THE REAL URBAN EMISSIONS INITIATIVE

Impacts of a low-emission zone in Sofia

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ACKNOWLEDGMENTS

FIA Foundation and the International Council on Clean Transportation (ICCT) have established The Real Urban Emissions (TRUE) Initiative. The TRUE initiative seeks to supply cities with data regarding the real-world emissions of their vehicle fleets and equip them with technical information that can be used for strategic decision making. TRUE will use a combination of measurement techniques to produce a granular picture of the on-road emissions of the entire vehicle fleet by make, model, and model year.

EXECUTIVE SUMMARY

The residents of Sofia, Bulgaria are exposed to air pollution levels that exceed European air quality standards and are among the highest observed in European cities. Motor vehicles are an important source of air pollutant emissions, and their contributions are exacerbated by the growing use of private cars and the relatively old vehicle fleet operating in the city.

Sofia Municipality has taken steps to address these challenges, most recently with the development of the Comprehensive Air Quality Improvement plan. The plan includes a proposal for the development of a low-emission zone (LEZ), a form of vehicle access restriction that has been applied in many European cities to control traffic-related pollution. As the details of the LEZ policy are under discussion, it is important to understand the levels of emission benefits different LEZ implementation schemes achieve and how quickly these benefits are delivered.

To provide insight on these questions and support Sofia in their efforts to develop an LEZ, this study assesses the impacts of two LEZ implementation schemes on the emissions of nitrogen oxides (NO_X) and particulate matter (PM) from passenger vehicles in the city. Using the TRUE database of real-world emissions from European vehicles and detailed information on the characteristics of the Sofia fleet, the study assesses two implementation timelines: one that tightens restrictions every two years and another that does annually. In each case, multiple scenarios were analyzed to investigate how differing responses by owners of restricted vehicles impacted the emissions benefits of the LEZ.

The analysis finds that older diesel cars certified to Euro 4 or prior standards, which make up around 30% of Sofia's fleet, are responsible for 56% of the total NO_X emissions and 85% of the total PM emissions from passenger cars in 2021. Figure ES1 shows that an LEZ designed to restrict these old, high-emitting vehicles is highly effective in delivering a substantial reduction in emissions. When the restrictions are implemented at two-year intervals, a 75% emissions reduction compared to current levels would be achieved six to eight years sooner for NO_X and four to five years sooner for PM than with natural fleet

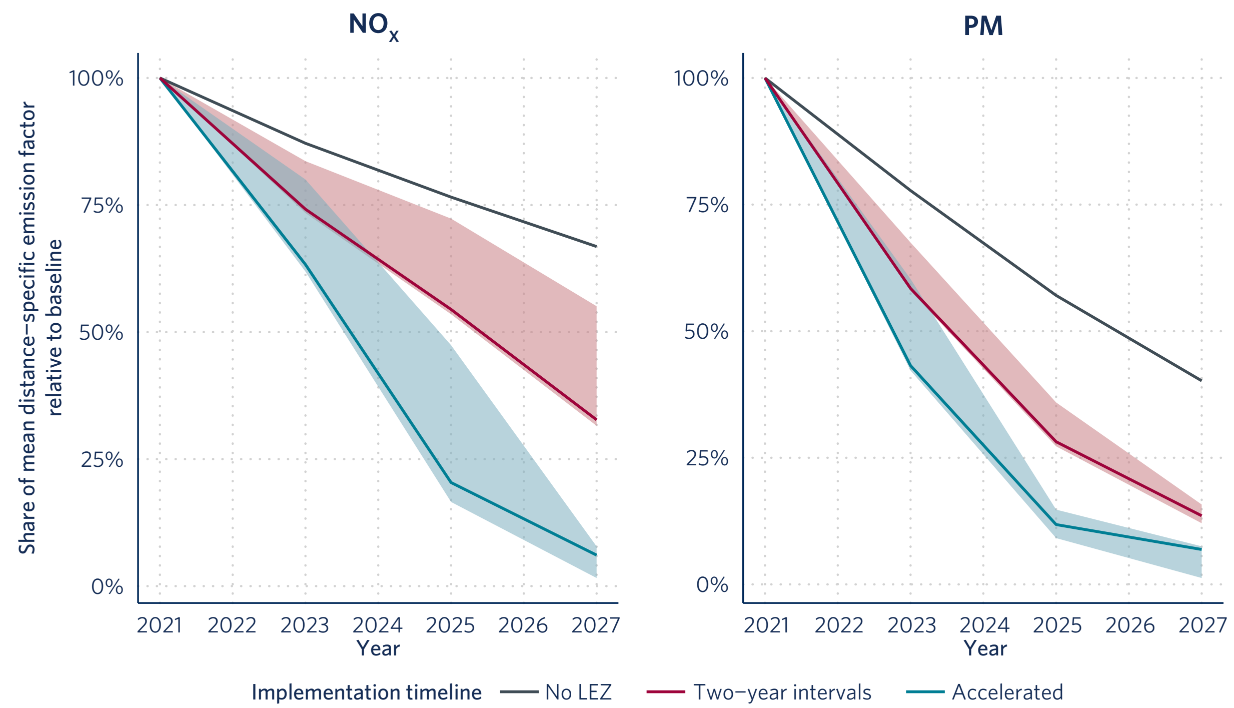

Figure ES1. Reduction in mean distance-specific emission factors of NO_X and PM relative to baseline (2021) levels as a result of "two-year intervals" and "accelerated" implementations of a low-emission zone as opposed to a case with no LEZ. Shaded areas show the ranges of possible emissions reductions that depend on the responses of vehicle owners affected by LEZ restrictions. Darker lines show the emissions impacts of a scenario in which vehicle owners replace their non-compliant vehicles with the cleanest available petrol vehicles. Additional scenarios considered include one in which vehicle owners switch to zero-emission activity (lower range of each shaded area) and a one in which vehicle owners buy the minimum compliant vehicles (upper range of each shaded area).

turnover, depending on the responses of affected drivers. The same level of emissions reduction would be accelerated by up to four and two years, respectively, for NO_x and PM in the scenario in which restrictions tighten every year. In all cases, the greatest emissions benefits are achieved when affected vehicle owners switch to zero-emission modes.

These findings demonstrate that a well-designed LEZ can significantly accelerate reductions in NO_x and PM emissions in Sofia. The conclusion also suggests that in order to achieve the greatest emissions benefits, an LEZ must incentivize drivers to choose zero-emission alternatives, like zero-emission vehicles, public transport, or walking. Simultaneously, a well-designed LEZ should be complemented with supporting policies, such as increased access to public transport and financial support to purchase clean vehicles, to reduce adverse impacts on lower-income populations. Finally, the effectiveness of an LEZ in reducing total emissions in Sofia will depend on the area the restrictions will effectively cover, which is currently under consideration. An ambitious LEZ policy that extends the LEZ to a greater geographic area would lead to greater emission benefits for a larger fraction of residents.

INTRODUCTION

Sofia, the capital of Bulgaria, is one of the most polluted cities in Europe. Particulate matter (PM) concentrations in Sofia regularly exceed the World Health Organization's annual limits and the European Union air quality standards. Air pollution exposure is responsible for a number of adverse health impacts, including respiratory and cardiovascular diseases. The European Environment Agency (EEA) estimates that 13,920 premature deaths in Bulgaria were attributable to the fine particulate matter (PM2.5), nitrogen dioxide (NO2), and ozone (O3) exposure in 2018, a level which, when normalized by population, is 2.2 times the average among the EU-27 countries and the United Kingdom.[1] Air quality is generally worse in large cities like Sofia than other parts of Bulgaria. Researchers have found that Sofia's social costs of air pollution, quantified by negative health impacts, are the highest in Bulgaria, and more than seven times those of the second most polluted city in the country.[2]

The use of private cars is one of the main sources of air pollution in Sofia,[3] and the city's population has become increasingly motorized in the last few years; the motorization level in 2020 of 663 cars per 1000 inhabitants is 29% higher than the 2016 level of 515 cars per 1000 inhabitants.[4] Other large European cities typically have a car usage level below 450 per 1000 people.

Besides its growing vehicle use, the age of Sofia's vehicle fleet also contributes significantly to air pollution. The average vehicle age in Sofia is 18 years old and over half of all motor vehicles in Sofia are over 16 years old.[5] In contrast, the average age of cars in the EU is 11.5 years.[6] The higher fraction of older vehicles is detrimental to the city's air quality, as older vehicles like pre-Euro 5 diesel vehicles emit significantly more PM and NO_x emissions than those certified to newer standards. However, there are currently no regulations in Sofia limiting the use of the older, more polluting cars.

Sofia Municipality recently adopted the Comprehensive Air Quality Improvement Programme, in which over 80% of the budget was set aside for transportation measures.[7] The Programme outlines preliminary plans for implementing a low-emission zone (LEZ), a form of vehicle access regulation which has been adopted in many European cities as a measure to reduce traffic-related pollution and other greenhouse gas emissions (GHG). LEZs typically limit the access of vehicles to a designated area based on their emission performance or standard. Especially in cities where the use of older, polluting vehicles is prevalent, an LEZ can be an effective way of reducing emission levels within the

1 European Environment Agency, "Bulgaria - Air Pollution Country Fact Sheet 2020," November 23, 2020, https://www.eea.europa.eu/themes/air/country-fact-sheets/2020-country-fact-sheets/bulgaria.

2 Sandra de Bryun, "Health Costs of Air Pollution in European Cities and the Linkage with Transport" (CE Delft, October 2020), https://cedelft.eu/wp-content/uploads/sites/2/2021/03/CE_Delft_190272_Health_costs_of_air_pollution_in_European_cities_and_the_linkage_with_transport_Def.pdf.

3 "Sofia Urban Challenge: Finding Agile Solutions to Air Quality," eit Climate-KIC, accessed July 23, 2021, https://www.climate-kic.org/success-stories/sofia-urban-challenge/.

4 SofiaPlan, "SofiaPlan's Analysis for Transport Infrastructure 2021 (Summary)," March 2021.

5 SofiaPlan. "SofiaPlan's Analysis for Transport Infrastructure 2021 (Summary)."

6 European Automobile Manufacturers' Association, "Average Age of the EU Vehicle Fleet, by Country," February 1, 2021, https://www.acea.auto/figure/average-age-of-eu-vehicle-fleet-by-country/.

7 European Public Health Alliance, "Fighting Air Pollution: There Are More Cars in Sofia than the Average for the EU's Largest Cities," June 2, 2021, https://epha.org/fighting-air-pollution-there-are-more-cars-in-sofia/.

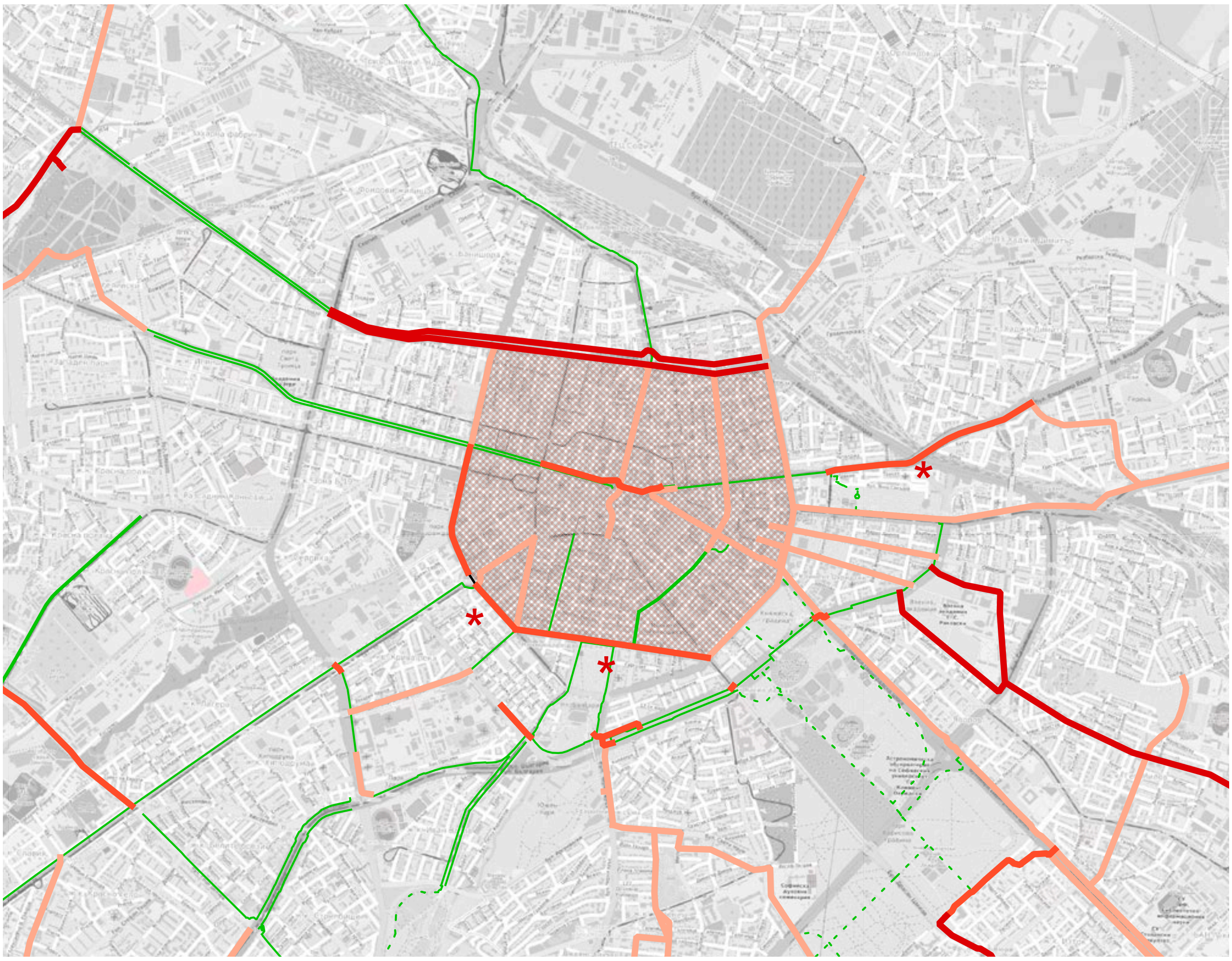

Figure 1. Area under consideration for Sofia's low-emission zone (shaded in red).

designated zone. The effectiveness of LEZs in achieving emission reductions is well documented, although reported emission reduction levels attributed to LEZ implementation vary by city.[8]

The initial steps of implementing an LEZ outlined in Sofia's Air Quality Improvement Programme include gathering real-world traffic data and introducing eco-stickers which rate the emission performance of vehicles.[9] The territorial scope of the LEZ currently under consideration mainly covers the central part of the city, as shown in Figure 1, with the possibility of expanding to a second zone.[10] This area partially corresponds to the city center where heavy trucks with the maximum permissible weight of 4 tonnes are currently not allowed to enter during certain hours of the day.[11] As the detailed parameters of the LEZ are currently being discussed for its implementation in the summer of 2022, our study provides a timely analysis

8 Jens Müller and Yoann Le Petit, "Low-Emission Zones Are a Success - but They Must Now Move to Zero-Emission Mobility" (Transport & Environment, September 2019), https://www.transportenvironment.org/sites/te/files/publications/2019_09_Briefing_LEZ-ZEZ_final.pdf; "ULEZ Reduces 13,500 Cars Daily & Cuts Toxic Air Pollution by a Third," Press release, Mayor of London, October 21, 2019, https://www.london.gov.uk/press-releases/mayoral/ulez-reduces-polluting-cars-by-13500-every-day.

9 Sofia City Council, "Annex 14: Comprehensive Air Quality Improvement Programme of Sofia Municipality for the Period 2021-2026," April 26, 2021, https://www.sofia.bg/documents/20182/10412985/%D0%9F%D1%80%D0%B8%D0%BB%D0%BE%D0%B6%D0%B5%D0%BD%D0%B8%D0%B5+14.pdf/d522f805-bcd8-4ed7-9b85-00a10bdc1cbe.

10 Sofia City Council, "Annex 14: Comprehensive Air Quality Improvement Programme of Sofia Municipality for the Period 2021-2026."

11 CLARS, "Sofia: Access Regulated by Other Requirements," Urban Access Regulations in Europe, accessed August 12, 2021, https://urbanaccessregulations.eu/countries-mainmenu-147/bulgaria/sofia-ar.

that explores the emissions reduction potential of an LEZ and other considerations for policy makers.

This report uses real-world emissions and activity data to examine the emissions reductions that could be achieved through an LEZ under different assumptions regarding the behavior of affected drivers. The analysis presented here is intended to support discussions regarding the implementation of an LEZ in Sofia and to inform the design to enhance its effectiveness. Based on our findings, the LEZ design used in this study can serve as a recommendation for an LEZ in Sofia in the absence of an existing framework. The paper concludes with policy implications, including discussions on other social and economic components that need to be further considered.

METHODS

In this paper, we evaluate the potential emission reduction benefits of a low-emission zone based on the real-world emission factors of European vehicles and the fleet composition specific to Sofia, Bulgaria. We assume that access restrictions of different vehicle groups are progressively applied to the central area of Sofia designated by the city (Figure 1). We consider two implementation timelines: one where the restrictions tighten every two years and another where they tighten every year, which we refer to as accelerated LEZ implementation.

Changes in emissions resulting from the LEZ implementation schedules are estimated by calculating fleet-average emission factors, which are used here as a proxy for changes in total emissions when the total vehicle activity remains constant. The analysis builds upon the approach developed and applied in a previous TRUE study which investigated the emissions impacts of the implementation of the Paris low-emission zone.[12] While the former study focused only on nitrogen oxide (NO_X) emissions, this work extends the approach to also consider tailpipe particulate matter (PM) emissions.

Our analysis focuses on the emissions of both NO_X and PM, two of the main pollutants of concern emitted by motor vehicles and important contributors to poor air quality in Sofia. In this analysis, we evaluate the impacts of LEZ implementation on emissions from passenger cars, the most common vehicle type on the roads of the city. While not included in this analysis, other vehicle types, such as light-commercial and heavy-duty vehicles are also important sources of traffic-related pollution and should be considered for inclusion in any LEZ designs for Sofia.

The analysis applies two primary data sources to define (1) pollutant emission factors for each vehicle group by fuel type and certified Euro standard, and (2) the distribution of vehicles operating in Sofia by fuel type, age, and emissions standard. The following sections describe these data sources in more detail.

EMISSION FACTOR ESTIMATION BASED ON REMOTE SENSING RECORDS

Our analysis derives distance-specific NO_X and PM emission factors by fuel type and emission standard from a database of over 1.5 million measurements from 19 European remote sensing campaigns. The remote sensing database provides a more accurate picture of emissions in the real-world setting, which may differ from those measured during type-approval tests due to various driving and environmental conditions, such as temperature, speed, acceleration, and road grade. The emission factors reflect the results from the most up-to-date database and, therefore, show some differences from those used in our previous study on the impacts of an LEZ in Paris.

Some conversions and calculations were necessary to obtain the emission factors used in the analysis. Remote sensing measurements provide fuel-specific emissions, expressed in grams per kilogram of fuel burned. Distance-specific NO_X and PM emission factors that we utilize in the study were thus estimated using methodologies developed previously by ICCT.[13] Emission factors for diesel and petrol Euro 0, or all vehicles with standards antecedent to Euro 1 for which we did not have sufficient coverage in the database, were estimated by applying the same relative change shown in the EEA emission factors.

Emission factors for Euro standards whose measurements were absent from our data sources were

12 Yoann Bernard, Joshua Miller, Sandra Wappelhorst, and Caleb Braun "Impacts of the Paris Low-Emission Zone and Implications for Other Cities" (Washington, D.C.: ICCT, March 12, 2020), https://theicct.org/publications/true-paris-low-emission-zone.

13 Yoann Bernard Uwe Tietge, John German, and Rachel Muncrief, "Determination of Real-World Emissions from Passenger Vehicles Using Remote Sensing Data" (Washington, D.C.: TRUE Initiative, June 5, 2018), https://theicct.org/publications/real-world-emissions-using-remote-sensing-data.

Table 1. Passenger car NO_x and PM emission factors by fuel type and Euro standard.

Emission standard	Type approval date	All registration date	Diesel		Petrol	
			NO_x (mg/km)	PM (mg/km)	NO_x (mg/km)	PM (mg/km)
Euro 0			1134	125.1	624	8.8
Euro 1	Jul 1992	Jan 1993	1105	47.7	644	4.9
Euro 2	Jan 1996	Jan 1997	1169	48.1	538	4.1
Euro 3	Jan 2000	Jan 2001	945	37.9	284	2.9
Euro 4	Jan 2005	Jan 2006	790	20.2	141	2.4
Euro 5	Sep 2009	Jan 2013	766	2.3	91	2.2
Euro 6	Sep 2014	Sep 2015	433	1.2	83	1.7
Euro 6d-TEMP	Sep 2017	Sep 2019	110	0.9	66	0.7
Euro 6d	Jan 2020	Jan 2021	75	0.9	45	0.7
Euro 7	Jan 2025	Jan 2026	25	0.9	25	0.7

Note: Type approval date refers to the date from when vehicles can be certified to the standard and all registration date refers to the date by when all new vehicles must be certified.

assigned based on the most recent regulations and information available from the European Commission. Euro 6d was only introduced starting 2020, so its NO_x emission factor was assigned based on the allowance reduction set by the European Commission, which permitted 6d-TEMP vehicles to emit 2.1 times more than the laboratory limit (conformity factor) under the on-road type-approval test, known as Real Driving Emissions (RDE), but lowered to 1.43 times under the final 6d implementation step.[14] We assume no further changes in PM emission factors for both diesel and petrol Euro 6d, as the remote sensing average emission factors were already below the current Euro 6 level (5 mg/km). Euro 7, a likely last and fuel-neutral standard before all vehicles are required to be zero-emission, is expected to come into force in 2025. Therefore, our analysis introduces Euro 7 from the model year 2025 with a fuel-neutral NO_x emission factor of 25 mg/km, a level corresponding to the average of the two foreseen scenarios most recently discussed by the CLOVE consortium.[15] Similar to Euro 6d, Euro 7 PM emission factors remain the same as the Euro 6d-TEMP and Euro 6d levels because the limit currently being discussed (2 mg/km) is above the remote sensing results. Our analysis makes an optimistic assumption that no further emission deterioration occurs over the remaining lifespan of all vehicles beyond the point of reference in 2020. Emission factors used in this study are summarized in Table 1.

Figure 2 presents a comparison of NO_x and PM emissions performance for all Euro standard and fuel type groupings from the remote sensing data, which is helpful in identifying those vehicle groups with the highest emissions of each species, the restriction of which may lead to the greatest benefits for an LEZ. The diesel Euro 0 group is not shown on the plot as its PM emission factor (125 mg/km) greatly exceeded (more than twofold) those of the next highest emitting vehicle groups—Euro 1 or Euro 2 diesels. Our estimated emission factors show that older diesel vehicles, namely pre-Euro (Euro 0) and Euro 1, 2, 3, 4 standards, emit significantly more than their petrol equivalents.

14 European Commission, "Commission Regulation (EU) 2018/1832 of 5 November 2018 Amending Directive 2007/46/EC of the European Parliament and of the Council, Commission Regulation (EC) No 692/2008 and Commission Regulation (EU) 2017/1151 for the Purpose of Improving the Emission Type Approval Tests and Procedures for Light Passenger and Commercial Vehicles, Including Those for in-Service Conformity and Real-Driving Emissions and Introducing Devices for Monitoring the Consumption of Fuel and Electric Energy (Text with EEA Relevance.)," Pub. L. No. 32018R1832, 301 OJ L (2018), http://data.europa.eu/eli/reg/2018/1832/oj/eng.

15 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.

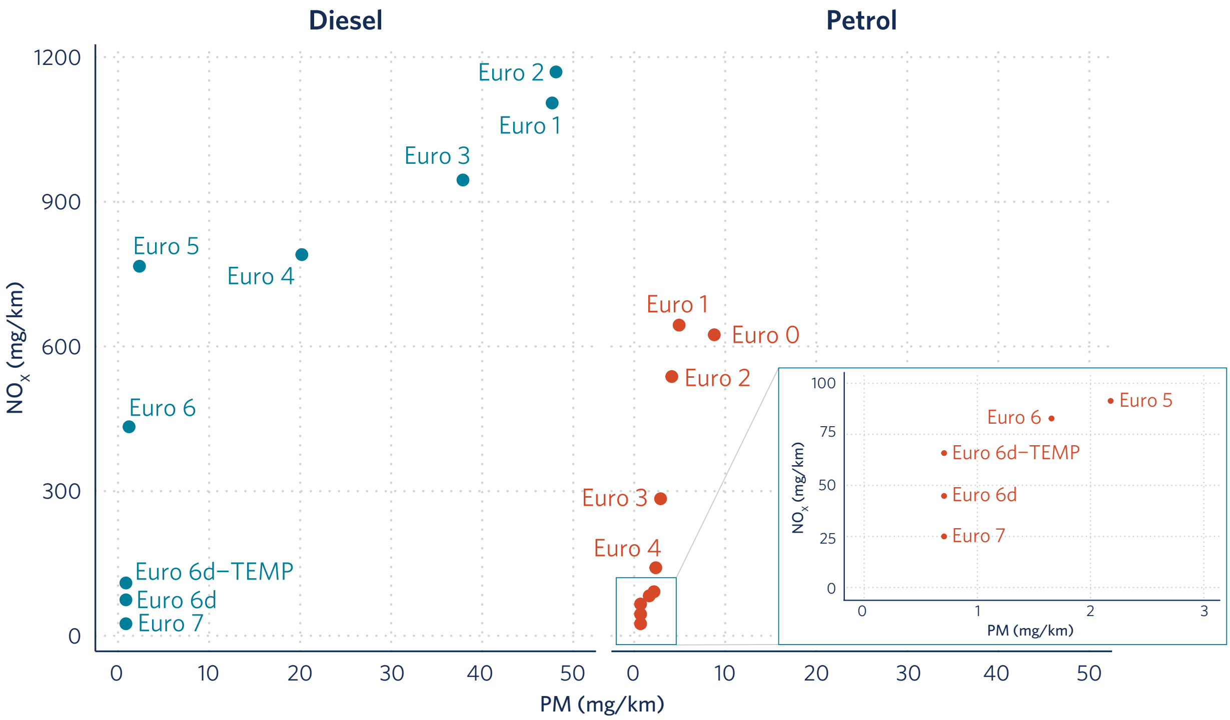

Figure 2. Comparison of NO_x and PM emissions performance by Euro standard and fuel type grouping.

CURRENT SHARE OF PASSENGER CAR ACTIVITY AND EMISSIONS BY VEHICLE GROUP

Sources such as vehicle registration and inventory data are commonly used to define fuel type, age, and emission standard distributions of a city's fleet. In the absence of such sources, however, we utilize the results from Sofia's 2020 remote sensing study as a proxy for Sofia's fleet activity and acknowledge that the selected source may not be fully representative of the fleet. The limitations are further discussed in the concluding section of this paper.

The remote sensing campaign was conducted by Sofiabus using the RSD AccuScan 5000 instrument over the period of 5 days between 25 September 2020 and 5 October 2020. The fleet inventory was taken from a location near Borisova Garden in the residential neighborhood of Yavorov in Sofia. In total, 10,621 measurements from 9,553 unique vehicles were collected during the campaign. Due to complications encountered during the campaign, remote-sensing emissions data were not usable. However, technical information on the sampled vehicle fleet was obtained via license plate information collected during the campaign and is used here to define characteristics of the Sofia passenger car fleet. Despite the somewhat limited nature of this dataset, it was able to give a more complete picture of vehicle activity by Euro standard and fuel type in Sofia than a recent mobility study, in which 56.5% of passenger cars had missing Euro standards.[16] However, we note that this may not accurately represent the citywide fleet distribution due to the small sample size, limited geographic coverage, and times the measurements were taken.

This raw dataset contained 6,957 measurements of 6,284 unique passenger cars of all fuel types, where liquefied petroleum gas and compressed natural gas vehicles represented 11% and 5% of the fleet, respectively. For simplification, these vehicles were grouped with petrol vehicles as they share the same type of positive ignition combustion and three-way catalyst aftertreatment systems, which for this analysis were assumed to lead to similar NO_x and PM emission factors. Despite the presence of Euro 6d, Euro 6d-TEMP was absent from the original data and therefore was identified by associating the vehicle registration dates with the Euro standard type approval dates. Specifically, all Euro 6d vehicles registered before the type-approval date of Euro 6d (January 2020) were considered to be Euro 6d-TEMP.

16 SofiaPlan.

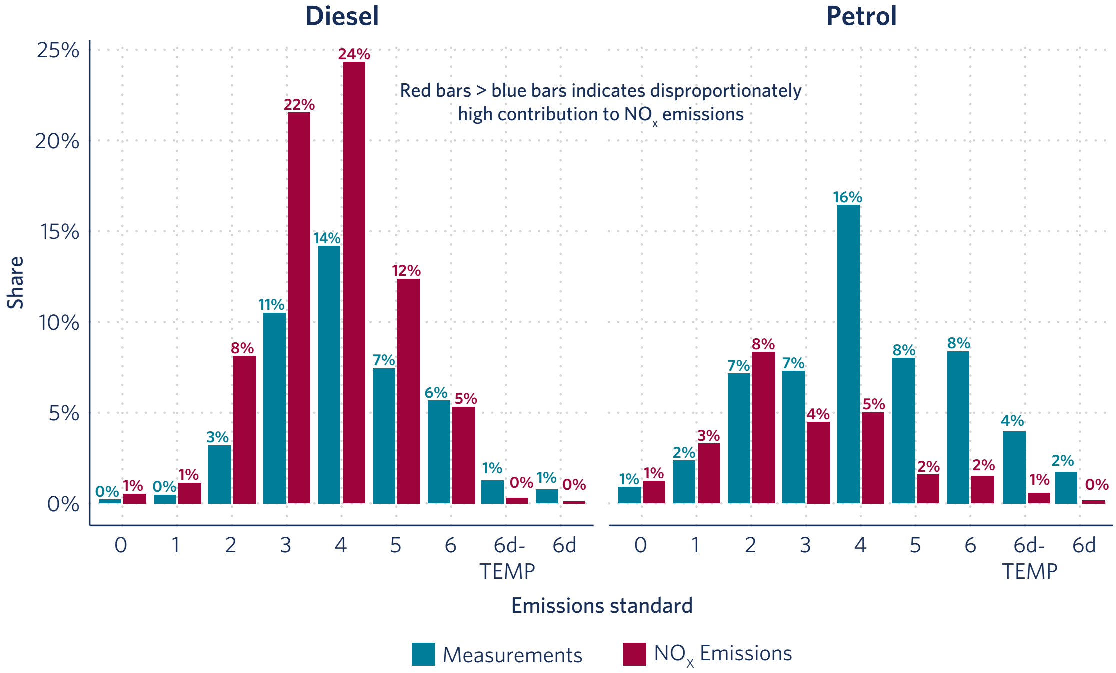

Figure 3. NO_x emission share and measurement share of each Euro standard and fuel type group from the Sofia 2020 remote sensing campaign.

Our initial assessment of the dataset shows the average age of unique passenger cars in Sofia is 13 years, a few years younger than the reported average of all vehicles in 2018 but nevertheless older than the average age of cars in the EU.[17] The measurements of passenger cars age 13 and above accounted for 56% of the total, which is in line with the passenger car statistics of SofiaPlan and implies these vehicles are actively used in the city.[18] More than half (54%) of cars of age 13 years and older were petrol-powered. Overall, petrol vehicles were observed more often than diesel in Sofia's 2020 remote sensing measurements, as shown by the higher share of petrol vehicles in total measurements (56% petrol and 44% diesel).

The measurement shares and NO_x and PM emission shares estimated for each vehicle group are shown in Figure 3 and Figure 4. The share of emissions of each vehicle group was obtained by multiplying the estimated distance-specific emission factor by the measurement counts of each group and calculating the share from the total level of each pollutant. The emission shares were then compared with the measurement shares to pinpoint vehicle groups that contribute disproportionately to the total emissions.

The NO_x emissions share results indicate diesel-powered vehicles are responsible for 74% of the total emissions from passenger cars in Sofia. Euro 3 and 4 diesels are the highest emitting vehicle groups, accounting for only about 25% of the total measurements but are estimated to contribute nearly 50% of the total NO_x emissions from the Sofia fleet. Only diesel cars certified to Euro 6 and later standards show a decreasing contribution to total NO_x emissions. This is not only because they emit less NO_x than their preceding standards but is also due to their relatively small share (6%) of the total passenger car fleet. However, it is important to note that although Euro 6 diesel vehicles have improved emission performance relative to older diesel cars, they show elevated levels of real-world NO_x that do not comply with EU limits.[19] Petrol-powered vehicles generally appear to contribute less to NO_x emissions than their diesel-powered equivalents. For example, the most frequently measured vehicle group, petrol Euro 4 cars, accounts for 16% of Sofia's fleet but is responsible for only 5% of the total NO_x emissions.

Figure 4 shows a similar distribution of PM emissions; 86% of the total PM emissions are attributed to diesel vehicles, and Euro 3 and 4 vehicles account for the

17 SofiaPlan.

18 SofiaPlan.

19 Yoann Bernard, "Real-World NO_x Emissions from Remote Sensing: An Update of the TRUE Rating," *ICCT Staff Blog* (blog), December 17, 2018, https://theicct.org/blog/staff/true-rating-update-dec2018.

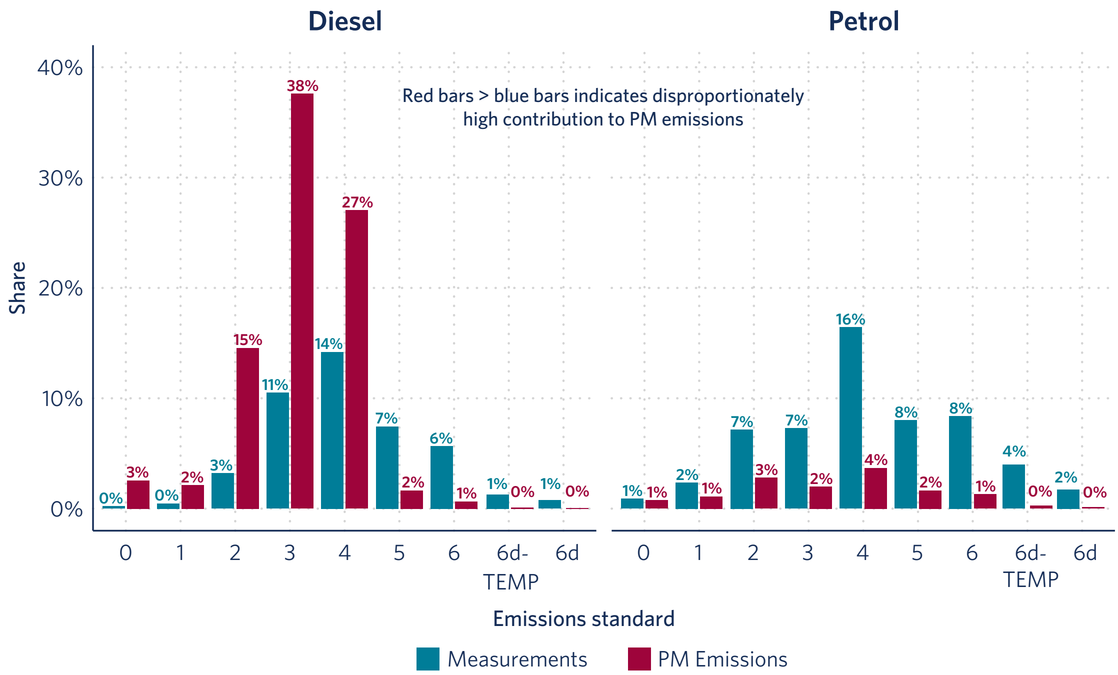

Figure 4. PM emission share and measurement share of each Euro standard and fuel type from the 2020 remote sensing campaign.

largest share of emissions, making up 65% of PM emissions with only 25% of the measurement share. However, post-Euro 4 vehicles show significantly lower PM levels as a result of the introduction of diesel particulate filters (DPFs). Similar to NO_X emissions, petrol vehicles perform better in terms of PM emissions than their diesel counterparts. In total, petrol vehicles are estimated to make up 56% of Sofia's passenger car fleet and contribute 14% of total PM emissions.

SOFIA LOW-EMISSION ZONE DESIGN

Based on the preliminary assessment of the 2020 remote sensing campaign data and the real-world emission factors, we are able to design a low-emission zone scheme. We assume that the suggested LEZ covers the area currently being discussed by city officials and shown in Figure 1. We examine the impacts of two different LEZ implementation schedules: one where a new phase is implemented every two years from 2022 to 2032 and a more accelerated schedule where a new phase is introduced each year from 2022 to 2027. This progressive implementation of restrictions is a standard practice of the existing LEZs in European cities such as Brussels, Milan, and Paris.

The LEZ scheme we designed for Sofia is presented in Table 2. The design primarily considers the age, the prevalence of the measurements in the 2020 remote sensing dataset, and the emissions shares of the affected vehicle groups to ensure that the emissions are reduced effectively without overburdening vehicle owners. In the case of Sofia, diesel Euro 3 and 5 vehicles and petrol Euro 2, 3, and 4 vehicles hold the largest shares of the total passenger car fleet and, therefore, are not phased out simultaneously. Furthermore, as older cars often belong to lower-income individuals, a scheme that gradually increases the number of Euro standards affected was preferred to promote a more equitable implementation of the LEZ.[20]

The LEZ was designed so that the older, more polluting cars are banned first starting in 2022, with further restrictions implemented over six phases. The vehicle groups allowed in the LEZ are progressively restricted until 2032, eventually allowing only diesel vehicles certified to Euro 7 standards and petrol vehicles certified to Euro 6d and 7 standards. The more accelerated implementation of the LEZ introduces new phases annually and reaches Phase 6 by 2027. Up to the fourth phase of the LEZ, all affected vehicles will be over 13 years old, which is around the average age of passenger vehicles in Sofia in 2020. This way, the initial phases of the LEZ will encourage the replacement of the oldest, highest emitting vehicles in the fleet while avoiding

20 Müller and Le Petit, "Low-Emission Zones Are a Success - but They Must Now Move to Zero-Emission Mobility."

Table 2. Low-emission zone design for Sofia.

Phase	Minimum standard		Implementation timeline (year)	
	Diesel	Petrol	Two-year intervals	Accelerated
	No restriction	No restriction	2021	2021
1	Euro 3	Euro 2	2022	2022
2	Euro 4	Euro 3	2024	2023
3	Euro 5	Euro 3	2026	2024
4	Euro 6	Euro 4	2028	2025
5	Euro 6d	Euro 5	2030	2026
6	Euro 7	Euro 6d	2032	2027

placing excessive burdens on owners of relatively new vehicles. Furthermore, the lead time of 6 to 11 years will give vehicle owners sufficient time to plan their vehicle purchases.

MODELING THE IMPACTS OF LEZ IMPLEMENTATION ON FLEET-AVERAGE EMISSION RATES

In order to simulate the effects of the proposed LEZ scheme on the emissions from passenger cars, average NO_x and PM emission factors were modeled for four different scenarios:

1. *No LEZ*: baseline scenario that depicts the natural fleet turnover with no LEZ in place
2. *Buy minimum requirement:* vehicle owners replace their current vehicles with the bare minimum standards in response to the restrictions
3. *Buy cleanest petrol*: vehicle owners replace their current vehicles with petrol vehicles type-approved to the latest available Euro standard[21]
4. *Switch to zero-emission activity*: people switch to zero-emission activities, such as driving zero-emission vehicles, taking public transportation, or walking[22]

In all the scenarios, we assume that Euro 7 standards are introduced from 2025 and all new vehicles produced after 2026 meet Euro 7 standards.

To simulate the natural fleet turnover of Sofia, we assume a constant age distribution of diesel and petrol vehicles over time. This distribution was obtained from the 2020 Sofia remote sensing campaign.[23] For the other scenarios, we assume that all vehicle owners affected by the LEZ implementation phases respond to the restrictions as specified by the scenarios described above. We also assume full compliance of all drivers with the LEZ restrictions. Our analysis does not consider changes in overall vehicle activity in the LEZ but focuses only on the changes in average emission factors as a result of LEZ restrictions.

To provide context for what a certain decrease in the average emission factor means, we present the emission impacts of the LEZ in terms of the time saved to reach certain emission reduction goals relative to the baseline *no LEZ* scenario. We look at two emission reduction goals: the points where the average emission factors are reduced by 50% and 75% from the 2021 level with no LEZ. Assuming the decrease in the average emission factor is linear between phases, we first derive the years in which all scenarios, including the baseline, halve and quarter the initial average emission factor by

21 These new vehicles would be type-approved to the Euro 6d emission standard for the 2022 to 2024 timeframe, and to the Euro 7 emission standard from 2025 onwards.

22 For zero-emission activities that do not involve passenger cars, such as public transportation and walking, we assume PM and NO_x emissions are expressed in per km distance that would have been driven in passenger cars otherwise.

23 Euro standards of vehicles are often determined by comparing the registration dates of individual vehicles with the type-approval dates or the implementation dates of Euro standards. However, this method does not consider the possibility of vehicles type-approved to different Euro standards in one year. In order to reflect Sofia-specific car activity more accurately, shares of different type-approved Euro standards in each model year were specified based on the remote sensing data and inputted into simulations. Sofia's vehicles tend to be registered closer to the date by which all vehicles need to implement the newer standard and show the oldest standard possible.

interpolation and compare the estimated timeframes to find how much earlier the selected emission reduction goals are achieved with the help of an LEZ.

PROJECTED IMPACT

To assess the effects of an LEZ on NO_x and PM emissions, distance-specific fleet-average emission factors (mg/km) are presented for the reference year and all phases of the LEZ for four different scenarios, including the baseline scenario. We use 2021 as the reference year, as we assume the LEZ to be phased in starting in 2022. The baseline scenario depicts the natural turnover of the passenger car fleet in Sofia, which shows declining average NO_x and PM emission factors as older vehicles are replaced with newer vehicles that tend to have better emission performance. It is important to note that we assume the total car activity to remain constant.

EMISSION IMPACTS OF LEZ IMPLEMENTATION STEPS AT TWO-YEAR INTERVALS

Compared to the baseline scenario, all three LEZ scenarios show steeper downward trajectories of average NO_x emission factors, as shown in Figure 5. In particular, the scenario in which non-compliant vehicles are replaced by the cleanest compliant petrol vehicles and the scenario in which they shift to zero-emission vehicles or modes draw similar trajectories until Phase 4. This is because in the former scenario, petrol vehicles that emit much less NO_x than their compliant diesel equivalents constitute an increasingly higher share in the total fleet. Moreover, high-emitting Euro 4 and 5 diesel vehicles are replaced by Euro 6d petrol vehicles, which emit 95% less NO_x emissions than Euro 5 diesel vehicles. This highlights that if affected drivers were to replace their non-compliant vehicles with the cleanest available petrol option, the potential effectiveness of the LEZ in addressing NO_x emissions is substantial even without considering zero-emission activities.

The effects of an LEZ on the average NO_x emission factors in the most pessimistic scenario, in which non-compliant vehicles are replaced by vehicles meeting the minimum standards allowed in the LEZ, show some delay compared with the other two scenarios. In Phase 3, the average NO_x emission factor for the *buy minimum requirement* scenario is only 5% lower than that for the *no LEZ* scenario, while the emission factors for the *buy cleanest petrol* and the *switch to zero-emission activity* scenarios are 37% and 38% lower, respectively, than for the baseline scenario. Restrictions prior to Phase 4

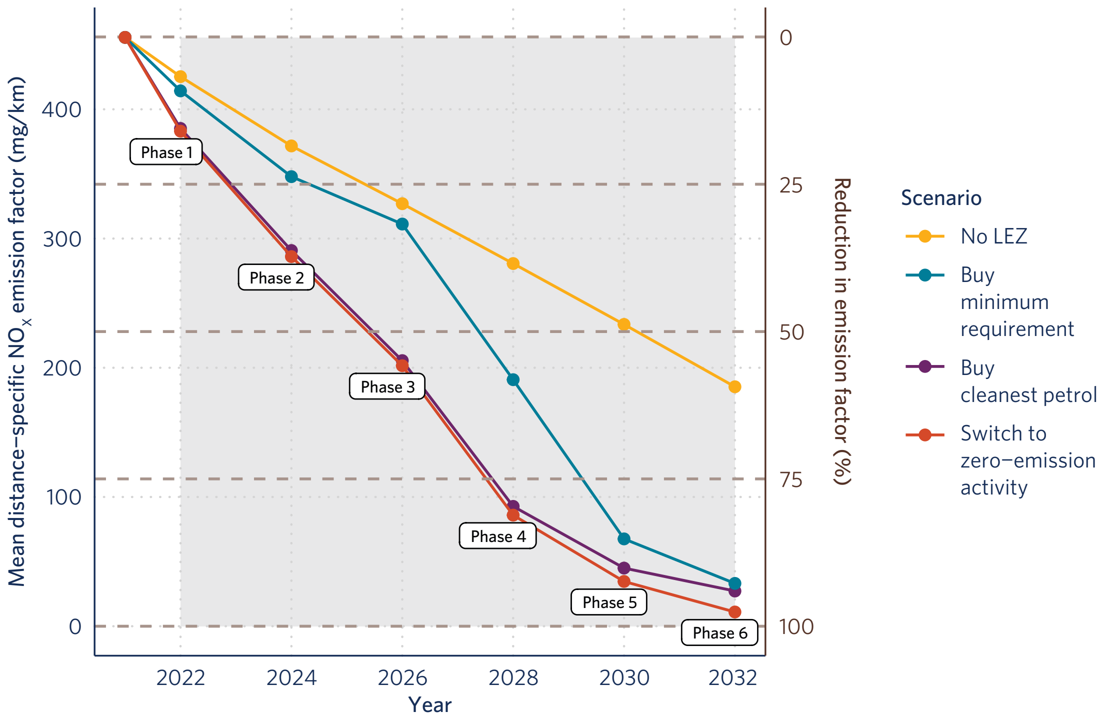

Figure 5. The effects of a low-emission zone on fleet-average passenger car NO_x emission factors for four scenarios. The grey shaded area indicates the timeframe the LEZ is in place.

Table 3. Years in which each scenario reaches 50% and 75% reduction in the average NO_x emission factor and the numbers of years accelerated in comparison to the scenario with no LEZ.

Reduction in average NO_x emission factor	Scenario	Year	Number of years accelerated
50%	No LEZ	2030	
	LEZ - Buy minimum requirement	2027	2.9
	LEZ - Buy cleanest petrol	2026	4.8
	LEZ - Switch to zero-emission activity	2025	4.9
75%	No LEZ	2035	
	LEZ - Buy minimum requirement	2029	6.1
	LEZ - Buy cleanest petrol	2028	7.7
	LEZ - Switch to zero-emission activity	2028	7.8

appear to provide little benefits as Euro 4 and 5 diesel vehicles still make up a large portion of car activity and they emit over 75% more NO_x than vehicles certified to their successive standard, Euro 6. In Phase 4, the *buy minimum requirement* scenario achieves the average NO_x emission factor that is 32% less than that of the baseline scenario, but the effects of a similar magnitude to the other LEZ scenarios are not achieved until 2030.

Compared to the 2021 level, all three LEZ scenarios deliver a greater than 90% reduction in the average passenger car NO_x emission factor by 2032. Without an LEZ in place this reduction is estimated to be only about 60% (right y-axis in Figure 5). The evolution of the fleet-average NO_x emission factors is summarized in Table A1 in the appendix.

To put these modeling results in perspective, Table 3 shows the impacts of the LEZ in terms of the difference in timeframes over which certain levels of emission reduction are achieved. If the goal is to achieve a 50% reduction in the average NO_x emission factor relative to the current level, the LEZ can deliver this five years earlier than when it would be reached without an LEZ in place. When changes in average emission factors are driven only by natural fleet turnover, this goal is not achieved until 2030. When considering a 75% reduction target, it becomes evident that the LEZ is necessary to achieve this goal before 2030. With an LEZ in place, a 75% reduction in the average NO_x emission factor can be achieved six to eight years earlier than in the case where no LEZ is implemented.

The implementation of an LEZ has a more accelerated impact on average PM emission factors than average NO_x emission factors, as shown in Figure 5. By Phase 3, the estimated average PM emission factors for all LEZ scenarios are 63%–69% lower compared to the average PM emission factor for the baseline scenario. The significant reduction in the average PM emission factors in Phase 3 is a result of banning diesel Euro 4 vehicles, the last standard that could be met without the use of a diesel particulate filter, a technology which greatly improves the PM emission performance of diesel vehicles. The effectiveness of the LEZ appears to be consistent regardless of how vehicle owners respond to the policy until the end of the LEZ implementation period. In 2032, the *switch to zero-emission activity* scenario achieves 57% more reduction than the *buy cleanest petrol* scenario, the scenario that achieves the second-best reduction in average PM emission factors.

The fleet-average PM emission factor is expected to decrease due to natural fleet turnover without an LEZ in effect, reaching 50% reduction relative to 2021 levels by 2026 and 75% by 2030. However, the same emission factor reduction levels would be achieved approximately two years and four to five years earlier, respectively, with the implementation of an LEZ, as summarized in Table 4. More details on the evolution of average PM emission factors are summarized in Table A1 of the appendix.

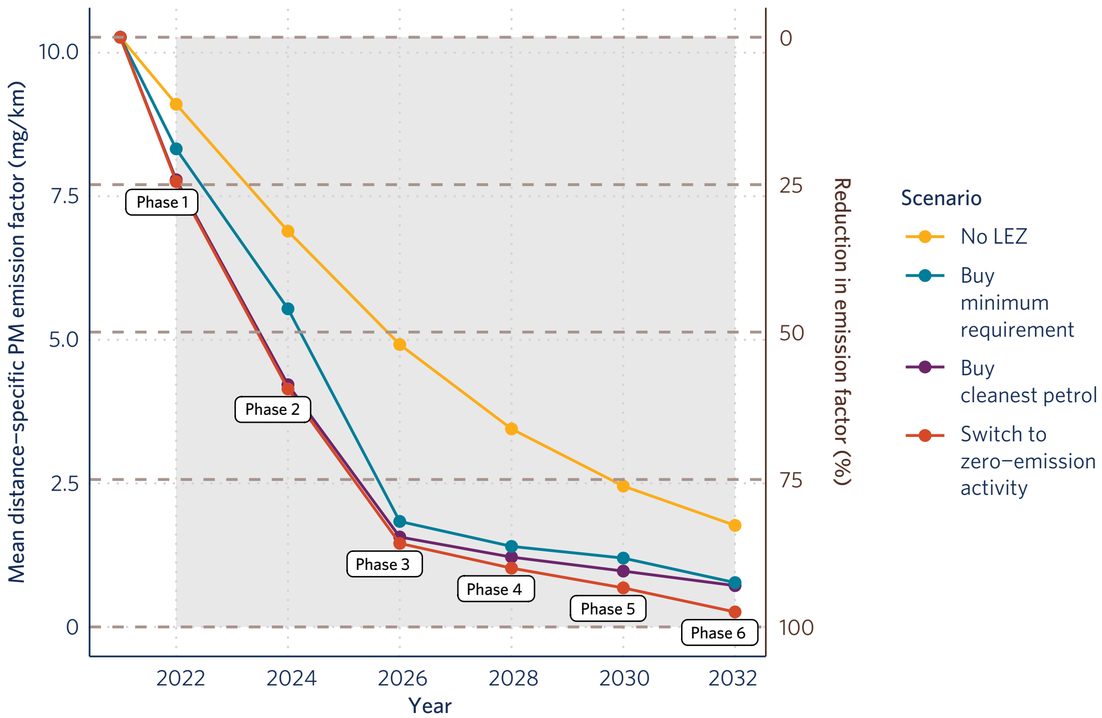

Figure 6. The effects of a low-emission zone on fleet-average passenger car PM emission factors for four scenarios. The grey shaded area indicates the timeframe the LEZ is in place.

Table 4. Years in which each scenario reaches 50% and 75% reduction in PM average emission factor and the numbers of years accelerated in comparison to the scenario with no LEZ.

Reduction in PM average emission factor	Scenario	Year	Number of years accelerated
50%	No LEZ	2026	
	LEZ - Buy cleanest petrol	2024	1.6
	LEZ - Buy minimum requirement	2024	2.3
	LEZ - Switch to zero-emission activity	2024	2.3
75%	No LEZ	2030	
	LEZ - Buy cleanest petrol	2026	4.2
	LEZ - Buy minimum requirement	2025	4.5
	LEZ - Switch to zero-emission activity	2025	4.6

EMISSION IMPACTS OF ACCELERATED LEZ IMPLEMENTATION

Accelerated implementation of the suggested LEZ design would bring about more immediate emission benefits. Under this implementation timeline, the same phases are implemented every year, instead of every other year, through 2027. As the timeframe of all LEZ phases moves forward while the natural fleet turnover remains the same, reductions in fleet-average NO_x and PM emission factors are achieved more rapidly.

Figure 7 shows the effects of the accelerated LEZ implementation on average NO_x emission factors. With the accelerated timeline, the last phase of the LEZ is implemented in 2027, five years earlier than that of the less rapid implementation timeline. By 2027, the projected NO_x emission factor reduction

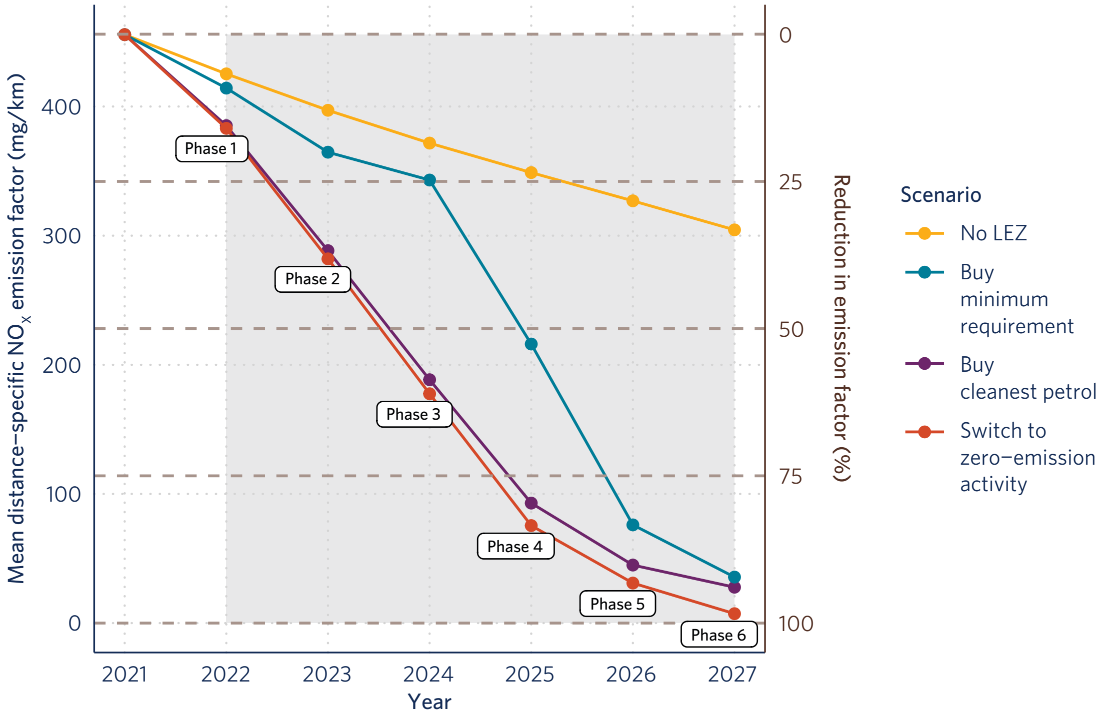

Figure 7. The effects of the accelerated implementation timeline of the low-emission zone on fleet-average passenger car NO_x emission factors for four scenarios. The grey shaded area indicates the timeframe the LEZ is in place.

Table 5. Years in which the baseline scenario and the scenarios that assume the accelerated LEZ implementation reach 50% and 75% reduction in average NO_x emission factor and the numbers of years accelerated in comparison to the scenarios with no LEZ.

Reduction in NO_x average emission factor	Scenario	Year	Number of years accelerated
50%	No LEZ	2030	
	LEZ - Buy minimum requirement	2025	5.3
	LEZ - Buy cleanest petrol	2024	6.6
	LEZ - Switch to zero-emission activity	2024	6.7
75%	No LEZ	2035	
	LEZ - Buy minimum requirement	2026	9.6
	LEZ - Buy cleanest petrol	2025	10.5
	LEZ - Switch to zero-emission activity	2025	10.7

for the *No LEZ* scenario is 33%. The accelerated LEZ implementation could achieve a similar level of reduction between 2023 and 2025 and exceed a 90% reduction by 2027. The responses of vehicle owners have a significant impact on the emission benefits until Phase 5. The *buy minimum requirement* scenario shows a significantly less reduction than the *buy cleanest petrol* or the *switch to zero-emission activity* scenarios because of the predominant shares of diesel Euro 5 and diesel Euro 6 in the city's total fleet in 2024 and 2025, respectively. Only from Euro 6d-TEMP, diesel vehicles show a significant improvement in emission performance and therefore help achieve a significant reduction in Phase 5.

Again, we take the points at which each scenario achieves a 50% and 75% reduction in the fleet-average NO_x emission factor relative to the 2021 level in order to compare the results with those of the less rapid LEZ implementation explored earlier in the study. Our results show that with the accelerated LEZ implementation, the 50% reduction goal is met approximately five to seven years earlier compared with the case with no LEZ and around two years earlier compared with the case of the less rapid LEZ implementation. With regards to the 75% reduction goal, the accelerated LEZ implementation reaches the target around 10 to 11 years earlier than the no LEZ case and around 3 to 4 years earlier than achieved by the slower LEZ implementation. These findings are summarized in Table 5.

Figure 8 shows the evolution of average PM emission factors for the four modeled scenarios in the case of the accelerated LEZ implementation. All LEZ scenarios show more expedited decrease in the average PM emission factor compared with the LEZ scenarios with implementation at two-year intervals. Notably, banning pre-Euro 5 vehicles, whether they are replaced by

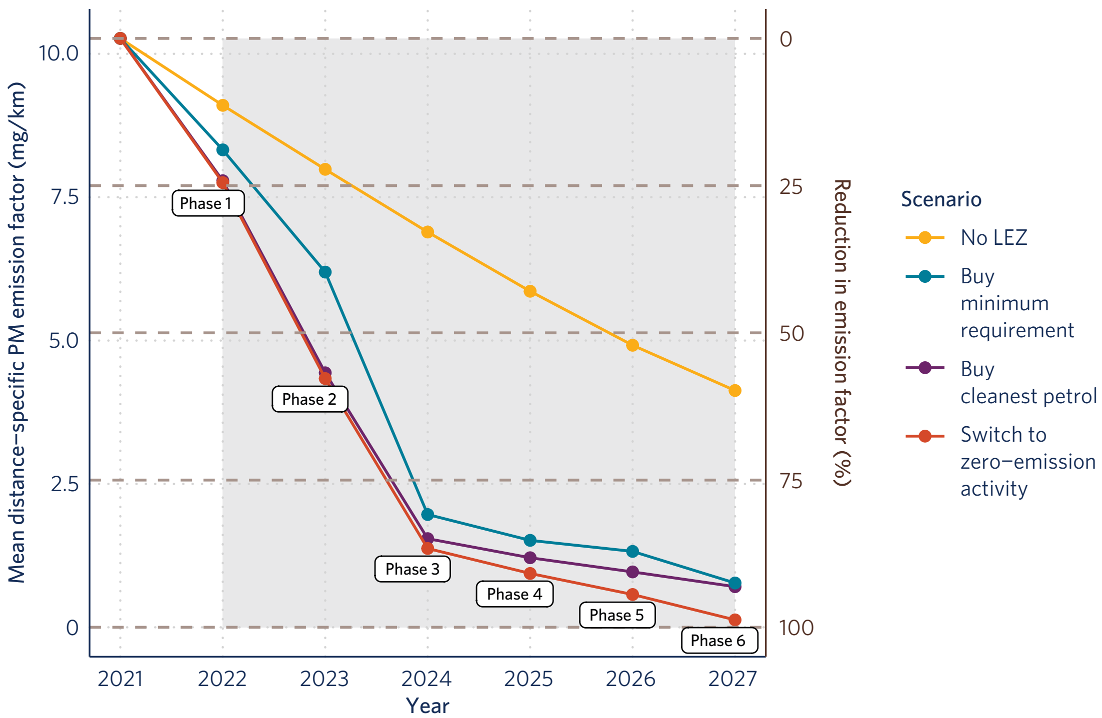

Figure 8. The effects of the more stringent low-emission zone on fleet-average passenger car PM emission factors for four scenarios. The grey shaded area indicates the timeframe the LEZ is in place.

Table 6. Years in which the baseline scenario and the scenarios that assume the accelerated LEZ implementation reach 50% and 75% reduction in average PM emission factor and the numbers of years accelerated in comparison to the scenarios with no LEZ.

Reduction in PM average emission factor	Scenario	Year	Number of years accelerated
50%	No LEZ	2026	
	LEZ - Buy minimum requirement	2023	2.5
	LEZ - Buy cleanest petrol	2023	3.0
	LEZ - Switch to zero-emission activity	2023	3.0
75%	No LEZ	2030	
	LEZ - Buy minimum requirement	2024	5.9
	LEZ - Buy cleanest petrol	2024	6.2
	LEZ - Switch to zero-emission activity	2024	6.2

other diesel vehicles equipped with diesel particulate filters, petrol vehicles, or zero-emission modes, will have substantial benefits. By 2027, the average PM emission factors estimated for all LEZ scenarios are at least 80% lower than in the baseline scenario, which is a greater relative reduction than what any LEZ scenarios can achieve at the end of the less rapid LEZ implementation timeline.

The accelerated implementation of LEZ shortens the time in which a 50% reduction in the average PM emission factor is achieved by about three years compared with the no LEZ scenario and by one year compared with the less rapid LEZ implementation case (Table 6). The differences are more striking for the 75% reduction goal. With the accelerated LEZ implementation, a 75% reduction in average PM emission factors is achieved around 1.7 years earlier than with the slower implementation.

More details on the evolution of average NO_x and PM emission factors in the case of the accelerated LEZ implementation are summarized in Table A2 of the appendix.

SUMMARY AND POLICY IMPLICATIONS

This analysis of the emissions impacts of a low-emission zone in Sofia reveals that the LEZ designed for this study can achieve a significant reduction in traffic-related NO_x and PM emissions regardless of how vehicle owners may respond to such a policy. In cities like Sofia, where the average vehicle is relatively old and thus more polluting, LEZs can accelerate transitions to cleaner transportation. A summary of our findings and how they can inform effective LEZ policy in Sofia are described below.

A well-designed LEZ could significantly accelerate reductions in NO_x and PM emissions in Sofia. A gradual phase-in of LEZ restrictions not only progressively increases emission benefits but also provides affected drivers adequate lead time to plan their future vehicle purchases. The implementation steps that phase out pre-Euro 6 diesel for NO_x emissions and pre-Euro 5 diesel vehicles for PM emissions are especially important for achieving emission reductions. Moreover, greater emission benefits can be achieved more quickly by tightening vehicle restrictions at a faster pace. The LEZ schedule that tightens restrictions every year would deliver a 75% reduction in NO_x emissions approximately three years earlier and PM emissions two years earlier than the two-year interval schedule.

Incentives to switch to clean or zero-emission vehicles would maximize the emission reduction benefits of the LEZ. When the non-compliant vehicles are replaced by clean vehicles or zero-emission transport, the LEZ yields a greater reduction in emissions. If affected drivers buy the minimum compliant vehicles, such as marginally cleaner used cars, the NO_x emission benefits of the LEZ are delayed significant until all pre-Euro 6d diesel vehicles are restricted. This finding implies that creating incentives for affected drivers to buy the best available standards or to opt for zero-emission transport options is necessary to maximize the impact of the LEZ. It is also important that these measures aim at helping lower-income drivers buy clean vehicles and more easily access zero-emission transport, such as public transit, cycling, and walking. For example, these can be purchase subsidies, development of charging infrastructure network, and consumer awareness campaign at both national and local levels. Ensuring that regular drivers in the LEZ are aware of the progressive restrictions that tighten every year or two could also help drivers make well-informed purchasing decisions rather than buying used vehicles that will have to be replaced in successive years.

Implementation of an LEZ should be supported with other policies to promote fair transition. An LEZ can play an important role in addressing the fact that low-income populations that are less likely to own a vehicle are disproportionately affected by air pollution.[24] An LEZ could alleviate the unequal distribution of health damages by tackling one of the main sources of air pollution in Sofia. Furthermore, lower-income drivers tend to be the least able to purchase new cars, as newer, cleaner vehicles are more costly. A just LEZ policy should thus consider increasing access to public transport by improving public transportation and cycling infrastructure and ensuring that public transport is more affordable than private cars. In addition, financial support could be offered to help lower-income groups purchase clean or zero-emission vehicles. A successful example of such a program is the French scrappage and EV replacement scheme that has helped France stabilize

24 Müller and Le Petit.

emissions from new passenger cars and increase sales of electric cars.[25] Establishing different rules for residents and small business owners and setting exceptions for emergency vehicles and drivers and passengers with disabilities should also be considered.

Monitoring and enforcement are key to ensure the effectiveness of the LEZ. The effectiveness of a LEZ in reducing emissions depends on numerous factors related to the LEZ design, such as enforcement mechanisms, the area covered, and stringency. City-specific factors can also impact its effectiveness, such as the contribution of road transport to air pollution, the prevalence of certain vehicle types and standards, and driver behavior. Projections can help shape how the LEZ is initially designed but monitoring is necessary to evaluate the effectiveness of the LEZ once put in place. Monitoring of ambient air quality in the LEZ, compliance rates, and the responses of affected drivers gives an opportunity to evaluate the policy performance and calibrate areas of improvement. Continuous investigation of real-world emissions would also help address uncertainties in long-term emission performance of new vehicles, such as Euro 6d diesel, and inform readjustments over time. Moreover, transparent communication of such process will be important to build public support around next phases or the expansion of the LEZ.

More ambitious LEZ options should be considered. The LEZ assessed in this study is one example of an LEZ that we designed based on the area currently under consideration. Aside from accelerated implementation, a more ambitious LEZ policy can include scaling up to cover the entire city or a greater geographic area over time to reap greater emission benefits for a larger fraction of residents. The Paris LEZ provides a good example of an LEZ first applied to the City of Paris and then and gradually expanding to the Greater Paris area over time, eventually covering the entire Metropolitan area.[26] Moreover, LEZ restrictions can be eventually extended to all vehicles that are certified below Euro 7, as the fuel-neutral standard that is expected to deliver a significant reduction in pollution.[27]

25 Sandra Wappelhorst, "Actions Speak Louder than Words: The French Commitment to Electric Vehicles," ICCT Staff Blog (blog), January 16, 2020, https://theicct.org/blog/staff/actions-speak-louder-words-french-commitment-electric-vehicles.

26 Bernard et al., "Impacts of the Paris Low-Emission Zone and Implications for Other Cities."

27 Eamonn Mulholland, Josh Miller, Caleb Braun, Lingzhi Jin, and Felipe Rodríguez, *Quantifying the long-term air quality and health benefits from Euro 7/VII standards in Europe*, (Washington, DC: ICCT, 2021), https://theicct.org/publications/eu-euro7-standards-health-benefits-jun21.

LIMITATIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

This study is based on modeling that relied on a number of assumptions which impact the results. The main assumptions included full compliance of all affected drivers, three purchasing patterns in response to an LEZ, and a constant total vehicle activity. Compliance rates and the behavior of affected drivers may vary depending, for example, on the level of awareness in drivers, the existence of a scrappage incentive scheme, or the accessibility of public transport. It is uncertain whether the total number of vehicles driven may decrease as a result of an LEZ or if there will be an influx of new vehicles, a phenomenon that Sofia has experienced in the last few years due to its growth. Further studies that track the changes in traffic activity, including the overall fleet composition, and survey compliance with the LEZ will be able to inform LEZ policies.

Future study should extend the focus to beyond passenger cars and other pollutants, such as hydrocarbons (HC), carbon monoxide (CO), and ammonia (NH_3), that pose a threat to human health. Light-commercial and heavy-duty vehicles made up 14% and 0.2% of the total measurements, respectively, and are likely to have higher distance-specific emissions than passenger cars but were not accounted for in this study. Capturing the entirety of the existing vehicle fleet will help account for the total emissions in the LEZ area. Including other pollutants that may come from sources other than tailpipes would further help address dangerous pollutants that are currently not regulated.

In addition, conducting new remote sensing campaigns in Sofia could be used to monitor and measure the effects of the LEZ. The additional remote sensing measurements would help define local emission factors that can be used to produce refined projections. Regular testing campaigns can also offer a means of continuous monitoring and evaluation of the LEZ implementation stages.

APPENDIX

The tables below show the changes in the emission factors and the percent changes compared to the reference year (2021) for both NO_x and PM. Table A1 corresponds to Figures 5 and 6 and Table A2 to Figures 7 and 8 in the results section.

Table A1. Mean distance-specific NO_x and PM emission factors for all scenarios when each phase of the LEZ is implemented every two years.

Scenario	Phase	Year	Change in NO_x emission factor (mg/km)	Percent change compared to 2021	Change in PM emission factor (mg/km)	Percent change compared to 2021
No LEZ	Phase0	2021	456	0%	10.3	0%
	Phase1	2022	425	-7%	9.1	-11%
	Phase2	2024	372	-18%	6.9	-33%
	Phase3	2026	327	-28%	4.9	-52%
	Phase4	2028	281	-38%	3.4	-66%
	Phase5	2030	234	-49%	2.5	-76%
	Phase6	2032	185	-59%	1.8	-83%
LEZ - Buy minimum requirement	Phase0	2021	456	0%	10.3	0%
	Phase1	2022	414	-9%	8.3	-19%
	Phase2	2024	348	-24%	5.5	-46%
	Phase3	2026	311	-32%	1.8	-82%
	Phase4	2028	191	-58%	1.4	-86%
	Phase5	2030	68	-85%	1.2	-88%
	Phase6	2032	33	-93%	0.8	-92%
LEZ - Buy cleanest petrol	Phase0	2021	456	0%	10.3	0%
	Phase1	2022	385	-15%	7.8	-24%
	Phase2	2024	291	-36%	4.2	-59%
	Phase3	2026	206	-55%	1.6	-85%
	Phase4	2028	93	-80%	1.2	-88%
	Phase5	2030	45	-90%	1	-91%
	Phase6	2032	27	-94%	0.7	-93%
LEZ - Switch to zero-emission activity	Phase0	2021	456	0%	10.3	0%
	Phase1	2022	383	-16%	7.8	-24%
	Phase2	2024	286	-37%	4.1	-60%
	Phase3	2026	202	-56%	1.5	-86%
	Phase4	2028	86	-81%	1	-90%
	Phase5	2030	35	-92%	0.7	-93%
	Phase6	2032	11	-98%	0.3	-97%

Table A2. Percentage decreases of NO_x and PM average emission factors for all scenarios in the more stringent LEZ design.

Scenario	Phase	Year	Change in NO_x emission factor (mg/km)	Percent change compared to 2021	Change in PM emission factor (mg/km)	Percent change compared to 2021
No LEZ	Phase0	2021	456	0%	10.3	0%
	Phase1	2022	425	-7%	9.1	-11%
	Phase2	2023	397	-13%	8	-22%
	Phase3	2024	372	-18%	6.9	-33%
	Phase4	2025	349	-23%	5.9	-43%
	Phase5	2026	327	-28%	4.9	-52%
	Phase6	2027	304	-33%	4.1	-60%
LEZ - Buy minimum requirement	Phase0	2021	456	0%	10.3	0%
	Phase1	2022	414	-9%	8.3	-19%
	Phase2	2023	365	-20%	6.2	-40%
	Phase3	2024	343	-25%	2	-81%
	Phase4	2025	216	-53%	1.5	-85%
	Phase5	2026	76	-83%	1.3	-87%
	Phase6	2027	36	-92%	0.8	-92%
LEZ - Buy cleanest petrol	Phase0	2021	456	0%	10.3	0%
	Phase1	2022	385	-15%	7.8	-24%
	Phase2	2023	288	-37%	4.4	-57%
	Phase3	2024	188	-59%	1.5	-85%
	Phase4	2025	93	-80%	1.2	-88%
	Phase5	2026	45	-90%	1	-91%
	Phase6	2027	28	-94%	0.7	-93%
LEZ - Switch to zero-emission activity	Phase0	2021	456	0%	10.3	0%
	Phase1	2022	383	-16%	7.8	-24%
	Phase2	2023	282	-38%	4.3	-58%
	Phase3	2024	178	-61%	1.4	-87%
	Phase4	2025	75	-83%	0.9	-91%
	Phase5	2026	31	-93%	0.6	-94%
	Phase6	2027	7	-98%	0.1	-99%

THE REAL URBAN EMISSIONS INITIATIVE

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