TECHNICAL NOTE
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Potential impacts of a low-emission zone on air pollutant emissions in Gliwice

Kaylin Lee, Rohit Nepali, Mallery Crowe, Jakob Schmidt, and Yoann Bernard

INTRODUCTION

The Silesia region in Poland, where Gliwice is one of the main urban centers with around 170,000 inhabitants, faces considerable air quality challenges.[1] It is also the most industrialized region in Poland and the biggest coal mining region in the European Union.[2] In 2022, the region reported an annual average particulate matter (PM)—in this case $PM_{2.5}$—concentration four times higher than World Health Organization (WHO) guidelines and an annual average nitrogen dioxide (NO_2) concentration approximately three times higher than WHO guidelines.[3] In the urban area of Upper Silesia where most of region's population lives, exposure to PM and NO_2 is significantly associated with increased respiratory diseases, including asthma, in children and adults.[4]

Vehicle transport is the second biggest source of the emissions of nitrogen oxides (NO_x) in Upper Silesia, accounting for 22% of total NO_x emissions.[5] In the urban areas of Upper Silesia, NO_x and PM emissions from road transportation are more elevated than in rural areas.[6] One widely adopted strategy to reduce transport-related emissions in cities is the low-emission zone (LEZ), an area in which vehicle access is restricted to limit highly polluting vehicles. LEZs have been effective in curbing pollutant emissions and have already been introduced in major Polish cities, including Krakow and Warsaw. A previous study conducted by The Real Urban Emissions (TRUE) Initiative found that a carefully designed LEZ in Warsaw could reduce NO_x and PM emissions by 50% in 2–3 years, compared with 2023 levels, and it highlighted the potential benefits LEZs can have in other Polish cities.[7]

This Technical Note assesses the potential vehicle emission reductions that could be achieved by implementing an LEZ in Gliwice between 2026 and 2035. Utilizing the real-world emission factors derived from an emissions testing campaign in Warsaw and methodology developed in a previous TRUE study, we evaluate changes in NO_x and PM emissions under three different scenarios of vehicle owner response to the LEZ. We conclude with policy recommendations for Gliwice based on the findings.

METHODOLOGY

There is currently no LEZ in Gliwice, and we first outline a potential LEZ design that could effectively reduce vehicle emissions in the city; this is based on real-world data of fleet activity and emissions. Next, we apply the same approach as the previous TRUE Warsaw study and use the International Council on Clean Transportation's (ICCT) LEZ model V2.1.8 to assess the impacts of implementing an LEZ on fleet emission factors for NO_x and PM.[8] The LEZ model uses real-world measurements of vehicle emissions and fleet composition to evaluate changes in fleet-average emissions for various scenarios of vehicle owners' reactions to LEZ implementation.

1 European Union, "Silesia, Poland - Regional Profile," 2023, https://energy.ec.europa.eu/system/files/2023-12/Silesia_2023.pdf.

2 European Union, "Silesia."

3 European Environment Agency, "Air Quality Statistics," 2022, https://www.eea.europa.eu/data-and-maps/dashboards/air-quality-statistics.

4 Joanna Kobza et al., "Exposure to PM2.5 and PM10 Pollution and the Risk of Respiratory Diseases in Upper Silesia Inhabitants," *Journal of Education, Health and Sport* 13, no. 5 (2023): 80–86, https://doi.org/10.12775/JEHS.2023.13.05.011.; Bernard Połednik, "Emissions of Air Pollution in Industrial and Rural Region in Poland and Health Impacts," *Journal of Ecological Engineering* 23, no. 9 (2022): 250–58, https://doi.org/10.12911/22998993/151986.

5 Energy production is the first biggest source of NO_x emissions in Poland, accounting for approximately 72% of total NO_x emissions. Andrzej Szczygieł et al., Annual Assessment of Air Quality in the Silesian Voivodeship. Voivodeship Report for 2018 - GIOŚ, 2019, https://powietrze.gios.gov.pl/pjp/publications/card/14063.

6 Połednik, "Emissions of Air Pollution."

7 Rohit Nepali et al., *Impacts of a Low-Emission Zone on Air Pollutant and Greenhouse Gas Emissions in Warsaw* (TRUE Initiative, 2023), https://www.trueinitiative.org/publications/reports/impacts-of-a-low-emission-zone-on-air-pollutant-and-greenhouse-gas-emissions-in-warsaw.

8 For a description of the functionality of the ICCT's LEZ model, see https://theicct.github.io/LEZ-doc/.

UNDERLYING DATA

We use the data from approximately 44,600 measurements of 20,847 unique passenger cars captured by the Automatic License Plate Recognition (ALPR) camera in Gliwice on June 20, 2022.[9] These cars had valid license plate records in the Polish Central Register of Vehicles and Drivers registry database, and from there we retrieved their fuel type, age, and emission standard information. The ALPR camera data were used as a proxy for vehicle activity in Gliwice instead of the registry data because the camera data more accurately reflect on-road vehicle composition. For example, that newer vehicles were captured by the camera more frequently than older vehicles implies that vehicle activity may vary by vehicle age.

Petrol was the most common fuel type, 50% of all passenger cars measured in 2022, and was followed by diesel, 34%, and liquefied petroleum gas (LPG), 14%. Hybrid cars made up 2% and electric cars less than 1%. As shown in Figure 1, a quarter of the cars measured were certified to the Euro 4 emission standard. Cars certified to Euro 5, Euro 6, and Euro 3 were approximately 18%, 18%, and 17%, respectively, of those measured. Newer vehicles certified to Euro 6d-TEMP and Euro 6d accounted for around 7% each, and the oldest vehicles certified to Euro 0–2 were 6%.[10]

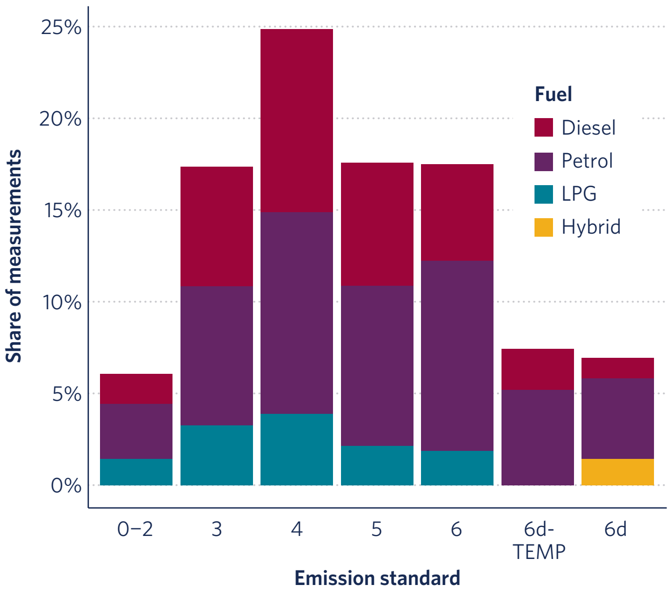

Figure 1. Fuel type and emission standard of passenger cars measured in Gliwice. Euro standards are emission standards for vehicle pollution first introduced by the European Union in 1992 and designed to become increasingly stringent over time.

Note: Only groups accounting for 1% or more of the total measurements are presented.

Passenger car activity in Gliwice is largely dominated by newer vehicles coming from outside the city. Information for only 40% of the measured vehicles was available from the city's registry database; 60% were vehicles registered elsewhere in Poland. The average age of cars operating in Gliwice, including those registered elsewhere, is 11 years and that of vehicles registered in Gliwice is 14 years. A large share—42%—of cars driven in Gliwice are imported used vehicles.

Our projections of the future composition of the Gliwice fleet are based on Gliwice-specific data and Poland-specific sales growth rates and Poland's year-over-year survival rate; the latter is the rate of vehicles that survive from one year to the next.[11] We assume that the growth in battery electric vehicles (BEVs) sales aligns with the European Union's "Fit for 55" package, the climate law designed to reduce the European Union's greenhouse gas emissions by 55% by 2030, and that includes a plan to end the sale of passenger cars with internal combustion engines by 2035.

In the absence of emission factors for the Gliwice fleet, we use the real-world emission factors derived from measurements collected in Warsaw in 2020, assuming similarities in fleet emissions across Poland. These emission factors represent emissions from vehicles operating under real urban driving conditions. The distance-specific NO_x and PM emission factors (mg/km) for passenger cars by fuel type and emission standard are summarized in Table 1.

9 Gliwice's vehicle registry database shows a total of 133,752 registered vehicles. However, this number does not reflect the number of in-use vehicles, as vehicles are not de-registered when no longer in use.

10 No information on Euro standard or fuel type was available for the remaining 3%.

11 Sales growth rates are calibrated to match the change in passenger transport activity projected in the EU Reference Scenario 2020, a baseline scenario developed by the European Commission based on the policy framework in place in 2020 and an analytical basis for assessing new policy proposals, https://energy.ec.europa.eu/data-and-analysis/energy-modelling/eu-reference-scenario-2020_en.

Table 1. Distance-specific tailpipe NO_x and PM emission factors for passenger cars in Poland

Fuel	Diesel		Petrol	
Standard	**NO_x (mg/km)**	**PM (mg/km)**	**NO_x (mg/km)**	**PM (mg/km)**
Euro 1	1,113	95	1,022	23
Euro 2	1,152	61	873	15
Euro 3	1,069	48	534	6.8
Euro 4	750	30	276	2.8
Euro 5	692	6.4	169	2.6
Euro 6	345	2.5	121	2.1
Euro 6d-TEMP	135	1.9	93	1.5
Euro 6d	92[a]	1.9	63[a]	1.5
Euro 6e - 7	71[a]	1.9	49[a]	1.5

[a] Due to insufficient measurements, the emission factors of vehicles certified to Euro 6d were estimated by applying the relative change in conformity factors, which were lowered from 2.1 to 1.43, to the emission factor of Euro 6d-TEMP vehicles. Euro 6e, an emission standard fully introduced from September 2024, further reduced the conformity factor to 1.10. The same method was used to estimate the emission factors of Euro 6e vehicles. Euro 7, planned to be fully implemented in November 2027, is not expected to achieve further reduction in emissions. Therefore, we assume the same emission factors for Euro 7 as Euro 6e.

POTENTIAL LEZ FOR PASSENGER CARS IN GLIWICE

An effective LEZ should maximize emission impacts while minimizing the burden on vehicle owners. Therefore, we designed an LEZ that prioritizes the phaseout of older diesel cars that disproportionately impact vehicle emissions in Gliwice, as shown in Table 2. Our LEZ design, informed by the fleet and emissions data described above, is for passenger cars only, as they made up 85% the vehicles measured in Gliwice, and applies to all vehicles within the boundaries of Gliwice.

In our design, starting in early 2026, only diesel cars certified to Euro 4 and above and petrol cars certified to Euro 3 and above would be allowed in the LEZ. Older diesel cars certified to Euro 3 or below, which would be restricted first, have NO_x and PM emissions 1.1–2.0 times and 4.1–7.1 times, respectively, higher than their petrol counterparts. In Gliwice, these vehicles accounted for 11% of the vehicle activity measured in 2022 and are projected to fall to 5% by 2026. LEZ restrictions would become progressively more stringent every 3 years until 2035; 3 years between phases provide sufficient time for vehicle owners to plan their vehicle purchases. In the last phase, only diesel cars certified to Euro 6d and above and petrol cars certified to Euro 6 and above would be permitted in the LEZ.

Table 2. LEZ implementation schedule with minimum emission standards of different vehicles allowed in the LEZ

Passenger car	Minimum standard				Implementation schedule
Phase	**Diesel**	**Age (in years)**	**Petrol**	**Age (in years)**	**LEZ**
0	n/a		n/a		2025
1	Euro 4	≤20	Euro 3	≤25	2026
2	Euro 5	≤18	Euro 4	≤23	2029
3	Euro 6	≤18	Euro 5	≤21	2032
4	Euro 6d	≤15	Euro 6	≤20	2035

Note: The exact age of vehicles might vary by ±1 year depending on the registration date of a vehicle certified to each emission standard.

MODELING LEZ SCENARIOS

We modeled the changes in fleet-average distance-specific NO_x and PM emissions from the implementation of the designed LEZ from 2025–2035. We evaluated the emission reductions for a baseline scenario representing no LEZ implementation and three scenarios representing different potential vehicle owner responses to the LEZ, as shown in Figure 2.[12] Actual vehicle owner responses to the LEZ are anticipated to fall within the spectrum of these scenarios. Figure 2 includes public transport in the switch to zero-emission alternatives scenario, as we assume the existing network (e.g., buses, trams, metro) can accommodate increases in passenger activity without a substantial increase in emissions.

Scenario with no LEZ

Baseline scenario,or No LEZ scenario
Natural fleet turnover with no LEZ in place.

Scenarios with LEZ implementation

Buy 100% used vehicles scenario
Vehicle owners replace their LEZ-non-compliant vehicles with used vehicles of varying emission standards and fuel types (including BEVs) that meet the LEZ requirement.

Buy 100% new vehicles scenario
Vehicle owners replace their LEZ-non-compliant vehicles with new vehicles of varying fuel types (including BEVs) certified to the best available standards.

Switch to zero-emission alternatives scenario
Vehicle owners replace their LEZ-non-compliant vehicles with BEVs or switch their means of mobility to walking, cycling, or public transportation.

Figure 2. LEZ scenarios considered in this analysis

12 In the *Buy 100% used vehicles* scenario, all non-compliant cars are replaced by used vehicles the fuel type compositions of which correspond to those of the fleet during the year of LEZ implementation. In the *Buy 100% new vehicles* scenario, all non-compliant cars would be replaced by vehicles of the newest available standard, the fuel type composition of which corresponds to that of the respective sales during the year of LEZ implementation. Fuel types considered in the model include diesel, petrol, and electricity (BEVs). In the *Switch to zero-emission alternatives* scenario, all non-compliant cars would be replaced by zero-emission mobility, including BEVs, cycling, and public transportation.

We evaluate emissions impacts assuming complete compliance of all vehicles entering the LEZ with the implementation of each phase. We further assume vehicle owners will modify their behavior in anticipation of the LEZ before its introduction at the start of 2026 and that the emissions decrease is linear between phases, as new vehicles replacing retiring vehicles would have improved emission standards and, therefore, lower emissions.

PROJECTED IMPACT ON AIR POLLUTANT EMISSIONS

To evaluate the effects of the LEZ on NO_x and PM tailpipe emissions from passenger cars, we analyzed the fleet-average distance-specific emissions (mg/km) for each phase of the LEZ. This analysis encompasses results for all scenarios for the years 2025–2035.

LEZ IMPACT ON NO_x EMISSIONS

Compared to the *No LEZ* scenario, all LEZ scenarios exhibit steeper declines in the fleet-average distance-specific NO_x emissions, as depicted in Figure 3. By targeting vehicle groups with disproportionate emissions, the LEZ could immediately achieve large emission benefits. While impacting only about 8% of the fleet, Phase 1 achieves a 21%–28% reduction in fleet-average NO_x emissions compared with 2025 levels in 2026, 3–4 times higher than the *No LEZ* scenario.

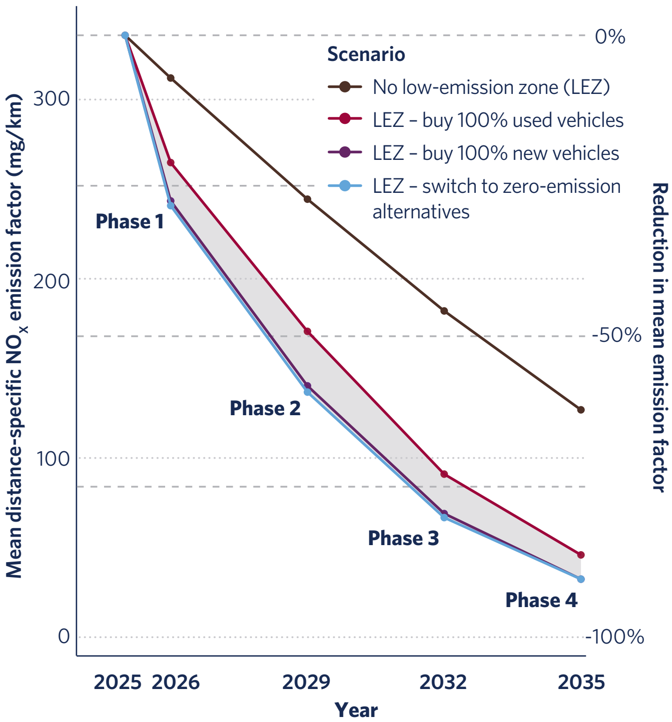

Figure 3. LEZ effects on fleet-average distance-specific NO_x emissions for passenger cars for four scenarios

Note: The shaded area shows the range of possible emission reductions that depend on responses of vehicle owners affected by LEZ restrictions.

In the *No LEZ* scenario, there is a gradual decrease in air pollutant emissions over time due to natural fleet turnover, as older vehicles retire and are replaced by a combination of new and used vehicles with improved emissions performance. However, the *buy 100% new vehicles and switch to zero-emission alternatives* scenarios achieve a substantially larger reduction in NO_x emissions. These two scenarios follow similar trajectories, because the uptake of BEVs is expected to increase notably over the years leading up to 2035, when 100% of new passenger cars sold are set to be zero-emission vehicles. Thus, under the *buy 100% new vehicles* scenario, many affected vehicle owners replace their non-compliant vehicles with BEVs, like the *switch to zero-emission alternatives* scenario. This highlights the benefits that can still be achieved if affected vehicle owners choose to replace their non-compliant vehicles with cars certified to newer emission standards, even without immediately transitioning to zero-emission alternatives.

The *buy 100% used vehicles* scenario closely resembles the downward trajectory of the *buy 100% new vehicles and switch to zero-emission alternatives* scenarios. This is primarily because the used vehicles introduced to meet LEZ requirements are primarily petrol vehicles and are cleaner than the older diesel vehicles they replace. For example, the NO_x emissions of Euro 5 petrol cars are one-tenth that of Euro 3 diesel cars.

In general, it is expected that in response to the implementation of an LEZ in Gliwice, vehicle owners would exhibit behavior that falls within the spectrum of these three scenarios. All LEZ scenarios could reduce NO_x emissions by more than 86% by 2035 (Phase 4). Although the *buy 100% new vehicles* and *switch to zero-emission alternatives* offer slightly greater average NO_x emissions reductions, the impact of the *buy 100% used vehicles* scenario on average NO_x emissions remains large.

LEZ IMPACT ON PM EMISSIONS

As illustrated in Figure 4, the implementation of an LEZ has a more immediate and pronounced effect on fleet-average PM emissions than fleet-average NO_x emissions. Phase 1 of the LEZ achieves a 37%–43% reduction in PM emissions while impacting 8% of the fleet. By Phase 2, all LEZ scenarios lead to estimated fleet-average PM emissions 73%–78% lower than in 2025. This substantial reduction in average PM emissions is primarily due to the restriction on Euro 4 diesel vehicles during Phase 2. Euro 4 diesel vehicles are the last diesel vehicles that could meet emission standards without the use of a diesel particulate filter (DPF), a technology that reduces the PM emissions of diesel vehicles. DPFs contributed to the 80% reduction in PM emissions between Euro 4 and Euro 5 diesel vehicles (Table 1).

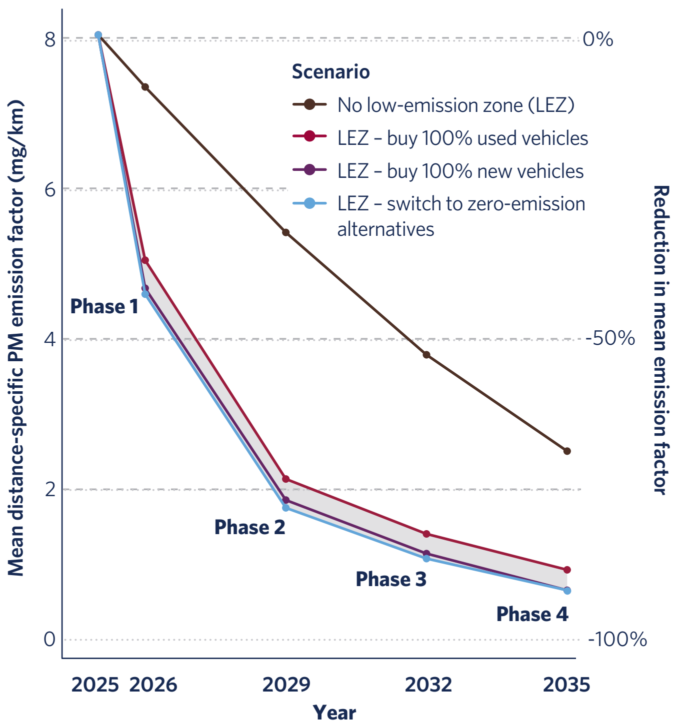

Figure 4. LEZ effects on fleet-average distance-specific PM emissions for passenger cars for four scenarios

Note: The shaded area shows the range of possible emission reductions that depend on responses of vehicle owners affected by LEZ restrictions.

After Phase 2, PM emissions continue to steadily fall in all scenarios but by a lesser magnitude. This is largely because both diesel (Euro 6 and above) and petrol cars (Euro 5 and above) permitted in the LEZ emit low PM emissions (≤2.6 mg/km); cars of subsequent emission standards achieve minor emission reductions compared with those achieved in preceding standards. By Phase 4, all LEZ scenarios would lead to, at minimum, an 88% reduction in fleet-average PM emissions, irrespective of vehicle-owner response.

TIME SAVED IN ACHIEVING 50% AND 75% REDUCTIONS IN EMISSIONS

This section examines and compares the years in which each LEZ scenario attains a 50% and 75% reduction in the fleet-average NO_x and PM emissions relative to 2025. Fleet-average NO_x emissions are expected to decrease by 50% by 2032 without an LEZ. However, with an LEZ, this reduction can be achieved as soon as 2028. Moreover, an LEZ could achieve a 75% reduction in NO_x by as soon as 2031 in the *buy 100% new vehicles* and *switch to zero-emission alternatives* scenarios, 7 years earlier than the scenario without an LEZ. The fleet-average PM emissions are expected to decrease by 50% in 2031 without an LEZ, but this reduction could be achieved as soon as 2026, during Phase 1 of the LEZ. An LEZ could achieve a 75% reduction in PM emissions by 2028, 8 years earlier than the scenario without an LEZ.

Table 3. Year in which each LEZ scenario attains a 50% and 75% reduction in the fleet-average NO_x and PM emissions relative to 2025 levels and the number of years saved compared with the No LEZ scenario

Reduction in average air pollutant emissions	Scenario	NO_x		PM	
		Year	Numbers of years sooner than No LEZ	Year	Numbers of years sooner than no LEZ
50%	No LEZ	2032		2031	
	LEZ – buy 100% used vehicles	2029	3.7	2027	4.5
	LEZ – buy 100% new vehicles	2028	4.6	2026	4.9
	LEZ – switch to zero-emission alternatives	2028	4.7	2026	5.0
75%	No LEZ	2038		2037	
	LEZ – buy 100% used vehicles	2032	5.9	2029	7.3
	LEZ – buy 100% new vehicles	2031	7.0	2028	8.1
	LEZ – switch to zero-emission alternatives	2031	7.1	2028	8.2

CONCLUSIONS AND POLICY RECOMMENDATIONS

This study used ALPR data from Gliwice in 2022 and passenger car emissions data from Warsaw in 2020 to evaluate the potential NO_x and PM emission reductions that could be achieved through the implementation of an LEZ in Gliwice. We analyzed a potential LEZ design that would first restrict the access of cars with disproportionate pollutant emissions, starting in 2026. Restrictions would become progressively more stringent every 3 years until 2035, when only diesel cars certified to Euro 6d and above and petrol cars certified to Euro 6 and above would be permitted in the zone. Three different scenarios of vehicle owner response to the LEZ were modeled to assess emission benefits. There are four key findings:

1. **An LEZ that restricts the oldest, highest-emitting vehicle groups first would have immediate benefits while minimizing impacts on vehicle owners.** By Phase 1, the LEZ could achieve a 21%–28% reduction in fleet-average NO_x emissions and a 37%–43% reduction in fleet-average PM emissions while impacting only about 8% of the passenger car fleet. Identifying vehicle groups with disproportionate impacts on emissions and prioritizing the restriction of these groups with an LEZ could help ensure the LEZ is immediately effective and minimize the impact on vehicle owners.
2. **Regardless of vehicle owners' exact response to the LEZ, the NO_x and PM benefits of an LEZ would be substantial compared with a scenario with no LEZ.** With the assumption that the uptake of BEVs would increase to align with the European Union's goal of 100% zero-emission vehicles by 2035, the LEZ designed for this study would achieve at least an 86% reduction in NO_x and an 88% reduction in PM emissions by Phase 4, compared with 2025 levels; that is at least 20%–24% more than the reduction achieved without an LEZ.
3. **Phasing out pre-Euro 5 diesel vehicles that are not equipped with DPFs would substantially reduce PM emissions in Gliwice.** By Phase 2, or in 2029, the LEZ could reduce 73%–78% of average PM emissions compared with 2025 levels, more than double the reduction that could be achieved without an LEZ. It will become important from the implementation of Phase 2 to also detect diesel vehicles with malfunctioning or removed DPFs that require repair. This could be done through particle number testing as part of periodic technical inspection (PTI), which is mandatory in some European countries, including Belgium, Germany, and Switzerland.[13]
4. **Promoting a swift transition to zero-emission alternatives, including BEVs, public transport, walking, and cycling, would help minimize the impact of LEZ implementation on vehicle owners.** For example, scrappage schemes, financial incentives for cleaner cars, and appropriate exemptions for seniors could alleviate the burdens on owners of older cars or people who use their cars infrequently.

13 "Emission Standards: European Union: Periodic Technical Inspections (PTI)," accessed August 15, 2024, https://dieselnet.com/standards/eu/pti.php.

APPENDIX

Table A1. Mean distance-specific NO_x and PM emission factors for passenger cars under all scenarios

Scenario	Phase	Year	Percent change in NO_x compared with 2025	Average NO_x emission factor (mg/km)	Percent change in PM compared with 2025	Average PM emission factor (mg/km)
No LEZ	0	2025	0%	335.9	0%	8
	1	2026	-7%	312	-9%	7.3
	2	2029	-27%	244.4	-32%	5.4
	3	2032	-46%	182	-53%	3.8
	4	2035	-62%	126.9	-68%	2.5
LEZ - buy 100% used vehicles	0	2025	0%	335.9	0%	8
	1	2026	-21%	264.8	-37%	5.1
	2	2029	-49%	170.7	-73%	2.2
	3	2032	-73%	91	-82%	1.4
	4	2035	-86%	45.9	-88%	1
LEZ - buy 100% new vehicles	0	2025	0%	335.9	0%	8
	1	2026	-28%	243.4	-42%	4.7
	2	2029	-58%	140.2	-76%	1.9
	3	2032	-79%	69	-85%	1.2
	4	2035	-90%	32.4	-91%	0.7
LEZ - switch to zero-emission alternatives	0	2025	0%	335.9	0%	8
	1	2026	-28%	240.8	-43%	4.6
	2	2029	-59%	136.8	-78%	1.8
	3	2032	-80%	66.7	-86%	1.1
	4	2035	-90%	32.4	-91%	0.7

THE REAL URBAN EMISSIONS INITIATIVE

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TO FIND OUT MORE

For details on the TRUE remote sensing database,
contact **Yoann Bernard**, **y.bernard@theicct.org**.
For more information on TRUE, visit **www.trueinitiative.org**.