BRIEFING

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Quantifying the long-term air quality and health benefits from Euro 7/VII standards in Europe

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INTRODUCTION

The introduction of the Euro emission standards for light-duty vehicles (LDVs) and heavy-duty vehicles (HDVs) has been a successful milestone in efforts to reduce levels of air pollution exposure over the past decades. The benefits of these standards extend far beyond the borders of the European Union (EU), with most G20 members and several emerging economies in Asia and Latin America setting standards based on the European-devised system. The European Commission has initiated the regulatory process to increase the stringency of emissions standards for LDVs and HDVs, also known as Euro 7/VII,[1] to align with the goals of the European Green Deal.[2] By adopting stringent yet realistic standards for Euro 7/VII, the European Commission has the opportunity to lead in improving air quality and thus reducing the associated health risks both across the EU and globally.

A clear link between air pollution exposure and mortality has been made evident by the Institute for Health Metrics and Evaluation, who have shown populations exposed to these emissions experience a reduced life expectancy due to greater risk of heart disease, acute lower respiratory disease, strokes, chronic obstructive pulmonary disease, and lung disease, with further links evident between air pollution exposure and diabetes and Alzheimer's disease.[3] According to the European Environment Agency (EEA), exposure to fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), and ozone (O_3) were responsible for approximately 412,500 premature deaths in the

1 Euro standards with Arabic numerals refer to LDV standards, while Roman numerals refer to HDV standards.

2 European Commission, "The European Green Deal," Communications from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, (December 11, 2019), https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF.

3 Institute for Health Metrics and Evaluation, "Global Burden of Disease (GBD)," (2020), http://www.healthdata.org/gbd/2019.

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27 EU Member States (hereafter, EU-27) in 2018.[4] An Institute for Health Metrics and Evaluation study corroborates this magnitude of air pollution attributable premature deaths, finding that ambient $PM_{2.5}$ and ozone accounted for 127,000 to 227,000 premature deaths in the EU-27 in 2019.[5] Furthermore, a study by the ICCT attributed 215,380 premature deaths in the EU-27 in 2015 to ambient $PM_{2.5}$ and O_3, finding that on-road vehicles were responsible for 67% of the burden.[6]

Urban populations are particularly at risk. In 2018, the percentage of the EU's urban population exposed to levels of $PM_{2.5}$ above the guidelines outlined by World Health Organization stood at 74%, with a corresponding value of 4% for NO_2 and 99% for O_3.[7] The contribution of transport air pollution is of particular concern, as the majority of urban populations live in close proximity to roads and, according to Health Effects Institute, the greatest indicator of exposure to traffic-related pollution is proximity to a roadway.[8] The transport sector was responsible for around 10% of total direct PM emissions and 39% of NO_x emissions in 2018, the latter of which is a precursor to both $PM_{2.5}$ and O_3.[9]

It is important to note that while both the European Union and the World Health Organization establish recommended air quality limits, there is compelling scientific evidence that a threshold for such limits is not justified as they do not guarantee a safe level of exposure, and negative health effects have been linked to air pollutant concentrations below the recommended limits of $PM_{2.5}$, NO_2, and O_3.[10]

As a means of alleviating these health risks, pollutant emission standards for vehicles were first introduced in Europe in 1970, transforming into the Euro standards in 1992. The setting of these emission standards has corresponded with a significant decrease in transport-related emissions, despite a concurrent overall rise in transport activity (see Figure 1).

4 European Environment Agency, "Air Quality in Europe – 2020 report," (EEA Report No 09/2020, 2020), https://www.eea.europa.eu/publications/air-quality-in-europe-2020-report.

5 Christopher Murray, et al., "Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019," The Lancet, (2020), 396:1223-1249, https://doi.org/10.1016/S0140-6736(20)30752-2.

6 Susan Anenberg, Joshua Miller, Daven Henze, and Ray Minjares, *A global snapshot of the air pollution-related health impacts of transportation sector emissions in 2010 and 2015*, (ICCT: Washington, DC, 2019), https://theicct.org/publications/health-impacts-transport-emissions-2010-2015.

7 European Environment Agency, "Air Quality in Europe – 2020 report."

8 Health Effects Institute, "Traffic-Related Air Pollution: A Critical Review of the Literature on Emissions, Exposure, and Health Effects," (Special Report 17 2010), https://www.healtheffects.org/system/files/SR17TrafficReview.pdf.

9 European Environment Agency, "European Union emission inventory report 1990-2018 under the UNECE Convention on Long- range Transboundary Air Pollution (LRTAP)," (EEA Report No 5/2020 2020), https://www.eea.europa.eu/publications/european-union-emission-inventory-report-1990-2018; European Environment Agency, "Annual European Union greenhouse gas inventory 1990-2018 and inventory report 2020," (Submission to the UNFCCC Secretariat, 2020), https://www.eea.europa.eu//publications/european-union-greenhouse-gas-inventory-2020.

10 See Qian Di, et al., "Air pollution and mortality in the Medicare population," New England Journal of Medicine, (2017) 376:2513-2522, https://www.nejm.org/doi/full/10.1056/nejmoa1702747; Liuhua Shi, et al., "Long-term effects of PM2·5 on neurological disorders in the American Medicare population: a longitudinal cohort study," The Lancet Planetary Health, 4(12): E557-E565, https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(20)30227-8/fulltext#%20; Qian Di, et al., "Association of Short-term Exposure to Air Pollution With Mortality in Older Adults," American Medical Association Journal, (2017), https://jamanetwork.com/journals/jama/article-abstract/2667069; Pattanun Achakulwisut, "Global, national, and urban burdens of paediatric asthma incidence attributable to ambient NO2 pollution: estimates from global datasets," The Lancet Planetary Health, 3(4): E166-E178 https://www.thelancet.com/article/S2542-5196(19)30046-4/fulltext#%20; and Karl M Seltzer, et al., "Measurement-based assessment of health burdens from long-term ozone exposure in the United States, Europe, and China," Environmental Research Letters, 13(10), https://iopscience.iop.org/article/10.1088/1748-9326/aae29d.

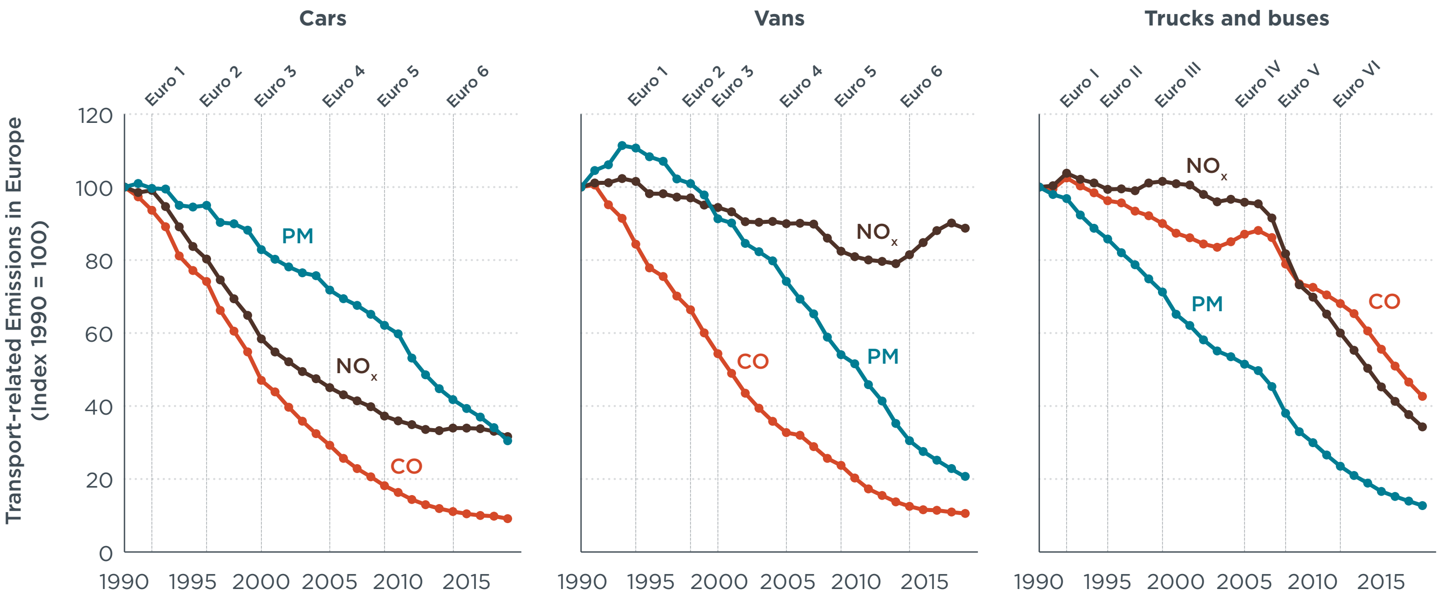


Figure 1. Transport-related emissions and implementation year of Euro Standards. Emissions data obtained from European Environment Agency, *Data on emissions of air pollutants submitted to the LRTAP Convention*, (July 23, 2020, https://www.eea.europa.eu/data-and-maps/data/national-emissions-reported-to-the-convention-on-long-range-transboundary-air-pollution-lrtap-convention-14.

As outlined by the European Green Deal, the European Commission aims to accelerate the shift to sustainable and smart mobility by ensuring transport becomes significantly less polluting, especially in urban settings. Also falling under the European Green Deal, the Zero Pollution Action plan aims to reduce air pollution deaths by 55% by 2030, and to reduce air pollution deaths to levels no longer considered harmful to human health by 2050.[11] In this light, the regulatory process for implementing the Euro 7/VII emission standards was launched by the European Commission in 2019. While the details of these standards have yet to be finalized, the Commission's consultants have put forward several scenarios that are expected to guide the development of the regulatory proposal, which is expected to be adopted in the final quarter of 2021.

This briefing paper quantifies the long-term pollution reductions and the corresponding health benefits from the implementation of ambitious, yet feasible, Euro 7/VII emission standards for LDVs and HDVs. In addition, we determine the additional benefits of high zero-emission vehicle (ZEV) uptake under both the current standards and Euro 7/VII. We exclusively focus on NO_x emissions given that PM emissions have been largely addressed by filter-based emission control systems used to comply with the current standards and that the current emissions of other pollutants that are precursors to $PM_{2.5}$, such as ammonia, are not well understood. Because our analysis does not consider tailpipe emission reductions from these other pollutants, our estimates of the air quality and health benefits of Euro 7/VII under this study are conservative.

SCENARIO OVERVIEW

In this analysis we consider four regulatory and market scenarios. We first present the expected impact of the continued roll out of the latest implementation of current Euro 6/VI standards across the entire EU-27 vehicle fleet. We then assess the impact of the implementation of the Euro 7/VII standards from 2027 onward. Finally, we assess the

11 European Commission, "Pathway to a Healthy Planet for All EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil'", Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, (May 5, 2021), https://ec.europa.eu/environment/pdf/zero-pollution-action-plan/communication_en.pdf

benefits of a high rate of ZEV uptake—100% of new LDVs are ZEVs in 2035, and 100% of HDVs are ZEV in 2045—to estimate the health benefits with and without Euro 7/VII implementation. This section introduces our assumptions of the adopted policies under Euro 6/VI, the stringency of the Euro 7/VII scenario that was modeled, and the details underlying the ZEV uptake.

ADOPTED POLICIES: EURO 6/VI STANDARDS

Euro 6/VI standards for LDVs and HDVs, which defined specific standards for passenger cars, vans, trucks, and buses, were first introduced under Regulation 715/2007 and Regulation 595/2009.[12] To address limitations of Euro 6/VI standards related to deviations in NO_x emissions between laboratory tests and real-world operation, the Commission amended the standards—with a focus on modifying the test procedures—through several implementing acts. This created a stepped approach, whereby the different implementation steps of the standards are identified by specific suffixes (e.g., Euro 6d for LDVs, Euro VI-D for HDVs).

For LDVs, laboratory testing was the sole type-approval requirement up to Euro 6c, under the World Harmonized Light Vehicles Test Procedure. Under Euro 6d, the test procedures were amended to include real driving emissions through on-road testing. The real driving emissions amendments introduced the concept of a conformity factor allowing for the exceedance of the Euro 6 emission limits during on-road testing. As a temporary measurement for Euro 6d-TEMP, this conformity factor was initially set at 2.1 for NO_x emissions. The Euro 6d final standards reduced the conformity factor further to 1.43.

The NO_x emission factors used in this analysis for Euro 6c are informed by the *European Monitoring and Evaluation Programme* (EMEP)[13] and the *Handbook Emission Factors for Road Transport* (HBEFA).[14] For Euro 6d-TEMP, the emission factors are determined from remote sensing data, which provided estimates of 110mg/km and 66mg/km for diesel and gasoline passenger cars, respectively.[15] The emission standards of Euro 6d—in its final implementation—are estimated from the available Euro 6d-TEMP emission factors and the ratio of the respective conformity factors, resulting in values of 75mg/km and 45mg/km for diesel and gasoline passenger cars, respectively. Remote sensing data was also used to estimate a NO_x emission factor for vans, which were found to have about 1.5 times higher emissions than their passenger car counterparts.

The HDV regulation, Euro VI, includes provisions for on-road tests from its first implementation step. Still, several amendments have taken place to extend the scope of such tests to better capture urban operation. For example, in the transition from Euro VI-C to Euro VI-D, the average engine power requirements during testing were reduced, capturing an additional portion of urban low-load operation. Similarly, the upcoming transition to Euro VI-E aims to capture a larger portion of cold-start operation.

12 European Union, "Regulation (EC) No. 715/2007 of the European Parliament and of the Council of June 20, 2007 on the type approval of motor vehicles with regard to emissions from light passenger cars and commercial vehicles (Euro 5 and Euro 6) and on access to repair and maintenance information for Vehicles," Official Journal of the European Union L 173 (June 20, 2007), https://eur-lex.europa.eu/legal-content/DE/TXT/?uri=celex%3A32007R0715; European Union, "Regulation (EU) 595/2009 of the European Parliament and of the Council of 18 June 2009 on type-approval of motor vehicles and engines with respect to emissions from heavy duty vehicles (Euro VI) and on access to vehicle repair and maintenance information and amending Regulation (EC) No 715/2007 and Directive 2007/46/EC and repealing Directives 80/1269/EEC, 2005/55/EC and 2005/78/EC," Official Journal of the European Union L 173 (June 18, 2009), https://eur-lex.europa.eu/eli/reg/2009/595/oj

13 European Monitoring and Evaluation Programme, Emissions database, https://www.ceip.at/webdab-emission-database

14 Handbook Emission Factors for Road Transport, database application, www.hbefa.net/e/index.html

15 Yoann Bernard, Uwe Tietge, Izabela Pniewska, *Remote sensing of motor vehicle emissions in Krakow*, (ICCT: Washington, DC, 2020), https://theicct.org/publications/remote-sensing-krakow-sept2020

As was the case for LDVs, the HDV Euro VI-C emission factors employed in this analysis are derived from EMEP and the HBEFA. The values are differentiated by HDV type: heavy-duty trucks, medium-duty trucks, and buses. The emissions factors for HDVs certified to Euro VI-D were developed based on real-world performance data gathered through portable emissions measurement system testing.[16] The data indicated a 12% reduction in NO_x emissions compared to Euro VI-C. Furthermore, the analysis shows that no further improvement is expected with the implementation of Euro VI-E, given that the tested Euro VI-D diesel HDVs can already comply with step E provisions. Therefore, the NO_x emission factors used for HDVs certified to step D and step E are those of Euro VI-C adjusted downwards by a factor of 0.88.

EURO 7/VII STANDARDS

The stringency and implementation date of the Euro 7/VII standards are currently under deliberation by the European Commission. A proposal, triggering the ordinary legislative procedure involving the European Parliament and the European Council, is expected by the final quarter of 2021.

The emission factors used in this analysis for Euro 7/VII standards are informed by global regulatory developments for LDVs and HDVs,[17] data stemming from demonstration programs by industry stakeholders,[18] and technology feasibility assessments carried out by the Commission's contractors.[19] For passenger cars, we assumed that stringent Euro 7 standards could achieve an average NO_x emission factor of 15 mg/km; that is, compared to Euro 6d, Euro 7 could lead to an 80% and 66% reduction in NO_x emissions for diesel and gasoline cars, respectively. The Euro 7 NO_x emission factor for vans is estimated by applying the aforementioned adjustment factor of 1.5, leading to a value of 23 mg/km for both diesel and gasoline powertrains. For HDVs, we assume that stringent Euro VII standards could lead to a 79% reduction in NO_x emissions for trucks and buses compared to Euro VI-D/E.[20]

ZERO-EMISSION VEHICLE UPTAKE

Electrification of the vehicle fleet will have a significant role to play in achieving the aims laid out by the European Green Deal, thus we carry out a sensitivity analysis of the benefits of stringent Euro 7/VII standards in combination with the rapid deployment of ZEVs. Under the adopted policies scenario and the Euro 7/VII scenario, we consider

16 Huzeifa Badshah, Francisco Posada, and Rachel Muncrief, *Current State of NOx Emissions from In-Use Heavy-Duty Diesel Vehicles in the United States*, (ICCT: Washington, DC, 2019), https://theicct.org/publications/nox-emissions-us-hdv-diesel-vehicles; Huzeifa Badshah and Felipe Rodríguez. Real World NO_x Performance of Euro VI-D Trucks, (ICCT: Washington, DC, forthcoming).

17 Felipe Rodríguez, Yoann Bernard, Jan Dornoff, and Peter Mock, *Recommendations for Post-Euro 6 Standards for Light-Duty Vehicles in the European Union*, (ICCT: Washington, D.C., 2019), https://theicct.org/publications/recommendations-post-euro-6-eu; Felipe Rodríguez and Francisco Posada, *Future Heavy-Duty Emission Standards: An Opportunity for International Harmonization*, (ICCT: Washington, D.C., 2019), https://theicct.org/publications/future-hdv-standards-harmonization.

18 Pablo Mendoza-Villafuerte et al., "Demonstration of Extremely Low NOx Emissions with Partly Close-Coupled Emission Control on a Heavy-Duty Truck Application" (42nd International Vienna Motor Symposium 2021, Vienna, 2021), 20, https://www.aecc.eu/wp-content/uploads/2021/05/210219_Vienna_HD-diesel-AECC-FEV-paper-final_v2.pdf; J. Demuynck et al., "Integrated Diesel System Achieving Ultra-Low Urban and Motorway NOx Emissions on the Road," 2019, https://www.aecc.eu/wp-content/uploads/2020/07/190516-AECC-IAV-IPA-Integrated-Diesel-System-achieving-Ultra-Low-NOx-on-the-road-Vienna-Symposium.pdf.

19 CLOVE Consortium, "Additional Technical Issues for Euro 7 LDV" (Advisory Group on Vehicle Emission Standards (AGVES), Brussels, April 27, 2021), https://circabc.europa.eu/w/browse/f57c2059-ef63-4baf-b793-015e46f70421; CLOVE Consortium, "Supplements to the Scenarios for HDVs Emission Limits and Test Conditions" (Advisory Group on Vehicle Emission Standards (AGVES), Brussels, April 27, 2021), https://circabc.europa.eu/w/browse/f57c2059-ef63-4baf-b793-015e46f70421.

20 This is aligned with California's Heavy-Duty Omnibus Regulation, which require a reduction in 90% in NOx emissions by 2027 compared to current standards. Such 90% reduction was applied to Euro VI-C emission factors.

the projected effects of the current 2025 and 2030 CO_2 standards for LDVs and HDVs.[21] The ZEV deployment under this scenario is set to maximize the incentives—that is, the relaxation of fleet-average targets—set by the LDV and HDV CO_2 standards. The deployment of zero-emission urban buses follows the minimum ZEV sales shares set out in the Clean Vehicles Directive.[22]

We also model a high ZEV uptake scenario, which is consistent with the moderate ambition scenario for electrification in a recent ICCT analysis on the post-2021 CO_2 standards for light-duty and heavy-duty vehicles.[23] Under this scenario, we assume the addition of new policies that achieve 100% ZEV sales for cars and vans by 2035 and for trucks and buses by 2045. This high ZEV uptake scenario is modeled in combination with both the Euro 6/VI standards—under the adopted policies scenario—and the Euro 7/VII scenario. A summary of all scenarios is presented in Table 1.

Table 1. Scenarios and definitions applied in this analysis.

Scenario	Description
Adopted policies	The latest Euro 6/VI standards continue to be rolled out across the LDV and HDV fleet. ZEV uptake is consistent with current CO_2 standards and the Clean Vehicles Directive.
Adopted policies and high ZEV uptake	The latest Euro 6/VI standards continue to be rolled out across the LDV and HDV fleet. LDV sales share are 100% ZEV by 2035. HDV sales share are 100% ZEV by 2045.
Euro 7/VII	Euro 7/VII standards are adopted by new LDVs and HDVs from 2027. ZEV uptake is consistent with current CO_2 standards and the Clean Vehicles Directive.
Euro 7/VII and high ZEV uptake	Euro 7/VII standards are adopted by new LDVs and HDVs from 2027. LDV sales share are 100% ZEV by 2035. HDV sales share are 100% ZEV by 2045.

METHODS

EMISSIONS BY SCENARIO

We implement these scenarios utilizing the ICCT's Roadmap model, a global stock-simulation model of the transport sector performing what-if scenario analysis at a yearly time resolution.[24] For this analysis, we assessed the impact of the scenarios described above in each of the EU-27 Member States, producing a variety of emissions data annually for each country. This study focuses particularly on the NO_x emissions results.

We also considered the effects of high emitters, i.e., vehicles whose emissions control systems are malfunctioning as a result of tampering, poor maintenance, or failure, and

21 European Union, "Regulation (EU) 2019/1242 of the European Parliament and of the Council of 28 June 2018 on the 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," Official Journal of the European Union L 173 (July 9, 2018), https://eur-lex.europa.eu/eli/reg/2019/1242/oj.

22 European Commission, "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," Official Journal of the European Union L 188 (June 20, 2019), http://data.europa.eu/eli/dir/2019/1161/oj.

23 Claire Buysse, Joshua Miller, Sonsoles Díaz, Arijit Sen, and Caleb Braun, *The role of the European Union's vehicle CO2 standards in achieving the European Green Deal*, (ICCT: Washington, DC, 2021), https://theicct.org/publications/eu-vehicle-standards-green-deal-mar21.

24 The International Council on Clean Transportation. ICCT's Roadmap Model Documentation (version 1.5), 2021. https://theicct.github.io/roadmap-doc/

produce emissions higher than the regulatory limits. Shares of high emitters and emission multipliers are applied to all regions based on region-specific estimates and general compliance and enforcement level for PM and NO_x. As tampering, mal-maintenance and malfunction affect emissions through age, we follow the approach of the California Air Resource Board's Emission Factor (EMFAC) model[25] and the EPA's Motor Vehicle Emission Simulator (MOVES) model,[26] to estimate emission deterioration with age, where emission rate increases linearly from the end of the warranty period up to the end of the useful life. The end of the useful life parameter in this regard is only used to determine the degradation of the vehicle emission factor, and it does not correspond with the retirement of the vehicle, which is determined by country-specific retirement profiles. We do not assume a warranty for vehicles in this analysis, as a mandatory warranty program for vehicle emissions does not exist in the European legislation.

HEALTH IMPACTS

Country-level emissions data generated from Roadmap are converted into health impacts through the use of the Fast Assessment of Transportation Emissions (FATE) model, a dedicated health impact model developed in collaboration with researchers at University of Colorado Boulder and George Washington University.[27] The FATE model uses source emissions data to calculate two health metrics: premature deaths and years of life lost due to premature mortality. The manner of evaluating the health effects of exposure to harmful pollutants follows the latest methodology of the Global Burden of Disease (GBD) study.[28]

For air quality simulation, we applied adjoint coefficients from the GEOS-Chem atmospheric chemistry model to convert emissions of BC, organic carbon (OC), NO_x, sulfur dioxide (SO_2) and ammonia (NH_3) to population-weighted average $PM_{2.5}$ exposure, and emissions of NO_x, carbon monoxide (CO) and non-methane volatile organic compounds (NMVOC) to population-weighted average O_3 exposure.[29] These coefficients were derived for each Member State using meteorology and population density for a recent year. These adjoint coefficients do not attempt to account for changes in meteorology or population density over time. The geographical analysis is done by calculating the air quality and population exposure over a grid with a resolution of 2.0°× 2.5° longitude-latitude.

We estimated the health effects of exposure to ambient $PM_{2.5}$ and O_3 following the methods developed by the Institute for Health Metrics and Evaluation for their GBD 2019 study.[30] The major health impacts from NO_x emissions assessed here are through its contributions to $PM_{2.5}$ and ozone formation. We did not evaluate the health impacts of direct NO_2 exposure, since these are not covered in the GBD methods, and evaluating NO_2 impacts requires a higher-resolution scale of spatial analysis.

The GBD 2019 health methods include updates to baseline disease rates, ambient pollutant concentrations, and relative risks. They also consider population age distributions for heart disease and stroke. We evaluated health impacts by specific clinical endpoints, including stroke, ischemic heart disease, chronic obstructive pulmonary disease, lower respiratory infection, lung cancer, and diabetes mellitus type 2. Future impacts to 2050 were determined by using population projections

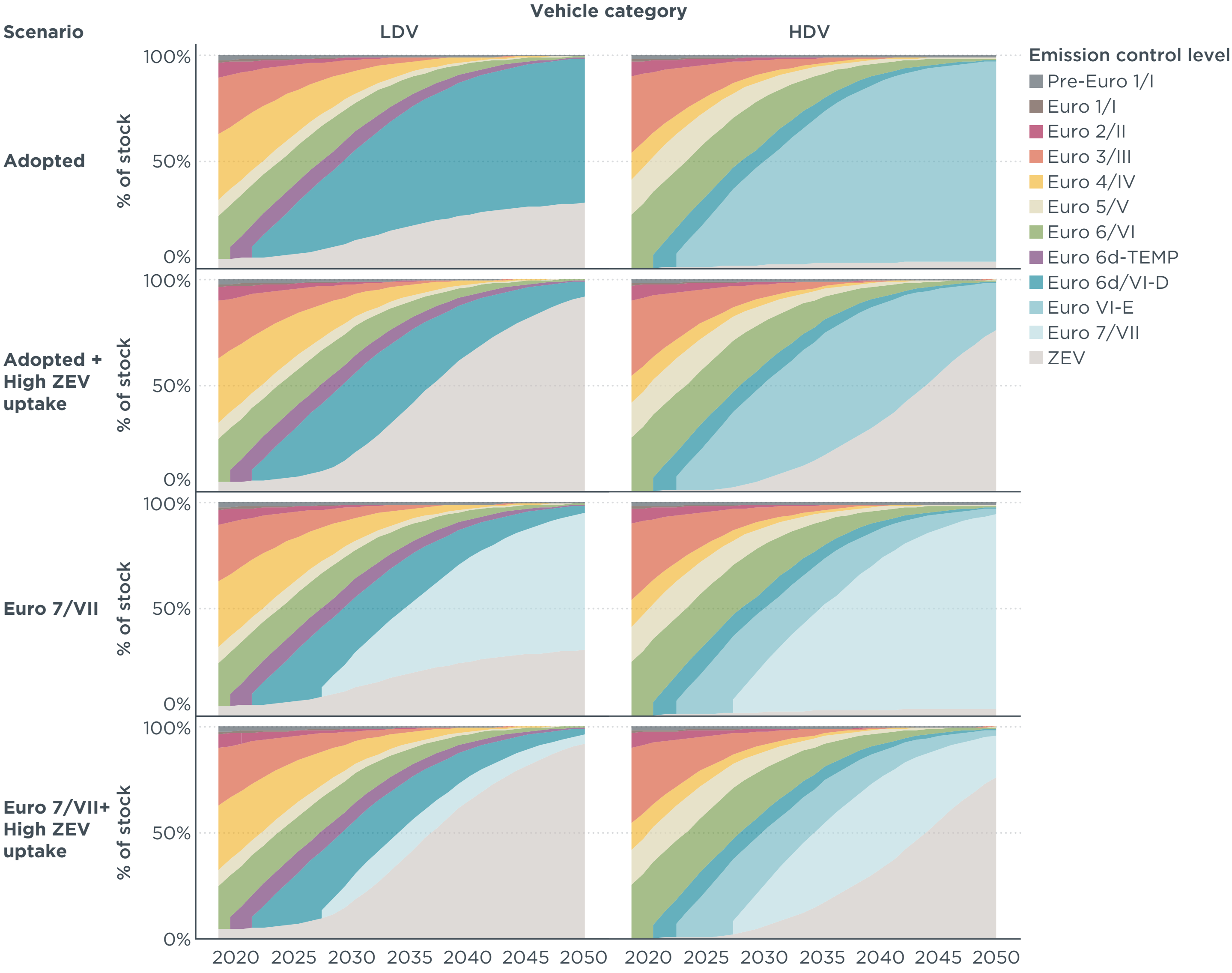
25 California Air Resource Board, EMission FACtor (EMFAC), arb.ca.gov/emfac
26 U.S. Environmental Protection Agency, MOtor Vehicle Emission Simulator (version 3), https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves
27 FATE documentation forthcoming.
28 Institute for Health Metrics and Evaluation, "Global Burden of Disease (GBD)," (2020), http://www.healthdata.org/gbd/2019.
29 GEOS-Chem is a global 3-D model of atmospheric chemistry driven by meteorological input and used by researchers around the world to assess a variety of atmospheric composition problems.
30 Institute for Health Metrics and Evaluation, "Global Burden of Disease (GBD)."

from United Nations World Population Prospects,[31] health rates projections from the GBD Foresights Project,[32] and baseline emissions projections from the Evaluating the Climate and Air Quality Impacts of Short-Lived Pollutants project (ECLIPSE).[33]

RESULTS

STOCK EVOLUTION

The evolution of the stock profile, segregated by Euro standard and ZEV uptake, plays a critical role in the emission reduction potential and associated health benefits. The evolution of the LDV and HDV stock under all scenarios is presented in Figure 2.



Zero-emission vehicles have a particularly important role to play in future emission reductions. Under the currently adopted policies, zero-emission HDV sales share is

Figure 2. EU-27 share of vehicle stock by Euro standard and zero-emission technologies for each scenario.

31 United Nations, Department of Economic and Social Affairs, "World Population Prospects 2019, Volume I: Comprehensive Tables." https://population.un.org/wpp/Publications/Files/WPP2019_Volume-I_Comprehensive-Tables.pdf

32 Institute for Health Metrics and Evaluation, Population forecasting, https://vizhub.healthdata.org/population-forecast/

33 Andreas Stohl et al., "Evaluating the climate and air quality impacts of short-lived pollutants," Atmospheric Chemistry and Physics, 15,(2015): 10529–10566, https://acp.copernicus.org/articles/15/10529/2015/acp-15-10529-2015.html

expected to increase from 0.3% in 2030 to 3% in 2050, driven by the current HDV CO_2 standards and an increased uptake of zero-emission buses, corresponding to a HDV stock share of 3% by 2050. The uptake of ZEVs is expected to be significantly larger in the LDV market, achieving a 31% stock share by 2050, driven by the current CO_2 standards for passenger cars and vans.

To be consistent with the climate goals of the European Union, future CO_2 standards must drive a larger uptake of ZEVs. Thus, under our high uptake scenario, the ZEV stock share is 92% for LDVs and 76% for HDVs by 2050.

The fleet-turnover is also a key variable in determining the rate of retirement of older Euro standard vehicles and their replacement with vehicles that comply to current standards. In general, countries with a younger aged fleet will retire or export vehicles faster than that of older fleets, resulting in a faster shift to the most recent Euro standard, lower associated emissions, and greater health benefits. Considering total stock shares across the EU-27, over 50% of all vehicles will be Euro 6/VI or newer by 2027, increasing to 90% of the internal combustion engine (ICE) stock by 2040. Under the Euro 7/VII scenarios, half of all ICE-vehicles will have been certified to Euro 7/VII standards by 2035, increasing to 90% by 2050.

Despite achieving a 100% zero-emission sales share by 2045 in the high ZEV uptake scenario described above, 24% of the HDV stock will remain powered by an ICE powertrain in 2050, owing in part to the generally longer lifespans relative to LDVs. Thus, the adoption of Euro VII standards for HDVs will be of particular importance in curbing long-term NO_x emissions, regardless of the level of ZEV uptake.

The future uptake of ZEVs will be highly dependent on the review of the CO_2 standards and the corresponding regulatory design. Thus, adopting Euro 7/VII standards ensures the continued reduction of NO_x emissions—and the respective health benefits— for all of the ICEs that are produced from 2027 until 100% ZEV uptake is achieved.

EMISSIONS

Annual tailpipe NO_x emissions from road transport are expected to gradually decrease under the currently adopted policies due to the replacement of older and higher emitting vehicles with those certified to Euro 6d and Euro VI-E. By 2050, NO_x emissions will be 74% below 2027 levels (the assumed year of implementation of Euro 7/VII). However, 16.3 million tonnes of NO_x will still be emitted between 2027 and 2050.

The introduction of Euro 7/VII standards would significantly reduce both the annual and cumulative emissions in the long term. By 2037, NO_x emissions would drop to 74% below 2027 levels—13 years earlier than the adopted policies scenario—and continue to decline to 93% below 2027 levels by 2050. Cumulative emissions are reduced by 26% over the same time period compared to adopted policies. This acceleration of emission reductions under the implementation of Euro 7/VII standards is particularly beneficial to HDVs, whereby the 2050 reductions achieved under the adopted scenarios is realized 15 years earlier (by 2035) compared to 10 years for LDVs (by 2040). Furthermore, HDV and LDV cumulative emissions under Euro 7/VII would be reduced by 36.5% and 20.0%, respectively, compared to adopted policies.

Increasing the adoption rate of ZEV provides further reductions to the implementation of Euro 7/VII standards. Under the combined Euro 7/VII and high ZEV uptake scenario, annual emissions are reduced 98% by 2050 compared to 2027. The benefit is also clear when considering cumulative emissions between 2027 and 2050, which are reduced by 30.8% relative to the adopted policies scenario.

Figure 3 presents the cumulative NO_x emission reductions and the individual contributions from the LDV and HDV sectors. Our analysis shows that, compared to adopted policies scenario, the implementation of Euro 7/VII standards has the propensity to reduce total cumulative NO_x emissions by 4.2 million tonnes over the period 2027 to 2050. Introducing a high ZEV uptake on top of Euro 7/VII standards reduces cumulative NO_x emissions further, by 5.0 million tonnes relative to the adopted policies scenario over the same period, compared to 3.5 million tonnes of NO_x under a high ZEV uptake combined with the adopted policies scenarios.

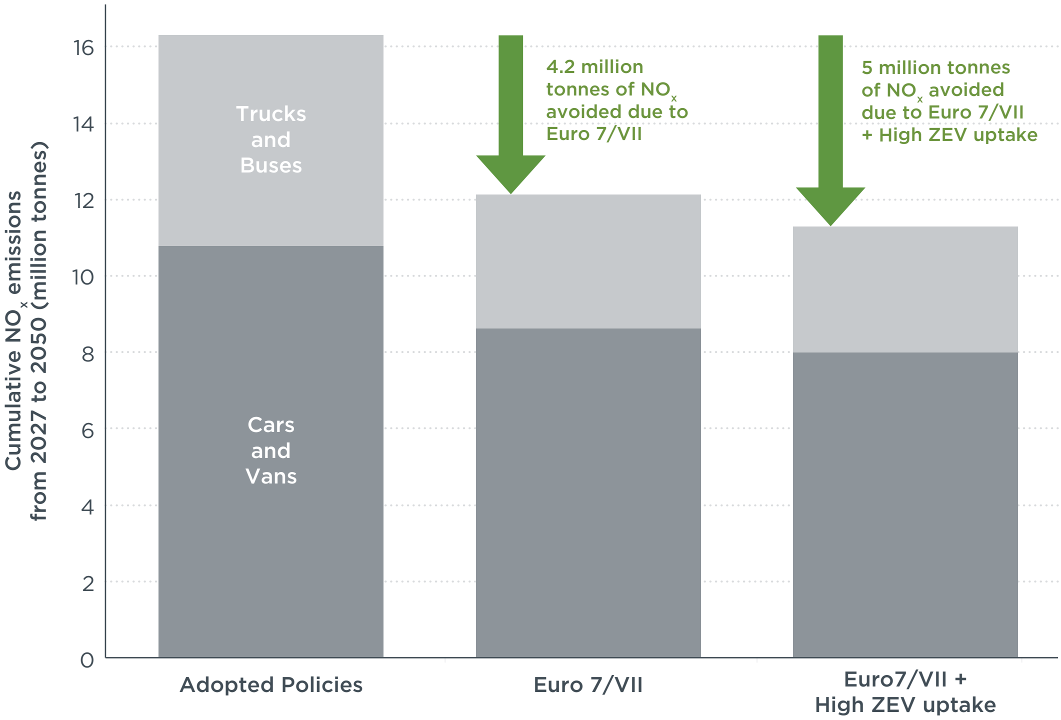


Figure 3. Cumulative NO_x emissions between 2027-2050 under currently adopted policies and reductions under future scenarios split by HDV and LDV.

The fraction of benefits that are attributable to each scenario depends on the choice of baseline. Assuming the adopted policies with high ZEV uptake as the baseline scenario, the marginal benefits of Euro 7/VII are 1.5 million tonnes of NO_x, or 30% of the benefit. Assuming the adopted policies as the baseline and neglecting a high ZEV uptake, the marginal benefits of Euro 7/VII are 4.2 million tonnes of NO_x, or 84% of the benefit. Greater NO_x reductions are realized through the implementation of Euro 7/VII compared to a high ZEV uptake.

We use Euro 7/VII as the baseline when understanding the additional health benefits from the high ZEV uptake scenario. From an implementation standpoint, the Commission is much closer to implementing Euro 7/VII standards than it is to setting CO_2 or ZEV policies that achieve 100% ZEV sales. Furthermore, even if ambitious CO_2 or ZEV policies are adopted, the lack of interim targets in such regulations could translate to step-like ZEV uptake in the new vehicle fleet to comply with regulatory requirements and avoid penalties only at the final moment, as already evidenced under the current LDV CO_2 standards.[34]

HEALTH IMPACTS

The reductions in tailpipe NO_x emissions generated by Euro 7/VII standards are projected to improve air quality across the EU-27, reducing ambient $PM_{2.5}$ and O_3 levels. According to our analysis, these improvements would prevent 35,000 premature

34 Peter Mock, "Europe's Lost Decade: About the Importance of Interim Targets," ICCT Staff Blog (blog), May 9, 2021, https://theicct.org/blog/staff/interim-targets-europe-may2021.

deaths over the period 2027-2050 compared to the currently adopted policies.[35] Over the same period, 568,000 years of life lost (YLL) due to premature mortality could be avoided, with the greatest benefit seen in Germany, France and Italy. Increasing ZEV sales under the high ZEV uptake scenario could further increase the overall health benefits, bringing the number of avoided premature deaths up to 42,000 and increasing the number of avoided years of life lost to 682,000. It is important to note that the health benefits identified within this paper only consider those associated with the reduction of tailpipe NO_x emissions. Thus, some of the benefits associated with a higher ZEV uptake may be offset by increased power plant related emissions following an increased electricity demand or hydrogen production for ZEVs.

These health benefits are presented in Figure 4 and Figure 5, which summarize our findings by country. Confidence intervals represent uncertainly in the concentration-response function. In both cases, we estimated only the impacts associated with changes in tailpipe NO_x emissions. Because our estimates do not consider the health impact of tailpipe emission reductions for other pollutants or of reduced direct exposure to NO_2, our estimates of the air quality and health benefits of Euro 7/VII are conservatively low.

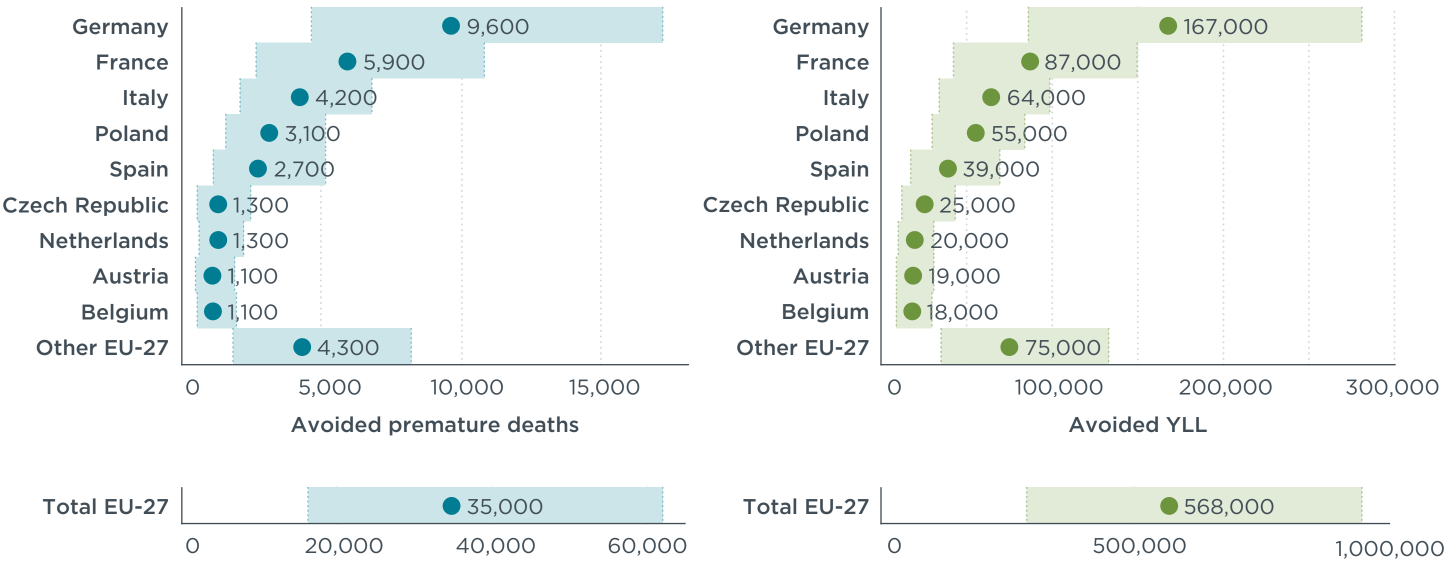


Figure 4. Cumulative health benefits of Euro 7/VII standards compared to adopted policies, 2027–2050.

35 The values reported are the central estimates of the modeled ranges. The complete ranges of the modeling results are found in Figure 4 and Figure 5.

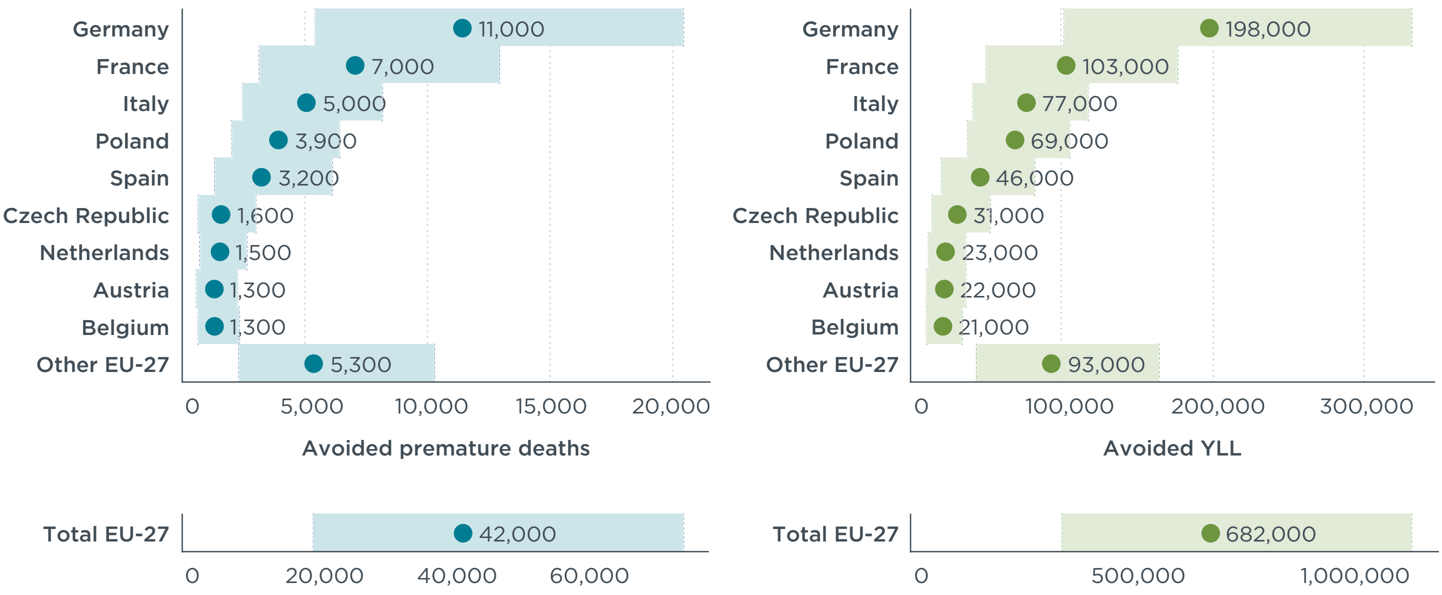


Figure 5. Cumulative health benefits of Euro 7/VII standards and High ZEV uptake compared to adopted policies, 2027–2050.

CONCLUSION

Air pollution poses a risk to human health at levels even below the emission limits established by the Air Quality Standards in Europe. To minimize the health risk and to reduce premature mortality rates associated with vehicular emissions, there is a very real need for more stringent emission standards. Given Europe's historic role in leading the way with vehicle emission standards, the adoption of stringent Euro 7/VII standards can enable the European Commission to make significant strides in improving air quality and reducing the associated health risks across the EU and globally. In this analysis, we have modelled the emission reductions and the health benefits associated with the introduction of Euro 7/VII standards, with an emphasis on attainable reductions in NO_x in LDVs and HDVs, and with a time horizon expanding out to 2050. Our analysis found the following key points:

Euro 7/VII will bring significant NO_x emissions reductions over the currently adopted Euro 6d/VI-E standards for both LDVs and HDVs. Euro 7/VII standards will significantly accelerate the reduction in NO_x emissions, achieving a 93% reduction in annual emissions by 2050 relative to 2027 compared to a 74% reduction under adopted policies. In addition, cumulative emissions over the 2027-2050 period will be reduced by 26% compared to currently adopted policies. Increasing the level of electrification further increases the reduction in emissions. Assuming LDVs and HDVs reach a 100% ZEV sales share by 2035 and 2045, respectively, reduces emissions by an additional 5% points. This translates to a 31% reduction in cumulative emissions from 2027 to 2050 relative to currently adopted policies and reduction in annual emissions by 98% in 2050 compared to 2027. Implementing Euro 7/VII standards are shown to also realize greater emissions reductions and associated health benefits compared to our high ZEV uptake scenario.

Euro 7/VII will prevent 35,000 premature deaths. The reductions in tailpipe NO_x emissions from Euro 7/VII standards will improve air quality across the EU, reducing ambient $PM_{2.5}$ and ozone concentrations. We project this reduction in emissions to prevent 35,000 premature deaths and avoid 568,000 years of life lost over the period 2027-2050. Increasing the ambition of ZEV uptake can further increase the associated health benefits, increasing the total amount of prevented premature deaths to 42,000 and avoiding 682,000 years of life lost due to premature death over the same period.

Heavy-duty vehicles will benefit proportionately more from Euro VII standards. Even under the high ZEV uptake scenario, nearly a quarter of the HDV stock will remain powered by an ICE powertrain by 2050. The adoption of Euro VII standards for HDVs will be of particular importance for curbing long-term NO_x emissions, regardless of the level of ZEV uptake. Compared to currently adopted policies, cumulative NO_x emissions from HDVs over the 2027-2050 period are reduced by 37% under the Euro 7/VII scenario, compared to 20% for LDVs.