effect on overall compliance.

Figure 8: $PM_{2.5}$ station compliance across the EU-28 for the Base Case and the ZEV Scenarios



Conclusion

The results of the study indicate that the latest Euro 6 technologies will deliver a significant reduction in emissions of nitrogen oxides compared to pre-2015 vehicles. Euro 6d is expected to achieve the 80 mg/km limit or better, under real-world driving conditions. Additionally, in the turnover of the vehicle fleet from older vehicles to new vehicles, the latest Euro 6d diesel vehicles will be as effective as zero-emission vehicles in helping cities become compliant with air quality standards. The modelling shows that almost no difference in population exposure is expected between the Ricardo Median and ZEV Scenarios.

In the case of particulates, given that diesel particulate filters have been effective in managing PM, emissions from modern passenger cars are largely independent of the drivetrain, with mechanical abrasion (brake, road and tyre wear) being the most significant source. This means that both electric and newer diesel passenger cars produce essentially equivalent emissions for a given vehicle weight and driving habit. Therefore, in any areas experiencing $PM_{2.5}$ or PM_{10} non-compliance, the level of improvement will be similar for both new ICEs and EVs.

Further developments in new vehicle emission standards or measures that exclude new diesel cars from cities are unlikely to deliver earlier compliance or a reduction in population exposure. An analysis of local sources of pollutants is needed to effectively address the remaining non-compliant areas and to identify the most effective mitigation measures.

References

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