EURO 7 IMPACT ASSESSMENT: THE OUTLOOK FOR AIR QUALITY COMPLIANCE IN THE EU AND THE ROLE OF THE ROAD TRANSPORT SECTOR

An independent study undertaken on behalf of ACEA

AERISEUROPE
Air Quality Intelligence

Executive Summary

This study quantifies the impact on measured air quality in urban environments throughout the EU[1] between 2020 and 2035 from the implementation of currently mandated emission reduction measures[2] in all contributing sectors, including road transport. The effect of these measures on atmospheric concentrations of NO_2, PM2.5, PM10 and Ozone at urban monitoring stations has been modelled and the impact on compliance with current EU legislated and WHO guideline values[a] is explored.

Although the main focus of the study is road transport, by including emissions from all source sectors the contribution from each sector can be evaluated to provide an overall EU air quality perspective. The additional impact on air quality from a series of scenarios that might additionally reduce road transport emissions (if this were the only regulatory measure) is also explored.

The emissions Base Case adopted for this study is consistent with the Thematic Strategy on Air Pollution Report #16 Current Legislation Baseline Scenario data from the GAINS[3] model for all sectors except road transport. Road transport emissions are derived from the SIBYL[4] baseline fleet and COPERT[5] emission tool. Specific elements of the base line fleet have been modified to more accurately reflect the anticipated real-world fleet composition predicted by ACEA.[6]

The results indicate that the introduction of the full range of Euro7/VII[7] NO_X and PM2.5 emission limit scenarios explored in this study result in very limited further reductions in road transport emissions beyond that achieved in the Euro 6d/VI Base Case. **Table 1** summarises the Base Case emission reductions from 2020 to 2030/35 and the range of additional reductions from all the scenarios explored in this study.

Table 1 - NO_X and PM2.5 - Emission reductions delivered by the Base Case and the range of additional reductions delivered by the various Euro 7/VII scenarios

NO_X Emissions - Road Transport	**2030 (% reductions from 2020)**		**2035 (% reductions from 2020)**	
	Base Case	**Scenarios**	**Base Case**	**Scenarios**
Euro 7 Final Scenarios (diesel cars and vans)	66.7%	0.9 - 3.4%	79.0%	1.1 - 4.6%
Euro VII Scenarios (heavy duty vehicles)		0.1 - 1.6%		0.1 - 2.4%
PM2.5 Emissions - Road Transport				
Euro 7 Final Scenarios (diesel cars and vans)	20.7%	0.8 - 1.6%	17.3%	1.1 - 2.1%

---

[1] For the purposes of this study, the 'EU' includes the EU 27 nations and the United Kingdom.

[2] Where it has not been possible to quantify the impact of a measure, for example the Medium Combustion Plant Directive, emissions have not been reduced.

[3] The Greenhouse gas - Air pollution Interactions and Synergies (GAINS) model, developed at the International Institute for Applied Systems Analysis (IIASA).

[4] SIBYL baseline: vehicle fleet and activity data projections for the member states of the of the EU.

[5] COPERT is the EU standard vehicle emissions calculator, developed and maintained by EMISIA SA for the EEA.

[6] The European Automobile Manufacturers' Association (ACEA) represents the 15 major Europe-based car, van, truck, and bus makers.

[7] Euro 7/VII refers to possible new standards beyond the current Euro 6/VI emission standard. The introduction of a range of potential Euro 7/VII standards are explored in this report.

The study also explores the benefits that result from the early replacement of Euro 3/III through to Euro 5/V vehicles with Euro 6/VI vehicles in the 2020/21 diesel passenger and heavy-duty vehicle parc. In contrast to the very limited further reductions resulting from the introduction of a 'zero-exhaust' Euro 7/VII emission standard, early replacement (via an incentivised early scrappage scheme for example) would, on a vehicle for vehicle basis, result in some 6 to 25 times the emission reduction benefits for NO_X and some 10 to 35 times the emissions reduction benefit for PM2.5. Importantly, these benefits would also be realised much earlier. The full monetised benefits of such schemes will be more fully set forth in the planned follow-up report exploring the cost-benefits of a future Euro 7/VII.

Concentrations at urban monitoring stations across the EU have been modelled using the AQUIReS+ model, developed by Aeris Europe and used in previously published works on urban air quality. [b, c]

Regarding the impact on air quality, the results of this study indicate that currently mandated (Base Case) measures will achieve widespread compliance with the current NO_2, PM2.5 and PM10 limit values by 2025. Furthermore, all of the 'beyond the baseline road transport scenarios' explored in this study have negligible impact on the compliance picture. This remains the case even if the current PM2.5 annual mean limit value were to be reduced to the WHO guide value.

If further reductions in concentration are to be realised, then the results indicate that the most effective strategy would be to target those sectors that are demonstrated to have the greatest scope for reduction, for example domestic and commercial combustion or agriculture. Since the remaining areas of NO_2 and PM2.5 non-compliance are limited to a small number of monitoring stations, achieving compliance in these instances would be more effectively realised by introducing local measures that target the specific contributors to non-compliance at these geographically limited areas. None of the modelling in this study suggests that any further European-wide measures are warranted to achieve compliance with the currently legislated Air Quality Limit Values (AQLV).[8]

In the case of urban ozone, the results indicate that widespread non-compliance with the targets in the current Ambient Air Quality Directive (AAQD)[d] will continue throughout the study period. The study also shows that the magnitude and extent of this non-compliance increases significantly if the lower threshold in the current WHO guidelines is applied. However, the effect of reducing road transport emissions beyond that achieved in the Base Case does not improve the ozone compliance situation in urban areas. Importantly, the reduced availability of NO from further reductions in NO_X emissions will, in a number of the cities studied (for example Madrid), cause an increase in ozone levels and non-compliance from decreased ozone titration. This is a recognised 'environmental tension' between NO_2 and ozone mitigation strategies in cities which is discussed more fully in the body of the report.

The most effective strategy demonstrated to reduce ozone is to target volatile organic compound (VOC) emissions from the 'solvent and product use' sector. This sector is the largest contributor to anthropogenic VOC emissions in the Base Case. The study shows that further emissions abatement in other sectors has only a small effect on ozone compliance.

The study also explores the impact of the outbreak of SARS-COV-2 (COVID-19) on air quality, with a particular focus on nine selected cities[9] and the 'Innsbruck Transit Corridor'. The COVID scenarios modelled were confined to a range of reduced road transport activities - ranging from 25% to 75% reduction in activity. In the case of PM2.5, as found in other studies, the lockdown resulted in a very

---

[8] For Air Quality Limit Values see Table 6.

[9] Berlin, Brussels, London, Madrid, Milan, Paris, Rome, Stuttgart, and Warsaw

limited impact on measured concentrations compared to recent years. The modelled response, as expected, was also found to be small. This is consistent with the small contribution of PM2.5 emissions from road transport to overall PM2.5 concentrations. In the case of ozone, given the strong inter-annual and monthly variations in concentration, it is difficult to discern any COVID related signal. Other studies have however shown that during lockdown periods, ozone levels have increased, particularly in city centres, due to the loss of the titrating effect of NO from reduced NO_X emissions. [e]

In the case of urban NO_2, measurement station data in almost all cases indicates a more significant reduction in concentrations during the lockdown periods than the modelled responses. This is in-line with the important additional NO_X contribution from domestic and commercial combustion systems in cities. During lockdown, the emissions from these sources were also significantly reduced (from the move from office to working from home for example) but the effect of this was not included in the COVID scenarios explored in this study. In the case of the Innsbruck Transit Corridor, the NO_2 measurements are within the range of the modelled scenarios.

A summary of findings for each pollutant follows:

Nitrogen Dioxide

The study finds almost universal compliance (approximately 99% of urban monitoring stations) with the currently legislated limit values for NO_2 by 2025 when implementing currently mandated measures across all sectors.

None of the additional road transport measures explored in this study result in any appreciable further impact on compliance. Domestic and commercial combustion systems are demonstrated to have the greatest scope for reducing urban concentrations of NO_2 beyond that achieved in the Base Case.

Particulates

The study finds almost universal compliance (over 99% of urban monitoring stations) with the currently legislated limit values for PM2.5 by 2025 when implementing currently mandated measures across all sectors. However, compliance with the WHO PM2.5 guideline value is shown to be a major challenge for most of the EU with over 50% of stations remaining non-compliant in the Base Case in 2030.

None of the additional road transport measures explored in this study have any appreciable impact on compliance with either the currently legislated limit values, or the much stricter World Health Organization's guideline value.

PM10 compliance remains an issue in specific regions of the EU out to 2035 in the current emissions Base Case. These regions demonstrate a clear clustering of non-compliance that show little response to the additional European scale reductions that have been modelled in this study. This suggests that a regional or possibly national approach, specifically targeting the sources contributing to non-compliance in these areas would be a more efficient and reliable strategy.

Reducing primary particulate emissions from solid fuel burning in domestic and commercial combustion systems or the reduction of ammonia emissions from the agriculture sector (an important pre-cursor emission for PM2.5) suggest considerable scope for reducing urban concentrations of PM2.5 and PM10 beyond the Base Case.

Ozone

The study finds that in the Base Case, ozone non-compliance is present in many urban areas of the EU.

Reducing NO_X emissions from road transport in cities (particularly city centres) beyond the baseline in a number of the cities studied (Brussels, London, Madrid and Paris) results in increased ozone concentrations due to the loss of the titrating effect of nitrogen oxide (NO) on ozone.

However, further reductions in VOC emissions (notably from the 'solvent and product use' sector) is predicted to result in ozone reductions and improved compliance across the EU.

---

[a] (WHO, 2005) *WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide*

[b] (Aeris Europe, 2016) *Urban Air Quality Study, #11/16*

[c] (Concawe, 2018) *A comparison of real driving emissions from Euro 6 diesel passenger cars with zero emission vehicles and their impact on urban air quality compliance*

[d] (Directive (EU) 2008/50/EC, 2008) *Directive 2008/50/EC Of The European Parliament And Of The Council on ambient air quality and cleaner air for Europe*

[e] (Lee, et al., 2020) *UK surface NO2 levels dropped by 42% during the COVID-19 lockdown: impact on surface O3*

Contents

Report prepared by: Les White, Adam Miles, Chris Boocock, John-George Cooper, Stephen Mills.

Revision: 1.5a

Introduction

Air Quality in European Cities continues to be an issue of policy and public concern at European, national and city level. Over the last five years attention has focussed almost exclusively on non-compliance with the current AQLV for ambient nitrogen dioxide (NO_2). The primary mechanism for reducing urban concentrations of NO_2 has been to target the emissions from road transport, with the more recent focus on diesel passenger cars.

The forthcoming revision of the AAQD is likely to reduce the permitted concentrations of specific pollutants, this would almost certainly intensify the current concerns over air quality and increase the focus on those emission sources that are believed to be major contributors to non-compliance.

In response to this, the European Commission have started to prepare draft regulatory proposals for the next iteration of vehicle emission standards. To assist in the formulation of these Euro 7/VII proposals, the Commission have contracted members of CLOVE (Consortium for Ultra Low Vehicle Emissions) to conduct a series of studies.

The aim of this independent study is to put the contribution of road transport emissions into a Europe-wide context by examining the impact on urban air quality that currently mandated emission reduction measures from all contributing sectors will achieve. This is followed by an assessment of what a further tightening of Euro standards, including a hypothetical ‘Euro 7/VII’ can offer to the improvement of air quality, compared to other available actions.

While a major focus of this study is NO_2, given the probable tightening of AQLVs for PM2.5, PM10 and possibly ozone, these additional pollutants are assessed to put the contribution of EU road transport emissions (and their further reduction) into an overall EU air quality perspective.

The AQUIReS+ model has been used to forecast the effect of emissions changes on atmospheric concentrations at urban monitoring stations across the EU from 2020 to 2035. This ensures the modelling is directly related to the individual measuring stations used to monitor compliance with the legislated limit values. In this regard, it is worth noting that these limit values, as set forth in the Ambient Air Quality Directive, are the result of a lengthy legislative process beginning with the ‘Risk Assessment’ step undertaken by the WHO and concluding with the ‘Risk Management’ step during the finalisation process of the Directive. As such, these limits represent the Legislator’s view of the appropriate level of managing the risk associated with human exposure to each pollutant in the context of a multi-risk world. Therefore, from an air quality perspective, compliance with limit values must be the priority for the protection of human health.

Methodology

Emissions Base Case

An emissions Base Case that reflects real-world emissions is vital if forecasts of future air quality are to be reliable. The AQUIReS+ model incorporates a back-casting methodology that utilises a set of Base Case emissions (for each measurement year) to generate a concentration baseline at each measuring station in the EU. More details of the AQUIReS+ model can be found later in this report.

The emissions Base Case used in this study is aligned with the January 2015 Thematic Strategy on Air Pollution Report #16 (TSAP16) Working Party for the Environment (WPE) Current Legislation Baseline Scenario [a,b]. This emissions data set was developed for the EU Air Policy Review process [c], and was generated by IIASA's GAINS model.

The reference activity projections included in the national, sectoral emissions totals are based on the PRIMES 2013 reference activity projections, however they obviously exclude the effects of further measures that were legislated in response to the findings of the Clean Air Programme for Europe. Examples of these are, the Medium Combustion Plants Directive (MCPD) and the latest National Emissions Ceilings Directive (NECD). [d,e] As a result, the Base Case adopted for this study should be considered as somewhat under-estimating anticipated overall emissions reductions.

The GAINS emissions data includes projections to the year 2030, however this study extended the time-horizon to 2035. For all non-transport sectors, the emission projections were linearly extrapolated to 2035. For the road-transport sector, the SIBYL baseline emissions projections (with some adjustments for future fleet electrification as explained in the following section) were used, these were available to 2035 and beyond.

As indicated above, road transport emissions in the Base Case are based on the 'SIBYL Baseline' fleet and activity dataset, produced by Emisia S.A. This dataset was chosen as it has been used by the CLOVE consortium in their work supporting the EU Commission review of future vehicle emission standards. The SIBYL Baseline includes vehicle fleet, activity, emissions, and energy consumption projections for the EU 27 member states and 6 additional countries, including the UK.

In this study the SIBYL Baseline fleet data set of May 2020, as presented in the Emisia ERTE 2020 report[f] was used as the starting vehicle fleet. This dataset was updated in 2019 to be fully compatible with the vehicle and technology classifications used by Emisia's COPERT tool, the EU standard vehicle emissions calculator. COPERT uses vehicle population, mileage, speed, and other data such as ambient temperature to calculate emissions and energy consumption for a specific country or region. It is internationally recognised and is used by many European countries for reporting official emissions data.

Modification of the SIBYL Fleet

A review of the SIBYL fleet data showed a somewhat ambitious uptake of plug-in hybrid and battery electric vehicles in the passenger car (PC) fleet category beyond 2020. It also showed no penetration of Zero or Low Emission Vehicles (ZLEV) in any of the other fleet categories. The SIBYL passenger car fleet is shown in **Figure 1**.

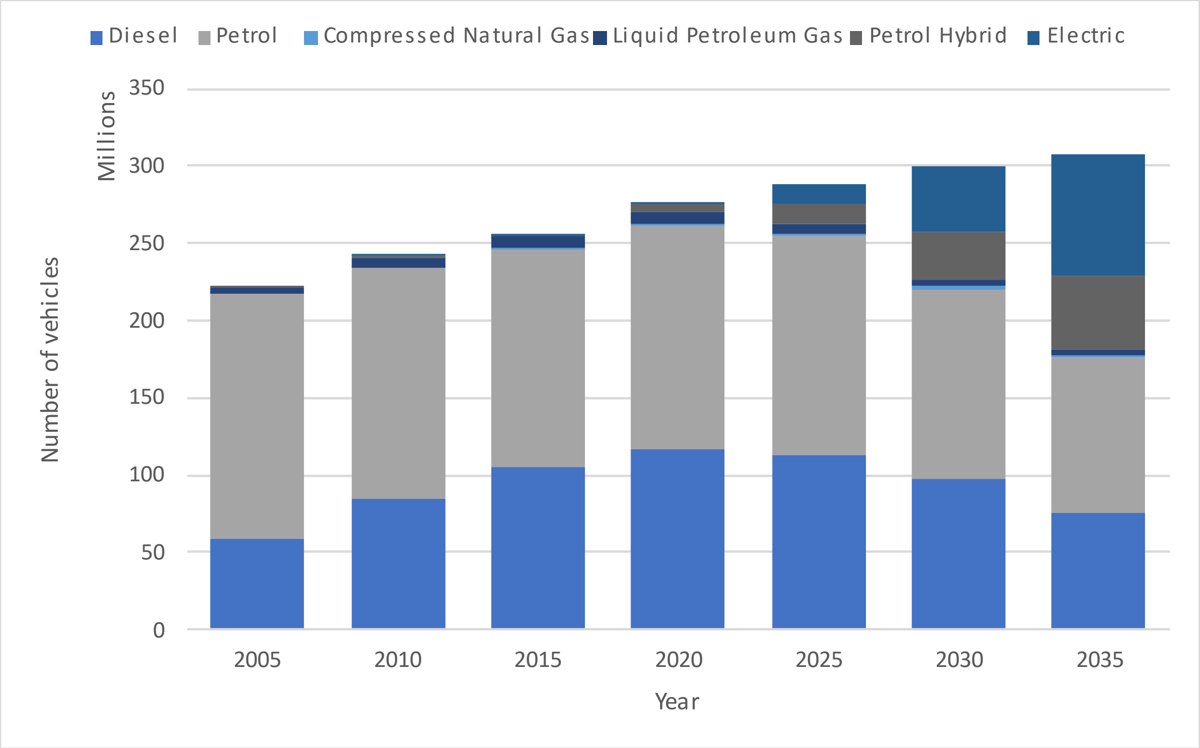


Figure 1 - SIBYL EU passenger car fleet development showing hybrid and electric passenger car uptake

In consultation with ACEA experts, an alternative view of new registration penetration rates for zero and low emission vehicles was developed across all fleet categories. For cars and HDVs an additional 'high-penetration' sensitivity case was also developed. These penetration rates are shown in **Table 2** and reflect ACEA estimates of fleet electrification based on the CO_2 benchmarks (2025/2030) in the case of light-duty vehicles[g] and CO_2 targets (2025/2030) in the case of heavy-duty vehicles[h], and the expected impact of the Clean Vehicle Directive[i]. In view of the 'Green Deal', the already considered greenhouse gas reduction targets for 2030, and the CO_2 reviews in 2020/21, these fleet electrification penetration rates are likely to be underestimates even considering the more ambitious penetration rates used in this study.

Table 2 - The share of ‘zero’ or ‘low’ emission vehicles in new registrations.

	Passenger Cars	Passenger Cars High-Penetration	Light Commercial Vehicles	Heavy Duty Vehicles	Heavy Duty Vehicles High-Penetration	Buses	Coaches
2020	0%	0%	0%	0%	0%	0%	0%
2021	1%	1%	1%	1%	1%	8%	0%
2022	2%	2%	2%	2%	2%	17%	0%
2023	3%	3%	3%	3%	3%	25%	0%
2024	4%	4%	4%	4%	4%	33%	0%
2025	5%	5%	5%	5%	5%	42%	5%
2026	10%	10%	10%	8%	8%	50%	8%
2027	15%	15%	15%	11%	11%	58%	11%
2028	20%	20%	20%	14%	14%	67%	14%
2029	25%	25%	25%	17%	17%	75%	17%
2030	30%	30%	30%	20%	20%	83%	20%
2031	35%	37%	37%	23%	28%	92%	28%
2032	40%	44%	44%	26%	36%	100%	36%
2033	45%	51%	51%	29%	44%	100%	44%
2034	50%	58%	58%	32%	52%	100%	52%
2035	55%	65%	65%	35%	60%	100%	60%

Fleet Modification Methodology

Reset to internal combustion engine only

For each year, in each member state beyond 2020, the passenger car stock elements of plug-in hybrid and battery electric vehicles were summed. This sum of ZLEV vehicles was then reallocated to the medium size diesel and gasoline passenger car stock elements. This reallocation was performed to match the ratio of the existing diesel to gasoline fleet split as calculated for each individual year and member state. In this way, total fleet numbers remained balanced and existing fuel splits were respected.

Implementation of ACEA ZLEV penetration rates

To assess how best to implement ACEA’s ZLEV new registration uptake rates into the reset SIBYL fleet, a detailed analysis was undertaken of the year-on-year stock changes. This showed that in the absence of the actual scrappage functions used in the SIBYL fleet, the annual increment in stock was the most appropriate basis for implementation. For each fleet element, from 2020 onwards, the new ZLEV component of registrations was calculated as the product of annual stock increment and ZLEV percentage of new registrations.

The newly created ZLEV elements were accrued beyond 2020 resulting in the growing ZLEV fleets. Similarly, the conventional internal combustion engine (ICE) elements of the fleet were reduced each year by the same number as the new ZLEV element to ensure balance in the total fleet numbers.

Results of the ACEA fleet adjustments

The results of these changes were reviewed for all combinations of the sensitivity cases and it was decided to use the more ambitious penetration rates for passenger car (PC), light commercial vehicles (LCV) and heavy-duty vehicles (HDV). These fleet elements, which are shown in **Figure 2**, **Figure 4**, **Figure 6**, **Figure 8** and **Figure 10** were used as the basis for the study. The impact on NO_X emissions in each of the vehicle categories are shown in **Figure 3**, **Figure 5**, **Figure 7**, **Figure 9** and **Figure 11**.

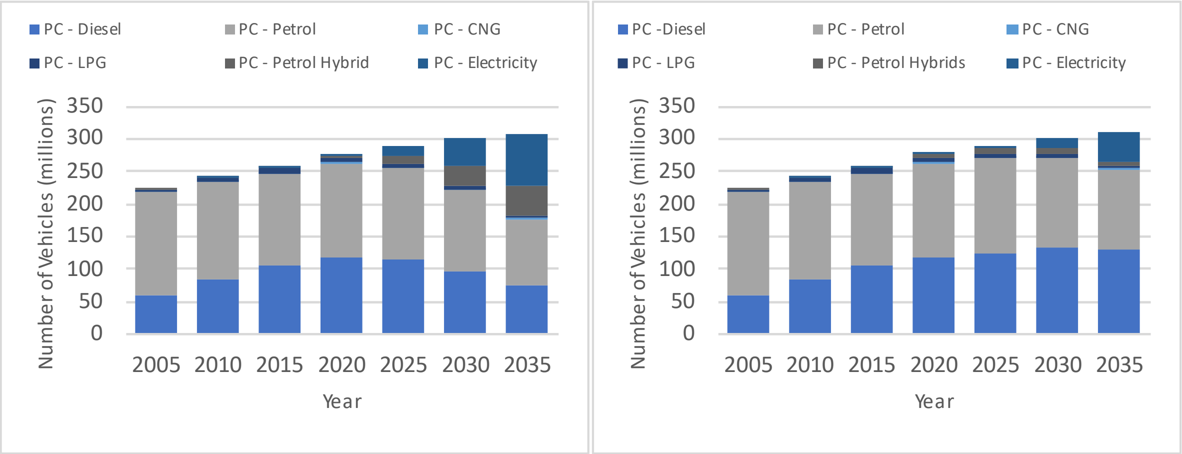


Figure 2 - EU total passenger car fleet numbers by fuel type. Left - SIBYL fleet. Right - ACEA fleet.

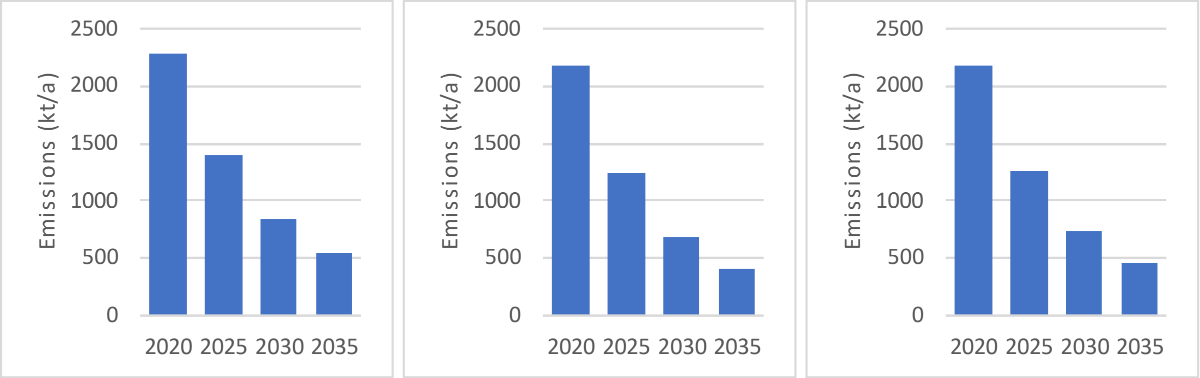


Figure 3 - EU Total fleet NO_X emissions. Left - SIBYL fleet. Middle - SIBYL fleet with adjusted emission factors. Right - ACEA fleet adjusted emission factors.

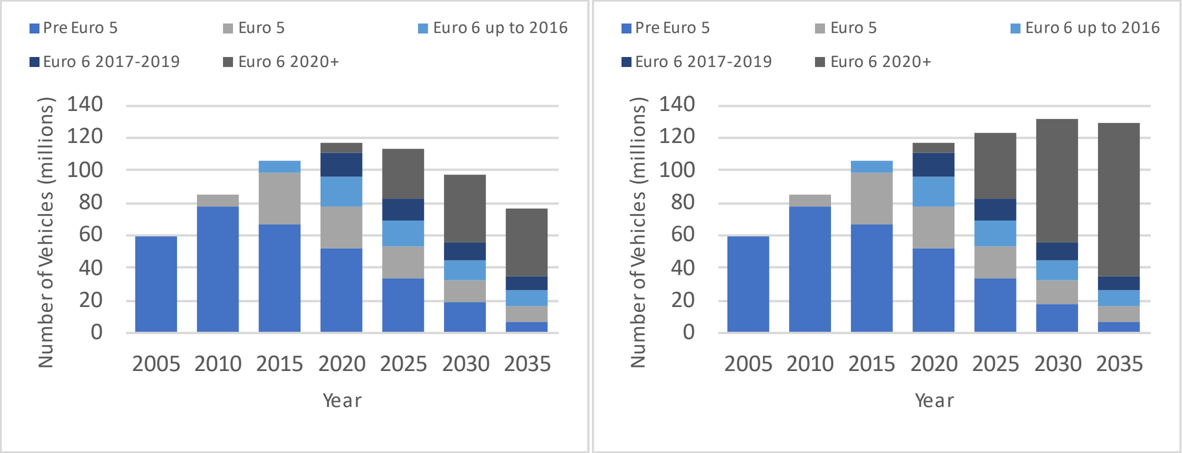


Figure 4 - EU diesel passenger car fleet numbers by technology. Left - SIBYL fleet. Right - ACEA Fleet.

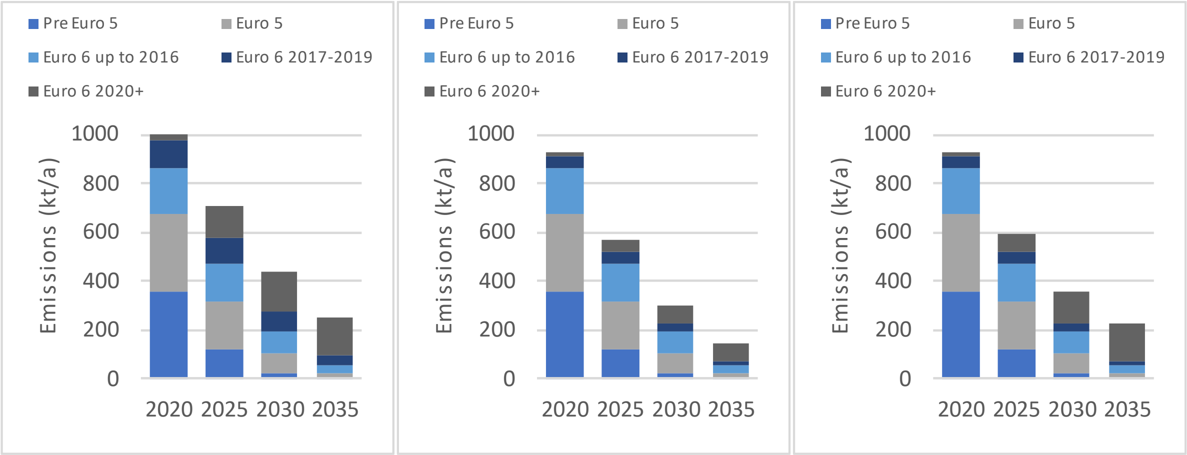


Figure 5 - EU passenger car diesel NO_X emissions by technology. Left - SIBYL fleet. Middle - SIBYL fleet with adjusted emission factors. Right - ACEA fleet.

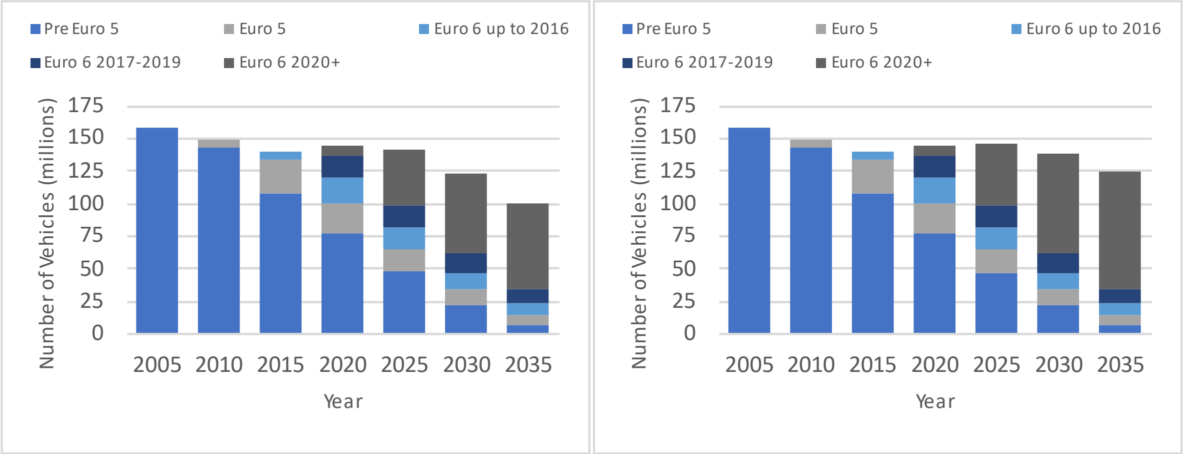


Figure 6 - EU gasoline passenger car fleet numbers by technology. Left - SIBYL fleet. Right - ACEA Fleet.

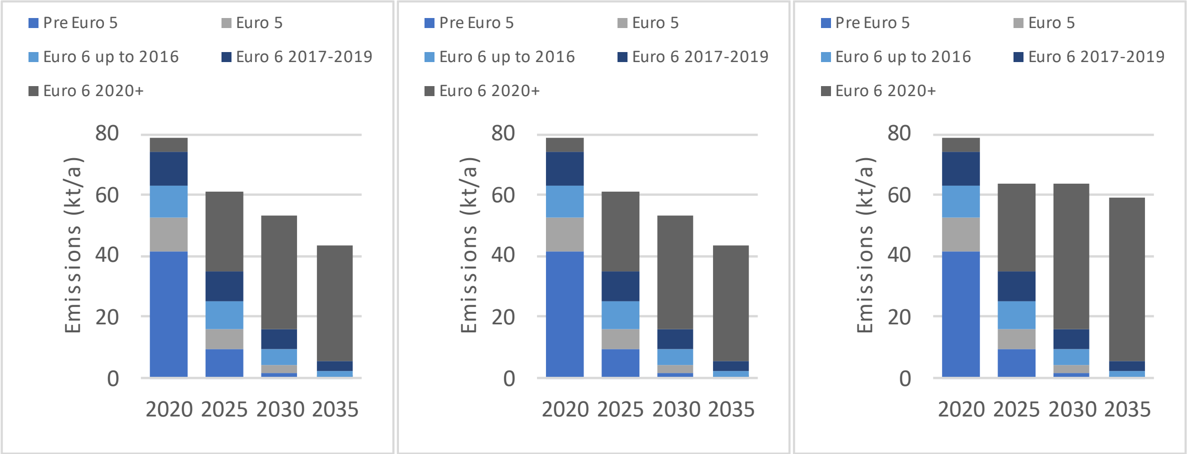


Figure 7 - EU gasoline passenger car NO_X emissions by technology. Left - SIBYL fleet. Middle - SIBYL fleet with adjusted emission factors. Right - ACEA fleet.

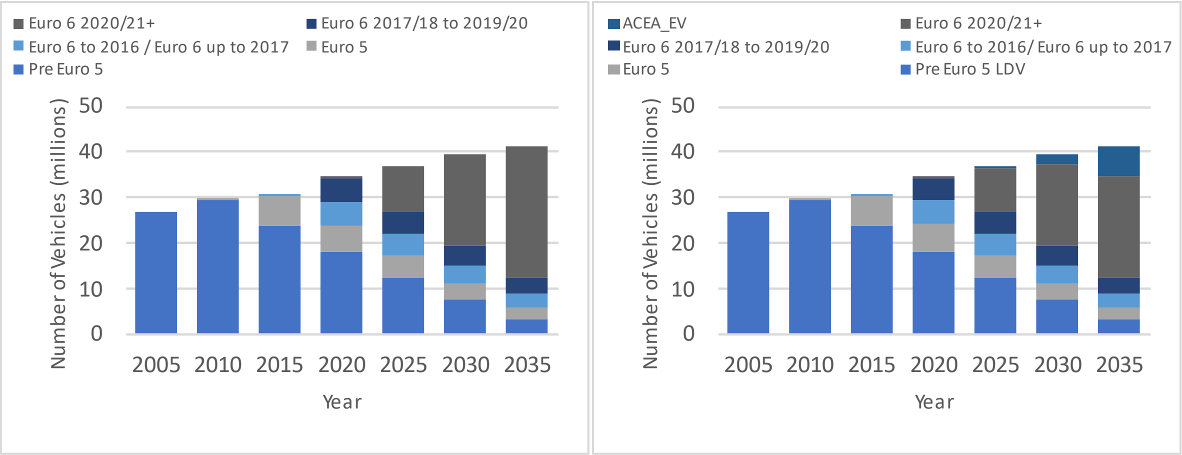


Figure 8 - EU light commercial vehicle fleet numbers by technology. Left - SIBYL fleet. Right - ACEA fleet.

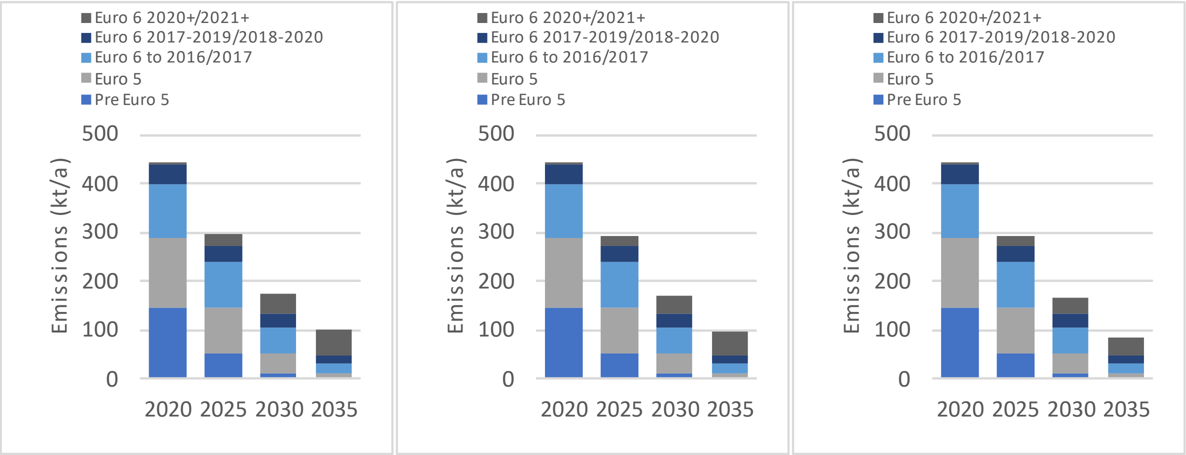


Figure 9 - EU light commercial vehicle NO_X emissions by technology. Left - SIBYL fleet. Middle - SIBYL fleet with adjusted emission factors. Right - ACEA fleet.

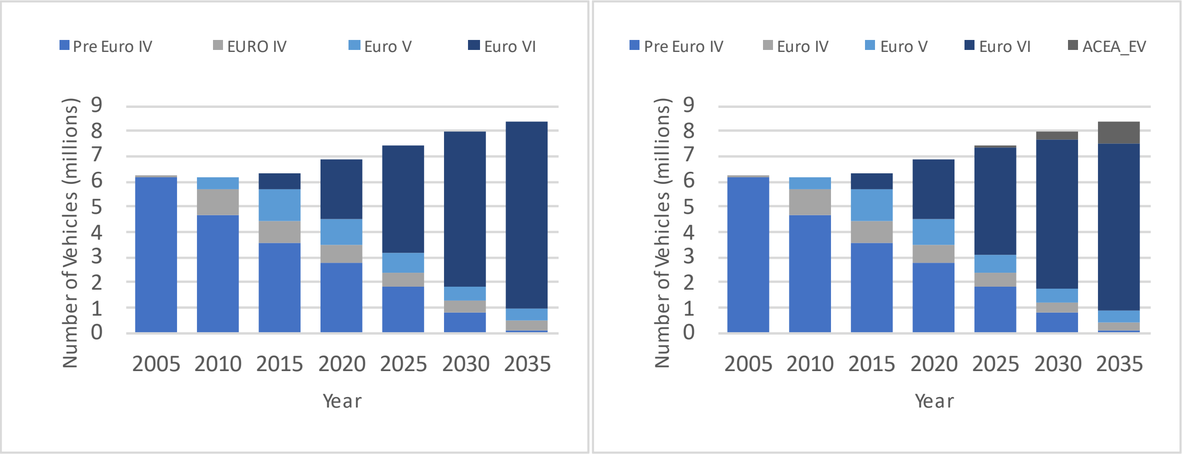


Figure 10 - EU heavy duty vehicle fleet numbers by technology. Left - SIBYL fleet. Right - ACEA Fleet.

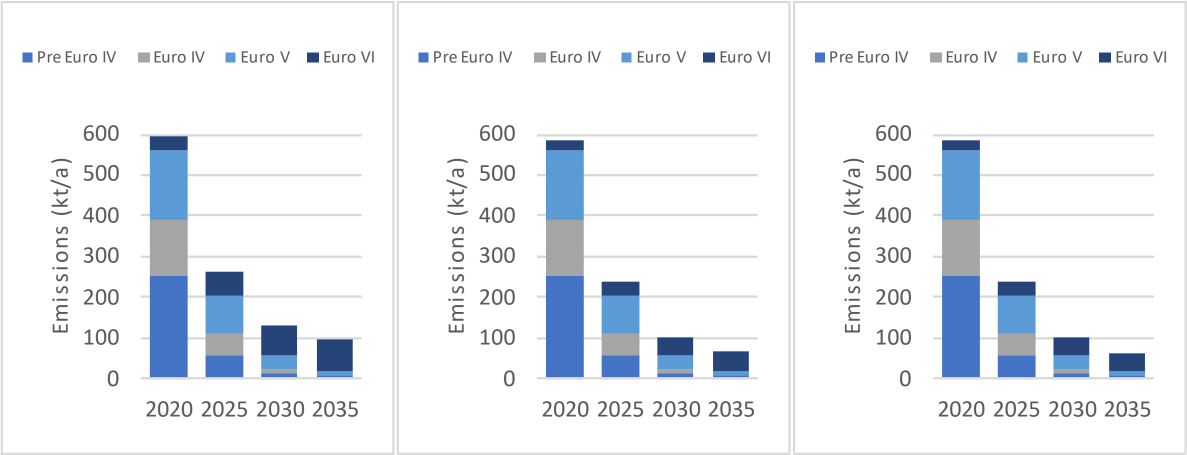


Figure 11 - EU heavy duty vehicle NO_X emissions by technology. Left - SIBYL fleet. Middle - SIBYL fleet with adjusted emission factors. Right - ACEA fleet.

Emission Factor Adjustments

The development of COPERT is coordinated by the European Environment Agency (EEA) in the framework of the activities of the European Topic Centre (ETC) for Air Pollution and Climate Change Mitigation. The EC Joint Research Centre (JRC) manages the scientific development of the model. Its methodology is part of the EMEP/EEA air pollutant emission inventory guidebook and is consistent with the 2006 IPCC Guidelines for the calculation of green-house gas (GHG) emissions.

COPERT version 5.3.26 was used in this study but with important modifications to Euro 6/VI diesel NO_X emission factors. These modifications were made following back calculation of emission factors from the SIBYL Baseline data which showed that Euro 6d temp (mandatory from 2017) and Euro 6d final (mandatory from 2020) emission factors were higher than are observed in use. Similarly, back calculations showed that Euro VI emission factors did not include the regulatory Steps D and E. Accordingly, to better reflect Euro 6 performance, the Euro 6d temp NO_X tailpipe emissions conformity factor (CF) was set to a conservative value of 2 and the Euro 6d final NO_X tailpipe emissions conformity factor was set to a conservative value of 1. These conformity factors were applied to all relevant Euro 6 technology passenger cars and light duty vans. To reflect the NO_X emissions of Euro VI Steps D and E more accurately, coefficients of 68% for articulated and 54% for rigid were applied to all relevant emissions from Euro VI technology HDV and heavy vans.

The above adjustments to emissions factors were made following consultation with ACEA and a review of measurement data. Since the technical analysis in this study was completed, COPERT has been updated to v5.4.30 - September 2020. This update has reduced Euro 6d temp and 6d final below the CF: 2 and CF: 1 described above.[1] The Euro VI emissions technology now has a classification for steps D and E, but initial checks do not show an associated change to emissions.

---

[1] EMISIA COPERT v5.4 Report: For PCD Euro 6d-temp there has been an approximate 85% reduction in NO_X exhaust emission factors. For Euro 6d the reduction is approximately 75% in NO_X exhaust emission factors. These new emission factors give an approximate conformity factor across the speed range of 0.9 for Euro 6d-temp and 0.75 for Euro 6d.

Overview of Base Case emissions by Sector - NO_X

One aim of this study is to put the emissions from each primary source sector into context. This is important for two reasons: It provides an historical perspective, and it facilitates appropriate prioritising of any new emission reductions.

Figure 12 shows the total EU Base Case NO_X emissions used in this study. Each source sector is shown separately so that the contribution of each sector to overall emissions can be clearly seen. Over the fifteen-year period, from 2005 to 2020, emissions from all major sectors have declined, however some sectors have experienced significantly greater reductions than others. Road-transport has seen the greatest reduction of all, some 54%.

By 2030, and beyond, road transport is forecast to no longer be the primary contributing sector, with energy production and industrial combustion some 25% and 33% larger, respectively. This is partly due to the fact that, unlike all the other major sectors, industrial combustion emissions are projected to increase from 2020, returning to pre-2010 levels by 2030.

The important point to be made here, is that the road transport contribution to the total in 2005 (some 40%) is forecast to fall to some 18% of the total by 2030.

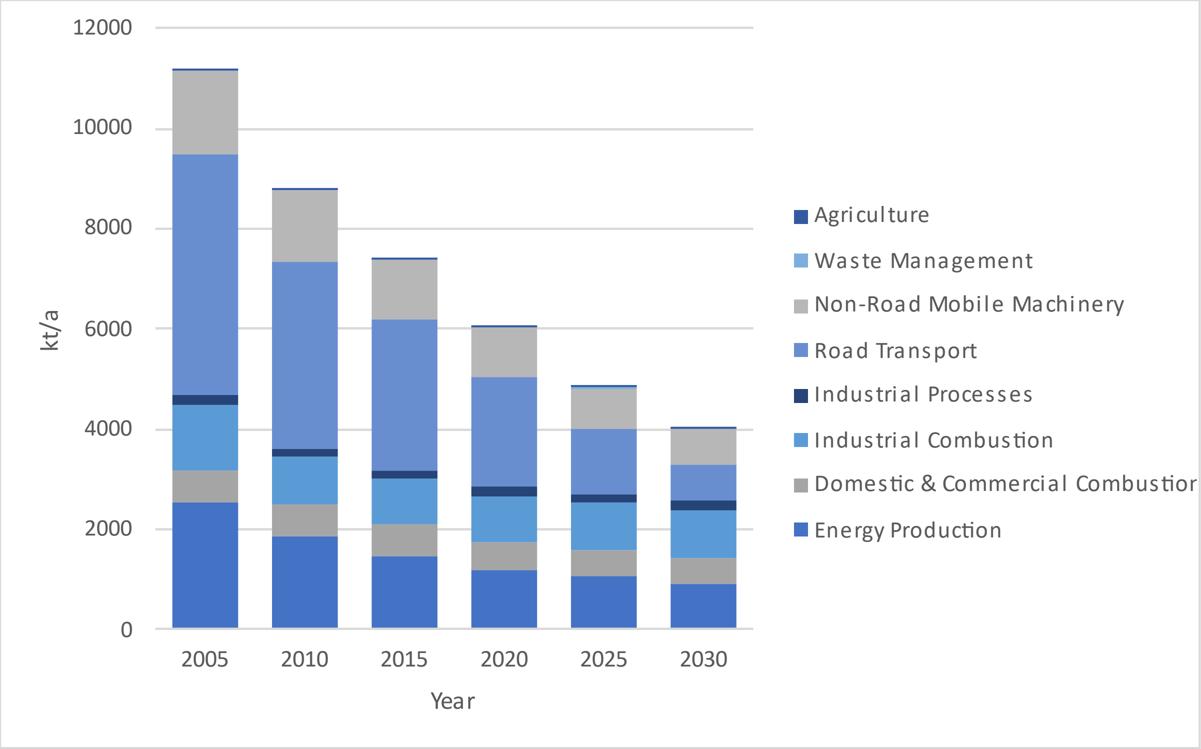


Figure 12 - EU - NO_X emissions Base Case. Excluding fuel extraction and solvent and product use as zero emissions. Source: GAINS IIASA

Overview of Base Case emissions by Sector - PM2.5

Figure 13 shows the total EU Base Case PM2.5 emissions used in this study. Each source sector is shown separately so that the contribution of each sector to overall emissions can be clearly seen. Over the fifteen years period from 2005 to 2020, emissions from a number of sectors have remained fairly constant showing increases or decreases of less than 20%. In a similar way to NO_X, the greatest emission reductions have been in the road transport sector, the energy sector and additionally, non-road mobile machinery.

There has been a 57% reduction in PM2.5 emissions from road transport between 2005 and 2020 and a similar reduction is observed in the non-road mobile machinery sector.

Between 2020 and 2030, emissions from most sectors are forecast to remain essentially unchanged, exceptions being the domestic and commercial combustion sector, road transport, and non-road mobile machinery.

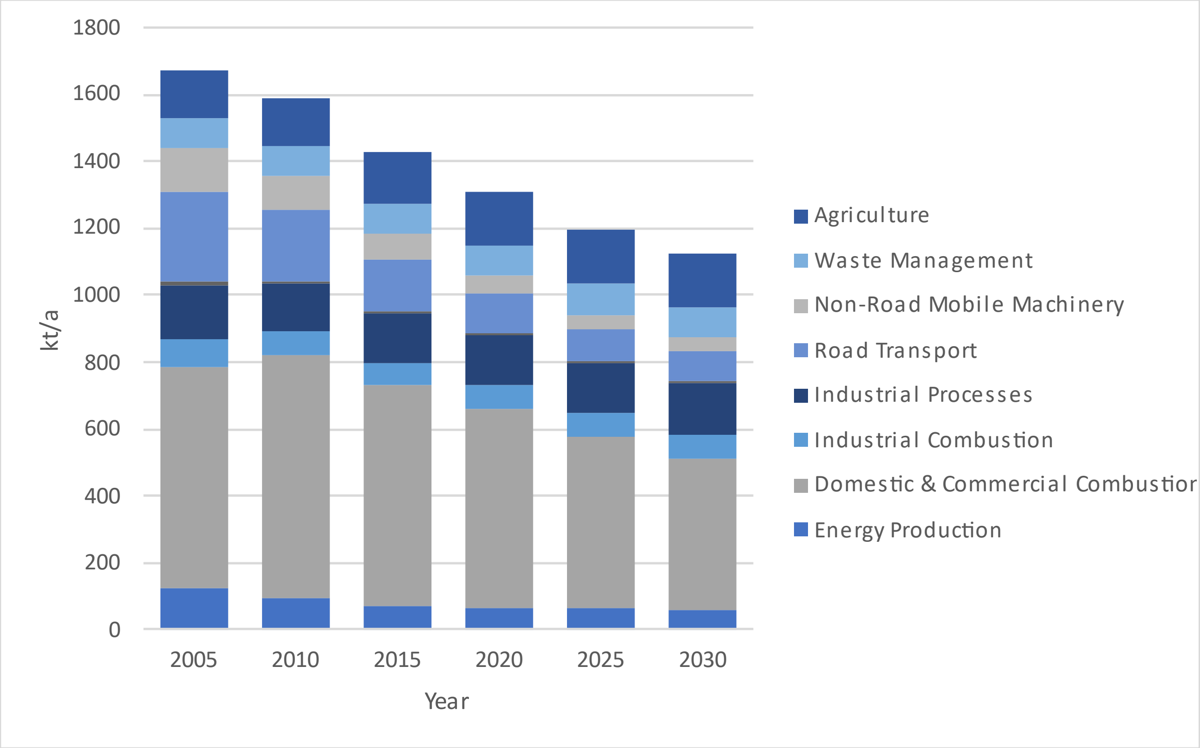


Figure 13 - EU - PM2.5 emissions Base Case. Excluding fuel extraction and solvent and product use as zero or negligible emissions. Source: GAINS IIASA

Exhaust and Non-Exhaust Emissions

PM2.5 emissions from road-transport are divided into two main sources; exhaust and non-exhaust. Exhaust emissions are produced by combustion within the engine. A gasoline engine produces much less mass of particulates than a diesel engine. However, all modern diesel engines are equipped with highly efficient particulate filters so almost all particulates are removed. Modern gasoline engines are now employing particle filter technology to meet current particle number (PN) limits.

Non-exhaust emissions are produced by mechanical abrasion and are present independent of the vehicle's powertrain. The primary sources of these emissions are abrasion between the road and tyres and between braking surfaces.

Whether electric vehicles produce different amounts of non-exhaust emissions compared to conventional vehicles is still being studied.[j] But given that any intrinsic difference in non-exhaust emissions between vehicles with all-electric, hybrid or conventional engines is likely to be small, no adjustments to these emissions have been made for the different powertrains in this study.

PM2.5 emissions from vehicle exhaust systems have reduced dramatically over the 15 years between 2005 and 2020 as particulate filters (required to meet the tighter Euro Standards for particle mass and number) have penetrated the vehicle parc (**Figure 14**). This trend is expected to continue as older vehicles are replaced by new technology. Despite increasing fleet numbers, the high efficiency of particulate control systems in modern cars and evolution of the fleet continues to result in a reduction in these emissions out to 2030 and beyond. By 2025, some 75% of all road-transport PM2.5 emissions are from non-exhaust sources and this increases to 87% by 2030 and 91% by 2035.

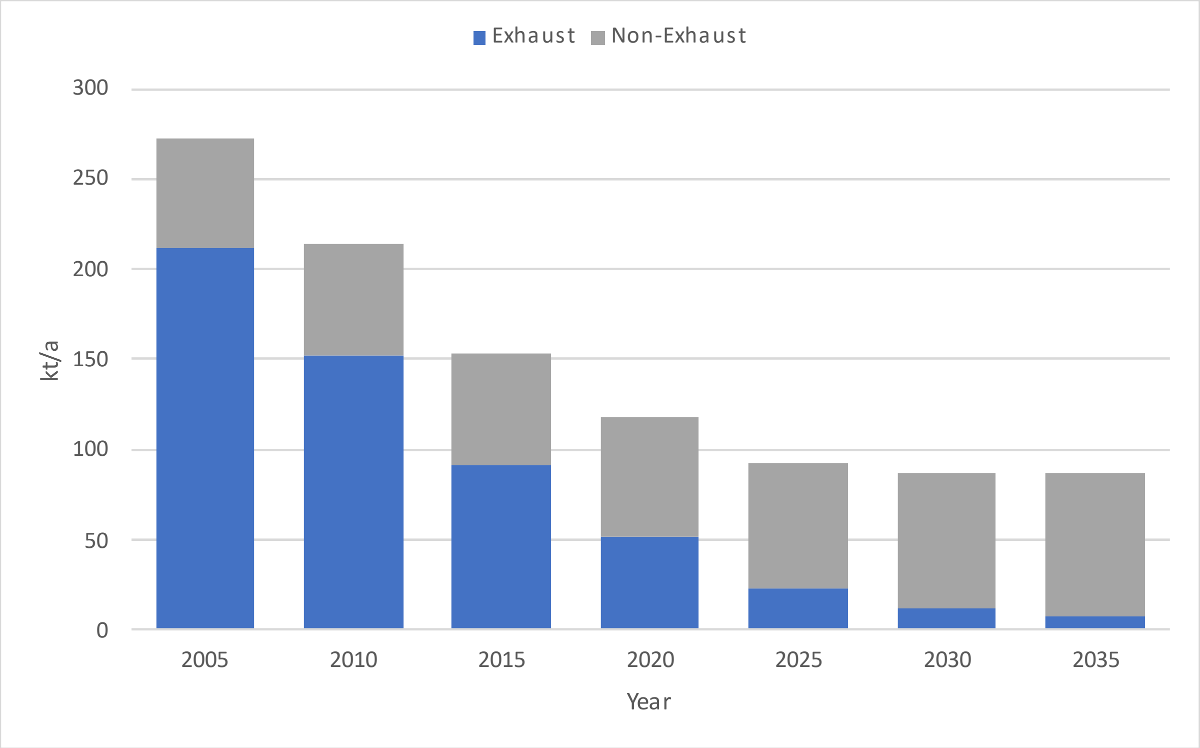


Figure 14 - PM2.5 Emissions from road transport in the EU, split into exhaust and non-exhaust fractions

Scenarios

While this study is primarily focussed on road transport emissions and their contribution in context with other emissions, some of the scenarios also model the effect of emission reductions from other sectors. These have largely taken the form of 'sensitivity scenarios' to help frame the contribution from these sectors in relation to other sources.

Throughout these scenarios (and the report as a whole) shorthand terms are used to describe different components of the vehicle fleet, these terms and their meanings are listed in **Table 3.**

Table 3 - Glossary of vehicle classifications

Term	Description
PC	Passenger Car
PCD	Diesel Passenger Car
PCG	Gasoline Passenger Car
LCV N1-I	Light Commercial Vehicles with a TPMLM[2] < 1305kg
LCV N1-II	Light Commercial Vehicles with a TPMLM > 1305kg and < 1760kg
LCV N1-III	Light Commercial Vehicles with a TPMLM > 1760kg and < 3500kg
LCV N2	Light Commercial Vehicles with a TPMLM > 3500kg and < 12000kg
LDV	Light Duty Vehicles: An aggregation of LCV N1-II and LCV N1-III
HDV	Heavy Duty Vehicles (trucks) with a TPMLM > 12000kg
HCV	Heavy Commercial Vehicles: An aggregation of LCV N2, buses and commercial vehicles with a TPMLM >12000kg

The scenarios were designed primarily to determine the impact on air quality and compliance with air quality limit values over a wide range of emissions reductions from diesel vehicles and other non-transport sources.

Each scenario was developed jointly between ACEA and Aeris Europe, with input in the form of comments and requests received from the AGVES[3] stakeholder group. Each of the transport scenarios was designed with implementation dates of 2025 and 2027 to test the impact on air quality of alternative 'Euro 7/Euro VII' start dates. The non-transport scenarios were all designed with implementation from 2025 and a series of hypothetical 'zero emission scenarios' were included as the 'highest possible impact' cases.

The scenarios and dates chosen in this study are for modelling purposes only. They do not represent any commitment to a level of technical feasibility, nor feasible timings which is highly dependent on any regulatory process.

The following descriptions explain the scenario rationale and detail the coefficients applied to the Base Case vehicle emission factors.

---

[2] TPMLM - Technically Permissible Maximum Laden Mass

[3] Advisory Group on Vehicle Emission Standards

Passenger Car and Light Duty Vehicle Scenarios

Scenario 1 - Alignment of diesel emissions limits with gasoline limits

PC and LCV N1-I, II, III technology neutral alignment of diesel NO_X emission limits with gasoline emission limits. Coefficients of 0.75 for diesel passenger cars and 0.65 for diesel light duty vehicles were applied to newly registered vehicles from both 2025 and then 2027. These coefficients were calculated by dividing the gasoline Euro 6d emission factor mg/km by the diesel equivalent i.e., 60/80 for PCD and LCV N1-I and 75/115 for LCV N1-II and LCV N1-III.

Scenario 2 - Reduced diesel emission limits: NO_X 25mg/km, PM2.5 2.5 mg/km

This scenario is a stakeholder-based request for a 'lower than Ricardo Scenario 3' (see below) [k] based on NO_X diesel emission factors of 25 mg/km and PM2.5 exhaust emission factors of 2.5mg/km. The corresponding NO_X emission coefficients were 0.31 for PCD and LCV N1-I and 0.22 for LCV N1-II and LCV N1-III. For PM2.5 exhaust a coefficient of 0.56 was applied to both the PCD and LDV elements of the fleet.

Scenario 3 - 'Ricardo' median EURO 7 diesel emission limits: NO_X 35mg/km, PM2.5 2.5mg/km

In an early stakeholder briefing, Ricardo presented a view of possible Euro 7/VII emission limits. This suggested a NO_X EF range of 30-40 mg/km and a PM2.5 EF of 2.5mg/km. Using the midpoint of the suggested NO_X EF resulted in coefficients for PC and LCV N1-I of 0.44 and (by interpolation) for LCV N1-II and LCV N1-III of 0.38. For PM2.5 exhaust a coefficient of 0.56 was applied to both fleet the PCD and LDV elements.

Scenario 7 - Diesel PC and LCV: NO_X 0, PM2.5 0

This scenario was run to give a hypothetical 'book end' to possible emissions reductions. For diesel PC and LCV N1-I both NO_X and PM2.5 exhaust emission factor coefficient were set to zero.

Scenario 8 - Diesel LCV N1-II and LCV N1-III: NO_X 0, PM2.5 0

This scenario was run to give a hypothetical 'book end' to possible emissions reductions. For diesel LCV N1-II and LCV N1-III both NO_X and PM2.5 exhaust emission factor coefficient were set to zero.

HDV and Bus Scenarios

Scenario 4 - Diesel LCV N2 and HDV aligning the WHTC with WHSC limits

This scenario tested the benefit of aligning the NO_X WHTC [4] limit with the stricter WHSC[5] limit. For both diesel LCV N2 and HDV the NO_X emissions coefficient was set to 0.87 (i.e., 400/460)

Scenario 5 - Low NO_X scenario (Diesel HCV) NO_X limit of 230 mg/kWh

Low NO_X scenario modelling a reduction in NO_X limit to 230 mg/kWh by applying a coefficient of 0.58 to diesel LCV N2 and HDV emissions.

---

[4] World Harmonized Transient Cycle (WHTC)

[5] World Harmonized Stationary Cycle (WHSC)

Scenario 6 - Very-Low NO_X scenario (Diesel HCV) NO_X limit of 100 mg/kWh

A more ambitious low NO_X scenario modelling a reduction in NO_X limit to 100mg/kWh by applying a coefficient of 0.25 to diesel LCV N2 and HDV emissions.

Scenario 12 - Ultra-Low NO_X scenario (Diesel HCV) NO_X limit of 30 mg/kWh

Stakeholder request for an ultra-low NO_X scenario modelling a reduction in NO_X limit to 30mg/kWh by applying a coefficient of 0.075 to diesel LCV N2 and HDV emissions.

Combined Scenarios

Scenario 13 - Scenario 1 + Scenario 4

Scenarios 1 and 4 emissions applied together in one scenario.

Scenario 14 - Scenario 3 + Scenario 5 (Introduction of combined Euro 7/VII)

Scenarios 3 and 5 emissions applied together in one scenario.

Other Scenarios

Scenario 9 - Zero Emissions from Domestic & Commercial Combustion

A hypothetical 'book end' scenario to test the impact on air quality if residential and commercial emissions of both NO_X and PM2.5 were reduced to zero from 2025.

Scenario 10 - NH_3 Emissions from Agricultural Sector: 50%

Scenario 11 - NH_3 Emissions from Road Transport: 50%

A pair of comparison scenarios to test the relative impacts on air quality of NH_3 emissions from agriculture (Scenario 10) or Road transport (Scenario 11) being halved from 2025 onwards.

Scenario 15 - VOC Emissions from Road Transport: Zero

A hypothetical 'book end' scenario to test the impact on air quality of eliminating all VOC emissions from road transport from 2025.

Scenario 16 - VOC Emissions from Solvent and Product Use sector: 50%

A hypothetical 'book end' scenario to test the impact on air quality of eliminating all VOC emissions from the 'solvent and product use' sector from 2025.

Scenario Emission Changes

Table 4 shows that, for the period to 2030, significant emissions reductions are forecast for both NO_X and PM2.5 as a result of existing measures and the impact of future fleet CO_2 targets. For NO_X, there are further reductions in emissions to 2035, although at a reduced rate. In the case of PM2.5, there is actually a small increase in emissions. This is due to increasing activity and consequent non-exhaust emissions outweighing tailpipe emission reductions, this is shown earlier in **Figure 14**.

Table 4 - NO_X and PM2.5 - Emission reductions delivered by the Base Case and the range of additional reductions delivered by the various Euro 7/VII scenarios

NO_X Emissions - Road Transport	**2030 (% reductions from 2020)**		**2035 (% reductions from 2020)**	
	Base Case	**Scenarios**	**Base Case**	**Scenarios**
Euro 7 Final Scenarios (diesel cars and vans)	66.7%	0.9 - 3.4%	79.0%	1.1 - 4.6%
Euro VII Scenarios (heavy duty vehicles)		0.1 - 1.6%		0.1 - 2.4%
PM2.5 Emissions - Road Transport				
Euro 7 Final Scenarios (diesel cars and vans)	20.7%	0.8 - 1.6%	17.3%	1.1 - 2.1%

For both NO_X and PM2.5, the significant emissions reductions delivered by the Base Case are in sharp contrast with the emissions reductions delivered by the scenarios. Even the most ambitious NO_X scenario only delivers an additional 4.6% reduction beyond the 79% reduction delivered in the Base Case. For PM2.5 this additional maximum emissions reduction is only 2.1%.

Early Replacement of Existing Vehicles

As part of this study, early scrappage scenarios were considered for both diesel passenger cars and heavy-duty vehicles. Several approaches were tested to simulate older vehicle replacement strategies and alternative uptake rates for vehicles meeting the current Euro 6d/VI standards.

At a fundamental level, the benefit of targeted scrappage compared to the introduction of a hypothetical Euro 7/VII was tested through a comparison of emission factors. To do this, the difference in older technology emission factors relative to the Euro 6d/VI emission factors as implemented in the COPERT and SIBYL versions used for this report[6], were examined.

The calculation made the ambitious 'best possible case' assumption that the Euro 7/VII standard would have zero emissions, hence the calculated ratio used was:

(Emission Factor Replaced - Emission Factor of Euro 6d/VI) / (Emission Factor of Euro 6d/VI)

The result of this calculation is a number which is the multiple of the zero-emissions case reduction. By using this emission factor test, the results are independent of activity levels.

---

[6] As noted in the section on *Emission Factor Adjustments* the most recent COPERT release (v5.4.36) made significant improvements to Euro 6 emission factors.

On this basis it was found that:

1. The range of Diesel Passenger Car (medium) NO_X emissions reductions from replacing a Euro 5 to Euro 3 vehicle with a Euro 6d vehicle is 6 to 8 times that of replacing a Euro 6d vehicle with a zero-tailpipe emission vehicle.
2. The range of Diesel Passenger Car (medium) PM exhaust emissions reductions from replacing a Euro 4 or Euro 3 vehicle with a Euro 6d vehicle is about 20 times that of replacing a Euro 6d vehicle with a zero-tailpipe emission vehicle.
3. The range of HDV NO_X emissions reductions (averaged across weight classes) from replacing a Euro V to Euro III vehicle with a Euro VI vehicle is 10 to 25 times that of replacing a Euro VI vehicle with a zero-tailpipe emission vehicle.
4. The range of HDV PM exhaust emissions reductions (averaged across weight classes) from replacing a Euro V to Euro III vehicle with a Euro VI vehicle is 10 to 35 times that of replacing a Euro VI vehicle with a zero-tailpipe emission vehicle.

Notably, through successful implementation of a targeted scrappage scheme, these significant reductions would be realised well before even the most ambitious Euro7/VII regulation could be implemented. Full details of the benefits of scrappage schemes will be explored at both EU and member state levels in a forthcoming publication on cost benefits.

SARS-COV-2 (COVID-19)

The outbreak of SARS-COV-2 across the world in early 2020 resulted in a substantial change in emissions across the EU. National and regional lockdowns, international travel restrictions, enforced home-working and a myriad of other behavioural changes provided a unique opportunity to study how changing emissions affected air quality. In this study, these changes have been handled in two ways.

For the emissions Base Case, emission changes due to the pandemic have deliberately been excluded, so in effect the Base Case represents a world where the pandemic did not happen. This allows for trends over time to be more effectively and easily observed and prevents a significant, but temporary event from impacting future air quality trends.

A series of SARS-COV-2 sensitivity scenarios have been formulated to reflect how different countries responded to the outbreak (**Table 5**). These are not intended to be exhaustive but are meant to provide an insight into how behavioural changes, particularly reductions in road transport activity, affect urban air quality. No other emissions changes were explored in this context, so any changes in emissions related to domestic or commercial combustion systems, for example, have not been considered.

Table 5 - SARS-COV-2 sensitivity scenarios

Cov-Scn-1a	Passenger Car and LCV Activity (vehicle kilometres) Reduced by 25%
Cov-Scn-1b	Passenger Car and LCV Activity (vehicle kilometres) Reduced by 50%
Cov-Scn-1c	Passenger Car and LCV Activity (vehicle kilometres) Reduced by 75%
Cov-Scn-2a	Total Road Transport Activity (vehicle kilometres) Reduced by 25%
Cov-Scn-2b	Total Road Transport Activity (vehicle kilometres) Reduced by 50%
Cov-Scn-2c	Total Road Transport Activity (vehicle kilometres) Reduced by 75%

EU Air Quality Limit Values

The current ambient air quality limit values as defined in the Ambient Air Quality Directive (AAQD) are referred to throughout this study and are summarised in **Table 6.** For those pollutants with more than one metric, the * indicates the statistically more significant limit, or the metric that will usually be exceeded first.

Table 6 - EU Ambient Air Quality Limit Values

Pollutant	Frequency	Value (µg/m^3)	Allowed Exceedances
Nitrogen Dioxide (NO_2)	Hourly Exceedance	200	18
Nitrogen Dioxide (NO_2)	Annual Mean *[l]	40	0
Particulate Matter ($PM_{2.5}$)	Annual Mean[7]	25	0
Particulate Matter (PM_{10})	Daily Exceedance *[m, n]	50	35
Particulate Matter (PM_{10})	Annual Mean	40	0

WHO Guideline Values

The World Health Organisation (WHO) have published a series of guideline values for ambient air quality[o] that in some cases are the same as those in the AAQD, and in some cases lower. The most recent guidelines at the time of writing are those published in 2005 and summarised in **Table 7**.

Table 7 - WHO Guideline Values

Pollutant	Frequency	Value (µg/m^3)
Nitrogen Dioxide (NO_2)	Hourly Exceedance	200
Nitrogen Dioxide (NO_2)	Annual Mean	40
Particulate Matter ($PM_{2.5}$)	Daily Exceedance	25
Particulate Matter ($PM_{2.5}$)	Annual Mean	10
Particulate Matter (PM_{10})	Daily Exceedance	50
Particulate Matter (PM_{10})	Annual Mean	20

Ozone Targets

The AAQD does not specify a binding limit value for ozone, instead there are target values for the protection of human health and protection of vegetation. The WHO have also published a guideline value for the protection of human health. These values are summarised in **Table 8**.

Table 8- AAQD and WHO Ozone values for the protection of human health

Source	Frequency	Value (µg/m^3)	Allowed Exceedances
AAQD - Protection of human health	Maximum daily eight-hour mean	120	25 days (averaged over 3 years)
WHO - Protection of human health		100	0

---

[7] The AAQD also includes an Exposure Concentration Obligation, please see *Annex - PM2.5 Average Exposure Indicator*

Air Quality Model - AQUIReS+

AQUIReS+ is Aeris Europe's air quality forecasting model. Designed to predict the concentration of the main pollutants covered by the AAQD, and compliance with air quality limit values at individual monitoring stations in the European Air Quality monitoring station network. The AQUIReS+ model has been used in several published works on European air quality [p,q] and is well suited to support the aims of this study.

For this study, the AQUIReS+ model was used to generate a series of predictions for three primary pollutants and four different metrics:

Oxides of Nitrogen

- NO_2 annual mean

Particulates

- PM2.5 annual mean
- PM10 annual mean
- PM10 daily exceedances

Ozone

- SOMO35[8]
- Maximum daily 8 hour means (rolling average)

AQUIReS - Air Quality Universal Information and Reporting System

Central to the functioning of AQUIReS+ is its sister tool 'AQUIReS'. AQUIReS is an air quality measurement interpretation and interrogation tool that is designed to draw on exogenous raw measurement datasets (multiple pollutants, multiple time-series) from different sources. It outputs carefully validated, and consistent data for inclusion in AQUIReS+. AQUIReS has a comprehensive system of validation and verification of both raw measurement data and station metadata to produce a consistent, Europe-wide, measurement and meta data set. For this study, to help ensure a consistent representation of countries, only data from the EEA AirBase[9] and e-Reporting[10] systems were included. It is worth noting that these stations alone are the means of the European Commission assessing compliance with the AAQD.

Additional features within AQUIReS allow for sub-yearly analysis, this is useful for examining weekly, monthly, or seasonal trends, for example that seen during the national and regional lockdowns implemented across Europe in response to the 2020 SARS-COV-2 outbreak.

To ensure the robustness of the AQUIReS+ model, it uses only established authoritative data sources. The primary data sources and dataflows are summarised in **Figure 15.**

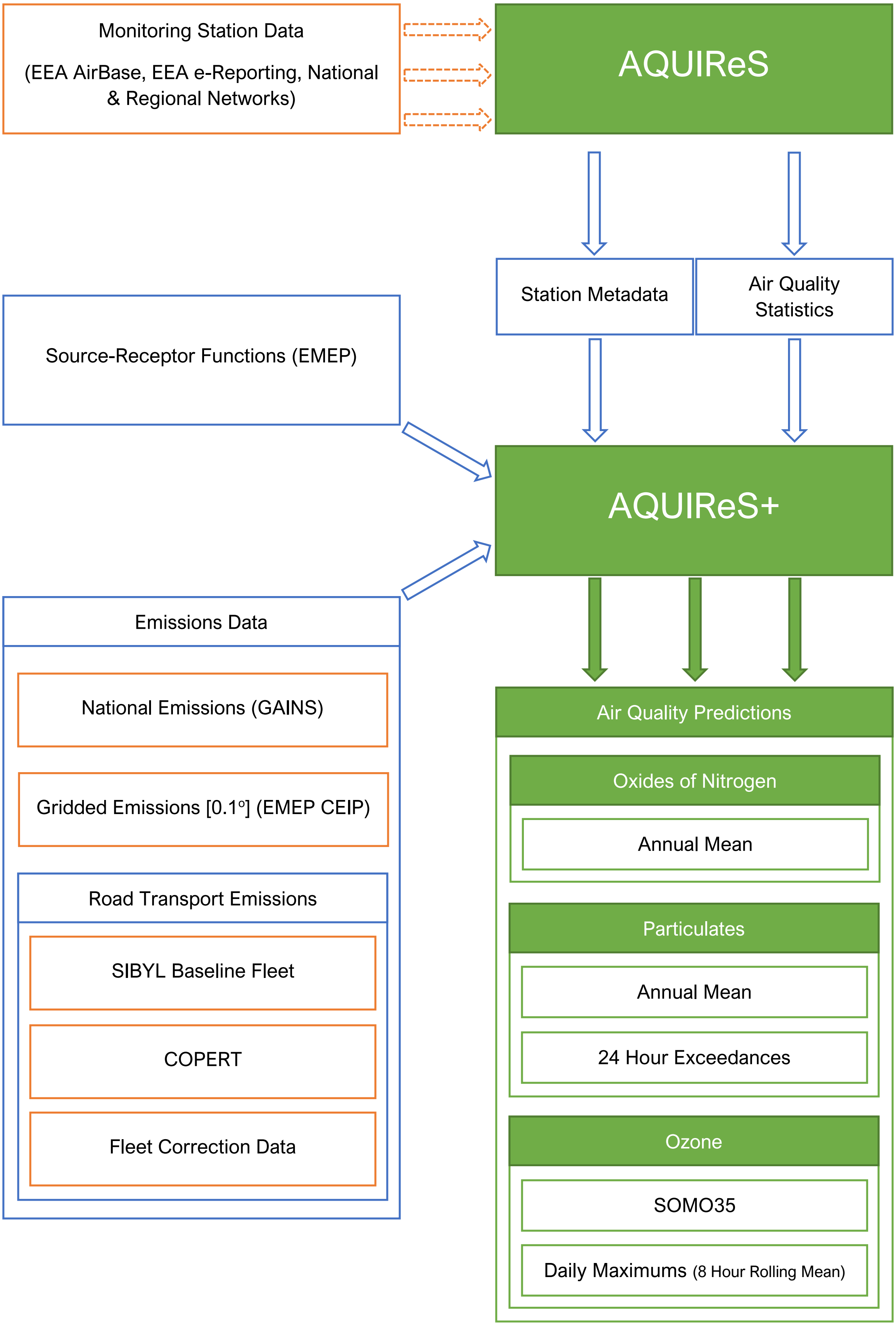
---

[8] SOMO35 - defined as the sum of means over 35 ppb from a daily maximum 8-hour rolling average

[9] AirBase - European air quality database (EEA, 2014 (b)) *AirBase - The European air quality database*

[10] E-Reporting - European air quality database (EEA, 2017) *Air Quality e-Reporting (AQ e-Reporting)*

Figure 15 - AQUIReS+ data sources and flows



Station Selection Criteria

For an air quality monitoring station to be included in the AQUIReS+ model, the system must first determine if that station is suitable for inclusion. Several criteria need to be passed to establish a given stations eligibility, however most of those stations that do not make it into the model fail for one of a few primary reasons. These are summarised in **Table 9.**

Table 9 - AQUIReS+ station eligibility criteria

Criteria	Description
Invalid Data	The same validity of measurement that is specified in the AAQD is required for a station to pass the AQUIReS+ validity check. These vary by component and metric; however, these generally rely on at least 75% of measurements in a year being valid.
Insufficient Time-Series	For most metrics (although in some cases this may vary) at least three years of valid measurements must be recorded. The years do not have to be contiguous.
Retired/Faulty	Only stations that have two valid measurements from 2015 onwards are included. This prevents older stations, that are likely to have been removed when the area they covered became compliant, from skewing the results.
Missing Data	Increasingly, concentrations of certain component are not being submitted to the EEA. For example, NO_X is increasingly rarely being submitted, even though it is almost certainly being measured as those same stations will submit NO_2 measurements. AQUIReS+ requires NO_X concentrations and attempts to fill in any missing data by using submitted NO_2 and NO concentrations, but again, NO is increasingly rarely being reported.

Modelling Uncertainty

The AQUIReS+ model incorporates a series of internal steps designed to assess the level of certainty of its predictions and whenever the certainty falls below a certain threshold, i.e., an unreliable prediction, the station is removed from the model. However only a small percentage of stations that pass the initial eligibility criteria fail the certainty checks. Those that pass are still subject to some uncertainty and this is quantified as follows:

The concentration in every year in AQUIReS+ is modelled, this includes historical years that cover a station's measurement history. It is therefore possible to employ a back-casting technique that compares 'historical predictions' with actual measurements in the same year. This is performed at every station to build an overall picture of the accuracy of modelling at any given station. This gives greater confidence in the future predictions.

As a final step, the root mean square (RMS) error at each station is calculated from the difference between actual measured concentrations and predicted concentrations. As seen in **Table 10, Figure 16** and **Figure 17**, the AQUIReS+ model exhibits low RMS errors.

Table 10 - Mean and median RMS errors, all stations in model domain

	Mean (µg/m^3)	Median (µg/m^3)
PM2.5	0.58	0.40
NO_2	2.27	1.80

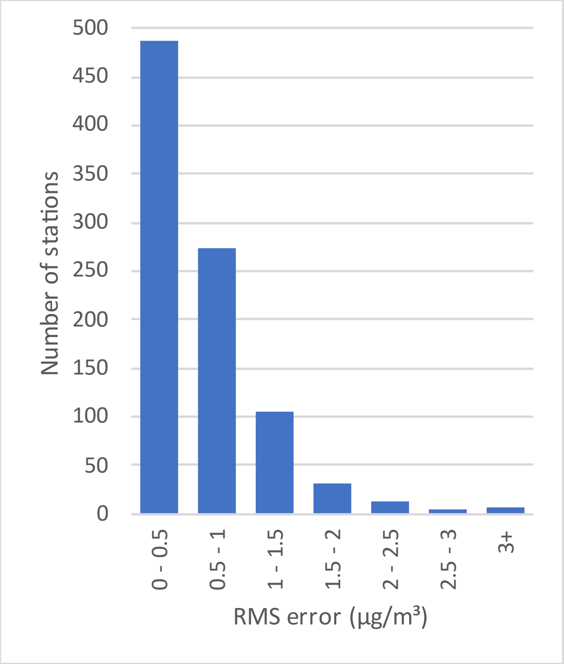


Figure 16 - AQUIReS+ domain PM2.5 RMS error

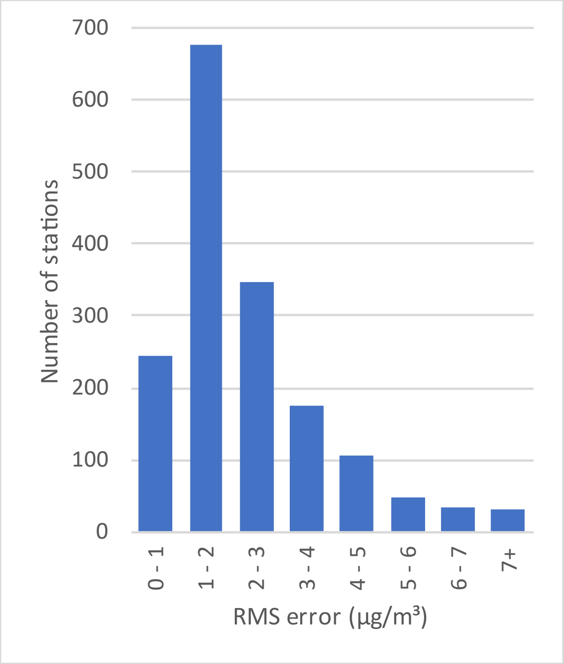


Figure 17 - AQUIReS+ domain NO_2 RMS error

Compliance banding

As the RMS error is calculated for each station individually, it is possible to assign a station specific band of uncertainty with respect to compliance with a given limit value. In this study each station has been grouped into one of the four categories defined in **Table 11.**

Table 11 - Station compliance categories

Abbreviation	Name	Description
C	Compliant	Modelled concentration is below the limit or guideline value by at least the RMS error of that station.
PC	Probably Compliant	Modelled concentration is below the limit or guideline value by less than the RMS error of that station.
PNC	Probably Non-Compliant	Modelled concentration is above the limit or guideline value by less than the RMS error of that station.
NC	Non-Compliant	Modelled concentration is above the limit or guideline value by at least the RMS error of that station.

The two categories ‘Probably Compliant’ and ‘Probably Non-Compliant’ may be grouped together into a single category of ‘Uncertain Compliance’.

Modelling PM10

As discussed in the PM10 results section of this report, measurements from EU monitoring stations indicate that compliance with PM10 daily exceedances is still an issue in some areas of the EU. Reliable modelling of future compliance with this metric is therefore important, however modelling of exceedances can be difficult. Fortunately, previous work has shown that there is a strong correlation between PM10 daily exceedances and PM10 annual mean.[r, s]

The first step, therefore, in modelling PM10 exceedances is to robustly model PM10 annual mean concentrations. **Figure 18** shows measurements of PM2.5 and PM10 at urban measuring stations in the AQUIReS+ model domain between 2015 and 2019. The shape shows the strong correlation between PM2.5 and PM10 annual mean concentrations and how the correlation between the two concentrations shows little inter-annual variability.[t]

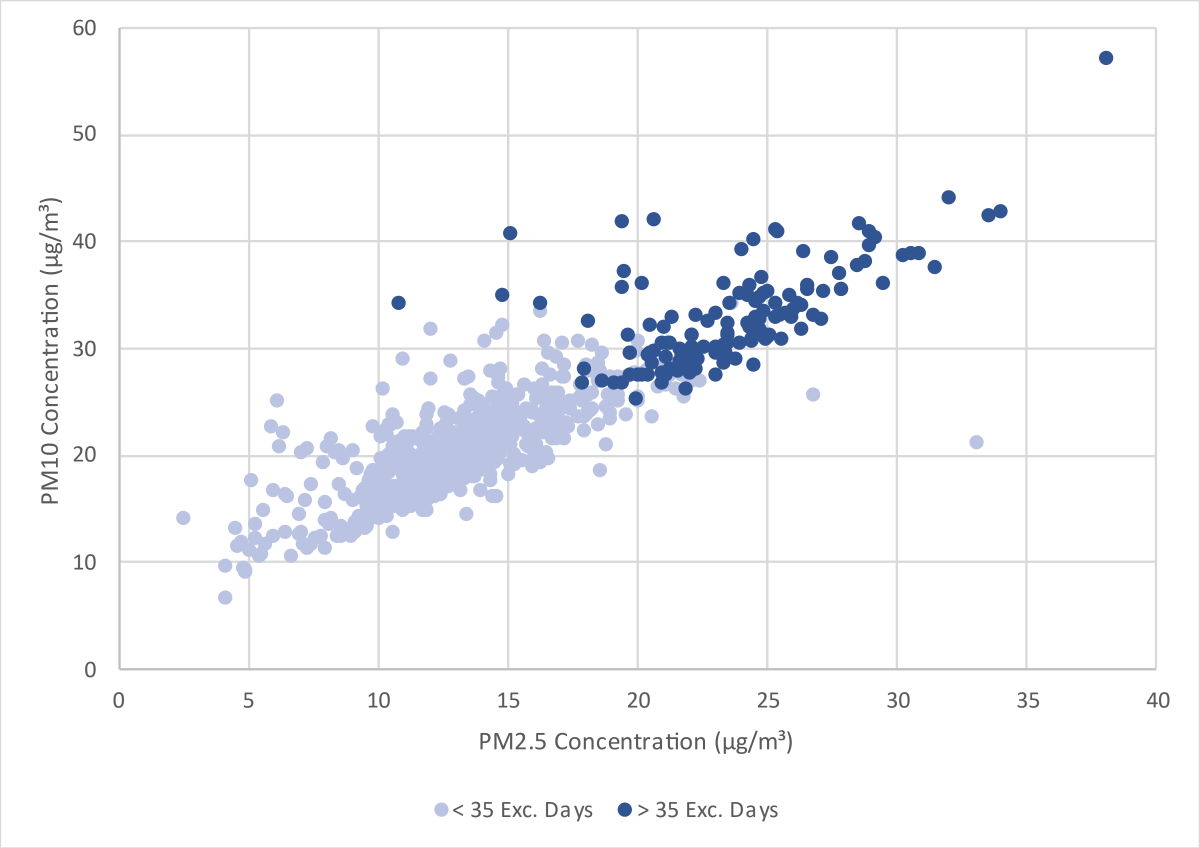


Figure 18 - PM2.5 vs PM10 annual mean concentrations at urban monitoring stations

While the trend is clearly shown in **Figure 18** there is still a significant amount of scatter indicating variations in the ratio of PM2.5 to PM10 between stations. However, at an individual measuring station level there is very little scatter and a 'station specific ratio of PM2.5/PM10' can be robustly determined. This means that it is possible to use measured annual mean PM2.5 concentration as a surrogate for PM10 annual mean concentration. This is the approach adopted in AQUIRES+.

The second step is to relate PM10 annual mean to the number of daily exceedances above the daily mean threshold of 50 µg/m^3. **Figure 18** indicates that at an overall EU level the annual mean PM10 that corresponds to complying with the limit of 35 exceedances of the daily threshold varies between an annual mean concentration of 24µg/m^3 (lowest blue point) and 36µg/m^3 (highest grey point).

This indicates a very wide band of uncertainty in adopting a single value for the whole EU, so again AQUIReS+ uses a station specific approach to relate the PM10 annual mean concentration at a given station to the maximum allowable number of PM10 daily exceedances.

---

[a] (IIASA, 2015a) *Adjusted historic emission data, projections, and optimized emission reduction targets for 2030 – A comparison with COM data 2013. Part A: Results for EU-28.*

[b] (IIASA, 2015b) *Adjusted historic emission data, projections, and optimized emission reduction targets for 2030 – A comparison with COM data 2013. Part B: Results for Member States.*

[c] (European Commission, 2011) *Review of EU Air Quality Policy - Commission Staff Working Document (SEC(2011)342)*

[d] (Directive (EU) 2016/2284, 2016) *The European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC*

[e] (Directive (EU) 2015/2193, 2015) *European Parliament and of the Council of 25 November 2015 on the limitation of emissions of certain pollutants into the air from medium combustion plants*

[f] (Papadimitriou & Mellios, 2020) *European Road Transport & Emissions Trends Report*

[g] (Regulation (EU) 2019/631, 2019) *Setting CO2 emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011*

[h] (Regulation (EU) 2019/1242, 2019) *Setting CO2 emission performance standards for new heavy-duty vehicles and amending Regulations (EC) No 595/2009 and (EU) 2018/956 of the European Parliament and of the Council and Council Directive 96/53/EC*

[i] (Directive (EU) 2019/1161, 2019) *Directive (EU) 2019/1161 of the European Parliament and of the Council of 20 June 2019 amending Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles*

[j] (Timmers & Achten, 2016) *Non-exhaust PM emissions from electric vehicles*

[k] (Ricardo, 2020) *Euro 7 / VII - New Emissions Limits, The Challenges and Solutions. Slide 9 - Diesel NOX emission factor range of 30-40 mg/km and a PM2.5 emission factor of 2.5mg/km*

[l] (de Leeuw & Ruyssenaars, 2011) *Evaluation of current limit and target values as set in the EU Air Quality Directive - ETC/ACM Technical Paper*

[m] (Buijsman, et al., 2005) *Particulate Matter: a closer look. MNP report no. 500037011*

[n] (Stedman, et al., 2007) *A consistent method for modeling PM10 and PM2.5 concentrations across the United Kingdom in 2004 for air quality assessment*

[o] (WHO, 2005) *WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide*

[p] (Aeris Europe, 2016) *Urban Air Quality Study, #11/16*

[q] (Concawe, 2018) *A comparison of real driving emissions from Euro 6 diesel passenger cars with zero emission vehicles and their impact on urban air quality compliance*

[r] (Buijsman, et al., 2005) *Particulate Matter: a closer look. MNP report no. 500037011*

[s] (Stedman, et al., 2007) *A consistent method for modeling PM10 and PM2.5 concentrations across the United Kingdom in 2004 for air quality assessment*

[t] (De Leeuw & Horálek, 2009) *Assessment of the health impacts of exposure to PM2.5 at a European level. ETC/ACC Technical Paper 2009/1.*

Results - Nitrogen Dioxide

Base Case

In the Base Case, almost universal compliance with the currently legislated annual mean limit value for NO_2 is predicted by 2025 from currently mandated measures. This is a conservative view as discussed earlier in the report since the NO_x emissions reductions in some non-transport sectors in the Base Case used in this study are likely to be understated.[1]

Across the EU, approximately 99% of urban monitoring stations (1,638 out of 1,661) are predicted to be compliant or probably compliant by 2025. The overall number of stations and their related compliance states are shown in **Figure 19**. As the annual mean limit value for NO_2 is statistically stricter, i.e., exceeded before the hourly exceedances, that metric is examined here.[a]

	2020	2025	2030	2035
Non-Compliant	55	13	4	4
Probably Non-Compliant	28	10	4	2
Probably Compliant	44	21	11	6
Compliant	1534	1617	1642	1649

Figure 19 - EU, NO_2 predicted compliance: 2020 - 2035 Base Case

---

[1] See Base Case methodology section for explanation.

Air Quality Response to Key Scenarios

To simplify discussion of the impact of additional emission abatement, those scenarios that introduce more extreme reductions of the pollutants are shown in **Table 12** .

Table 12 - NO_2 - Non-compliant station summary under key scenarios in the EU (total of 1661 stations)

	2020	2025	2030	2035
Base Case	**83** (5%)	**23** (1.4%)	**8** (0.5%)	**6** (0.4%)
Introduction of Combined Euro 7/VII (2025) ***Scenario 14***	**83** (5%)	**23** (1.4%)	**6** (0.4%)	**5** (0.3%)
Diesel PC and LCV - NO_X: 0, PM2.5: 0 (2025) ***Scenario 7***	**83** (5%)	**23** (1.4%)	**6** (0.4%)	**5** (0.3%)
Zero Emissions from Domestic & Commercial Combustion (2025) ***Scenario 9***	**83** (5%)	**12** (0.7%)	**5** (0.3%)	**3** (0.2%)

From an NO_2 compliance perspective, the results from the two road transport scenarios in **Table 12** show little further improvement beyond that achieved in the Base Case.

The modelling indicates that already mandated measures will achieve above 99% compliance by 2030, and from then onwards, even in the extreme scenario of eliminating all NO_X emissions from domestic and commercial combustion, there is little further impact on compliance. Only a handful of stations are non-compliant by 2030, and most of these remain stubbornly non-compliant regardless of the measures taken nationally. This indicates that action on specific local sources, identified by a thorough source attribution analysis, rather than further national or European wide measures, should be pursued.

Of all the countries that have been modelled, half of the residual non-compliant stations across the EU in the Base Case are found in France. A summary of station compliance in France is listed in **Table 13.**

Table 13 - France, NO_2 non-compliant stations (total of 332 stations)

	2020	2025	2030	2035
Base Case	**20** (6%)	**10** (3%)	**4** (1%)	**3** (1%)
Introduction of Euro combined 7/VII (2025) ***Scenario 14***	**20** (6%)	**10** (3%)	**3** (1%)	**3** (1%)
Diesel PC and LCV: NO_X 0, PM2.5 0 (2025) ***Scenario 7***	**20** (6%)	**10** (3%)	**3** (1%)	**3** (1%)
Zero Emissions from Domestic & Commercial Combustion (2025) ***Scenario 9***	**20** (6%)	**5** (1.5%)	**3** (1%)	**3** (1%)

City Focus - NO_2

Although all the urban monitoring stations in the EU were included in the scope of this study, nine cities were selected for closer examination: Berlin, Brussels, London, Madrid, Milan, Paris, Rome, Stuttgart, Warsaw.

In the Base Case, modelled non-compliance in 2025 is predicted at monitoring stations in London, Paris and Stuttgart. Paris, as the 'worst case' example is examined in more detail below. Uncertain compliance is also predicted for the cities of Madrid, Milan, and Rome in 2025, but by 2030 these cities are predicted to become compliant.

One of the air quality monitoring stations that is predicted to remain non-compliant in 2035 is located in Paris; 'Auto A1 -Saint-Denis'. This station has a history of recording high NO_2 annual mean concentrations, and is sited in a particularly highly trafficked, commercial area with a series of busy roads and junctions in close proximity. The station is also some distance from the nearest residential area. The stations modelled in Paris can be seen in **Figure 20**, along with the predicted compliance/non-compliance at each site. Between 2025 and 2035, under the Base Case, the compliance picture in Paris is predicted to improve further with only two stations non-compliant by 2030 and a single station: 'Auto A1 -Saint-Denis' non-compliant in 2035.

With almost complete compliance predicted in the Base Case by 2030, and no scenario bringing about compliance for the remaining non-compliant station even by 2035, a closer examination of the causes of non-compliance at this station seems warranted. It is likely that, following such an analysis, specific localised measures would be more effective and efficient in achieving compliance than any further national or international steps.

Although Paris has been chosen to highlight this issue, the very few sites of non-compliance in the EU that are predicted to remain beyond 2030 would all benefit from a similar, targeted approach given that none of the measures that affect entire sectors are predicted to be effective in achieving compliance.

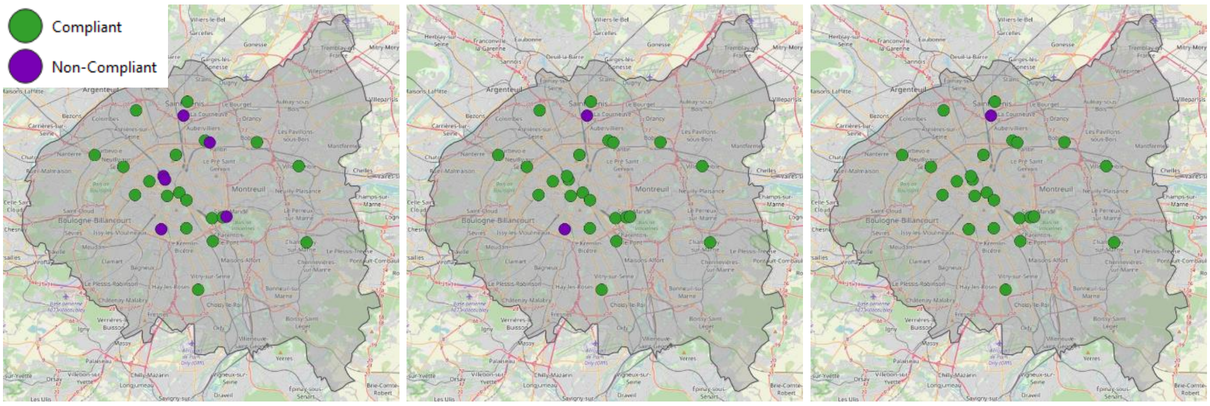


Figure 20 - Paris, NO_2 compliance with AAQD - 2025, 2030 and 2035

The Innsbruck Transit Corridor

The A12 (E45) from Innsbruck to Wörgl in Austria is a heavily trafficked, high-altitude road, along which are sited a series of air quality monitoring stations recording nitrogen dioxide concentrations (**Figure 21**). Of the nine stations along this route, including those in urban environments, only a single station is currently non-compliant, and this is predicted to achieve compliance by 2022 in the Base Case (**Table 14**). The location of the non-compliant station (AT72821) is shown inset in **Figure 21**, where it is located at the exit of a slip-road from the Vomp services. This station is only a few metres from the roadside and exposed to vehicles undergoing heavy acceleration, it is also only a short distance from an urban area, so is subject to road traffic, commercial and domestic emissions of NO_X.

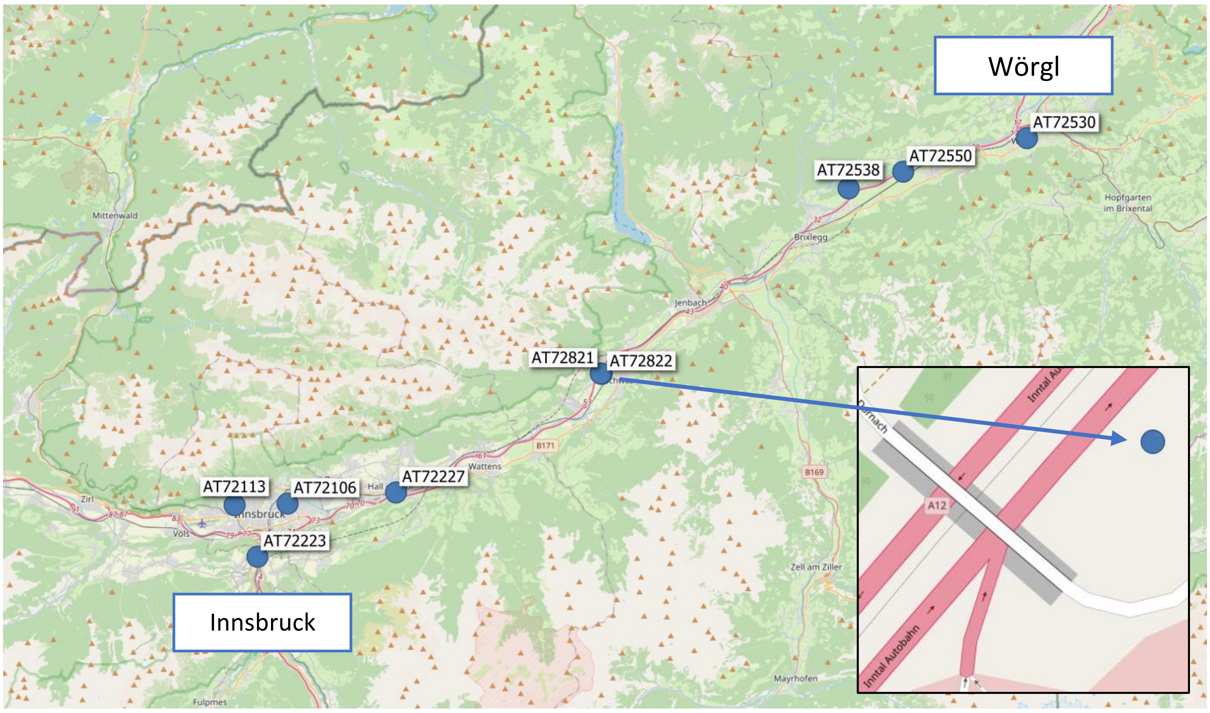


Figure 21 - Innsbruck Traffic Corridor - NO_2 stations

Table 14 - Innsbruck Transit Corridor, predicted NO_2 µg/m^3

	2020	2025	2030	2035
AT72106	29	26	24	24
AT72113	17	14	13	13
AT72223	28	20	17	16
AT72227	28	22	20	19
AT72530	22	18	16	15
AT72538	16	12	10	10
AT72550	34	24	20	18
AT72821	**44**	**34**	**29**	**28**
AT72822	28	22	19	18

The modelled concentrations at the nine stations located along or near the transit corridor from 2020 to 2035 under Base Case emissions are shown in **Table 14**. This shows that by 2020 all but one station (AT72821) is predicted to be compliant. Since this modelling work was undertaken, the actual measurement data for the whole of 2020 has become available. This reveals that the actual annual mean, based on measurements, was 36 µg/m^3 (i.e., compliant). **Figure 22** shows the modelled versus measured NO_2 concentrations at this station for the period 2010 to 2020. This shows the very good agreement between modelled and measured concentrations from 2010 to 2019. During this period, the very significant impact on NO_2 concentrations from the penetration of new vehicles meeting the latest Euro standards is evident. In 2020 Europe was significantly impacted by responses to the COVID crisis, this appears to be evident from the significant downward departure from the trend in annual mean for 2020 given that the predicted concentrations were consistent with Base Case activity levels prior to this. The reduction of some 8µg/m^3 is consistent with the responses at this station for the simulated reduced activity COVID-scenarios, for example, the COVID 2b scenario (50% Reduction in all road traffic activity) predicts a 9 µg/m^3 reduction at this station.

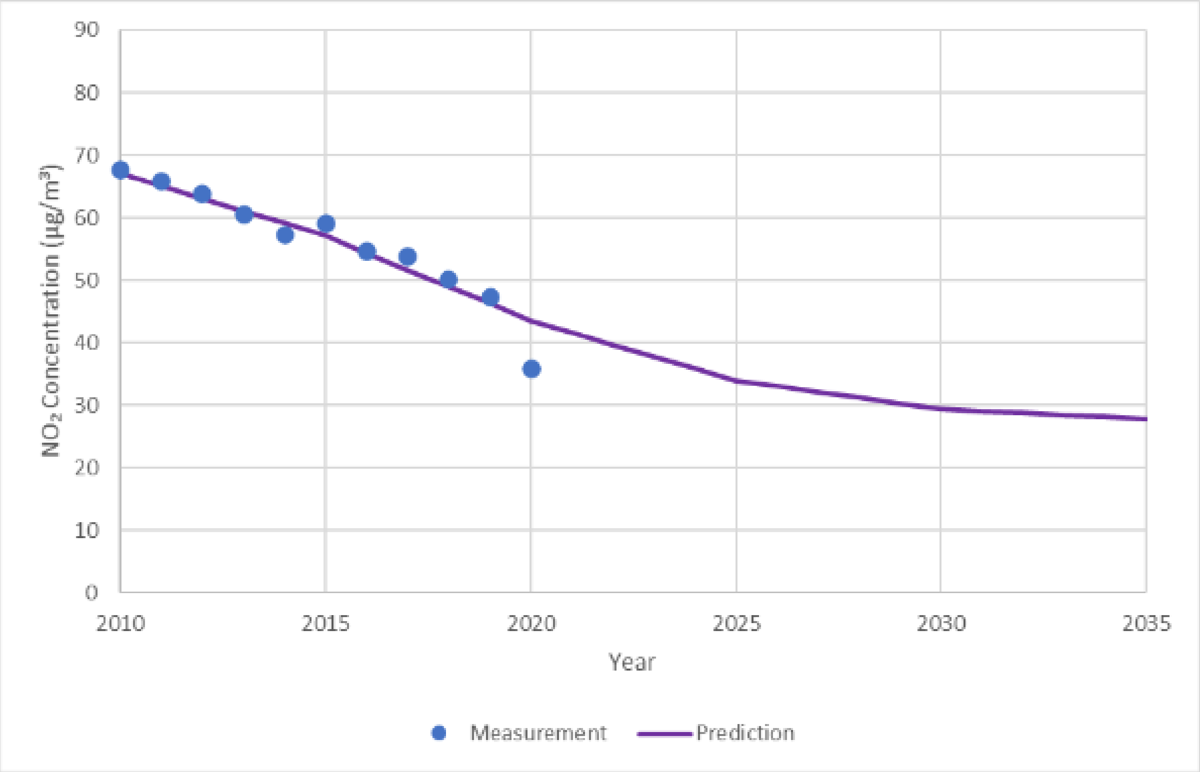


Figure 22 - Modelled versus measured annual mean NO_2 at station AT72821

Air Quality Responses to Key Scenarios

To explore the impact of additional abatement measures on concentrations at this location, the results of modelling the three scenarios that most significantly impact NO_X emissions are shown in **Table 15**. As expected, there are no changes in 2025 (the year of introduction) in either of the scenarios that impact road transport emissions. By 2030 small changes (a single microgram) are predicted at some of the stations along this route, a consequence of the small change in emissions that these measures are able to induce and the already low emissions from the Base Case reductions. In common with the cities explored in this study, reducing NO_X emissions from the nearby domestic and commercial combustion sources, in this case the roadside services and urban areas, is predicted to have a larger impact on emissions with a further reduction in NO_2 of up to 4µg/m^3 predicted at some stations.

Table 15 - Innsbruck Transit Corridor - NO_2 Concentrations (µg/m^3) - Selected Scenarios

	Diesel PC and LCV NO_X: 0, PM2.5: 0 (2025) *Scenario 7*			**Introduction of Euro 7/VII (2025) *Scenario 14***			**Domestic & Commercial Combustion - NO_X: 0 (2025) *Scenario 9***		
	2025	**2030**	**2035**	**2025**	**2030**	**2035**	**2025**	**2030**	**2035**
AT72106	26	24	24	26	24	23	24	23	22
AT72113	14	13	13	14	13	13	13	12	12
AT72223	20	17	16	20	17	15	17	14	13
AT72227	22	20	19	22	19	18	20	17	16
AT72530	18	16	15	18	16	15	16	14	13
AT72538	12	10	10	12	10	9	10	8	7
AT72550	24	20	18	24	20	18	20	16	15
AT72821	**34**	**29**	**28**	**34**	**29**	**28**	**29**	**25**	**24**
AT72822	22	19	18	22	19	18	19	17	14

Results - PM2.5

Base Case

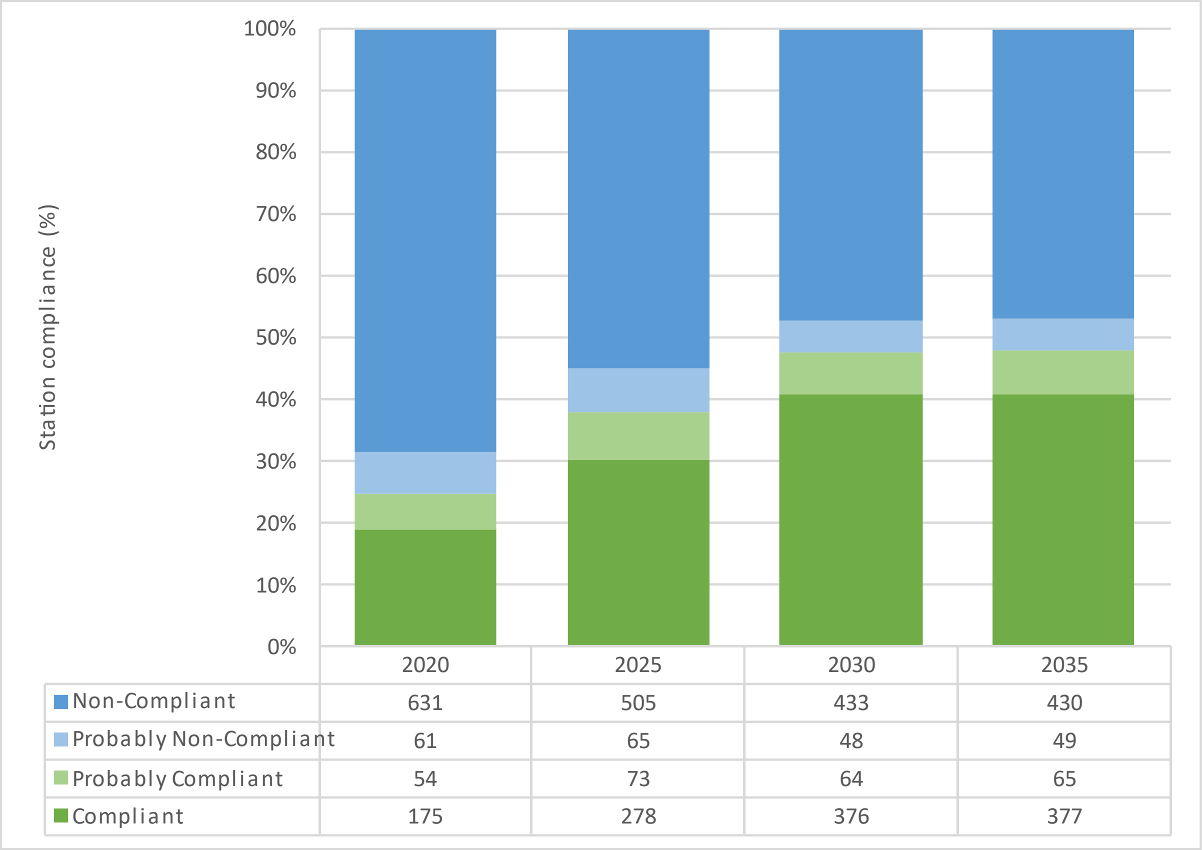
In the Base Case, widespread compliance with the currently legislated annual mean limit value for PM2.5 is already realised across the EU with nearly complete compliance predicted by 2025 from the currently mandated measures alone (**Figure 23**). This is a conservative view of compliance (as discussed earlier in the report), since the PM2.5 emissions reductions in some non-transport sectors in the Base Case used in this study are likely to be understated.[2] However, introduction of the WHO 10µg/m^3 guideline value would result in widespread and persistent non-compliance in almost every EU country (**Figure 24**). Therefore, its introduction as a binding limit value would be a major compliance challenge for almost every member state.

	2020	2025	2030	2035
🟦 Non-Compliant	21	4	2	2
🟦 Probably Non-Compliant	5	3	2	2
🟩 Probably Compliant	16	3	1	1
🟩 Compliant	879	911	916	916

Figure 23 - EU, PM2.5 predicted compliance with 25µg/m^3 EU AQLV: 2020 - 2035 Base Case

---

[2] See Base Case methodology section for explanation.



	2020	2025	2030	2035
Non-Compliant	631	505	433	430
Probably Non-Compliant	61	65	48	49
Probably Compliant	54	73	64	65
Compliant	175	278	376	377

Figure 24 - EU, PM2.5 predicted compliance with 10µg/m^3 WHO Guideline: 2020 - 2035 Base Case

Air Quality Response to Key Scenarios

To simplify discussion of the impact of additional emission abatement, those scenarios that introduce more extreme reductions of the pollutants responsible for PM2.5 concentrations in urban environments are highlighted in **Table 16** for compliance with the EU annual mean limit value of 25µg/m^3, and **Table 17** for compliance with the WHO guideline value of 10µg/m^3.

Table 16 - PM2.5 - Non-compliant station summary under key scenarios in the EU - EU AQLV (total of 921 stations)

	2020	2025	2030	2035
Base Case	**26** (3%)	**7** (0.8%)	**4** (0.4%)	**4** (0.4%)
Diesel PC and LCV: NO_X 0, PM2.5 0 (2025) ***Scenario 7***	**26** (3%)	**7** (0.8%)	**3** (0.3%)	**4** (0.4%) [3]
Zero Emissions from Domestic & Commercial Combustion (2025) ***Scenario 9***	**26** (3%)	**0**	**0**	**0**
NH_3 Emissions from Agricultural Sector: 50% (2025) ***Scenario 10***	**26** (3%)	**3** (0.3%)	**1** (0.1%)	**1** (0.1%)

---

[3] Increasing vehicle numbers result in increased non-exhaust PM2.5 emissions between 2030 and 2035.

Given that widespread compliance with the current PM2.5 EU AQLV is already achieved and only a few isolated stations are predicted to remain non-compliant by 2025, there is little justification for further measures that target PM2.5 emissions.

Applying further emissions abatement technologies to road transport is projected to have a negligible effect on compliance since the major source of vehicular PM2.5 emissions is from non-exhaust sources. Of all the measures explored in this study, only those that target non-transport emissions show that full compliance is achievable.

An analysis of the residual non-compliance from 2025, shows that all stations except one are in Poland, the exception being a single station in Croatia (**Figure 25**). Both countries burn significant amounts of solid fuel (largely coal) in the domestic sector. The results from the 'zero emissions from the domestic & commercial sector' scenario (a surrogate for eliminating solid fuel burning in this sector) confirms the efficacy of such a step by bringing about full compliance.

When comparing predicted concentrations of PM2.5 to the WHO guideline value, widespread non-compliance is seen through most of the EU (**Table 17**). This can also be seen in **Figure 25** where all but the white coloured stations are non-compliant in 2025. The European Commission have adopted the WHO guide value as their long-term goal in the 7th Environmental Action Programme.

Further road-transport measures only offer a marginal improvement in compliance with the WHO guideline value, however reducing emissions from domestic and commercial combustion to zero, while greatly improving the number of stations compliant with the WHO guideline still leaves at least a quarter of urban stations non-compliant.

Table 17 - PM2.5 - Non-compliant station summary under key scenarios in the EU - WHO Guideline (total of 921 stations)

	2020	2025	2030	2035
Base Case	**692** (75%)	**570** (62%)	**491** (53%)	**479** (52%)
Diesel PC and LCV: NO_X 0, PM2.5 0 (2025) ***Scenario 7***	**692** (75%)	**570** (62%)	**474** (51%)	**471** (51%)
Zero Emissions from Domestic & Commercial Combustion (2025) ***Scenario 9***	**692** (75%)	**284** (31%)	**231** (25%)	**229** (25%)
NH_3 Emissions from Agricultural Sector: 50% (2025) ***Scenario 10***	**692** (75%)	**421** (46%)	**354** (38%)	**351** (38%)

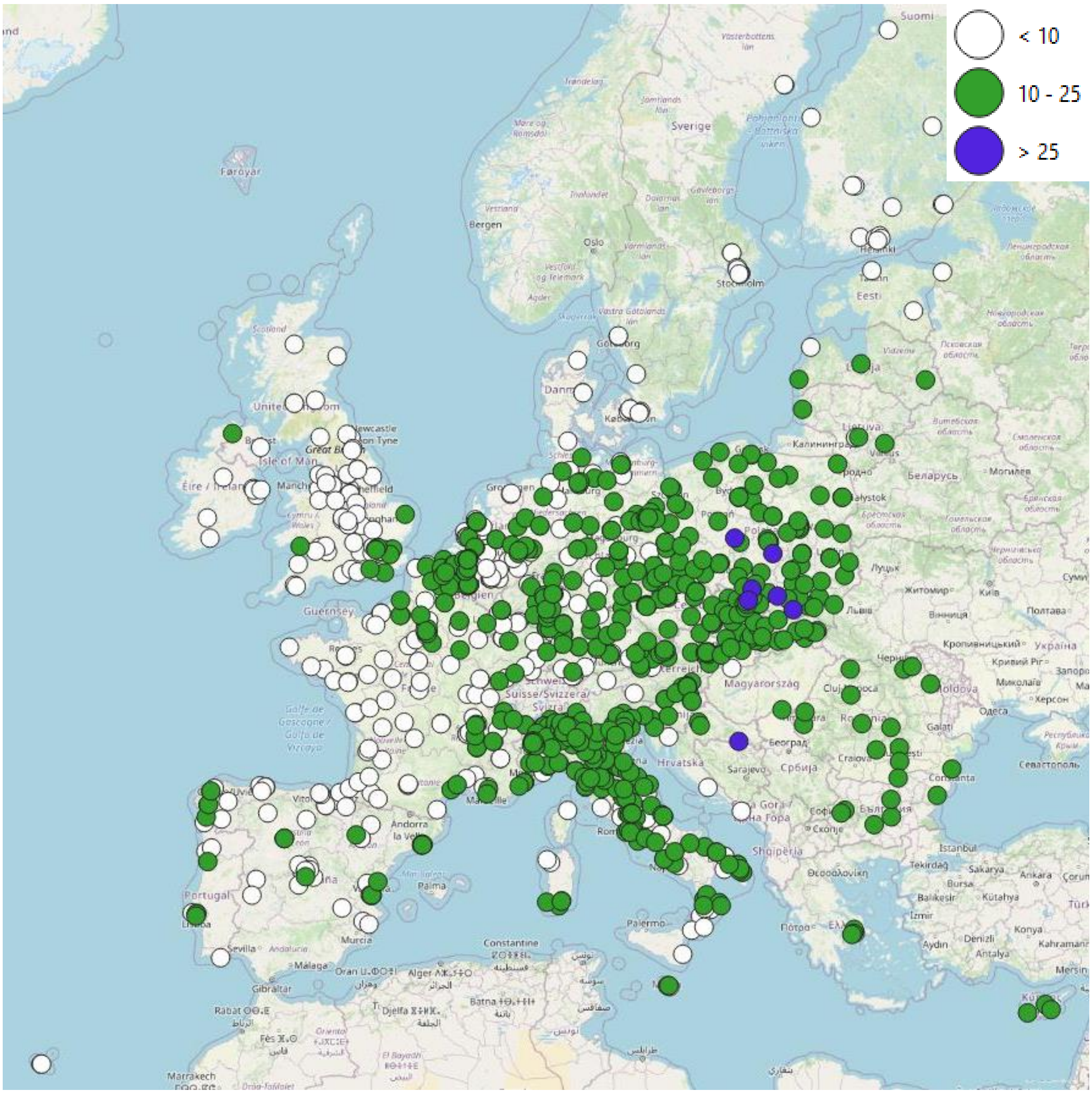


Figure 25 - PM2.5 Compliance with WHO Guideline and EU AQLV - EU - 2025

City Focus - PM2.5

In the Base Case, seven of the nine cities are already compliant in 2020 with the AAQD legislated limit (annual mean 25µg/m^3). The remaining two cities of Milan and Warsaw were predicted to be close to compliance (within the uncertainty band) in 2020 and forecast to be fully compliant by 2025. However, the application of the WHO guide value of 10µg/m^3 would cause widespread non-compliance in all of the cities with the exception of Madrid. None of the road transport scenarios significantly reduce the non-compliance seen within these cities at the suggested lower limit. Even under the extreme 'zero exhaust' emission scenarios (i.e., electrification of elements of the fleet) concentrations are not significantly reduced due to the overwhelming contribution from the non-exhaust component.

A closer look at the city of Rome, which is currently fully compliant with the EU AQLV provides a good example of the impact that adoption of a 10µg/m^3 PM2.5 limit value would have on compliance. In **Figure 26** compliance with the current EU AQLV is shown on the left, and compliance with the WHO 10µg/m^3 guideline value shown on the right. Such a move would drive every station in the city into non-compliance.

The prediction in 2035 is little better from a compliance point of view (**Figure 28**). Only one station in Rome manages to achieve compliance with the 10µg/m^3 limit. This illustrates that compliance with a 10µg/m^3 limit is unachievable without significant further measures on non-transport sectors, for example, even with the entire elimination of domestic and commercial combustion in the EU, one station remains non-complaint in 2035 (**Figure 27**).

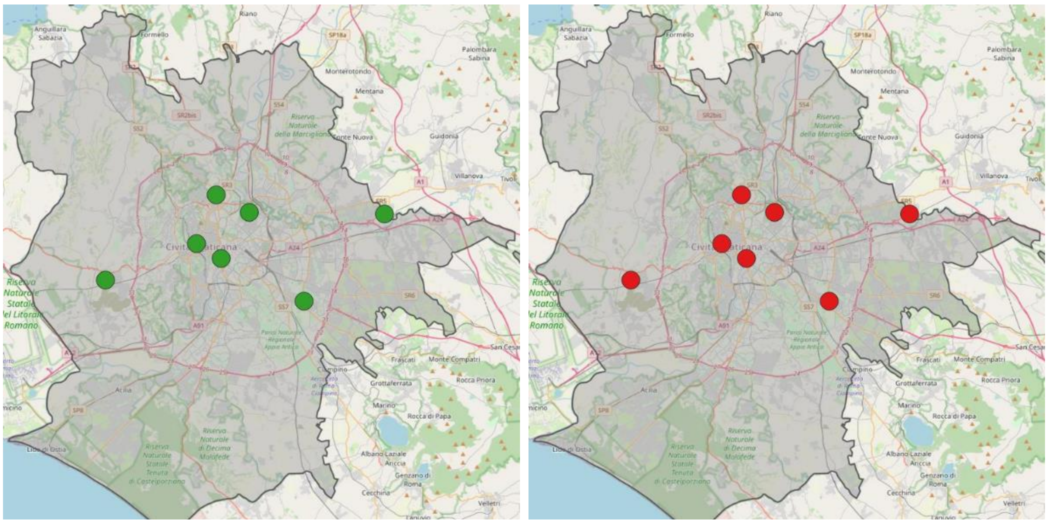


Figure 26 - PM2.5 compliance in Rome, 2025, Base Case. EU AQLV, left. WHO guideline, right.

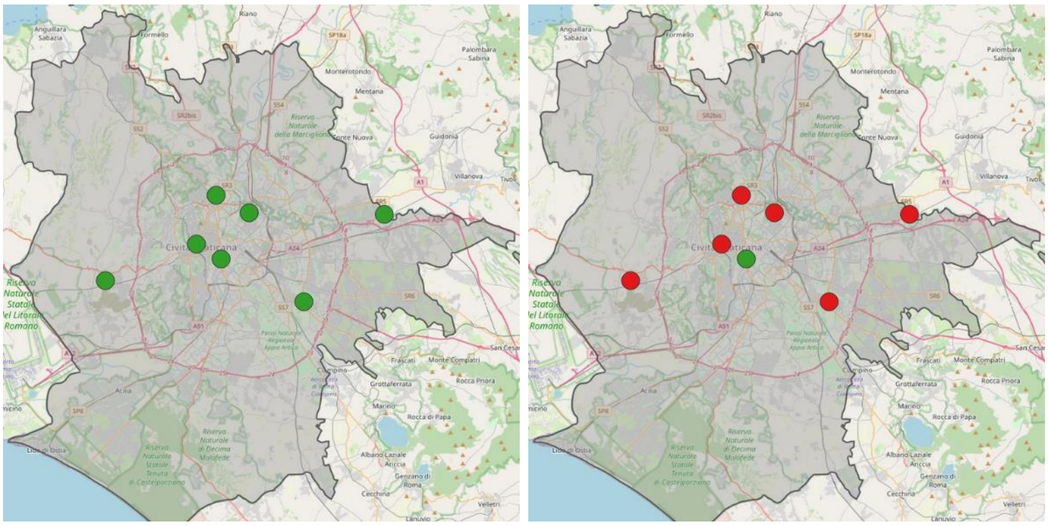


Figure 28 - PM2.5 compliance in Rome, 2035 Base Case. EU AQLV, left. WHO guideline, right.

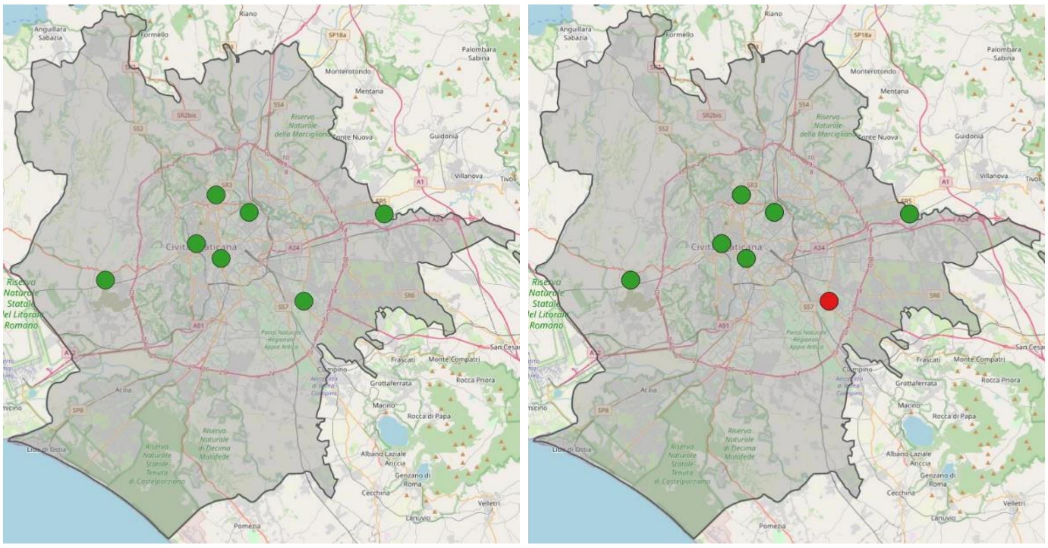


Figure 27 - PM2.5 compliance in Rome in 2035 (Complete elimination of all domestic and commercial combustion in the EU). EU AQLV, left. WHO guideline, right.

Results - PM10

Base Case

Daily PM10 exceedances and annual mean concentrations have been modelled but given that the current PM10 daily exceedance limit value is a tougher standard to achieve, compliance with this metric alone is examined here.

While compliance with the daily PM10 exceedances is achieved across most of the EU as a result of measures already in place, distinct areas of non-compliance exist, in particular in Poland and the Po Valley area of Italy (**Figure 29**). In the emissions Base Case, although improvements are observed, over 5% of stations are predicted to remain non-compliant in 2025, 2030 and beyond (**Figure 30**).

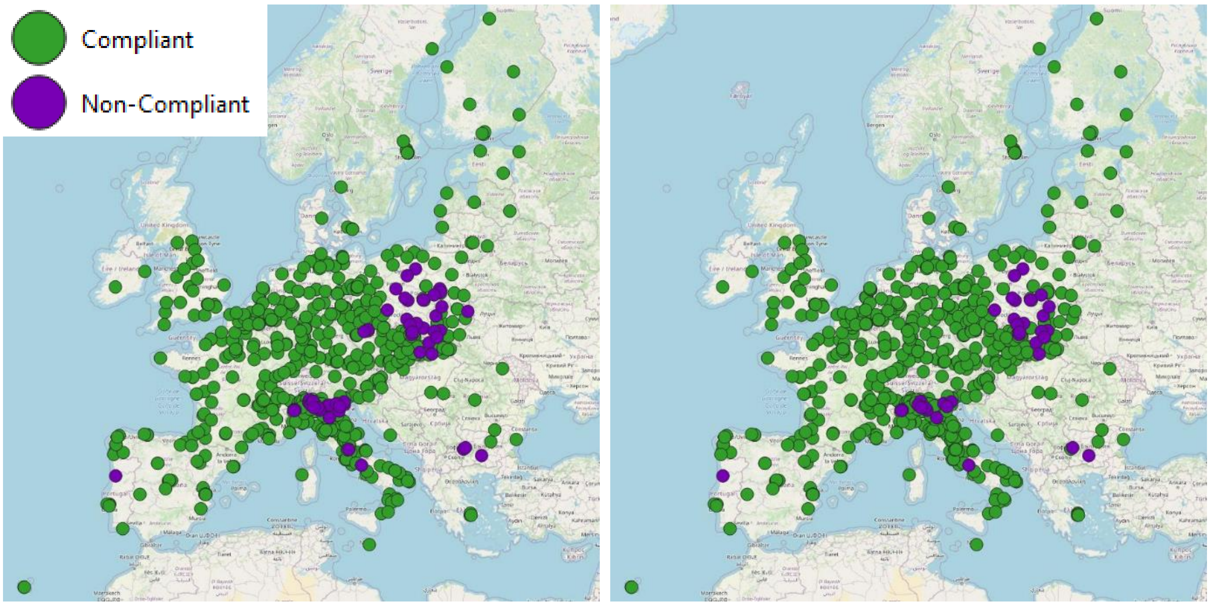
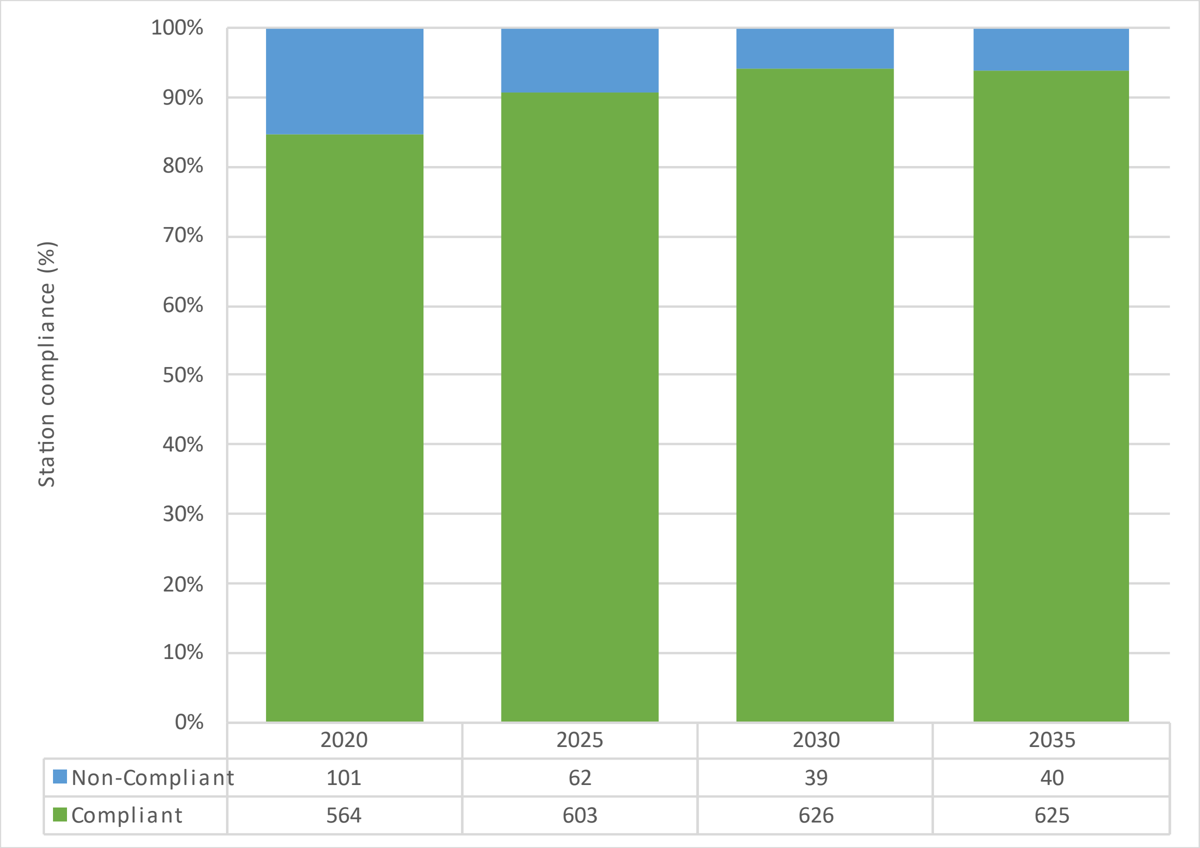


Figure 29 - PM10 Exceedances in the EU emissions Base Case, 2025 left, and 2030, right.



	2020	2025	2030	2035
🟦 Non-Compliant	101	62	39	40
🟩 Compliant	564	603	626	625

Figure 30 - EU, PM10 predicted compliance with daily exceedance EU AQLV: 2020 - 2035 Base Case

Air Quality Response to Key Scenarios

To simplify discussion of the impact of additional emission abatement, those scenarios that introduce more extreme reductions of the pollutants responsible for PM10 concentrations in urban environments are highlighted in **Table 18**.

Table 18 - PM10 - Non-compliant station summary under key scenarios in the EU - EU Daily Exceedances (total of 665 Stations)

	2020	2025	2030	2035
Base Case	**101** (15%)	**62** (9%)	**39** (6%)	**40** (6%)
Diesel PC and LCV: NO_X 0, PM2.5 0 (2025) ***Scenario 7***	**101** (15%)	**62** (9%)	**39** (6%)	**38** (6%)
Zero Emissions from Domestic & Commercial Combustion (2025) ***Scenario 9***	**101** (15%)	**17** (3%)	**13** (2%)	**13** (2%)
NH_3 Emissions from Agricultural Sector: 50% (2025) ***Scenario 10***	**101** (15%)	**33** (5%)	**18** (3%)	**17** (3%)

City Focus PM10

In the Base Case, five of the nine cities are already compliant in 2020 with the legislated thirty-five exceedances of a 50µg/m^3 daily mean. By 2025, one more of the cities; Paris is predicted to be compliant while Milan, Stuttgart and Warsaw remain non-compliant. However, none of the road transport scenarios significantly reduce the non-compliance seen within these cities. Even under the extreme ‘zero exhaust’ emission scenarios (i.e., electrification of elements of the fleet) concentrations are not significantly reduced due to the contribution from the non-exhaust component. Milan as an example city is examined in more detail below.

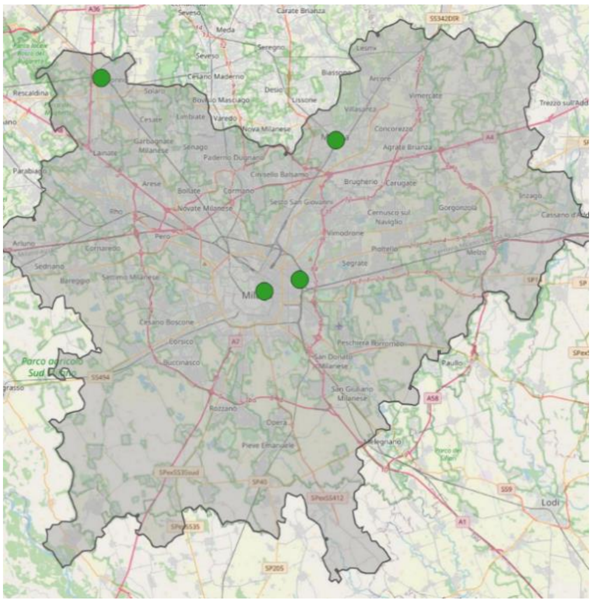


Figure 31 - Milan PM2.5 compliance - 2025 Base Case

Every PM2.5 measuring station modelled in Milan is currently compliant and this is not predicted to change in the future (**Figure 31**). However, this is not so for PM10, which shows that every modelled station is likely to be non-compliant in 2025 with the PM10 daily exceedance AQLV.

The impact of each of the main scenarios on PM10 compliance in Milan in 2025 is shown in **Figure 32**. The two scenarios that result in a change in compliance are the complete elimination of domestic combustion and a halving of ammonia emissions from agriculture, however even this is not enough to ensure compliance at every station in 2025.

Given that no scenario resulted in complete compliance with the PM10 daily exceedance AQLV in Milan even in 2035, this suggests that implementing specific local measures (identified through a suitable source attribution study) would be much more likely to achieve compliance.

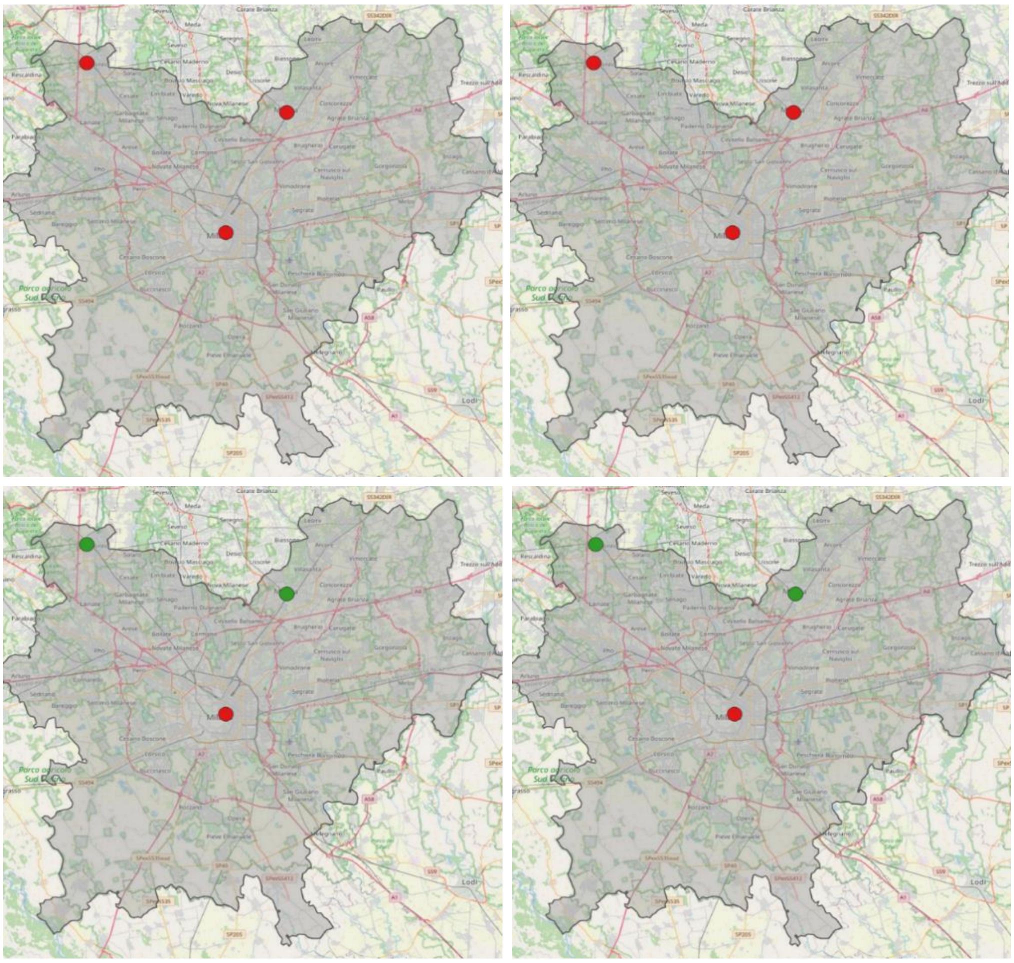


Figure 32 - PM10 (>35 daily exceedances) compliance in Milan in 2025. Clockwise from top left: Base Case, Zero emissions PCD, 50% Agricultural NH_3, 100% reduction in domestic and commercial combustion

Results - Ozone

The current AAQD specifies a non-binding target value for the protection of human health from exposure to ozone. This is based on limiting the number of exceedance days in one year to 25 days of the rolling eight-hour average concentration above an ozone concentration threshold of 120µg/m^3, averaged over three-years.

The WHO 2005 Guidelines reduce the daily threshold from 120µg/m^3 to 100µg/m^3. This study therefore examines the implications of this lower threshold, should it be adopted in a future revision of the AAQD.

The formation of ozone in the atmosphere is a complex photochemical process involving reactive hydrocarbons (NMVOC[4]) and oxides of nitrogen. Complex chemical models have been developed to represent these reactions, including the EMEP model developed and maintained by the Norwegian Meteorological Institute. [5]

Data from the EMEP model is used to generate European 'source-receptor' (SR) functions which relate emissions (e.g., NMVOC and NO_X) from each country/sea area to their contribution to pollutant concentrations in each 'receptor grid' of the model domain. As discussed previously in this report, Aeris generate detailed SR functions for the whole of Europe from this data and incorporate them into AQUIReS+.

City Focus - Ozone

In urban environments, especially in highly trafficked city centres, the levels of ozone produced by complex photochemical processes are reduced by the simple titrating effect of NO (the dominant component of NO_X emissions from combustion sources, including the internal combustion engine) to produce NO_2 and molecular oxygen (O_2). Without this effect, the concentration of ozone in a city would be higher and, in some cities, considerably higher.

This is well illustrated in **Figure 33** which shows the levels of SOMO35[6] (the ozone health impact metric) in Madrid based on ozone measurement station data from the city and its surrounding area. Here the SOMO35 for ozone has been calculated at each ozone measuring station for 2005, 2010 and 2015.

In 2005 (with road transport made up of a mix of Pre-Euro, Euro I, Euro II, and a few Euro III vehicles) the NO component of NO_X emissions from road transport activity in the city centre substantially reduces the ozone levels from those seen in the suburban and rural areas around the city centre. In terms of SOMO35, the health impact metric, the reduction is fivefold.

Over the next ten years, NO_X vehicle emission limits were progressively reduced, and NO_X/NO emissions fell. By 2010 the effect of the reduced NO emissions is already visible with the SOMO35 level in the city centre doubling from the 2005 level, and by 2015 increasing to three to four times the 2005 level.

---

[4] NMVOC - Non-Methane Volatile Organic Chemicals

[5] The co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe: 'European Monitoring and Evaluation Programme' (EMEP). A scientifically based and policy driven programme under the Convention on Long-range Transboundary Air Pollution (CLRTAP) for international co-operation to solve transboundary air pollution problems. The EMEP model has been used to support European Air Quality Policy for more than three decades.

[6] SOMO35 - defined as the sum of means over 35 ppb from a daily maximum 8-hour rolling average

Of course, these reductions in NO_X have made an important contribution to the reduction of NO_2 in the city of Madrid and to compliance with the NO_2 limit value. However, ozone also has important health impacts and this ‘environmental tension’ between reducing NO_2 and increasing ozone is an important consideration in the development of any further action to address NO_x emissions.

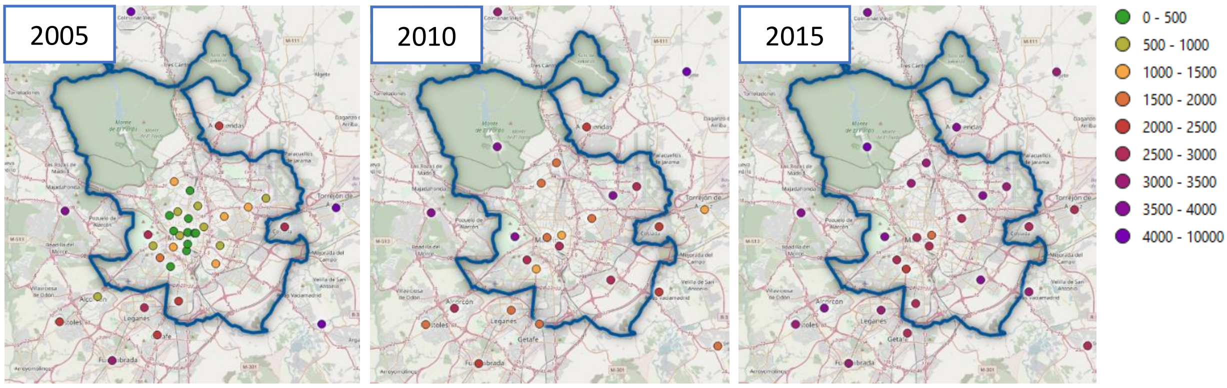


Figure 33 - SOMO35 based on monitoring data in Madrid: 2005-2010-2015

Base Case

By 2025, ozone concentrations in the Base Case are predicted to meet the EU target of 25 exceedance days at all but 12% of the 1166 monitoring stations currently located in urban areas of the EU that have recorded exceedances in the last five years. In the same year this increases to 74% of stations if the limit is reduced to 100µg/m^3. A summary of Base Case compliance is shown in **Table 19**.

Table 19 - Ozone exceedances in the Base Case at EU target value and WHO guide value [7]

	2020	**2025**	**2030**	**2035**
EU AAQD: 120µg/m^3 (> 25 days)	**204** (17%)	**145** (12%)	**116** (10%)	**110** (9%)
WHO: 100µg/m^3 (> 25 days)	**921** (77%)	**884** (74%)	**851** (71%)	**841** (70%)

Between 2020 and 2030 the number of stations that are non-compliant with the EU limit value reduces by nearly 44% as a result of currently mandated emission reductions. However, this reduction is not seen when compared to the WHO guide value of 100µg/m^3. Against the WHO value, the reduction is only 8%, with over 70% of stations remaining non-compliant and only marginal further improvement by 2035. Compliance with the WHO guide value would therefore be exceptionally challenging in the EU. This difference in compliance is clearly shown in **Figure 34**.

---

[7] AQUIReS+ requires a monitoring station to have recorded exceedances in the past five years to be able to predict exceedances. Therefore, stations which have never recorded an exceedance are excluded from these totals. This also means that there are slightly different numbers of stations for the two concentrations:

- 120µg/m^3 - 1166 stations
- 100µg/m^3 - 1198 stations

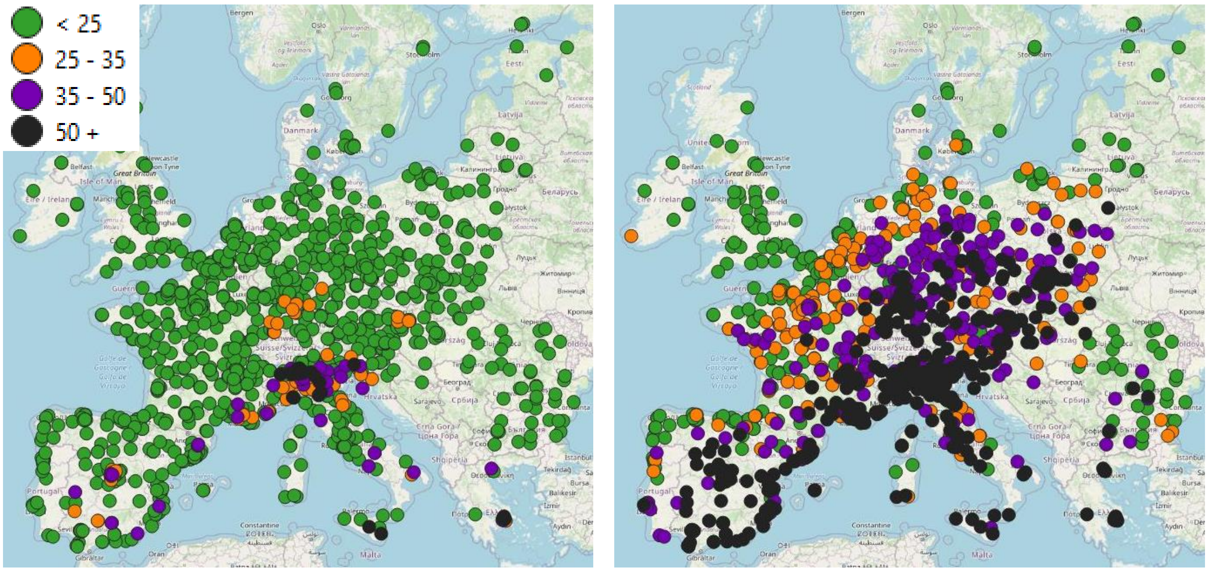


Figure 34 - Ozone exceedance days in 2030 against the AAQD 120µg/m^3 target and WHO 100µg/m^3 guideline

Air Quality Response to Key Scenarios

As discussed earlier in the report, reducing NO_X emissions can increase ozone concentrations, whereas reducing NMVOC emissions does reduce ozone concentrations. Therefore, to ascertain the scale of possible reductions in ozone concentration, the scenarios that have the greatest impact on VOC emissions are briefly looked at here.

Table 20 shows that eliminating VOC emissions from road transport has a marginal impact on compliance across the EU. This is the case for both the EU AAQD target value and the WHO guideline value. This very small impact is consistent with the small contribution modern gasoline and diesel vehicles make to total VOC emissions. This clearly indicates that any further tightening of VOC emission limits for road transport (exhaust or evaporative) would have no meaningful impact on ozone compliance.

Conversely, reducing emissions from the ‘solvent and product use’ sector is foreseen to have an immediate and meaningful impact on ozone compliance in the EU. This reflects the significant contribution from this sector to VOC emissions in the Base Case as shown in **Figure 35**.

Table 20 - Station compliance with ozone exceedances for key scenarios at 120µg/m^3 and 100µg/m^3

	2020	2025	2030	2035
120µg/m^3 (> 25 days)				
Base Case	**204** (17%)	**145** (12%)	**116** (10%)	**110** (9%)
VOC Emissions from Road Transport: Zero ***Scenario 15***	**204** (17%)	**138** (12%)	**109** (9%)	**108** (9%)
VOC Emissions from Product Use sector: 50% ***Scenario 16***	**204** (17%)	**107** (9%)	**88** (8%)	**83** (7%)
100µg/m^3 (> 25 days)				
Base Case	**921** (77%)	**884** (74%)	**851** (71%)	**841** (70%)
VOC Emissions from Road Transport: Zero ***Scenario 15***	**921** (77%)	**870** (73%)	**839** (70%)	**824** (69%)
VOC Emissions from Product Use sector: 50% ***Scenario 16***	**921** (77%)	**839** (70%)	**800** (67%)	**770** (64%)

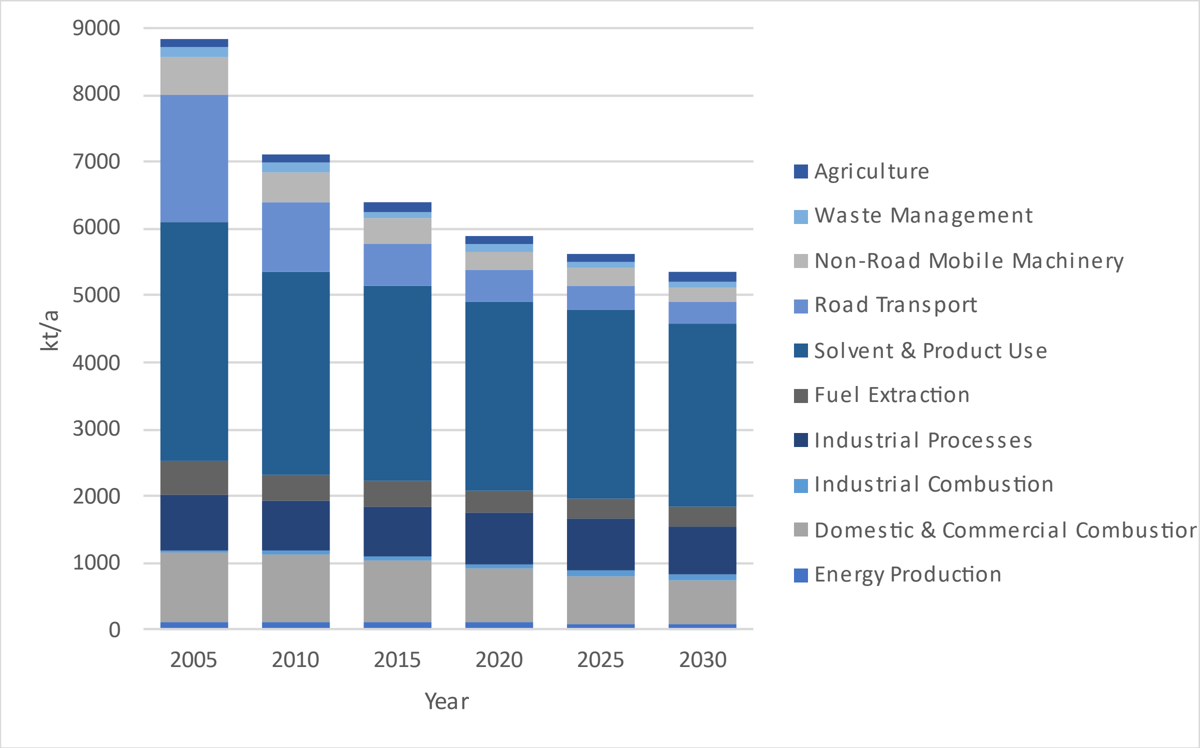


Figure 35 - NMVOC emissions in the EU split by sector. Source GAINS IIASA

Results - SARS-COV-2 (COVID-19)

The outbreak of SARS-COV-2 across Europe in early 2020 resulted in a substantial change in emissions in urban areas across the EU. National and regional lockdowns, international travel restrictions, enforced home-working and a number of other behavioural changes provided a unique opportunity to study how changing emissions affected air quality.

As part of this study, a series of SARS-COV-2 'reduced activity' sensitivity scenarios were designed to provide an insight into how behavioural changes, particularly reductions in road transport activity, might impact urban air quality.

As only annual mean concentrations are directly modelled in AQUIRES+, the assumption made in each 'COVID scenario' was that the lockdown period was sustained over the whole of 2020. This enabled the difference between the annual mean concentration in the Base Case and in each COVID scenario to be determined. This delta concentration was then compared to the observed difference in monthly mean concentration during each lockdown month in 2020 versus the same monthly mean in the previous five years. For each pollutant, a typical urban traffic and background station were chosen.

The six road transport scenarios modelled are summarised in **Table 21**.

Table 21 - SARS-COV-2 sensitivity scenarios

Cov-Scn-1a	Passenger Car and LCV NO_X, PM2.5 and VOC Emissions Reduced by 25%
Cov-Scn-1b	Passenger Car and LCV NO_X, PM2.5 and VOC Emissions Reduced by 50%
Cov-Scn-1c	Passenger Car and LCV NO_X, PM2.5 and VOC Emissions Reduced by 75%
Cov-Scn-2a	Total Road Transport NO_X, PM2.5 and VOC Emissions Reduced by 25%
Cov-Scn-2b	Total Road Transport NO_X, PM2.5 and VOC Emissions Reduced by 50%
Cov-Scn-2c	Total Road Transport NO_X, PM2.5 and VOC Emissions Reduced by 75%

While the air quality impact of all these scenarios, in each of the nine cities included in the scope of this study were modelled, here the results are given for a single representative city for each pollutant. For NO_2, this is the city of Madrid and for PM2.5, the city of Milan.

NO_2 Results

Figure 36 shows NO_2 concentrations at an urban traffic station in Madrid from 2015 to 2020. The solid grey line shows the measured monthly mean concentrations and highlights the large seasonal variations. The winter months exhibit significantly higher monthly means compared to the warmer months. This is consistent with increased domestic and commercial combustion in the winter period and higher traffic activity compared to the quieter summer months.

The winter period of 2019/2020 shows much less of a peak than previous years, the reason for this is unclear since no formal 'lockdown' measures in Spain were announced until March of 2020[b]. However, this significant reduction versus the previous 'winter peak' is not seen in the urban background station discussed below. This may indicate a change in traffic patterns at this road-side station during this period.

The previous five years of monthly measurements indicate that April typically has some of the lowest NO_2 concentrations at this station; some 5-6µg/m^3 below the annual mean in 2018 and 2019. This increases to 27 µg/m^3 below the annual mean in 2020, a very significant decrease that coincides with the lockdown in Spain [c].

The drop in concentration in April compared to previous years is greater than any of the changes induced by the modelled COVID scenarios. This indicates that decreased road transport activity during the lockdown is unlikely to be solely responsible for observed reductions in NO_2 concentrations. The residual monthly concentration during the lockdown (both measured and modelled) serves to highlight that non-traffic sources are an important contribution to NO_2 concentrations in cities.

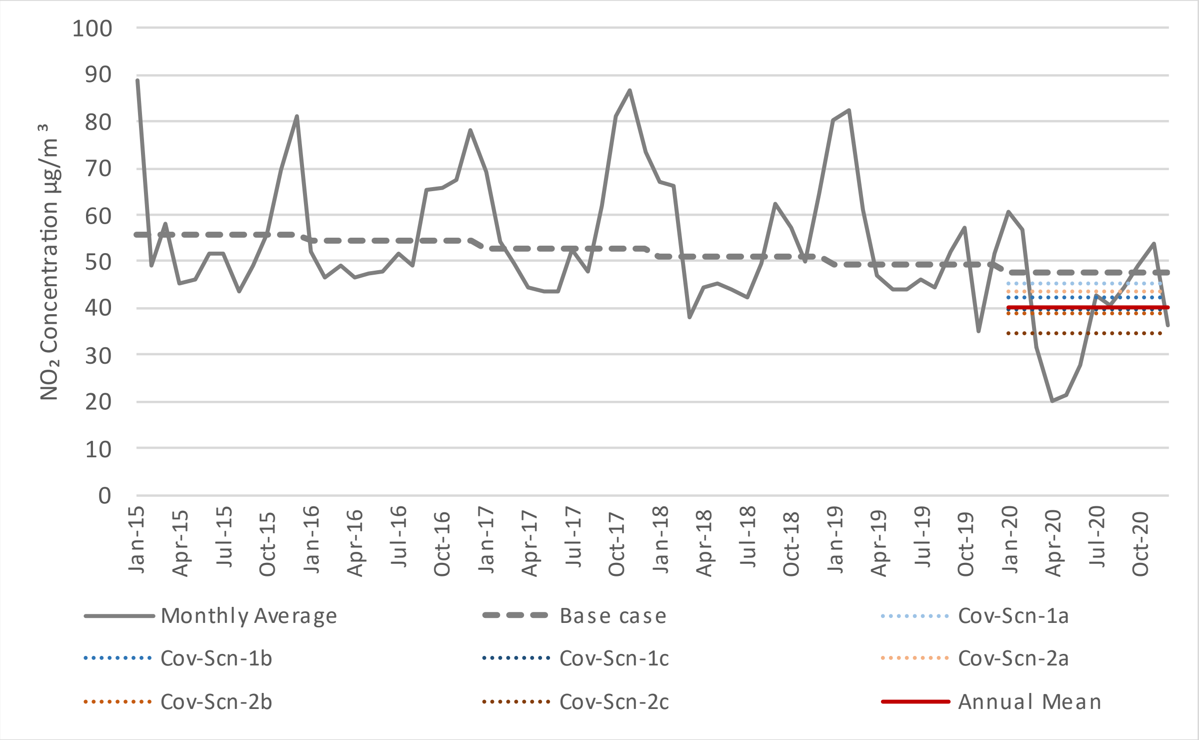


Figure 36 - ES1943A - Urban Traffic Station in Madrid - NO_2 - 2020

Figure 37 shows NO_2 concentrations at another station in Madrid, this time monitoring urban background concentrations. At this station, April is again a month that exhibits lower than average NO_2 concentrations.

Although as a background station, the impact of emissions from road transport are less dominant, there is still a significant decrease in observed monthly concentration during the lockdown period in April compared to observations in previous years. Again, the most extreme (75% reduction in traffic activity) modelled scenario shows less reduction in concentration when compared to the observed change indicating that the lockdown impacted not just traffic sources in Madrid.

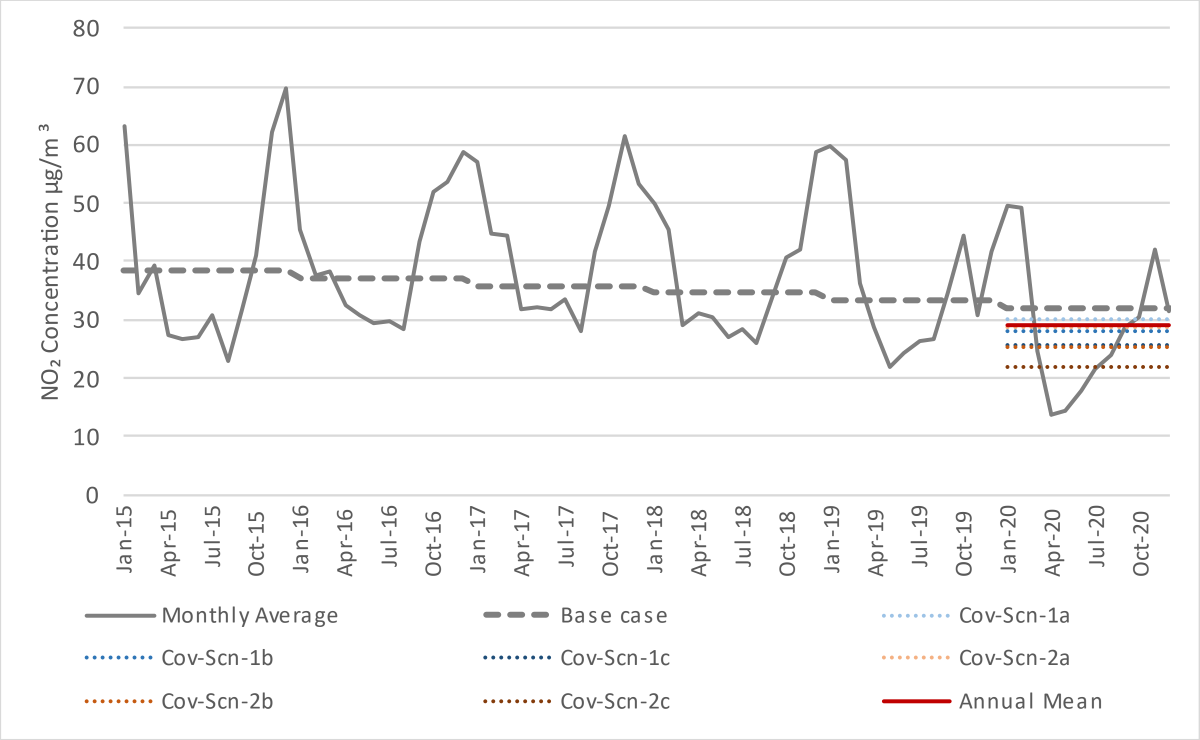


Figure 37 - ES1532A - Urban Background Station in Madrid - NO_2 - 2020

PM2.5 Results

Figure 38 and **Figure 39** show observed PM2.5 concentrations at an urban traffic station and an urban background station in Milan from 2015 to 2020. The solid grey line represents monthly mean concentrations and highlights the large seasonal variation. The winter months exhibit significantly higher monthly means compared to the summer months, likely as a result of increased domestic and commercial combustion, increased traffic activity (compared to the summer months) and a higher component of secondary PM2.5 sources.

In both cases, it is difficult to discern a 'COVID lockdown' effect from the observations since the inter-annual variations in monthly means is so large. The modelled scenarios indicate a reduction of just 5µg/m^3 for the 50% reduction in activity case. Identifying such a small change in the observations is clearly very difficult. This small response in PM2.5 concentrations during lockdown has also been reported by others. [d]

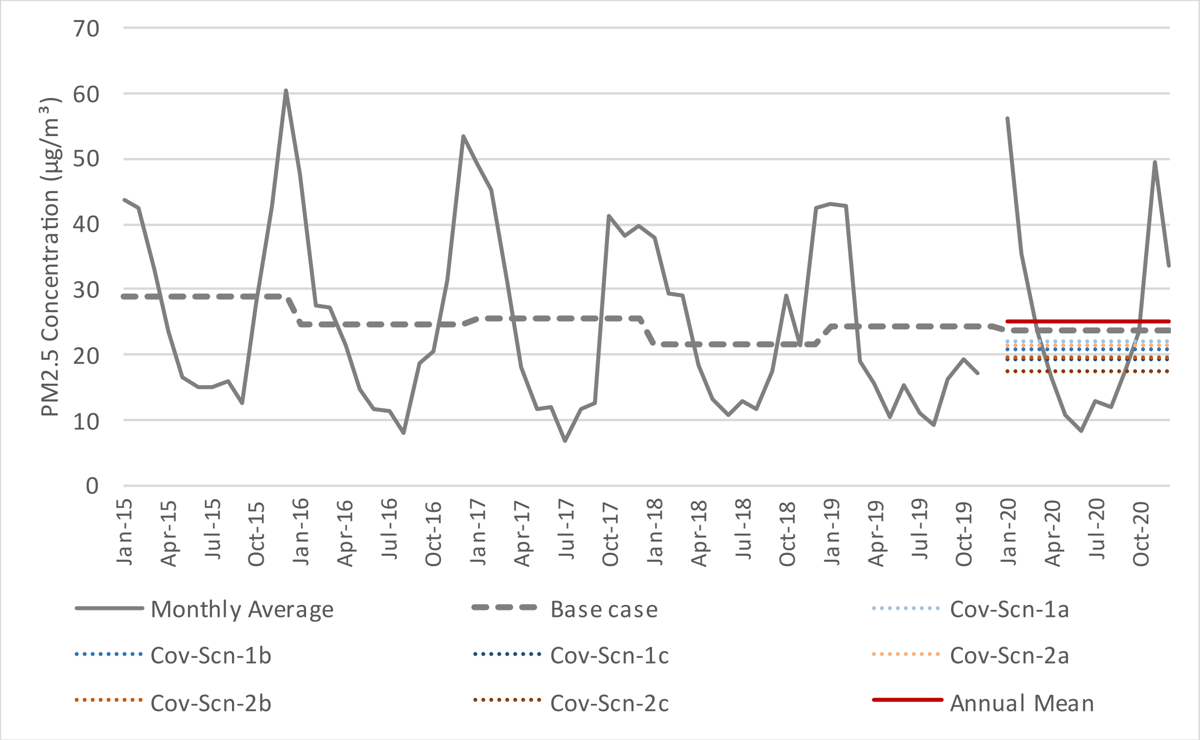


Figure 38 - IT1016A - Urban traffic station in Milan - PM2.5 [8]

---

[8] The breaks in the monthly average line are due to gaps in the measurement data

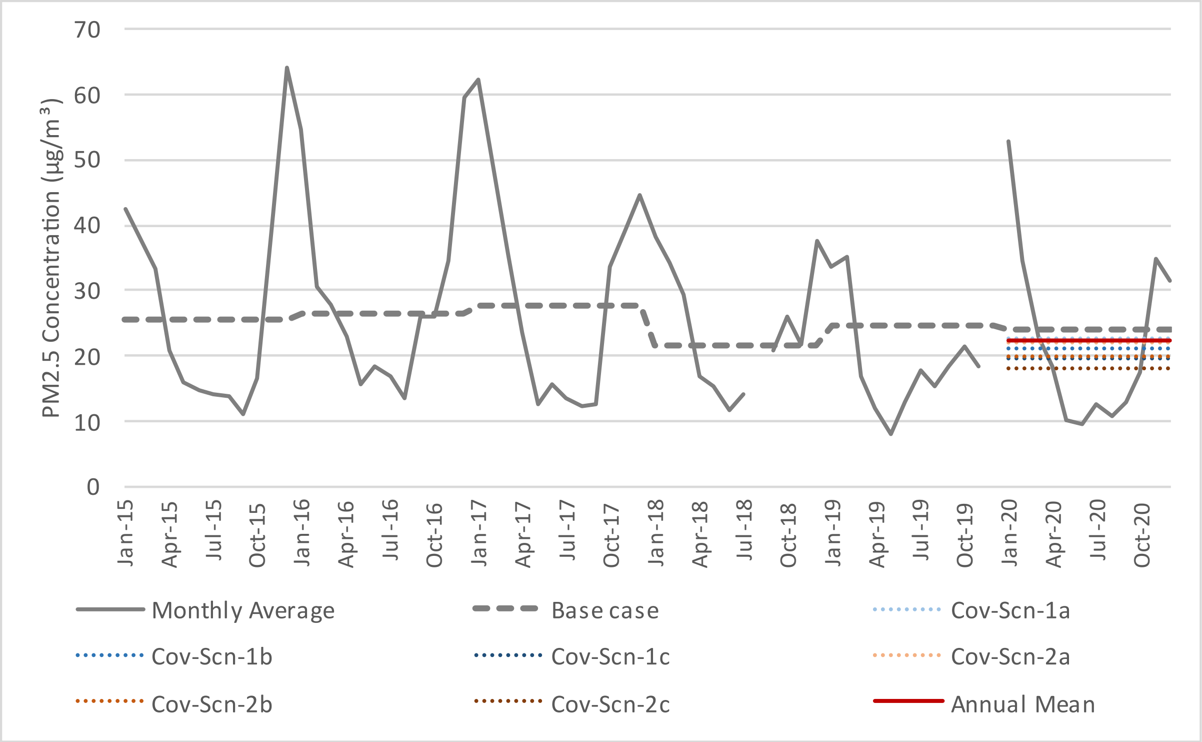


Figure 39 - IT1743A - Urban background station in Milan - PM2.5 [9]

---

[a] (de Leeuw & Ruyssenaars, 2011) *Evaluation of current limit and target values as set in the EU Air Quality Directive - ETC/ACM Technical Paper*

[b] (Blas, et al., 2020) *Sánche decreta el estado de alarma durante 15 días*

[c] (José, 2020) *Paralizada toda actividad no esencial en España*

[d] (Shi & Song, 2021) *Abrupt but smaller than expected changes in surface air quality attributable to COVID-19 lockdowns*

---

[9] The breaks in the monthly average line are due to gaps in the measurement data

Conclusions

NO_X Emissions

NO_X emissions from road transport do not reduce significantly beyond the baseline for any of the Euro 7/VII scenarios explored in this study. For example, the introduction of the full range of 'Euro 7/VII' emission limits for diesel passenger cars and vans results in 'beyond the Baseline' reductions in EU NO_X emissions (versus the 2020 Baseline) of only 0.9 - 3.4% by 2030 and only 1.1 - 4.6% by 2035. Similarly, the introduction of the full range of Euro 7/VII emission limits for HDVs results in reductions in EU NO_X emissions of only 0.1 - 1.6% by 2030 and only 0.1 - 2.4% by 2035. In comparison, the reductions in Baseline emissions by 2030 are 67% and by 2035, 79% from 2020 Baseline levels. Furthermore, any change in vehicle emission limits has a minimal impact compared to natural fleet renewal with the latest Euro 6/ VI new vehicles.

The study also explored the NO_X emission reduction benefits from early replacement of Euro 3/III through to Euro 5/V in the 2020/21 diesel passenger and HDV vehicle parc with Euro 6/VI vehicles. In contrast to the very limited further NO_X emission reductions resulting from the introduction of a Euro 7/VII standard, early vehicle replacement (via an incentivised early scrappage scheme for example) on a vehicle for vehicle basis would result in some 6 to 25 times the emission reduction benefits for NO_X compared to the introduction of a zero exhaust emission Euro 7/VII vehicle. Importantly, these benefits would also be realised much earlier.

NO_2 Compliance

By 2025 there is a high degree of compliance (99%) at urban monitoring stations in the EU from Base Case emissions with no additional reductions. All of the 'beyond the baseline road transport scenarios' explored in this study have negligible further impact on the baseline NO_2 compliance picture. This is also the case in the each of the nine selected cities and the Innsbruck Transit Corridor. In contrast, for urban areas and the nine selected cities, further action on domestic and commercial combustion systems is found to have a more significant impact. The importance of emissions from these non-transport combustion sources is further highlighted by the COVID scenario findings.

PM Emissions

PM2.5 emissions from road transport do not reduce significantly beyond the Baseline for any of the scenarios explored at this stage of the study. For example, the introduction of the full range of 'beyond Euro 6d final' emission limits for diesel passenger cars and vans results in 'beyond the Baseline' reductions in EU PM2.5 (exhaust + non-exhaust) emissions (versus the 2020 Baseline) of only 0.8 - 1.6% by 2030 and only 1.1 - 2.1% by 2035. In comparison, the reductions in Baseline emissions by 2030 are 21% and by 2035, 17% from 2020 Baseline levels (exhaust + non-exhaust).

The study also explored the PM2.5 exhaust emission reduction benefits from early replacement of Euro 3/III through to Euro 5/V in the 2020/21 diesel passenger and HDV vehicle parc with Euro 6/VI vehicles. In contrast to the very limited further PM exhaust emission reductions resulting from the introduction of a Euro 7/VII standard, early vehicle replacement (via an incentivised early scrappage scheme for example) on a vehicle for vehicle basis would result in some 10 to 35 times the emissions reduction benefit for PM2.5 exhaust compared to the introduction of a zero exhaust emission Euro 7/VII vehicle. Importantly these benefits would also be realised much earlier.

PM2.5 Compliance

By 2025 there is a high degree of compliance (>99%) with the current AQLV at urban monitoring stations in the EU from Base Case emissions with no additional reductions. In the 'Big Five' EU Member States (France, Germany, Italy, Poland, and Spain) compliance is better than or equal to 99% of stations. All of the 'beyond the baseline scenarios' explored at this stage have negligible impact on the baseline $PM_{2.5}$ compliance picture in these countries and in each of the nine selected cities. This is also the case were the current AQLV to be lowered to the WHO guide value of 10µg/m^3 (annual mean).

PM10 Compliance

While compliance with the daily PM10 exceedances is achieved across most of the EU as a result of measures already in place, distinct areas of non-compliance exist, with some 5% of stations predicted to remain non-compliant in 2025, 2030 and beyond. This picture is reflected in the nine selected cities with five of the nine cities compliant in 2020. By 2025, one more of the cities; Paris is predicted to be compliant while Milan, Stuttgart and Warsaw remain non-compliant beyond 2030. However, none of the road transport scenarios significantly reduce the non-compliance seen within these cities. Even under the extreme 'zero exhaust' emission scenarios (i.e., electrification of elements of the fleet) concentrations are not significantly reduced due to the overwhelming contribution from the non-exhaust component.

Ozone Compliance with the Current AAQD Requirements

The current AAQD requirements are based on an ozone threshold of 120µg/m^3 and a maximum annual number of 25 days in exceedance of this value. By 2025 the Baseline scenario results in about 87% of the urban/suburban monitoring stations in the EU as a whole achieving the non-binding limit on exceedance days. All the 'beyond the baseline road transport scenarios' explored in the study, have a very limited further impact on the baseline situation. This is especially so for further NO_X emission reductions due to the loss of the titrating effect of NO in reducing ozone over urban areas. In contrast to this, further action to reduce VOC emissions from the 'solvent and product use' sector has a more significant impact on compliance.

At the more stringent ozone threshold in the WHO Guidelines, ozone compliance in 2025 falls to just 25% of the urban/suburban monitoring stations in the EU. Despite this high level of 'non-compliance', all the 'beyond the baseline road transport scenarios' explored at this stage, have a very limited further impact on the baseline situation. Again, in contrast to this, further action to reduce VOC emissions from the 'solvent and product use' sector has a more significant impact on ozone compliance.

The Impact on NO_2, PM2.5 and Ozone from COVID Related Factors

In the case of NO_2, the city measurement station data, in almost all cases, indicates a more significant reduction in concentrations during the lockdown periods than the modelled responses. This is consistent with the important additional NO_X contribution from commercial combustion systems in cities. During periods of lockdown, the emissions from these sources were also significantly reduced (e.g., from the move from offices to working from home) but this was not included in the COVID scenarios explored in this study.

In the case of the Innsbruck Transit Corridor, the NO_2 measurements are within the range of the modelled scenarios. This serves to illustrate that, in urban areas in particular, non-transport sources of NO_X are significant contributors to NO_2 levels.

In the case of PM2.5, as found in other studies, the lockdown resulted in a very limited impact on the measured concentrations compared to recent years. The modelled response, as expected, was also found to be small. This is consistent with the small contribution of road transport PM2.5 emissions to overall PM2.5 concentrations.

In the case of ozone, given the strong inter-annual/monthly variations in concentrations, it was difficult to discern the 'COVID' signal. Other studies have however shown that during lockdown periods, ozone levels have increased, particularly in city centres, due to the loss of the titrating effect of NO emissions.[a]

Implications for Future Euro Standards

Overall, the findings of this study clearly demonstrate that all potential Euro 7/VII scenarios considered in this study show only marginal benefits compared to the Base Case.

This is clearly reinforced by the findings from the 'early replacement of pre-Euro 6/VI vehicles by Euro 6/VI vehicles' comparisons. These clearly demonstrate that for diesel, on a 'vehicle for vehicle' basis the NO_X emission reduction benefits from such an accelerated replacement scheme are some 6 to 25 times greater than the emission reduction benefit of a 'zero exhaust' Euro 7/VI standard; for PM2.5 exhaust, the corresponding benefits are 10 to 35 times that offered by the introduction of a zero exhaust emission Euro 7/VI standard. In addition, these benefits are realised much earlier.

---

[a] (Lee, et al., 2020) *UK surface NO2 levels dropped by 42% during the COVID-19 lockdown: impact on surface O3*

Appendices

National Emissions

NO_X Base Case Emissions (kt/a)

	2005	2010	2015	2020	2025	2030	2035
AT	213	166	139	101	75	63	59
BE	305	241	213	173	141	124	119
BG	145	118	83	79	66	55	51
HR	76	67	62	57	48	43	40
CY	21	17	13	9	7	6	5
CZ	287	219	180	146	119	101	94
DK	177	134	113	89	71	61	59
EE	35	30	30	27	23	19	19
FI	181	171	147	126	109	96	91
FR	1395	1112	937	753	578	461	409
DE	1428	1266	1064	846	681	558	536
GR	373	279	223	191	152	126	121
HU	146	121	106	82	67	56	51
IE	133	84	79	69	54	44	39
IT	1207	905	779	645	501	422	387
LV	44	39	32	30	26	23	22
LT	46	40	41	33	23	20	19
LU	30	22	16	11	7	5	5
MT	9	8	7	4	3	2	2
NL	362	291	240	193	162	142	135
PL	790	823	635	532	426	358	341
PT	247	183	153	135	112	97	90
RO	277	220	196	177	155	137	129
SK	99	79	69	61	55	50	47
SI	51	44	37	26	19	15	13
ES	1385	877	734	624	518	449	415
SE	184	147	125	101	80	68	65
GB	1537	1074	956	727	561	437	409
EU	11183	8778	7406	6047	4838	4041	3770

PM2.5 Base Case Emissions (kt/a)

	2005	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**
AT	22	20	18	16	15	14	14
BE	37	38	36	34	33	32	33
BG	39	37	29	28	25	23	23
HR	15	14	13	12	12	11	11
CY	3	2	1	1	1	1	1
CZ	36	35	31	28	26	25	25
DK	28	29	23	17	15	13	13
EE	20	22	20	15	14	13	13
FI	31	31	29	25	22	21	20
FR	244	209	184	159	139	124	125
DE	125	118	107	94	89	86	86
GR	59	45	37	31	31	29	29
HU	32	32	28	24	21	20	20
IE	12	9	8	7	7	7	7
IT	139	136	120	115	96	90	90
LV	30	27	26	24	20	18	18
LT	22	21	21	20	16	15	15
LU	2	2	2	2	2	2	2
MT	1	0	0	0	0	0	0
NL	25	21	20	18	17	17	17
PL	223	268	249	240	213	196	196
PT	59	48	44	41	39	36	36
RO	145	140	116	106	97	89	89
SK	35	32	26	24	23	22	22
SI	15	15	14	13	13	11	11
ES	144	128	123	120	117	117	118
SE	29	26	24	23	23	23	23
GB	98	83	78	72	67	69	70
EU	1671	1588	1427	1309	1194	1124	1128

NMVOC Base Case Emissions (kt/a)

	2005	2010	2015	2020	2025	2030	2035
AT	170	138	129	116	111	105	105
BE	151	128	122	119	118	114	114
BG	128	108	79	67	60	53	53
HR	101	78	71	64	59	56	56
CY	11	9	7	7	6	6	6
CZ	196	167	155	136	127	112	112
DK	112	91	78	66	62	58	58
EE	37	34	33	32	31	28	28
FI	118	100	86	74	67	63	63
FR	1217	849	731	659	617	593	593
DE	1185	1024	944	900	877	818	818
GR	263	199	168	142	135	117	117
HU	130	110	97	85	78	73	73
IE	59	47	46	45	44	41	41
IT	1165	890	811	755	700	670	670
LV	56	47	44	39	36	34	34
LT	80	66	64	60	53	47	47
LU	14	9	8	8	7	7	7
MT	4	3	3	3	3	3	3
NL	172	150	148	143	141	139	139
PL	605	549	502	457	429	403	403
PT	224	171	154	146	143	134	134
RO	394	337	268	231	208	179	179
SK	71	72	64	61	59	56	56
SI	45	40	37	35	34	31	31
ES	871	728	666	637	625	615	615
SE	206	177	160	137	131	125	125
GB	1063	785	711	681	677	673	673
EU	8846	7105	6386	5901	5637	5350	5350

SO_2 Base Case Emissions (kt/a)

	2005	2010	2015	2020	2025	2030	2035
AT	27	21	21	20	17	17	17
BE	140	64	64	62	59	59	59
BG	762	414	116	113	118	101	101
HR	65	40	24	20	19	18	18
CY	38	21	17	2	2	2	2
CZ	221	184	123	89	78	72	72
DK	24	16	11	11	10	9	9
EE	76	85	31	25	23	21	21
FI	69	69	53	48	47	46	46
FR	465	287	210	157	144	134	134
DE	458	428	331	292	270	234	234
GR	529	266	113	101	70	51	51
HU	43	29	28	19	19	19	19
IE	71	26	26	22	17	14	14
IT	407	228	189	188	158	160	160
LV	7	5	5	5	4	4	4
LT	41	35	28	26	22	22	22
LU	3	2	2	2	2	2	2
MT	11	5	5	1	1	1	1
NL	64	34	33	32	31	29	29
PL	1207	962	639	528	485	410	410
PT	179	57	54	53	49	49	49
RO	642	364	190	107	102	100	100
SK	90	69	28	25	24	24	24
SI	39	9	8	6	6	5	5
ES	1245	328	246	238	214	216	216
SE	36	35	34	32	31	31	31
GB	721	408	362	234	209	147	147
EU	7680	4489	2987	2453	2230	1997	1997

NH_3 Base Case Emissions (kt/a)

	2005	2010	2015	2020	2025	2030	2035
AT	62	62	65	66	68	69	69
BE	72	71	74	73	72	71	71
BG	39	40	38	37	38	37	37
HR	40	37	39	39	40	41	41
CY	6	5	6	6	6	6	6
CZ	71	62	65	64	64	57	57
DK	77	68	61	57	57	56	56
EE	10	11	10	11	12	12	12
FI	39	37	36	35	36	36	36
FR	694	676	676	663	654	638	638
DE	588	569	569	573	558	545	545
GR	58	56	49	48	48	46	46
HU	79	67	69	69	67	60	60
IE	111	106	102	104	105	104	104
IT	435	396	405	403	403	399	399
LV	15	16	15	16	17	17	17
LT	35	37	35	37	38	38	38
LU	6	7	6	6	6	6	6
MT	2	2	1	2	2	2	2
NL	144	128	122	119	118	117	117
PL	329	330	330	330	329	331	331
PT	54	51	50	50	52	51	51
RO	186	163	172	170	167	162	162
SK	29	22	25	24	24	23	23
SI	19	18	18	18	18	17	17
ES	377	353	348	358	360	354	354
SE	54	49	49	48	49	49	49
GB	310	283	284	281	287	286	286
EU	3937	3725	3721	3706	3692	3630	3630

Baseline Vehicle Fleet

EU Road Transport Emissions of NO_X by Vehicle Category

	Buses	Heavy Duty Trucks	L-Category	Light Commercial Vehicles	Passenger Cars	Total
2005	422	2111	27	500	1766	4825
2010	340	1618	23	437	1322	3739
2015	249	1074	19	452	1222	3016
2020	142	606	13	444	1010	2215
2025	62	253	9	294	661	1279
2030	28	106	6	167	428	735
2035	18	66	4	86	290	464

EU Road Transport Emissions of PM2.5 by Vehicle category

	Buses	Heavy Duty Trucks	L-Category	Light Commercial Vehicles	Passenger Cars	Total
2005	14	72	6	62	117	272
2010	9	49	4	45	107	213
2015	6	34	3	28	82	152
2020	4	27	2	19	66	117
2025	3	23	2	13	55	95
2030	2	22	1	11	56	93
2035	2	23	1	11	60	97

National Forecasts

This section contains counts of stations in each country and the relationship between the forecast value and the relevant air quality limit and guideline values.

The total number of stations modelled are listed in the first column. Please note that these stations are those that were found suitable for modelling in AQUIReS+, meaning that they must meet the minimum eligibility criteria for the model. Please see the earlier section on the AQUIReS+ model for more information relating to eligibility criteria. In the case of Latvia, none of the air quality monitoring stations were suitable for modelling NO_X.

The next column contains the ISO2 country code, then four bands of compliance for each year follow.

Each station is grouped into one of four categories defined in **Table 11** and repeated here for convenience.

Table 22 - Station compliance categories

Abbreviation	Name	Description
C	Compliant	Modelled concentration is below the limit or guideline value by at least the RMS modelling error for that station.
PC	Probably Compliant	Modelled concentration is below the limit or guideline value by less than the RMS modelling error for that station.
PNC	Probably Non-Compliant	Modelled concentration is above the limit or guideline value by less than the RMS modelling error for that station.
NC	Non-Compliant	Modelled concentration is above the limit or guideline value by at least the RMS modelling error for that station.

Nitrogen Dioxide - Compliance with 40μg/m^3 EU AQLV

		2020				2025				2030				2035			
Stations	**Country**	**C**	**PC**	**PNC**	**NC**	**C**	**PC**	**PNC**	**NC**	**C**	**PC**	**PNC**	**NC**	**C**	**PC**	**PNC**	**NC**
85	**AT**	84	1	0	0	85	0	0	0	85	0	0	0	85	0	0	0
18	**BE**	18	0	0	0	18	0	0	0	18	0	0	0	18	0	0	0
14	**BG**	14	0	0	0	14	0	0	0	14	0	0	0	14	0	0	0
2	**CY**	2	0	0	0	2	0	0	0	2	0	0	0	2	0	0	0
50	**CZ**	49	0	1	0	50	0	0	0	50	0	0	0	50	0	0	0
285	**DE**	252	9	9	15	275	5	3	2	281	2	1	1	283	0	1	1
1	**DK**	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0
4	**EE**	4	0	0	0	4	0	0	0	4	0	0	0	4	0	0	0
238	**ES**	226	8	1	3	235	3	0	0	237	1	0	0	238	0	0	0
18	**FI**	17	1	0	0	18	0	0	0	18	0	0	0	18	0	0	0
332	**FR**	310	2	5	15	321	1	2	8	325	3	1	3	329	0	0	3
112	**GB**	97	4	5	6	107	3	0	2	110	2	0	0	110	2	0	0
14	**GR**	12	1	0	1	12	1	1	0	13	0	1	0	13	1	0	0
4	**HR**	4	0	0	0	4	0	0	0	4	0	0	0	4	0	0	0
13	**HU**	13	0	0	0	13	0	0	0	13	0	0	0	13	0	0	0
10	**IE**	10	0	0	0	10	0	0	0	10	0	0	0	10	0	0	0
223	**IT**	194	12	5	12	212	7	4	0	220	3	0	0	220	3	0	0
3	**LT**	3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0
3	**LU**	2	1	0	0	3	0	0	0	3	0	0	0	3	0	0	0
0	**LV**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	**MT**	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0
36	**NL**	36	0	0	0	36	0	0	0	36	0	0	0	36	0	0	0
104	**PL**	99	1	2	2	103	1	0	0	104	0	0	0	104	0	0	0
32	**PT**	31	0	0	1	31	0	0	1	31	0	1	0	31	0	1	0
18	**RO**	16	2	0	0	18	0	0	0	18	0	0	0	18	0	0	0
20	**SE**	20	0	0	0	20	0	0	0	20	0	0	0	20	0	0	0
6	**SI**	6	0	0	0	6	0	0	0	6	0	0	0	6	0	0	0
15	**SK**	13	2	0	0	15	0	0	0	15	0	0	0	15	0	0	0
1661	**EU**	1534	44	28	55	1617	21	10	13	1642	11	4	4	1649	6	2	4

Particulate Matter (PM2.5) Compliance with 25µg/m^3 EU AQLV

		2020				2025				2030				2035			
Stations	**Country**	**C**	**PC**	**PNC**	**NC**	**C**	**PC**	**PNC**	**NC**	**C**	**PC**	**PNC**	**NC**	**C**	**PC**	**PNC**	**NC**
35	**AT**	35	0	0	0	35	0	0	0	35	0	0	0	35	0	0	0
33	**BE**	33	0	0	0	33	0	0	0	33	0	0	0	33	0	0	0
7	**BG**	6	0	0	1	7	0	0	0	7	0	0	0	7	0	0	0
3	**CY**	3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0
46	**CZ**	42	0	1	3	45	1	0	0	46	0	0	0	46	0	0	0
138	**DE**	138	0	0	0	138	0	0	0	138	0	0	0	138	0	0	0
7	**DK**	7	0	0	0	7	0	0	0	7	0	0	0	7	0	0	0
3	**EE**	3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0
60	**ES**	60	0	0	0	60	0	0	0	60	0	0	0	60	0	0	0
14	**FI**	14	0	0	0	14	0	0	0	14	0	0	0	14	0	0	0
125	**FR**	125	0	0	0	125	0	0	0	125	0	0	0	125	0	0	0
68	**GB**	68	0	0	0	68	0	0	0	68	0	0	0	68	0	0	0
5	**GR**	5	0	0	0	5	0	0	0	5	0	0	0	5	0	0	0
6	**HR**	4	0	0	2	5	0	0	1	5	0	0	1	5	0	0	1
2	**HU**	2	0	0	0	2	0	0	0	2	0	0	0	2	0	0	0
8	**IE**	8	0	0	0	8	0	0	0	8	0	0	0	8	0	0	0
171	**IT**	159	5	2	5	170	1	0	0	171	0	0	0	171	0	0	0
4	**LT**	4	0	0	0	4	0	0	0	4	0	0	0	4	0	0	0
3	**LU**	3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0
4	**LV**	4	0	0	0	4	0	0	0	4	0	0	0	4	0	0	0
3	**MT**	3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0
28	**NL**	28	0	0	0	28	0	0	0	28	0	0	0	28	0	0	0
80	**PL**	58	10	2	10	73	1	3	3	76	1	2	1	76	1	2	1
10	**PT**	10	0	0	0	10	0	0	0	10	0	0	0	10	0	0	0
13	**RO**	13	0	0	0	13	0	0	0	13	0	0	0	13	0	0	0
18	**SE**	18	0	0	0	18	0	0	0	18	0	0	0	18	0	0	0
3	**SI**	3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0
24	**SK**	23	1	0	0	24	0	0	0	24	0	0	0	24	0	0	0
921	**EU**	879	16	5	21	911	3	3	4	916	1	2	2	916	1	2	2

Particulate Matter (PM2.5) Compliance with 10µg/m^3 WHO Guideline

		2020				2025				2030				2035			
Stations	**Country**	**C**	**PC**	**PNC**	**NC**	**C**	**PC**	**PNC**	**NC**	**C**	**PC**	**PNC**	**NC**	**C**	**PC**	**PNC**	**NC**
35	**AT**	4	0	1	30	6	1	0	28	12	1	5	17	13	0	5	17
33	**BE**	3	0	2	28	4	1	5	23	5	3	3	22	5	3	3	22
7	**BG**	0	0	0	7	0	0	1	6	1	0	0	6	1	0	0	6
3	**CY**	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0	3
46	**CZ**	0	0	0	46	0	0	0	46	0	0	0	46	0	0	0	46
138	**DE**	5	8	9	116	23	13	16	86	49	13	11	65	48	14	12	64
7	**DK**	3	1	3	0	4	3	0	0	5	2	0	0	5	2	0	0
3	**EE**	3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0
60	**ES**	26	10	7	17	35	7	5	13	35	6	6	13	35	6	7	12
14	**FI**	14	0	0	0	14	0	0	0	14	0	0	0	14	0	0	0
125	**FR**	31	15	22	57	62	27	19	17	94	18	5	8	94	19	4	8
68	**GB**	41	12	3	12	55	4	1	8	63	0	3	2	63	0	2	3
5	**GR**	0	1	0	4	0	1	1	3	0	2	0	3	0	2	0	3
6	**HR**	3	0	0	3	3	0	0	3	3	0	0	3	3	0	0	3
2	**HU**	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	1
8	**IE**	6	0	0	2	8	0	0	0	8	0	0	0	8	0	0	0
171	**IT**	10	0	3	158	26	3	5	137	38	3	5	125	38	4	6	123
4	**LT**	1	0	0	3	1	0	0	3	1	0	0	3	1	0	0	3
3	**LU**	0	1	0	2	1	0	0	2	1	0	0	2	1	0	0	2
4	**LV**	0	0	0	4	0	1	0	3	1	0	1	2	1	0	1	2
3	**MT**	0	0	0	3	0	1	0	2	1	0	0	2	1	0	0	2
28	**NL**	1	6	7	14	8	8	8	4	15	9	3	1	16	8	3	1
80	**PL**	0	0	1	79	0	1	1	78	2	1	0	77	2	1	0	77
10	**PT**	7	0	1	2	7	1	0	2	7	2	1	0	7	2	1	0
13	**RO**	0	0	0	13	0	0	2	11	0	3	2	8	0	3	2	8
18	**SE**	17	0	1	0	17	1	0	0	17	1	0	0	17	1	0	0
3	**SI**	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0	3
24	**SK**	0	0	0	24	0	0	1	23	0	0	3	21	0	0	3	21
921	**EU**	175	54	61	631	278	73	65	505	376	64	48	433	377	65	49	430

Annex - PM2.5 Average Exposure Indicator (AEI)

The AAQD specifies an average exposure indicator (AEI) for PM2.5. The following is taken from the directive:

The Average Exposure Indicator expressed in µg/m^3 (AEI) shall be based upon measurements in urban background locations in zones and agglomerations throughout the territory of a Member State. It should be assessed as a three-calendar year running annual mean concentration averaged over all sampling points established pursuant to Section B of Annex V.

The directive sets an exposure concentration obligation expressed as a AEI with a limit value of 20µg/m^3. Modelled concentrations of PM2.5 have been used to calculate the three-yearly mean of concentrations for each of the years 2020, 2025, 2030 and 2035. **Figure 40** shows these concentrations plotted against the 20µg/m^3 limit value. Only two countries show minor exceedance of this limit value: Bulgaria, and Poland, both by 2µg/m^3. These two countries rapidly achieve compliance as time progresses and compliance across the whole EU is expected in the near future.

Note: Greece has no urban background stations in the model.

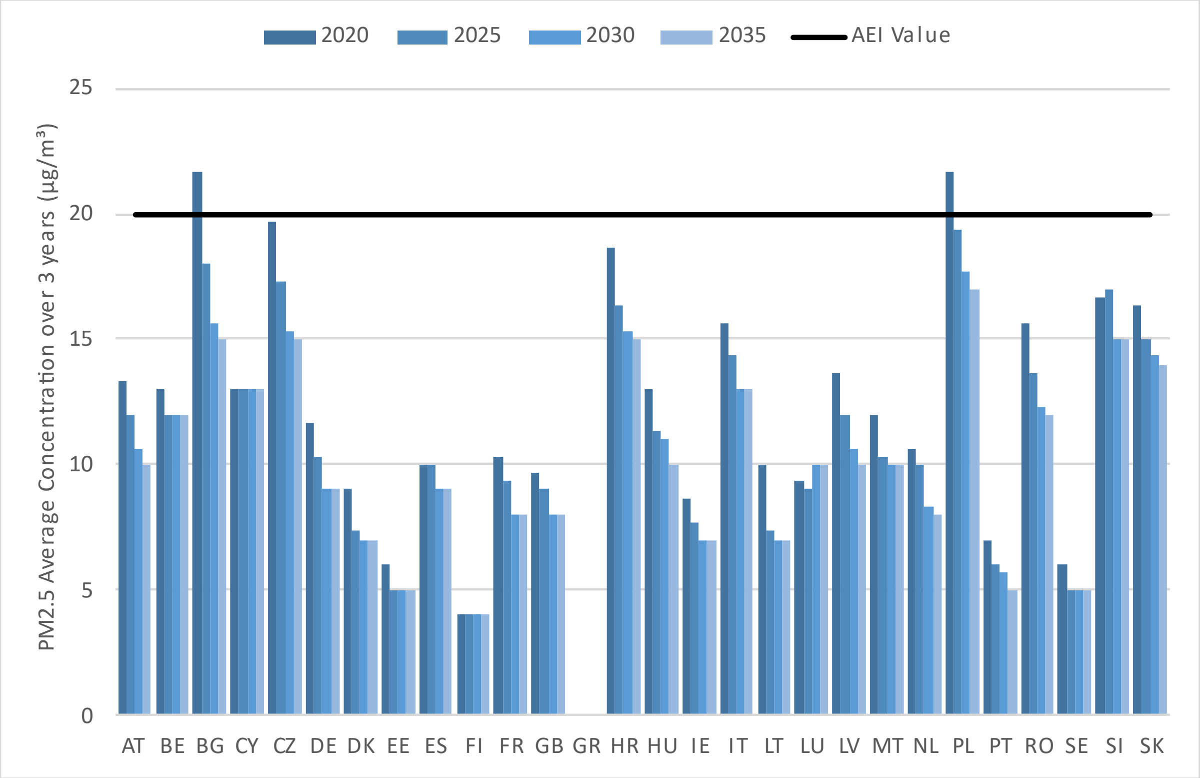


Figure 40 - PM2.5, 3-yearly mean of background-urban stations in each EU country

References

Aeris Europe, 2016. *Urban Air Quality Study, #11/16,* www.concawe.eu: Concawe.

Blas, E. Cué, C., Pérez, C. & García de, E., 2020. *Sánche decreta el estado de alarma durante 15 días.* [Online] Available at: https://elpais.com/espana/2020-03-13/el-gobierno-debate-decretar-el-estado-de-alarma.html

Buijsman, E. et al., 2005. *Particulate Matter: a closer look. MNP report no. 500037011,* Bilthoven: Netherlands Environmental Assessment Agency (MNP).

Concawe, 2018. *A comparison of real driving emissions from Euro 6 diesel passenger cars with zero emission vehicles and their impact on urban air quality compliance,* Brussels: Concawe.

De Leeuw, F. & Horálek, J., 2009. *Assessment of the health impacts of exposure to PM2.5 at a European level. ETC/ACC Technical Paper 2009/1.,* Bilthoven, The Netherlands: The European Topic Centre on Air and Climate Change (ETC/ACC).

de Leeuw, F. & Ruyssenaars, P., 2011. *Evaluation of current limit and target values as set in the EU Air Quality Directive - ETC/ACM Technical Paper,* Bilthoven: The European Topic Centre on Air Pollution and Climate Change Mitigation (ETC/ACM).

Directive (EU) 2008/50/EC, 2008. *Directive 2008/50/EC Of The European Parliament And Of The Council on ambient air quality and cleaner air for Europe,* COD 2005/0183: European Parliament, Council of the European Union.

Directive (EU) 2015/2193, 2015. *European Parliament and of the Council of 25 November 2015 on the limitation of emissions of certain pollutants into the air from medium combustion plants,* Brussels: European Parliament, Council of the European Union.

Directive (EU) 2016/2284, 2016. *The European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC,* Brussels: European Parliament, Council of the European Union.

Directive (EU) 2019/1161, 2019. *Directive (EU) 2019/1161 of the European Parliament and of the Council of 20 June 2019 amending Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles,* Brussels: European Parliament.

EEA, 2014 (b). *AirBase - The European air quality database.* [Online]
Available at: https://www.eea.europa.eu/data-and-maps/data/airbase-the-european-air-quality-database-8
[Accessed 08 2017].

EEA, 2017. *Air Quality e-Reporting (AQ e-Reporting).* [Online]
Available at: https://www.eea.europa.eu/data-and-maps/data/aqereporting-2
[Accessed 01 2018].

European Commission, 2011. *Review of EU Air Quality Policy - Commission Staff Working Document (SEC(2011)342),* Brussels: European Commission.

IIASA, 2015a. *Adjusted historic emission data, projections, and optimized emission reduction targets for 2030 – A comparison with COM data 2013. Part A: Results for EU-28.,* Laxenburg: International Institute for Appied Systems Analysis.

IIASA, 2015b. *Adjusted historic emission data, projections, and optimized emission reduction targets for 2030 – A comparison with COM data 2013. Part B: Results for Member States.,* Laxenburg: International Institute for Applied Systems Analysis.

José, M., 2020. *Paralizada toda actividad no esencial en España.* [Online]
Available at: https://elpais.com/espana/2020-03-28/el-gobierno-amplia-el-confinamiento-los-trabajadores-de-actividades-no-esenciales-deberan-quedarse-en-casa.html

Lee, J. D. et al., 2020. UK surface NO2 levels dropped by 42% during the COVID-19 lockdown: impact on surface O3.

Papadimitriou, Y. & Mellios, G., 2020. *European Road Transport & Emissions Trends Report,* s.l.: Emisia.

Regulation (EU) 2019/1242, 2019. *Setting CO2 emission performance standards for new heavy-duty vehicles and amending Regulations (EC) No 595/2009 and (EU) 2018/956 of the European Parliament and of the Council and Council Directive 96/53/EC,* s.l.: The European Parliament And The Council Of The European Union.

Regulation (EU) 2019/631, 2019. *Setting CO2 emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011,* s.l.: The European Parliament And The Council Of The European Union.

Ricardo, 2020. *Euro 7 / VII - New Emissions Limits, The Challenges and Solutions. Slide 9 - Diesel NOX emission factor range of 30-40 mg/km and a PM2.5 emission factor of 2.5mg/km.* s.l.:s.n.

Shi, Z. & Song, C., 2021. Abrupt but smaller than expected changes in surface air quality attributable to COVID-19 lockdowns. *Science Advances.*

Stedman, J. et al., 2007. A consistent method for modeling PM10 and PM2.5 concentrations across the United Kingdom in 2004 for air quality assessment. *Atmospheric Environment 41,* pp. 161-172.

Timmers, V. R. & Achten, P. A., 2016. Non-exhaust PM emissions from electric vehicles. *Atmospheric Environment,* Volume 134, pp. 10-17.

WHO, 2005. *WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide,* Geneva: World Health Organisation.