The toll of fossil fuel air pollution: A case for clean transportation

Key findings

- Recent research has established that the chronic health impacts of exposure to NO_2, a pollutant associated with fossil fuel burning, are much more severe than previously thought.
- EU and UK air quality standards for concentrations of NO_2 are far higher than the WHO guideline values, which are based on the latest scientific information on the impacts of NO_2 on human health.
- Real-world vehicle-related NO_x emissions have not decreased together with the stricter European standards.
- Our data shows that NO_2 levels in European capitals have fallen in the past five years, but the levels in most cities remain too high and are unsafe for human health.
- Annual mean NO_2 concentrations exceed the WHO guideline value in all EU27+UK capitals in 2022.
- 250,000 NO_2-related deaths could be avoided and 70,000 children could be saved from getting asthma should the EU and the UK achieve the 2021 WHO Global air quality guidelines.

Introduction

The EU has recently announced a ban on the sale of new petrol and diesel cars starting from 2035 as a part of the Union's overall goal of achieving climate neutrality by 2050. However, whereas the ban will be an important contributor to driving down European carbon dioxide (CO_2) emissions, vehicles that will continue driving post-2035 will be a major source of the emissions of nitrogen oxides (NO_x) emissions.

Road transportation was the largest source of NO_x emissions (37%) in the EU in 2020 — followed by agriculture (19%) and the manufacturing and extractive industry (15%) — and a significant source also in the UK. The sector represented 28% of all emissions of nitrogen oxides (NO_x) emissions in the UK in 2020, while other forms of transportation including aviation, rail, and shipping only accounted for 13%. This is problematic for public health because much of road transport emissions occur in urban areas where population density is high, which results in high levels of human exposure for this sector.

In 2021, the World Health Organisation (WHO) updated its Global air quality guidelines in light of new scientific data. A key revision was the introduction of a daily (24-hour) limit, and a tightening of the annual average limit, for NO_2. Although the guidelines are not legally binding, as they are based on the latest scientific understanding from epidemiological studies, their scope extends far, and they are used by many countries as a precedent, or a guide, for setting national standards. Our research finds that the EU and the UK are the only jurisdictions that have responded to the update by announcing some sort of explicit policy action. Hence, our analysis in this report focuses on the policy landscape and NO_2 emissions of these actors. We find that, across UK and EU capitals, while emissions from transportation have decreased, concentrations of NO_2 continue to exceed the new WHO guideline value — with our estimates showing that over 250,000 Europeans may be saved from NO_2-related deaths annually by achieving the new limits — and are predicted to do so in the near future, too. Conclusively, we strongly recommend urgent policy actions to bring European standards in line with these guidelines.

The 2021 WHO update

Monitoring ambient air quality and setting threshold values for various pollutants aid countries in the work of reducing emissions and improving their air quality. The World Health Organization contributes to this work by providing their ambient air quality

guidelines. Though not legally binding to any country, they are used as a reference for setting national standards. The newest set of guidelines was published in September 2021, replacing the previous guidelines from 2005.

In the new guidelines, the WHO introduces a maximum recommended level of NO_2 pollution within 24 hours, and tightens the maximum level of recommended NO_2 pollution on an annual basis. According to these recommendations, the NO_2 levels should not exceed an average of 25 µg/m^3 for 24 hours and 10 µg/m^3 for a year. However, as can be observed in Table 1, these changes are mirrored neither in the Ambient Air Quality (AAQ) Directive (2008/50/EC) of the EU, nor in the National Air Quality objectives of the UK. This is a continuation of the trend, as EU legislation has already been lagging behind WHO guidelines from 2005 for certain pollutants.[1] For instance, the guideline value for yearly average NO_2 concentrations in the EU and UK are 40 µg/m^3, whereas the WHO health-based guideline value is 4 times lower (10 µg/m^3).

Table 1 - *Ambient air quality standards in the EU, the UK and WHO 2021 and 2005*

	WHO 2021 (µg/m^3)	**WHO 2005** (µg/m^3)	**The EU** (µg/m^3)	**The UK** (µg/m^3)
$PM_{2.5}$ annual / 24-hour	5 / 15	10 / 25	25 / -	25 / -
PM_{10} annual / 24-hour	15 / 45	20 / 50	40 / 50	40 / 50
O_3 8-hour / peak season	100 / 60	100 / -	120 / -	100 / -
NO_2 annual / 24-hour / 1-hour	10 / 25 / 200	40 / - / 200	40 / - / 200	40 / - / 200
SO_2 24-hour / 1-hour / 10-minute	40 / - / -	20 / - / 500	125 / 350 / -	125 / 350 / 266[2]

The EU is seeking to align more closely with the air quality recommendations of the WHO. In 2022, the Commission proposed a revision of the Ambient Air Quality Directive which explicitly states that it seeks to achieve closer alignment with the WHO guidelines. If

[1] Non-matching and less stringent EU values: Annual $PM_{2.5}$, 24-h $PM_{2.5}$, annual PM_{10}, 8-h O3, 24-h SO_2, 10-minute SO_2

[2] 15-minute

adopted, it will bring EU air quality standards closer to the scientifically grounded recommendations of the WHO. Space for improvement is however left open, as 'closer alignment' is less than the full alignment called for by the European Environmental Bureau.

Figure 1 - *The EU's 4-year roadmap of Clean Air Policy Milestones*

Also in the UK, the updated WHO guidelines spurred developments to align air quality standards with scientific evidence on the health impacts of air pollution. UK officials recognize that the WHO data demonstrates "that there is evidence of health impacts at levels significantly lower than the existing legally binding limit … within the Air Quality Standards Regulations 2010". Consequently, the 2021 Environment Act introduced a legally-binding duty on the UK government to propose at least two air quality targets by October 2022. A public consultation was opened from mid-March to late-June 2022 to advise the government on a maximum annual mean concentration target, and long term population exposure target, for $PM_{2.5}$. Additionally, the UK government aims to publish a new National Air Quality Strategy in 2023.

Policy measures targeting transportation and air quality

Transportation emissions incorporated into several policies

Multiple EU directives and UK policies target transportation-related emissions and aim to improve the air quality of Europe. Many of these policies overlap, and a full list of policies may be found in the Appendix.

The most central of the EU's policies on this field is the Ambient Air Quality Directive (2008/50/EC) which seeks to reduce the levels of air pollutants across the EU. It sets out objectives that are binding to each Member State and requires them to monitor and report on their air quality. Additionally, Member States must report on abatement measures they have put in place in areas where air quality limits are exceeded. As the transportation sector is noted as being the main reason for NO_2 exceedances, most of the reported measures directly address the road transportation sector[3]. Such measures include shifts to less polluting modes of transportation, better urban planning, improved public transport, and targeted public procurement measures. Among these measures, technological improvements have been crucial as the largest cuts in emissions reductions are attributed to such improvements. However, the implemented measures have not been sufficient, as reductions in road transportation emissions, such as NO_2, have been lower than expected.

The 2016 National Emissions Ceilings (NEC) Directive complements the AAQ directive by forcing EU Member States to develop national policies on air quality. Through the submission of National Air Pollution Control Programmes (NAPCPs), EU Member States must report on national policies and measures to be taken to reduce their emissions between 2020 and 2029. In 2019, between 12% (Spain) and 69% (Malta) of policies and measures reported in the NAPCPs were related to transportation, showing the significance of the sector in reducing air pollution in the EU.

In July 2021, the EU Commission proposed a new legislative package called Fit for 55 aiming for a 55% decrease in EU-wide GHG emissions by 2030. This package includes a goal of reducing CO_2 emissions from light-duty vehicles and vans by 55% and 50%, respectively, within 2034 compared to 2021 levels. Along with these targets, the EU is

[3] Between 2014–2016

promoting the uptake of electric vehicles (EVs) to curb emissions. However, despite the EU's announcement in June stating that the sale of new petrol and diesel cars will be prohibited from 2035 onwards, uncertainty remains on how quickly EVs will be adopted. As EVs allow NO_x-free mobility, their adoption is crucial for Europe's success in reducing air pollution from transportation and consequently improving public health in urban areas.

Despite Brexit, the UK has continued to maintain air quality legislation similar to that of the EU. Recognizing the negative effect of NO_2 emissions on public health and the environment, the UK announced the 2017 UK Roadside NO_2 Concentrations Plan which seeks to ban the sale of new fossil-driven cars and vans by 2040, with the goal being that "nearly every car and van on UK roads are zero emission by 2050". This aim is complemented by the provision of funding for EV charging infrastructure, cycling and walking infrastructure, and public transport. The plan also includes the establishment of a Clean Air Fund. Reflective of the nature of NO_2 emissions, this fund will be available for local authorities wishing to invest in infrastructure and public transportation that reduces local NO_2 concentration levels.

Euro vehicle standards

The EU first introduced the Euro emission standards for vehicles in 1992 and has updated them around every four to five years. Since the first Euro standard was implemented, the successive standards have gradually tightened the permissible emission limits. A total of six standards exist from Euro 1 to Euro 6 — Euro 6 being the most recent one from 2014. These standards are EU-wide and concern all vehicles admitted to the market in EU countries. The standards are widely recognized beyond Europe and have been adopted by multiple countries outside the EU, but the adopted versions are often older, more lenient versions of the Euro standard.

As a former member of the European Union, the UK retains legislation highly similar to that of the EU. Until December 2021, the UK retained the EU's 2019 "CO_2 emission performance standards for new passenger cars and for new light commercial vehicles", and subsequent changes have only consisted of minor amendments. Moreover, the UK continues to apply the Euro 6 standard for vehicles, and implement clean air zones where non-compliant vehicles are penalized in the same way as they are across cities on the continent.

Strict vehicle emission standards are important as a significant amount of NO_2 and NO_x emissions result from the use of petrol and diesel vehicles. The emissions come from the combustion of petrol products, mechanical abrasion and corrosion of vehicle parts, and

vapors escaping from fuel systems. NO_x produced in the combustion process reacts with ozone and oxygen to produce NO_2 particles harmful to human health, and the particles may also contribute to the forming of secondary pollutants like particulate matter (PM) that are also harmful to human health. This is true for both diesel and petrol cars, but whereas diesel cars emit significantly less CO_2 and GHGs than petrol vehicles, they emit significantly more NO_2. This divergence in technology and outputs causes diesel and petrol cars to have different emission standards as can be seen in Table 2. However, despite NO_x emission standards having been tightened multiple times for both vehicle types since 2000, the NO_x emissions from diesel vehicles have not decreased in tandem with the restrictions. Tests under real-world driving conditions show that the average diesel car emits 0.6 g of NO_x per km, which is seven times higher than in official tests, and above the Euro 6 limit of 0.08 g/km. Hence, it is clear that the EU and the UK must complement stricter limits with effective enforcement mechanisms.

Table 2 - *Euro standards for light-duty petrol and diesel NO_x emission limits, parentheses include real-world measurements of NO_x emissions*

Euro standards	Petrol – NO_x emission limit (real-world measurement), g/km	Diesel – NO_x emission limit (real-world measurement), g/km
Euro 1 (1992)	-	-
Euro 2 (1996)	-	-
Euro 3 (2000)	0.15 (0.2)	0.5 (1.0)
Euro 4 (2005)	0.08 (0.1)	0.25 (0.8)
Euro 5a (2009)	0.05 (0.06)	0.18 (0.8)
Euro 6 (2014)	0.06 (0.06)	0.08 (0.6)
Euro 7 (2025)	0.06 (0.06)	0.06 (0.06)

Sources: ICCT, 2014 ; Emisia, 2015 via EEA, 2016; EU Commission 2022

In adherence to the Euro 6 standards, new and improved testing procedures are also being deployed. This is largely in response to criticism of the previous procedures being outdated.

The next, and ultimately the last, set of Euro standards for light-duty vehicles — Euro 7 — is set to come into force in July 2025 for light-duty vehicles and in 2027 for heavy-duty vehicles. A study modeling implementation of the Euro 7 standards found a 93% reduction in NO_x emissions by 2050 relative to 2027, compared to a 74% reduction under the current

Euro 6 policies. The study further shows significant improvements to air quality and public health from implementing the stricter standard.

Trends in Europe — Emissions fall but concentrations continue to exceed limits

Predictions that most EU countries were unlikely to meet their NO_x reduction commitments under the National Emission Ceilings Directive by 2020 was proven wrong. The European Environment Agency's 2021 briefing suggests that all EU27 Member States achieved their ceilings for NO_x, NMVOC, and SO_2 in 2019. Indeed, the data shows that all EU Member States have complied with the NO_x emission ceiling since 2016. Belgium, Croatia, Czechia, France, Greece, Italy, the Netherlands, Portugal, and Slovenia have even achieved their emission reduction commitments[4] for the 2020-2029 period. This is also true for the UK with regards to the NO_x target. Cyprus, Germany, Latvia, Lithuania, Poland, Romania, and Sweden are however still overshooting the NO_x target for the 2020-2029 period, leaving important work to be done. Looking beyond the 2020-2029 period, it is only Estonia that is compliant with the NO_x limits beyond 2030. Ten countries will need to reduce NO_x emission by more than 30%, and Malta requires a reduction of over 50% by 2030. As a whole, the EU needs a 36% cut in NO_x emissions relative to 2019 levels to achieve its goal for 2030.

Reductions in NO_2 levels

The past five years display a positive trend with falling NO_2 levels in European capitals (Figure 2). Between 2016 and 2021, most EU capitals have seen a consistent reduction in annual average NO_2 concentrations, with the exception of 2021 as 2020 concentrations were low because of reductions in road transport during COVID-19 and the related restrictions. However, some cities including Rome, Lisbon, Berlin, Amsterdam, and Bratislava managed to hinder this bounce-back and continue on the pathway of reduced NO_2 levels.

[4] For all five key pollutants

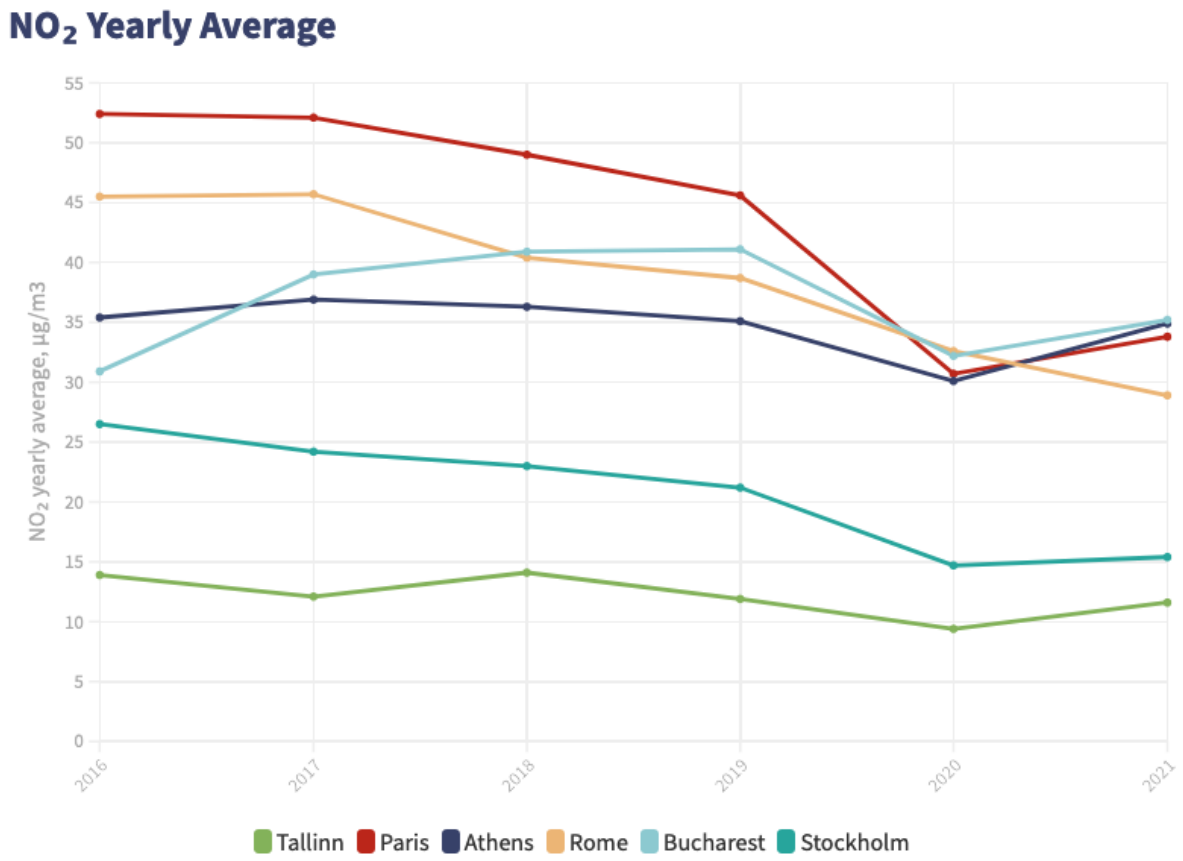

Figure 2 - *NO_2 yearly averages in selected EU capital cities between 2016–2021. Source: CREA analysis based on EEA and Defra.*

Currently, some of the lowest NO_2 levels in European capitals are found in Estonia and Sweden. Tallinn's levels have been low and stable for a long time, exceeding the WHO 2021 guidelines only by a margin, and even complying with the new WHO standards during the height of the pandemic in 2020. Stockholm has slightly higher NO_2 levels than Tallinn, but has seen a steeper decline than the Estonian capital over the last 5 years. In 2021, the average NO_2 level in Stockholm measured 15.4 µg/m^3 down from 26.5 µg/m^3 in 2016.

At the other end of the spectrum, Athens and Bucharest were competing with the highest NO_2 levels of all EU capitals in 2021 due mainly to the burning of solid fuels for industrial and heating purposes. Bucharest had an average NO_2 level of approximately 35.2 µg/m^3, slightly above Athens' average of 34.9 µg/m^3. Interestingly, Greece nevertheless achieved its 2020 emissions reduction target, while Romania failed to do the same. It will be important to monitor the future progress of these cities, and observe whether the

increasing emissions after the pandemic continue, and whether the states will be able to push their stable NO_2 levels into a declining trend.

Rome and Paris are among the cities that have seen the largest decreases in average annual NO_2 levels in absolute terms. From 2016-2021, NO_2 levels in Rome dropped from 45.7 µg/m^3 to 28.9 µg/m^3, with similar progress in Paris with a reduction from over 50 µg/m^3 to less than 34 µg/m^3. While this represents magnificent progress, these levels are still way above the healthy limits suggested by the 2021 WHO guidelines. Conclusively, it is clear that people in these countries may still live with significantly elevated health risks due to NO_2 despite the countries achieving their national NO_2 emission reduction commitments.

Concentrations exceed guideline values across all cities

Despite the overall reduction in NO_2 levels from all emitting sources throughout the EU and the UK, the levels in cities remain too high. To illustrate this, we analyzed the overshoot days for each EU and UK capital city. A city's overshoot day is the date at which the annual average limit for a given pollutant would be exceeded even if the concentrations dropped to zero for the rest of the year after that date. Figure 3 shows the overshoot days of European capitals given the 2021 WHO guidelines for maximum annual average NO_2 levels (10 µg/m^3).

In 2022, all the EU27+UK capitals exceeded the WHO 2021 annual average limit for NO_2. 21 cities had their overshoot days in the months of April, May, and June, within less than half a year, showing that progress is needed. Paris had the overwhelmingly earliest overshoot day — on 31 March — and Tallinn had the latest one, on 29 November. Moreover, progress is required both towards the annual average target and the daily average target, as some cities regularly fluctuate highly above and below the daily limit suggested by the WHO.

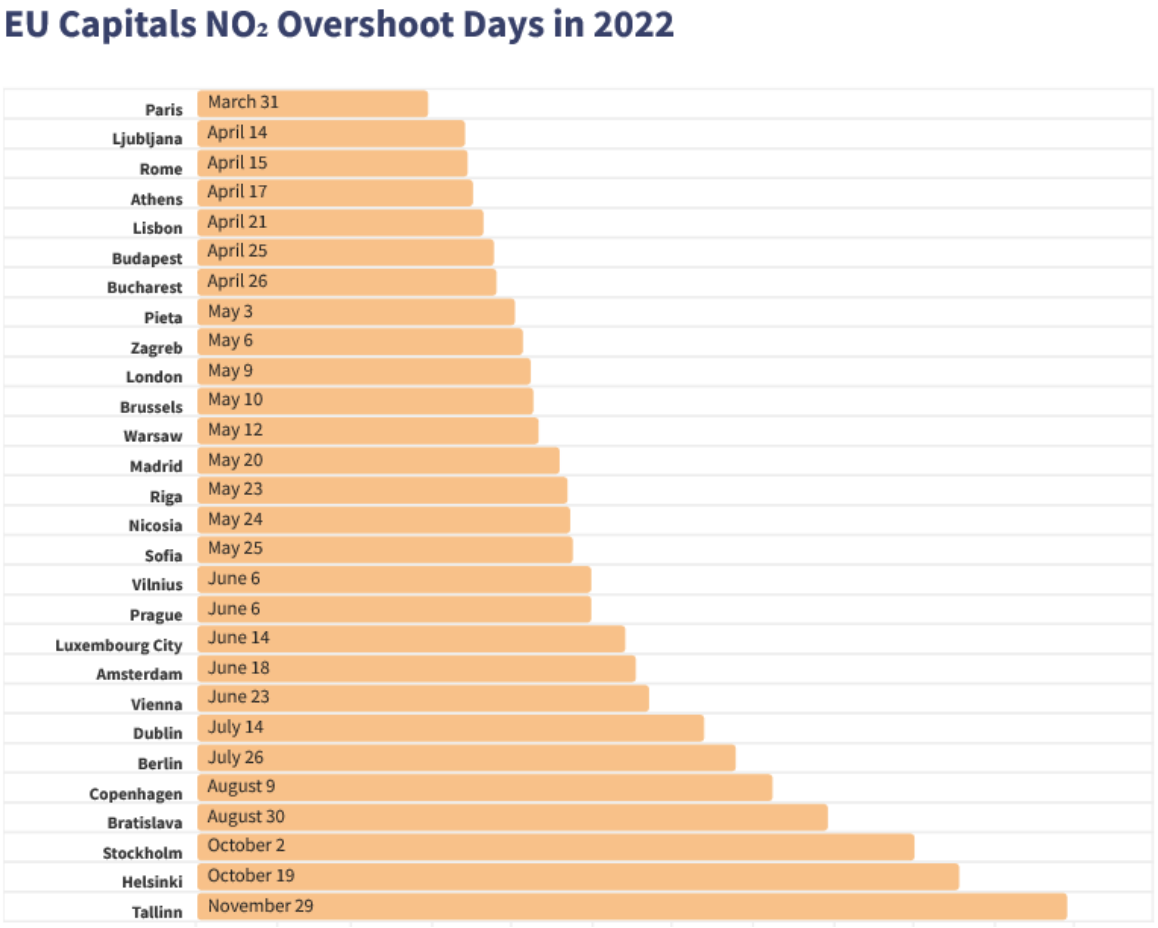

Figure 3 - *Overshoot days in EU capital cities for NO_2. Source: CREA analysis based on EEA and Defra.* [5]

Adopting the World Health Organization's NO_2 emission standard would significantly improve Europe's health

While invisible and inaudible, the occurrence of overshoot days is not insignificant. Across the European Union and the British Isles, hundreds of thousands of Europeans die every year as a consequence of conditions caused by NO_2 pollution. Figure 3 displays the lethal effects of Europe's loose NO_2 emission standards, and underlines the benefits of adopting the WHO guidelines. Our analysis based on local pollution data, population distribution,

[5] Data for Malta's capital Valletta was non-existent, Pieta instead was chosen as it is located on the outskirts of the capital.

and studies on the health impacts of pollutants, shows that over 200,000 European lives may be saved annually by adopting the WHO standards.

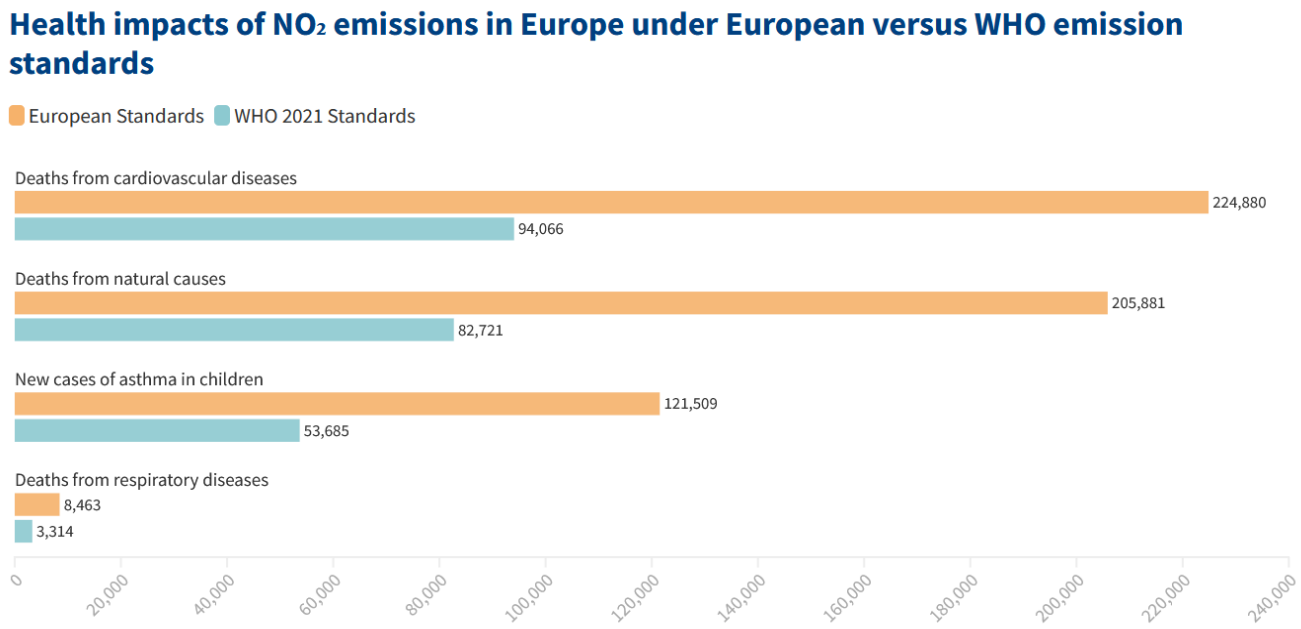

Figure 4 - *The numbers show deaths and cases of asthma attributable to NO_2 annually in the EU27 and the UK annually[6]. Source: CREA air pollution health impact portal.*

The estimates suggest that over 430,000 Europeans die annually as a consequence of NO_2 levels compliant with European emission standards. This number would drop by almost 60% to under 180,000 individuals if Europe achieved the recommendations of the World Health Organization. Simultaneously, Europe would save almost 70,000 children from getting asthma every year. While it is clear that adopting the WHO's standard would significantly improve public health in Europe, it would also have significant economic benefits resulting from fewer sick days and lower public and private health expenditures. Consequently, there is good reason for European policymakers to align the standards of Europe with the scientifically grounded recommendations of the 2021 WHO Global air quality guidelines.

[6] Calculations are based on countries representing 87,4% of the EU27+UK population. The following countries are excluded due to unavailable data: Austria, Croatia, Cyprus, Denmark, Estonia, Finland, Hungary, Ireland, Latvia, Lithuania, Luxembourg, Malta, Slovakia, Slovenia and Sweden.

Policy recommendations

In light of the significant negative health impacts of NO_2 emissions in the European Union and the UK resulting from too relaxed emission standards, CREA recommends that:

- the European Commission follow through on its commitment to adhere to the WHO's new Air Quality Guidelines when revising the Ambient Air Quality Directive;
- the European Union include stronger emission standards for stationary sources through the Industrial Emissions Directive revision;
- the UK follow suit in revisions of existing air quality policies;
- more ambitious targets be established for the uptake of electric vehicles and alternative fuels;
- the electric charging station network be expanded to cover all European roads as currently 70% of charging stations exist in only three countries;
- the upcoming Euro 7 emission standards be implemented as soon as possible, and reflect the criticisms made on measurement and leniency, especially regarding NO_x emissions from diesel cars;
- air quality standards be more stringent to reflect that over 200,000 Europeans may be saved annually from NO_2-related deaths by aligning European standards with the 2021 WHO Global air quality guidelines.

Annex 1 — EU and UK air quality and transportation related policies in order of implementation

Table A1 - *Ambient air and transportation policies (EU, UK specified separately)*

Policy	Area	Year	Comments
Euro 7	Transportation: vehicles	2025 most likely	
EU Ambient Air Quality Guidelines	Ambient air	2022 revision, unclear when implemented	
Fit for 55 package – CO_2 and transportation	Transportation: cars and vans	2022 / re: 2035 ban of petrol/diesel car sales	2035 ban announced July 2022 and approved February 2023
UK Environment Act	Air quality	2021	Legally-binding duty on government to bring forward at least two air quality targets, published December 2022: cut exposure to $PM_{2.5}$
Fit for 55 package	Climate policy	2021	
UK CO_2 emission standards post-Brexit-transition-period	Transportation	January 2021	
EU CO_2 emission performance standards for new passenger cars and for new light commercial vehicles	Transportation	2019 / applying from 2020, 2025, and 2030	Repealed 2009 and 2011 legislation Emission targets and mechanism to incentivise uptake of zero- and low-emission vehicles

Worldwide Harmonised Light Duty Test Procedure	Transportation	September 2017 (new car models), September 2018 new car registrations	Laboratory test cycle alongside RDE test
Real Driving Emissions (RDE) test	Transportation	September 2017 (for new car models) // September 2019 for all new registrations - more stringent January 2020 and January 2021	Making Euro 6 more stringent // On road emissions test — urban, rural and motorway driving
UK Plan for Tackling Roadside Nitrogen Dioxide Concentrations	Transportation	2017	Clean Air Fund, ban on sale of new petrol/diesel cars/vans by 2040
National Emissions Reduction Commitments (NEC) Directive	Ambient air/pollution control	2016	Reporting/measurement and pollution control programmes (NAPCP)
Euro 6	Transportation	September 2014 (and certain testing specifications tightened further - in 2017, 2019, 2020, 2021)	
EU emission performance for new vans	Transportation	2011	Replaced by 2019 legislation
UK Air Quality Standards Regulations	Ambient Air	2010	
Euro 5	Transportation	September 2009 (new type approvals from January 2011, vehicles 2013)	
EU emission performance standards for new passenger cars	Transportation	2009	Replaced by 2019 legislation
EU Ambient Air Quality	Ambient air	2008	Limit value for NO_2

Directive			obligatory since 2010