



Assessment of real-world vehicle emissions in Bogotá, Colombia

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FIA Foundation and the International Council on Clean Transportation 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.

EXECUTIVE SUMMARY

Vehicle-related air pollution is a major challenge for the city of Bogotá, Colombia's capital. Yearly ambient concentrations of particulate matter (PM) in Bogotá surpass World Health Organization standards of 5 mg/m³ by over 3 times, the transport sector contributing a substantial share of the city's PM.

Policies underway to tackle vehicle-related pollution in Bogotá include national vehicle emission standards, progressive electrification of the extensive public bus network, traffic restriction policies, and prioritization of areas for targeted air pollution reduction. Although Colombia adopted Euro VI/6-equivalent emission standards in 2023 for heavy-duty vehicles as well as diesel and compressed natural gas (CNG) light-duty vehicles, gasoline light-duty vehicles are subject to less stringent Euro 4 emission standards. At the city level, Bogotá boasts one of the largest bus rapid transit networks worldwide. This network operates with over 1,400 electric buses, with ongoing efforts to replace diesel buses with lower- or zero-emitting alternatives to reach the goal to be fully electric by 2036. Bogotá's peak and plate (*pico y placa*) policy restricts vehicle travel by license plate letters every weekday to combat vehicle congestion in the city. The Urban Zones for Better Air (*Zonas Urbanas por un Mejor Aire* [ZUMA]) initiative designates areas of the city to be prioritized for interdisciplinary initiatives to reduce air pollution.

This study, conducted by The Real Urban Emissions (TRUE) Initiative, provides insights on real-world exhaust emissions of nitrogen oxides (NO_x), hydrocarbons (HC), carbon monoxide (CO), and PM from vehicles in Bogotá collected in September and October 2023. The report examines the distribution, characteristics, and emissions of vehicles measured in Bogotá and identifies ways that policies can help reduce vehicle-related pollution in the city.

This analysis demonstrates that progressive implementation of emission standards has reduced emissions in Bogotá; however, certain vehicle segments continue to exhibit high emission levels and warrant targeted policy intervention. The results support the following conclusions and policy recommendations:

Diesel vehicles showed NO_x and PM emissions above certification limits, highlighting the importance of prioritizing these segments for inspection and maintenance and real-world vehicle emission

surveillance. All diesel vehicles measured showed little improvement in NO_x emissions with increasing emission standards. Diesel minibuses and light trucks showed NO_x emissions over 4 times the Euro 4 type-approval limit. Diesel buses and heavy-duty vehicles showed PM emissions 7 and 15 times Euro IV type-approval limits, respectively. Roadside remote sensing could be employed to detect high-emitting diesel vehicles and serve as a tool for market surveillance to verify that vehicles meet emission standards under real-world operating conditions. These results also highlight the importance of Bogotá's accelerated phase-out of diesel buses in favor of lower-emitting and electric buses.

Gasoline passenger car emissions in Colombia have decreased through progressive vehicle emissions standards, and further reductions could be achieved by adopting Euro 6 requirements. Gasoline passenger cars manufactured since 2023 emitted 88%–96% lower average NO_x, PM, HC, and CO emissions compared with pre-1998 vehicles, which were manufactured before emission standards were established in Colombia. Evidence from other cities shows that transitioning to Euro 6 standards, with stricter NO_x emission limits and on-road testing, can help reduce real-world emissions.

Pre-2010 gasoline passenger cars contribute disproportionately to emissions of all pollutants studied, indicating that restrictions on their operation could effectively reduce emissions. Gasoline passenger cars manufactured before 2010 (prior to Euro 2 emission standards in Colombia), which made up 24% of the gasoline passenger car fleet measured, contributed between 43% and 58% of cumulative NO_x, PM, HC, and CO distance-specific emissions. Existing policies that could progressively limit the operation of pre-2010 vehicles include the *pico y placa* policy and the ZUMA initiative. These restrictions could be paired with incentives to support vehicle owners to transition to newer, lower-emitting models.

CNG light-duty vehicles emitted over double the NO_x emissions of their gasoline counterparts. CNG passenger cars and light trucks were shown to emit over double the real-world NO_x of comparable gasoline vehicles. Higher emissions among CNG vehicles may be attributable to vehicles retrofitted to use CNG rather than manufactured to use CNG, as these groups were not distinguishable in this study. Presently, owners of certain CNG-powered vehicles receive multiple benefits, including exemption from the *pico y placa* traffic restrictions and discounted annual vehicle tax

and annual vehicle insurance. Emission reductions could be maximized by focusing on incentivizing electric light-duty vehicles over internal combustion engine vehicles.

Policies to address the highest emitting taxis through maintenance and scrappage would help to reduce their elevated real-world emissions. Taxis in Bogotá showed up to 3 to 5 times higher real-world average NO_x , CO, HC, and PM emissions compared with private counterparts of the same model year, indicative of likely widespread CNG retrofitting and accelerated

emissions control system deterioration. Adding an NO_x limit to mandatory periodic testing could help to identify and address high-emitting taxis. Additionally, a rebate program could support taxi owners in Bogotá to scrap older taxis and purchase newer models of Euro 4 emission standards or higher. Focusing on the oldest 25% of taxis—those that are 13 years or older—can help phase out the highest-emitting vehicles.



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INTRODUCTION

Air pollution is a major issue in Bogotá, Colombia's capital and largest city with a population of over 7 million people.¹ Yearly ambient concentrations of fine particulate matter (PM_{2.5}) have consistently exceeded 16 mg/m³ over the last 10 years, which is over 3 times the World Health Organization standard of 5 mg/m³.² Findings from Colombia's National Planning Department estimated that 100 deaths per 100,000 were associated with urban air pollution in Bogotá in 2015, with an estimated economic cost of COL\$3.3 billion.³ Children and the elderly are at particular risk: increased daily air pollution concentrations in Bogotá, including PM_{2.5}, nitrogen dioxide (NO₂), and carbon monoxide (CO), were found to increase emergency hospital visits for respiratory disease among these groups.⁴ Furthermore, exposure to air pollution in Bogotá is not evenly distributed. The south western region of the city, home to over 30% of the city's residents, is most impacted by air pollution; in addition to facing higher ambient pollution levels, the area is home to many lower-income residents.⁵

The transport sector is a major contributor to air pollution in the city, with studies estimating exhaust from transport contributes 17% to 31% of the total

PM emissions.⁶ Diesel-powered vehicles contributed most to on-road nitrogen oxide (NO_x; 56%) and PM_{2.5} (82%) emissions in Bogotá.⁷ Although the city boasts an extensive public transport network, traffic congestion remains a major challenge.⁸ Bogotá was ranked the most congested city worldwide in 2020, with drivers spending an estimated 133 hours per year in traffic and an average vehicle speed of 18 km per hour at the peak hours of the day.⁹

Addressing transport-related pollution and associated health impacts is a priority for Bogotá, which joined the Breathe Cities initiative with the aim of reducing air pollution by 30% relative to 2019 levels by 2030.¹⁰ There is also widespread support among the population, with 98% of Bogotá residents wanting leaders to take action to reduce air pollution.¹¹ Bogotá has introduced several policies aiming to reduce vehicle-related pollution, including electrifying buses, reducing congestion through traffic restrictions, and introducing zones targeted for air pollution reduction. Nationally, Colombia has adopted Euro VI/6-equivalent emission standards for heavy-duty vehicles as well as diesel and CNG light-duty vehicles, although emission standards for gasoline light-duty vehicles remain less stringent, with Euro 4 standards in effect for these vehicles since 2023.¹²

- 1 Departamento Administrativo Nacional de Estadística, "Censo Nacional de Población y Vivienda: 2018 - Colombia" [National population and housing census: 2018 - Colombia], last modified August 30, 2019, <https://sitios.dane.gov.co/cnqv/#/>.
- 2 Alcaldía Mayor de Bogotá D.C., "Concentración de Material Particulado Inferior a 2.5 Micrómetros {PM2.5} Promedio Anual - PM2.5PA" [Concentration of particulate matter less than 2.5 micrometers {PM2.5} annual average - PM2.5PA], Ambiente Bogotá, 2024, <https://oab.ambientebogota.gov.co/concentracion-de-material-particulado-inferior-a-2-5-micrometros-pm2-5-promedio-anual/>; Aidan Farrow, *Evaluation of Air Pollution Monitoring in Bogotá, Colombia* (Greenpeace, April 2021), <https://www.greenpeace.to/greenpeace/?p=3933>.
- 3 Ana María Vargas Rodríguez et al., *Valoración Económica de la Degradación Ambiental en Colombia 2015* [Economic valuation of environmental degradation in Colombia 2015] (Departamento Nacional de Planeación, 2018), <https://colaboracion.dnp.gov.co/CDT/Prensa/Valoraci%C3%B3n%20econ%C3%B3mica%20de%20la%20degradaci%C3%B3n%20ambiental.pdf>.
- 4 Laura Andrea Rodríguez-Villamizar et al., "Short-Term Joint Effects of Ambient Air Pollutants on Emergency Department Visits for Respiratory and Circulatory Diseases in Colombia, 2011-2014," *Environmental Pollution* 248 (May 2019): 380-387, <https://doi.org/10.1016/j.envpol.2019.02.028>.
- 5 Luis A. Guzman et al., "Inequality in Personal Exposure to Air Pollution in Transport Microenvironments for Commuters in Bogotá," *Case Studies on Transport Policy* 11 (March 2023): 100963, <https://doi.org/10.1016/j.cstp.2023.100963>; Ivan Mura et al., "A Decade of Air Quality in Bogotá: A Descriptive Analysis," *Frontiers in Environmental Science* 8 (May 2020), <https://www.frontiersin.org/journals/environmental-science/articles/10.3389/fenvs.2020.00065>.

- 6 Secretaría de Ambiente SDA, *Inventario de Emisiones de Bogotá: Contaminantes criterio y carbono negro 2022* [Bogotá emissions inventory: Criteria pollutants and Black Carbon 2022] (2024), https://www.ambientebogota.gov.co/todas-las-investigaciones/-/asset_publisher/pibvwzUnZiNr/document/id/6881078; Secretaría de Ambiente SDA, *Inventario de Emisiones de Bogotá: Contaminantes criterio y carbono negro 2023* [Bogotá emissions inventory: Criteria pollutants and Black Carbon 2023] (2025), https://ambientebogota.gov.co/documents/10184/397082/INVENTARIO+EMISIONES_2023_w_apnds.pdf; David Jaime and Sonia Mangones, "Benefits of Transportation Strategies to Reduce On-Road Traffic Pollution Emissions: Evidence from Bogotá, Colombia," *Case Studies on Transport Policy* 21 (September 2025): 101527, <https://doi.org/10.1016/j.cstp.2025.101527>.
- 7 Jaime and Mangones, "Benefits of Transportation Strategies to Reduce On-Road Traffic Pollution Emissions."
- 8 Ricardo Alirio Gonzalez et al., "Government and Governance in Intelligent Cities, Smart Transportation Study Case in Bogotá Colombia," *Ain Shams Engineering Journal* 11, no. 1 (March 2020): 25-34, <https://doi.org/10.1016/j.asej.2019.05.002>.
- 9 Bob Pishue, *2020 Global Traffic Scorecard* (INRIX Research, 2020), https://www.valoraaanaltik.com/wp-content/uploads/2021/03/2020_INRIX_Scorecard_Report_US.pdf.
- 10 Clean Air Fund, "The City of Bogotá Joins Breathe Cities Initiative to Tackle Global Air Pollution," Clean Air Fund, September 23, 2024, <https://www.cleanairfund.org/news-item/bogota-breathe-cities/>.
- 11 C40 Cities, "C40 Cities Mayors Launch Global Air Quality Marathon as New Poll Reveals Widespread Support," press release, July 25, 2024, <https://www.c40.org/news/c40-global-air-quality-campaign-poll-its-in-the-air/>.
- 12 Euro 6 standards can only be adopted for gasoline light-duty vehicles with higher quality fuel of 10 ppm sulfur content or lower. See Martin Williams and Ray Minjares, *A Technical Summary of Euro 6/VI Vehicle Emission Standards* (International Council on Clean Transportation, 2016), https://theicct.org/sites/default/files/publications/ICCT_Euro6-VI_briefing_jun2016.pdf.

Information on the real-world exhaust emissions of Bogotá's vehicle fleet is important for the design and implementation of effective emission reduction policies to meet the city's goal to cut air pollution by 30% by 2030. As the city introduces the Urban Zones for Better Air (*Zonas Urbanas por un Mejor Aire* [ZUMA]) program, an initiative for creating zones for cleaner air in the city, such data are key for identifying vehicle segments that need to be targeted to maximize air quality benefits. Additionally, information on fleet emissions provides useful insight into current policy gaps, helping to prioritize future policies and design additional programs to address high-emitting vehicles and effectively regulate the real-world emissions of future vehicles.

This study addresses these knowledge gaps by presenting an analysis of real-world vehicle exhaust emissions data from Bogotá. The Real Urban Emissions (TRUE) Initiative conducted vehicle-emissions testing in Bogotá over 35 days in September and October 2023, using remote sensing technology to measure real-world tailpipe NO_x, hydrocarbon (HC), CO, and PM exhaust emissions. The study collected 272,025 measurements across nine different roadside measurement sites, capturing exhaust emissions from passenger cars, taxis, light- and heavy-duty vehicles, buses, and motorcycles. This study builds on TRUE Initiative's ongoing work in Latin America, with previous studies conducted in Mexico City and São Paulo.¹³ We present real-world emissions by vehicle type, examine fleet composition and emission contributions, and include a comparative case study of passenger car and taxi emissions in Bogotá and Mexico City. We conclude with tailored policy recommendations to reduce emissions from vehicles in Bogotá.

POLICY CONTEXT

Substantial progress has been made to improve the air quality in Bogotá over the last few decades. Efforts have included the implementation of national vehicle emission standards, routine vehicle inspection, fuel quality requirements, expansion of the public transport system, and promotion of areas for cleaner air.

13 Michelle Meyer et al., *Assessment of Real-World Passenger Vehicle and Taxi Emissions in Mexico City* (TRUE Initiative, 2024), <https://trueinitiative.org/research/assessment-of-real-world-passenger-vehicle-and-taxi-emissions-in-mexico-city/>; Kaylin Lee et al., *Assessment of Real-World Emissions in São Paulo* (TRUE Initiative, 2025), <https://trueinitiative.org/research/assessment-of-real-world-vehicle-emissions-in-sao-paulo/>.

Colombia introduced the first national vehicle emission requirements in 1996 with Resolutions 909 and 005.¹⁴ The stringency of these emission standards has since progressively increased (Table 1).¹⁵ Early vehicle emission requirements allowed certification to either European or U.S. vehicle emission standards.¹⁶ Current requirements only define limits based on European standards. For simplicity and to reflect current standards, Table 1 highlights only the European emission standards. In 2022, the Ministry of Environment and Sustainable Development issued Resolution 762, which built upon Ley 1972, a 2019 measure requiring all new gasoline vehicles to meet Euro 4 equivalent standards and all diesel and CNG vehicles to meet Euro 6/VI equivalent standards by 2023.¹⁷ Most vehicles driven in Colombia are imported, primarily from Mexico, Argentina, Brazil, and South Korea,¹⁸ and national regulations specify that only new vehicles can be imported.¹⁹

In addition to emission standards for newly imported vehicles, all vehicles in Colombia are required to undertake periodic vehicle emissions inspection. Private vehicles are subject to their first emissions inspection test 5 years after first registration and every 2 years thereafter. Public service vehicles are required to undertake their first mandatory inspections 2 years after first registration and every year thereafter.²⁰ During mandatory periodic inspection, gasoline and CNG vehicles are subject to CO and HC limits introduced in 2022, and diesel vehicles are subject to opacity limits.²¹ Additionally, new diesel vehicles subject to Euro VI

14 Resolución Conjunta 909 de 1996, Ministerio de Transporte, <https://www.alcaldia bogota.gov.co/sisjur/normas/Norma1.jsp?i=20678>; Resolución Conjunta 005 de 1996, Ministerio de Transporte, <https://www.alcaldia bogota.gov.co/sisjur/normas/Norma1.jsp?i=20677>.

15 A vehicle is required to meet the standards for a given year based on the date it was built and is not subject to standards of phases subsequently implemented throughout its lifetime. See Resolución 2604 de 2009, Ministerios de Minas y Energía, de la Protección Social y De Ambiente, Vivienda y Desarrollo Territorial, <https://www.minambiente.gov.co/documento-normativa/resolucion-2604-de-2009/>; Resolución 1111 de 2013, Ministerio de Ambiente y Desarrollo Sostenible, <https://www.alcaldia bogota.gov.co/sisjur/normas/Norma1.jsp?i=111937>.

16 "Regions: Colombia," TransportPolicy.net, accessed February 18, 2026, <https://www.transportpolicy.net/region/south-america/colombia/>.

17 Resolución No. 0762 de 2022, Ministerio de Ambiente y Desarrollo Sostenible, <https://www.minambiente.gov.co/documento-entidad/resolucion-0762-de-2022/>.

18 Observatory of Economic Complexity, "Small Sized Cars in Colombia," 2023, <https://oec.world/en/profile/bilateral-product/small-sized-cars/reporter/col>.

19 Decreto 1676 de 2005, <https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=16631>.

20 Ley 769 de 2002, <https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=5557>.

21 Resolución No. 0762 de 2022.

Table 1. Euro vehicle emission standard in Colombia from 1998 onward

Year	Vehicle category	Fuel type	Euro standard
1998 (MY)	Light-duty vehicle	Gasoline	Euro 1
2010 (MY)			Euro 2
2023			Euro 4
1998 (MY)		Diesel	Euro 1
2010 (MY)			Euro 2
2015			Euro 4
2023			Euro 6
2023		CNG	Euro 6
1998 (MY)	Bus	Diesel	Pre-Euro
2001 (MY)			Euro I ^a
2010			Euro II ^b / Euro IV ^{c,d}
2015			Euro IV ^d
2023			Euro VI
2015	Bus	CNG	Euro IV
2023			Euro VI
1998 (MY)	Heavy-duty vehicle	Diesel	Pre-Euro
2001 (MY)			Euro I ^a
2010 (MY)			Euro II ^b
2015			Euro IV ^d
2023			Euro VI
2015	Heavy-duty vehicle	CNG	Euro IV
2023			Euro VI
2010	Motorcycle	Gasoline	Euro 2
2023			Euro 3

Note: Year refers to the year the standard became mandatory for all newly manufactured or imported vehicles. Certain requirements were applied by vehicle model year instead of the year it was built, indicated by "MY" in the table.

^a Emissions limits do not align with Euro standards but are closest to Euro I.

^b Many manufacturers were already importing Euro III due to fuel quality.

^c Limit applies to urban buses.

^d Many manufacturers were already importing Euro V due to fuel quality.

standards must have on-board diagnostic systems.²²
Local authorities are required to monitor emissions

directly from mobile pollution sources to identify cases of non-compliance with regulations.²³

²² Ley 1972 de 2019, <https://www.suin-juriscol.gov.co/viewDocument.asp?ruta=Leyes/30036665>.

²³ Resolución 910 de 2008, Ministerio de Ambiente, Vivienda y Desarrollo Territorial, <https://www.suin-juriscol.gov.co/viewDocument.asp?id=30033825>.

Aligned with Colombia's progress on vehicle emission standards, sulfur fuel quality has also improved. Beginning in 2012, all diesel fuel used in Colombia was required to contain sulfur content of 50 ppm or lower, and this limit was further reduced to 10–15 ppm in 2023 and 10 ppm in December 2025.²⁴ Requirements of sulfur content in gasoline fuel were reduced from 300 ppm to 100 ppm in 2021 and further to 50 ppm from 2022 onward, with the plan to reach 10 ppm by the end of 2030.²⁵

Vehicles powered by CNG are widespread and gaining popularity in Colombia.²⁶ It is estimated that between 2000 and 2023, 645,000 vehicles that were originally gasoline vehicles were converted to run on CNG.²⁷ The comparably lower cost of CNG fuel relative to gasoline contributes to its popularity, with reported savings of 52%.²⁸ These lower fuel prices have made CNG particularly desirable for taxi owners in Colombia, with taxis representing nearly 98% of estimated CNG conversions in the first half of 2023.²⁹ In addition to fuel cost savings, there are local and national policies that incentivize the use of CNG fuel. While the annual vehicle tax generally ranges from 1.7% to 3.7% of the vehicle's value, it is capped at 1% for dedicated CNG vehicles (certified to CNG emission standards); the same cap is applied to electric vehicles.³⁰ Similarly, these vehicles receive a 10% discount on the annual mandatory *Seguro Obligatorio de Accidentes de Tránsito* insurance.³¹ The Bogotá city government exempts certain CNG-powered vehicles, along with all electric and hybrid vehicles, from

its *pico y placa* policy, which combats vehicle congestion in the city by restricting travel of different vehicles each weekday based on their license-plate letters.³²

Bogotá also boasts one of the world's largest bus rapid transit (BRT) systems and is transitioning toward electric buses. The city's BRT system, TransMilenio, has been in operation since 2000.³³ Bogotá's public transport system, the *Sistema Integrado de Transporte Público* (SITP), includes the core BRT TransMilenio buses operating in dedicated lanes, feeder buses connecting neighborhoods to BRT corridors, zonal buses operating within specific areas, and cable cars that work together as a unified network. The mayor's office of Bogotá estimated that in March 2025, the system was used over 103 million times, which is approximately 15 uses per person.³⁴ In September 2025, 1,486 electric buses were in operation in the city, with an additional 364 expected to enter the fleet in 2026.³⁵ The bus fleet currently operates with a mix of powertrains: in March 2025, 14% of the system was electric powered, 20% CNG powered, 63% diesel powered, and 3% hybrid powered.³⁶

Finally, the ZUMA initiative aims to create zones within Bogotá prioritized for interdisciplinary initiatives to reduce air pollution.³⁷ Bogotá aims to have two ZUMAs fully operational by 2027.³⁸ The first ZUMA, the Bosa Apogeo Emission Reduction Zone, was established in

24 Ley 1205 de 2008, <https://www.suin-juriscol.gov.co/clp/contenidos.dll/Leyes/1675542>; Ley 1972 de 2019.

25 Resolución 40103 de 2021, Ministerio de Minas y Energía y Ministerio de Ambiente y Desarrollo Sostenible, <https://www.minambiente.gov.co/documento-entidad/resolucion-40103-de-2021>; Resolución 40444 de 2023, Ministerio de Minas y Energía y Ministerio de Ambiente y Desarrollo Sostenible, <https://www.suin-juriscol.gov.co/viewDocument.asp?ruta=Resolucion/30046844>; EcoPetrol, "Fuel Quality: More than Three Decades of Continuous Improvement," February 18, 2022, <https://www.ecopetrol.com.co/wps/portal/Home/tesg/environmental/clean-air/fuel-quality>.

26 "En un 63% aumentó la conversión de vehículos de gasolina a gas natural durante el año 2023" [The conversion of gasoline vehicles to natural gas increased by 63% during 2023], *Naturgas*, January 23, 2024, <https://naturgas.com.co/en-un-63-aumento-la-conversion-de-vehiculos-de-gasolina-a-gas-natural-durante-el-ano-2023/>.

27 Isbel Lázaro, "Colombia Reached More than 10,000 Conversions to CNG in the First Half of 2023," *Inspenet*, August 11, 2023, <https://inspenet.com/en/noticias/colombia-more-than-10-thousand-gnv-conversions/>.

28 Naturgas, "The Conversion of Gasoline Vehicles."

29 Lázaro, "Colombia Reached More than 10,000 Conversions."

30 Mónica Espinosa and Camilo Sarmiento, *Status Quo of Energy Efficiency Regulation in Colombia's Transportation Sector: Scoping Study* (GIZ GmbH, May 2024), https://changing-transport.org/wp-content/uploads/GIZ.-2024.-Vehicle-Efficiency-in-Colombia_EN.pdf.

31 Espinosa and Sarmiento, *Status Quo of Energy Efficiency*.

32 Decreto 546 de 2021, Alcaldía Mayor de Bogotá, D.C., <https://www.alcaldiabogota.gov.co/sisjur/normas/Norma1.jsp?i=119621>; Decreto 652 de 2025, Alcaldía Mayor de Bogotá, D.C., <https://www.alcaldiabogota.gov.co/sisjur/normas/Norma1.jsp?i=191872>; Espinosa and Sarmiento, *Status Quo of Energy Efficiency*.

33 Michael Kimmelman, "How One City Tried to Solve Gridlock for Us All," *New York Times*, December 7, 2023, <https://www.nytimes.com/interactive/2023/12/07/headway/bogota-bus-system-transmilenio.html>.

34 Alcaldía Mayor De Bogotá D.C., *Transmilenio en Cifras*, no. 94 (March 2025), <https://www.transmilenio.gov.co/comunicaciones/publicaciones/2025/estadisticas-de-oferta-y-demanda-del-sistema-integrado-de-transporte-publico-sitp-marzo-2025>.

35 Álvaro Clavijo, "TransMilenio se Transforma con 364 Nuevos Buses Eléctricos" [TransMilenio is transformed with 364 new electric buses], Bogotá, June 26, 2025, <https://bogota.gov.co/mi-ciudad/movilidad/bogota-contara-con-364-nuevos-buses-electricos-en-transmilenio>; E-bus radar, "Electric Buses in Latin America," September 2025, <https://ebusradar.org/en/#>.

36 Alcaldía Mayor De Bogotá D.C., *Transmilenio en Cifras*.

37 The ZUMA initiative was established in 2023 and stipulates the establishment of an emission reduction zone within the first year of declaration, followed by a low-emission zone extending over 6 years and an ultra-low-emission zone after the 7th year. The requirements for each phase of the zone are laid out in the ZUMA's Action Plan. Secretaría de Ambiente SDA, *Plan de Acción de las Zonas Urbanas por un Mejor Aire - ZUMA* [Urban areas action plan for better air - ZUMA] (2024), <https://www.ambientebogota.gov.co/documents/10184/7697369/Plan+de+Accio%C2%B4n+ZUMA+Bosa+Apogeo+06052025.pdf/36cbb82f-16ba-4eb0-b1db-2038e96eedaf>.

38 Alcaldía Mayor De Bogotá D.C., "Plan Distrital de Desarrollo 2024-2027" [District development plan 2024-2027], *Movilidad Bogotá*, July 16, 2024, <https://bogota.gov.co/plan-distrital-de-desarrollo-2024-2028/>.

2023.³⁹ Located in the southwestern part of the city, the zone, home to over 35,000 inhabitants in the Bosa locality,⁴⁰ has been prioritized due to the high level of vehicle emissions in this area. To date, policies targeting Bosa have included planting trees, paving roads, and expanding the air quality monitoring network.⁴¹ Elements of the Bosa Apogeo ZUMA outlined in the 2025 ZUMA Action Plan include improved walking and cycling infrastructure, low- and zero-emission bus deployment, preferential parking for zero-emission vehicles, traffic management or restriction of private vehicles within the ZUMA, and a pilot program using zero-emission cargo vehicles.⁴² The Action Plan presently does not include details on the kinds of private vehicles that may be restricted to reduce emissions.⁴³

REMOTE SENSING STUDY

DATA COLLECTION

The TRUE initiative conducted a roadside remote sensing campaign to measure real-world vehicle exhaust emissions in Bogotá, Colombia, over 35 days from September 5 to October 26, 2023. The sampled fleet included passenger vehicles, taxis, light trucks, heavy-duty vehicles, buses, minibuses, and motorcycles.⁴⁴ In total, 272,025 measurements were collected across nine different sites. Sites were selected based on their potential to provide valid measurement readings and to measure a wide range of vehicles. Sites were also chosen to represent typical vehicle activity across the city, with the aim to also measure emissions for the fleet of public buses and trucks. One site (BOG003) was specially selected to measure trucks in a tolling plaza, while three sites (TRANSMI1, TRANSMI2,

and TRANSMI3) were selected to measure buses at TransMilenio urban depots. The locations of the nine measurement sites are shown in Figure 1.

In partnership with Indra Colombia, Opus Inspection undertook vehicle emissions testing. Data were collected using the Opus portable RSD5700 instrument (Figure 2); as vehicles drove past the instrument (Figure 2); as vehicles drove past the instrument, it measured tailpipe carbon dioxide (CO₂), NO_x, nitrogen oxide (NO), NO₂, HC, and CO emissions, in addition to UV smoke (as a proxy for PM).⁴⁵ The instrument also captured each vehicle's speed and acceleration, which was used to estimate engine power. Additionally, license plate numbers were recorded to facilitate retrieval of the vehicle's technical characteristics.

SAMPLE OVERVIEW

Of the 272,025 measurements collected, 146,698 (54%) had valid speed and acceleration values and positive vehicle specific power (VSP). License plate information was used to match the measured vehicles with vehicle characteristics data from three sources: Secretaría Distrital de Ambiente (SDA), the Department of Environment of Bogotá; Registro Único Nacional de Tránsito (RUNT), the national vehicle registry; and computer vision classifications using Opus Software.⁴⁶ In total, we matched 163,425 measurements (60%) with vehicle characteristic data, of which 98,235 (36%) had valid speed, acceleration, and VSP values (Table 2). To maximize data utilization, we applied different inclusion criteria depending on the analysis. Analyses examining only vehicle characteristics used all measurements matched with vehicle information (60%), while analyses of vehicle exhaust emissions included those with matched vehicle information and valid speed, acceleration, and VSP values (36%).

We considered the SDA data to be a more reliable subset of the RUNT data and therefore gave the SDA

39 Secretaría de Ambiente SDA, *Plan de Accion*.

40 "ZUMA de Bosa Apogeo," C40 Cities, accessed November 21, 2025, <https://www.c40reincities.org/en/students/sites-in-competition/zuma-de-bosa-apogeo-2106.html>; Alcaldía Mayor De Bogotá D.C., "Fichas de Acciones: ZUMA Bosa Apogeo" [ZUMA Bosa Apogeo: Stock cards], accessed February 18, 2026, <https://www.ambientebogota.gov.co/documentos/10184/7697369/Anexo+1.+Fichas+acciones+ZUMA+Bosa+Apogeo++06052025.pdf/083c9019-332c-4ca2-a809-38b2c83af9e6>.

41 Álvaro Clavijo, "Bogotá Fortalece la Primera Zona Urbana por un Mejor Aire en Bosa para Beneficiar a Más de 30.000 Personas" [Bogotá strengthens the first Urban Zone for Better Air in Bosa to benefit more than 30,000 people], March 21, 2026, <https://bogota.gov.co/mi-ciudad/ambiente/bogota-fortalece-la-primera-zona-urbana-por-un-mejor-aire-en-bosa>.

42 Alcaldía Mayor De Bogotá D.C., "Fichas de Acciones"; Decreto 670 de 2025, Alcaldía Mayor de Bogotá, D.C., <https://www.alcaldiabogota.gov.co/sisjur/normas/Norma1.jsp?i=191905#1526>.

43 Alcaldía Mayor De Bogotá D.C., "Fichas de Acciones."

44 Quadricycles, tractor trucks, and tricycles were measured, but due to small sample size (less than 1% of the measured fleet) they were not included in this analysis.

45 UV smoke is measured by the ratio of opacity to fuel burned. The measurement is dependent on various physical and chemical characteristics of the exhaust PM and therefore is used primarily for comparative analyses. See Michelle Meyer et al., *Particulate Matter Emissions from U.S. Gasoline Light-Duty Vehicles and Trucks* (TRUE Initiative, 2023), <https://trueinitiative.org/research/particulate-matter-emissions-from-u-s-gasoline-light-duty-vehicles-and-trucks/>. PM measurement relies on opacity readings with ±1% absolute tolerance across the currently verifiable reference range.

46 Opus used computer vision (CV) software from Plate Recognizer to estimate vehicle specifications. The software returned the following vehicle attributes: category, make, model, and color. CV vehicle specifications were used as surrogates for measurements that lacked a vehicle identifier or vehicle specifications from other sources. See Plate Recognizer, "Accurate, Fast, Developer-Friendly ALPR," accessed March 12, 2026, <https://platerecognizer.com/>.

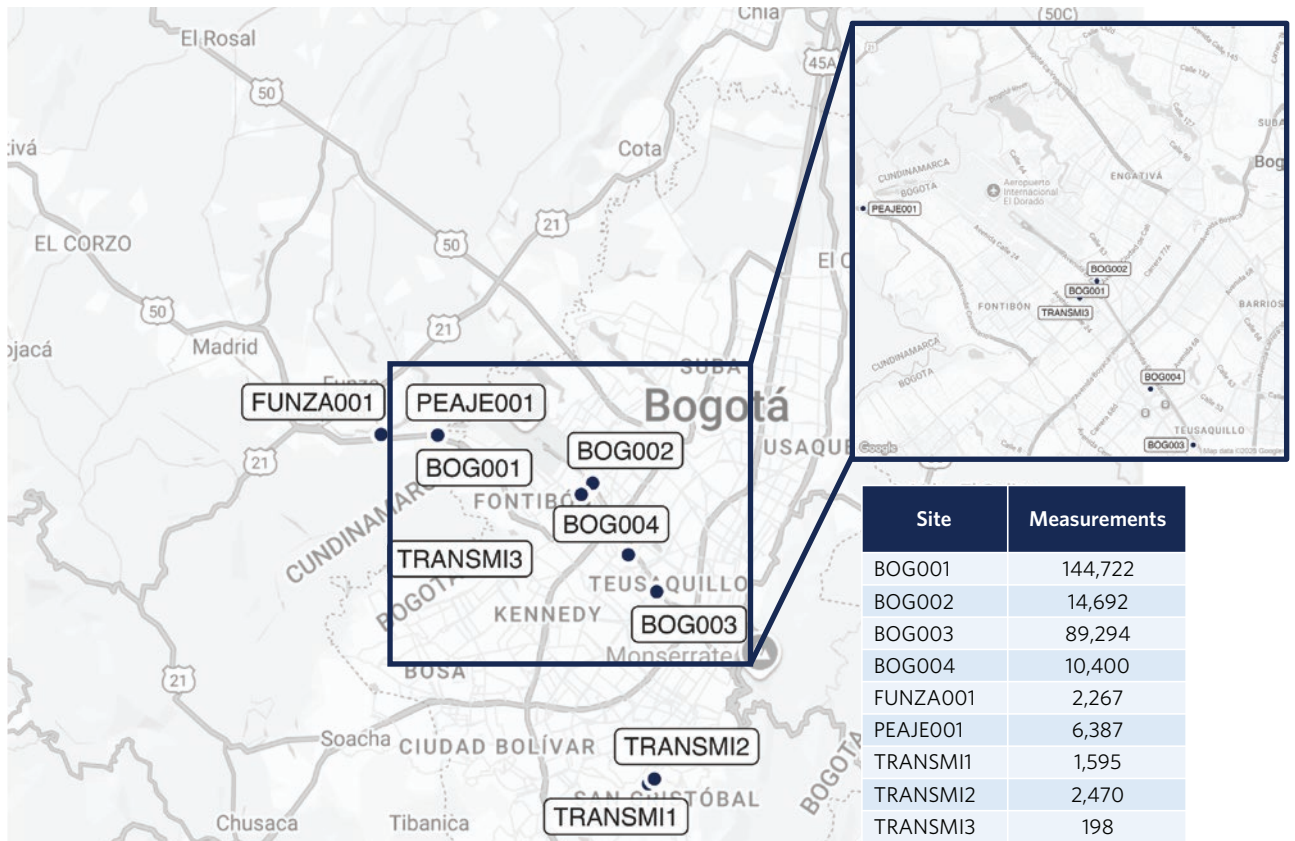


Figure 1. Map of measurement sites for the remote sensing campaign



Figure 2. Remote sensing data collection using an Opus portable RSD5700 instrument

Table 2. Summary of measurements collected in Bogotá and their validity for analysis

Valid speed, acceleration, and positive VSP values	License plate reading matched with vehicle information ^a	Count	Share of total measurements
Yes	Yes	98,235	36%
	No	48,463	18%
No	Yes	65,190	24%
	No	60,137	22%

^a Indicates license plate could be matched and at least vehicle class was available; data completeness of vehicle specifications varied.

data precedence whenever both were available. We used the computer vision data—including vehicle class, make, model, and color—only in cases where data from other sources were unavailable. Due to gaps in vehicle characteristic data, the complete set of technical information was not available for each vehicle; while these gaps limited the detail of our analysis, the data were still useful for characterizing the real-world emissions of the Bogotá fleet.

Vehicle emission standard certification information was not available in the SDA or RUNT data. To compare measured real-world emissions with certification limits, we aggregated measurements by vehicle model year groups aligned with emission standards as outlined in Table 1. For simplicity, we focused only on comparison with the European standards and associated limits, although vehicles could also be certified to U.S. Environmental Protection Agency limits.

Consistent with previous TRUE analyses, we express emission values in fuel-specific values (g/kg fuel) or, where possible, further convert emission values to distance-specific or energy-specific values—a unit consistent with the European regulatory limits—using the method developed in earlier TRUE publications.⁴⁷ We used the International Energy Agency’s Mobility Model to estimate fuel economy in Colombia and calculate the conversion of emissions per kilometer traveled (g/km) for all vehicle groups measured, excluding CNG-powered buses, for which no fuel

economy estimates were available.⁴⁸ We also converted heavy-duty vehicle emissions into energy-specific emissions, expressed per kilowatt-hour (kWh).⁴⁹

Figure 3 summarizes testing conditions, including speed, acceleration, VSP, and temperature. The median values were 25 km/h for speed, 1.3 km/h/s for acceleration, 4 kW/t for VSP, and 24 °C for ambient temperature. The median VSP of this sample was slightly lower than the median values of the TRUE Mexico City campaign (5.9 kW/t) and the TRUE Europe database (8.2 kW/t).

FLEET CHARACTERISTICS

As shown in Figure 4, gasoline passenger cars were the most frequently measured vehicle-fuel group in this study, making up 45% of the sample, followed by dual gasoline-CNG taxis with 25% and gasoline light trucks with 18%.⁵⁰ The vehicles measured are considered representative of the composition of Bogotá’s vehicle fleet, apart from buses and motorcycles, which were underrepresented in the measurements. Motorcycles are estimated to represent 62% of the vehicle fleet in Bogotá but are typically challenging to measure

47 Yoann Bernard et al., *Determination of Real-World Emissions from Passenger Vehicles Using Remote Sensing Data* (TRUE Initiative, 2018), <https://trueinitiative.org/research/determination-of-real-world-emissions-from-passenger-vehicles-using-remote-sensing-data/>.

48 Fuel economy data used to calculate emissions per kilometer traveled are based on the national fleet average. Fuel economy can vary based on altitude and other operating conditions. This analysis does not include an adjustment for altitude, which would be expected to increase emissions estimates. “Transport,” International Energy Agency, updated July 11, 2023, <https://www.iea.org/energy-system/transport>. Fuel-economy data for CNG-powered buses were not available, therefore distance-specific emissions for this vehicle class were not calculated.

49 Since the regulatory emission limits for heavy-duty vehicles are established on an energy specific basis (g/kWh), the fuel specific emissions were converted to energy-specific emissions using brake-specific fuel consumption of the vehicle in g/kWh by using the methodology outlined in Sina Kazemi Bakhshmand et al., *Remote Sensing of Heavy-Duty Vehicle Emissions in Europe* (International Council on Clean Transportation, 2022), <https://theicct.org/publication/remote-sensing-of-heavy-duty-vehicle-emissions-in-europe/>.

50 Due to widespread formal and informal gasoline-to-CNG retrofitting of taxis in Bogotá, all taxis were considered as dually CNG-gasoline powered, despite their fuel type in the vehicle characteristic data.

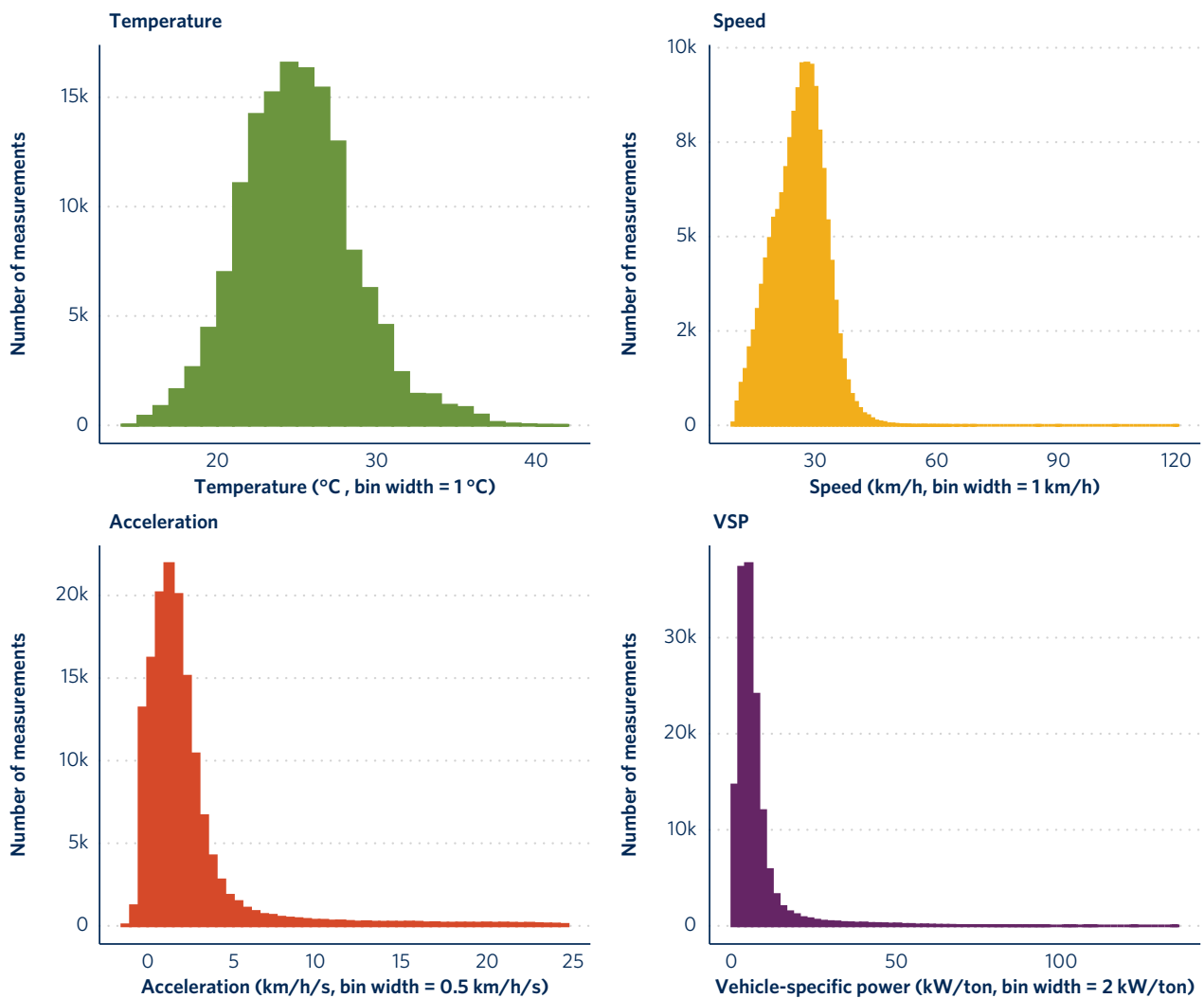


Figure 3. Summary of testing conditions

via remote sensing.⁵¹ A limited number of buses were measured because the BRT fleet operates in dedicated lanes, meaning it was only possible to measure them at dedicated sites. The Spanish-language vehicle classes provided in vehicle characteristic data were mapped to corresponding vehicle classes categories presented in this report (Table A1 in the Appendix).

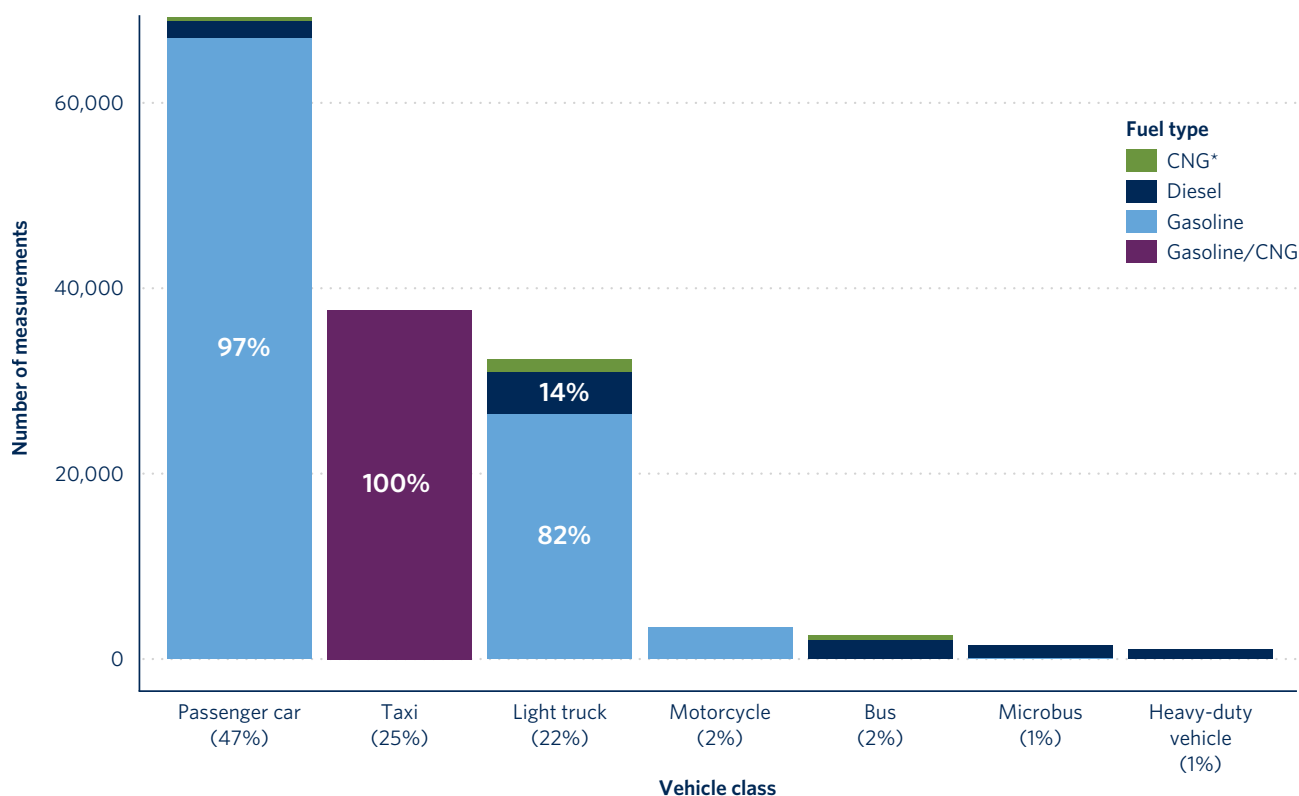
Using the available vehicle characteristic data, it was not possible to identify vehicles built to run on CNG versus those retrofitted. Given the popularity of CNG conversions among taxi owners and the lower cost of CNG fuel in Colombia, it is likely that many taxis were retrofitted to run on CNG.

On average, gasoline passenger cars were 10 years old at the time of measurement (Table 3).⁵² Gasoline/CNG powered taxis, all of which were passenger cars, were 9 years of age on average. Half of the taxi fleet in Bogotá was between 5 and 13 years of age, with the oldest measured taxi aged 30. The oldest vehicle-fuel group on average was bi-fuel CNG/gasoline passenger cars, with an average age of 13 years.⁵³ CNG-powered buses were the youngest vehicle-fuel group, with an average age of 2 years, 5 years younger than the average age of diesel buses. These results align with the TransMilenio

51 Julián Forero, "Los Motociclistas Somos una Realidad" [Motorcyclists are a reality], Concejo de Bogotá, March 5, 2025, <https://concejodebogota.gov.co/los-motociclistas-somos-una-realidad/cbogota/2025-03-05/150819.php>.

52 Vehicle age was calculated as the difference between vehicle build year and year of measurement.

53 Passenger vehicles classified as CNG are likely retrofitted to operate on CNG, though this cannot be confirmed from the vehicle database. Retrofitted vehicles are typically bi-fuel, CNG and gasoline. These vehicles are assumed to primarily use CNG due to lower fuel costs.



Note: Share of fuel type within vehicle class indicated within bars and overall share of vehicle class indicated in parentheses.

* CNG passenger cars are likely primarily retrofitted bi-fuel CNG/gasoline vehicles.

Figure 4. Number of measurements by vehicle class and fuel type

announcement that new CNG-powered buses have been incorporated into the fleet since 2019.⁵⁴

The region of registration was available for 46% of the vehicles measured (124,860). There were 30 different registration locations among measured vehicles, with the three most common regions being Bogotá D.C. (77%), Cundinamarca (14%), and Antioquia (2%). Although most passenger cars, taxis, buses, and light trucks were registered in Bogotá D.C., 63% of heavy-duty vehicles and 78% of microbuses were registered in Cundinamarca (see Figure A1 in the Appendix).

Taxis were identified in this study using vehicle characteristic data indicating yellow passenger cars used as public service vehicles. Due to their distinct

Table 3. Average age by vehicle class and fuel type

Vehicle class	Fuel type	Average age
Passenger car	Gasoline	10
	Diesel	8
	Bi-fuel CNG	13
Taxi	Gasoline/CNG	9
Light truck	Gasoline	7
	Diesel	9
	CNG	12
Motorcycle	Gasoline	9
	Diesel	7
Bus	CNG	2
	Diesel	11
Heavy-duty vehicle	Diesel	12

⁵⁴ Ana María Cuevas, "Con 320 Buses Zonales, TransMilenio Sigue Renovándose para Reverdecer a Bogotá" [With 320 zonal buses, TransMilenio continues to renew itself to make Bogotá greener], Bogotá, June 20, 2020, <https://bogota.gov.co/mi-ciudad/buses-nuevos-de-transmilenio-para-componente-zonal>; Jenny Suache, "Empiezan a Rodar los Primeros 140 Buses de TransMilenio a Gas Natural en Bogotá" [The first 140 TransMilenio buses powered by natural gas begin operating in Bogotá], Bogotá, July 1, 2019, <https://bogota.gov.co/mi-ciudad/movilidad/transmilenio/llegaron-los-nuevos-buses-de-gas-natural-vehicular-transmilenio>.

emission performance, we analyzed taxis separately from other passenger cars in this report. As shown in Figure 5, the set of taxis sampled also had a unique composition compared with private passenger cars. Taxis in Bogotá were primarily Hyundai (55%) and Kia (29%) vehicles, brands that made up a comparatively lower share of private passenger cars (5% and 6%, respectively).

VEHICLE EMISSIONS ANALYSIS

In this section, we present the average NO_x, PM, HC, and CO emissions of vehicles in Bogotá. First, we provide an overview of the average distance-specific emissions across all vehicle-fuel groups. We then present detailed vehicle emission trends for the two most common vehicle classes in this study—passenger cars and taxis—followed by diesel vehicles. The minimum number of measurements

considered for subgroup analysis was generally 100; one exception was trends by vehicle model year and model year group, for which the minimum number of measurements was 30.

Detailed vehicle emission trends are presented by vehicle model year groups, which reflect the timeline of European vehicle emissions standard adoption in Colombia across different vehicle-fuel groups (see Table 1). Such figures include the European vehicle emissions standard limits applicable for those model year groups. European emission limits are provided as a reference to contextualize the results, but it is possible that vehicles measured in this study were certified to U.S. emission standards rather than European standards. Data on vehicle weight were scarce in the vehicle characteristic databases; where emission limits vary by gross vehicle weight, we used the European emission limits corresponding to the heaviest vehicle subclass.

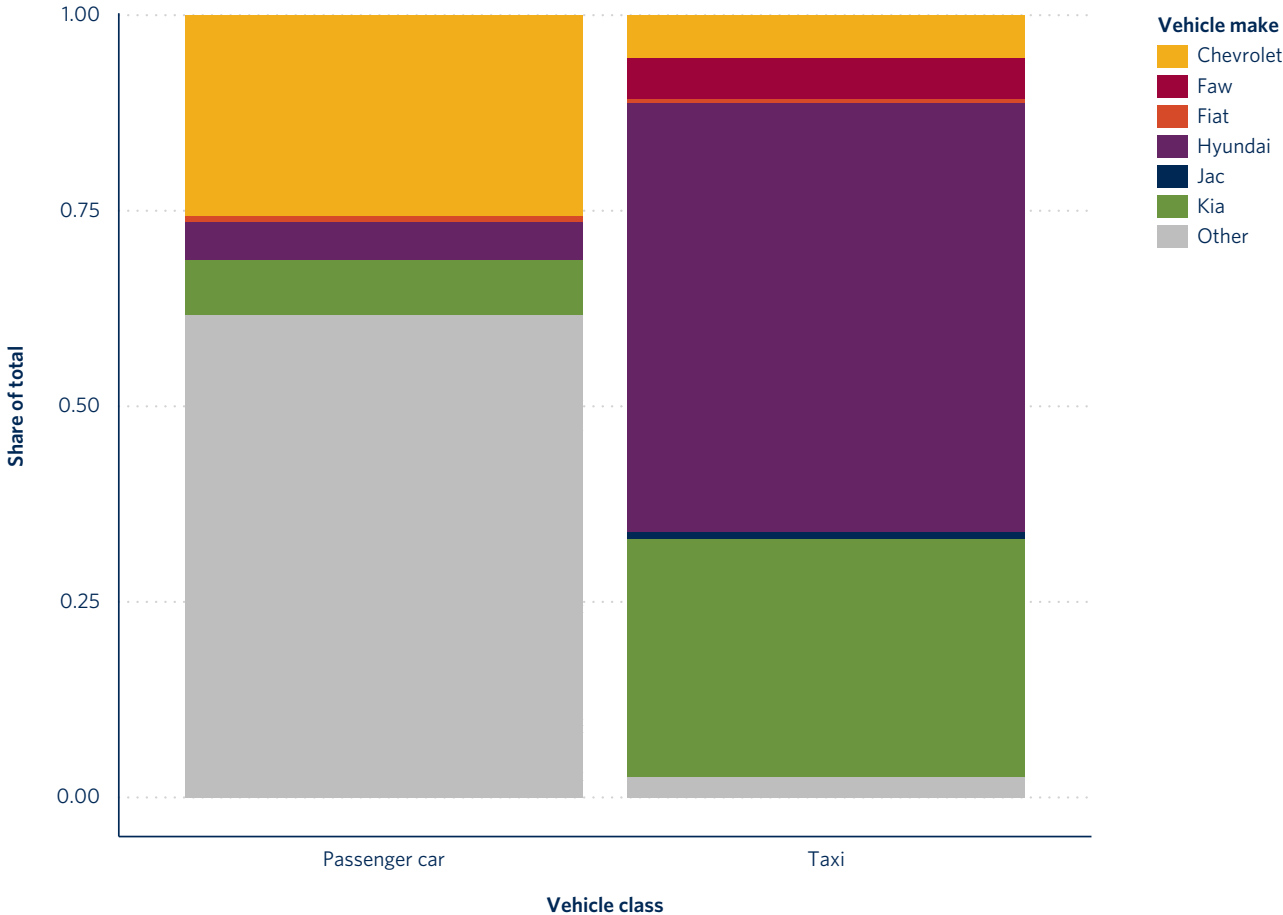


Figure 5. Share of vehicle make of taxis versus private passenger cars in Bogotá

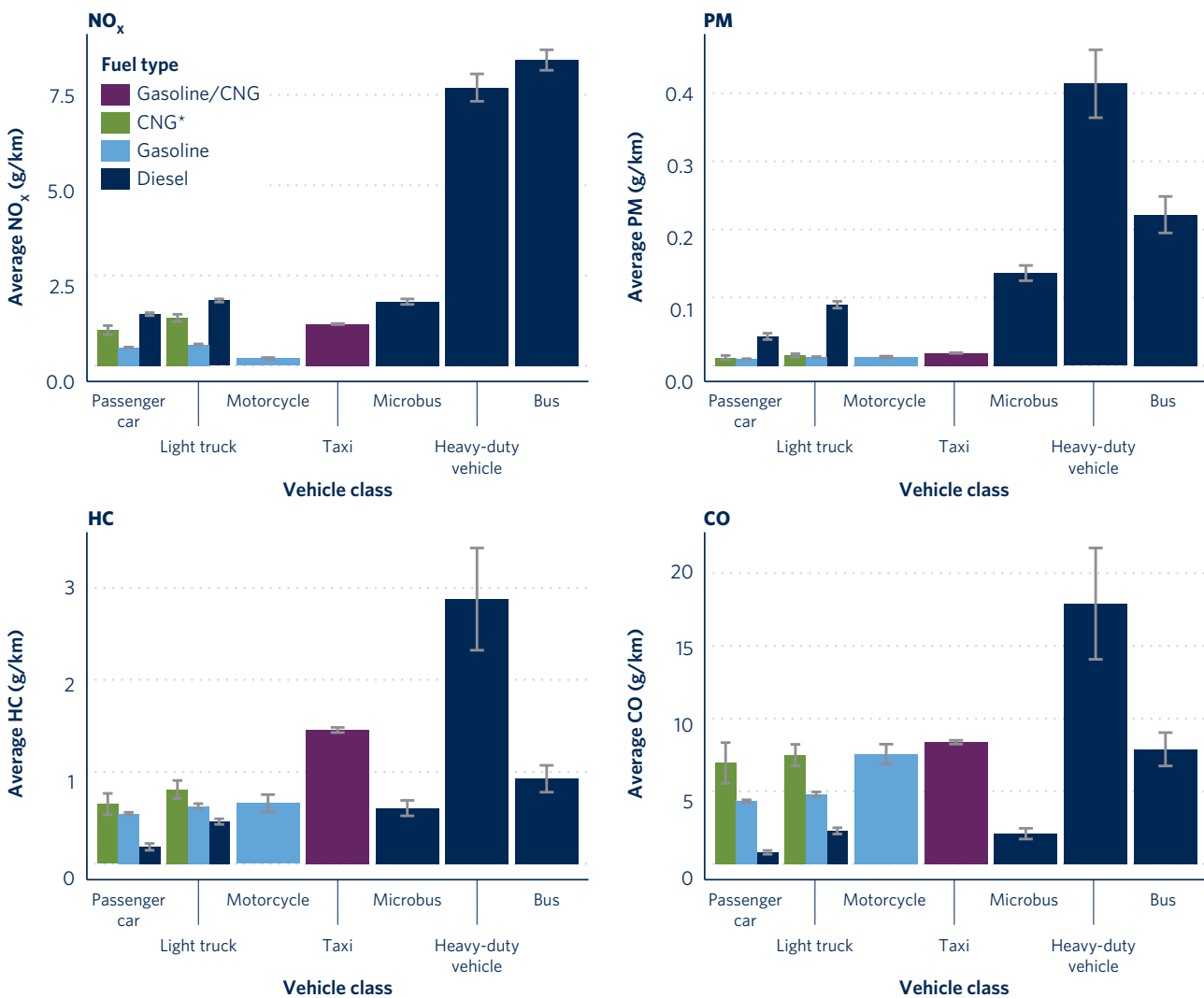
EMISSIONS BY VEHICLE CLASS

As shown in Figure 6, diesel buses exhibited the highest average distance-specific NO_x emissions of all vehicle classes measured, while diesel heavy-duty vehicles exhibited the highest average PM, HC, and CO emissions.⁵⁵

Bi-fuel CNG passenger cars exhibited higher average emissions across all pollutants compared with gasoline passenger cars: 18% higher PM, 19% higher HC, 61% higher CO, and 95% higher NO_x . A similar trend was evident among CNG-powered light trucks compared

with gasoline-powered light trucks. The older average age of both CNG-powered passenger cars and light trucks compared with gasoline could contribute to the higher average emissions among these vehicle-fuel groups (Table 3).

Gasoline/CNG taxis exhibited particularly elevated HC emissions, with 2 times the emissions of both CNG- and gasoline-powered passenger cars. Gasoline/CNG taxis in Bogotá are typically high-usage vehicles that accumulate mileage rapidly, likely contributing to accelerated deterioration of emissions control systems



Note: Error bars represent the 95% confidence interval.

* CNG passenger cars are likely primarily retrofitted bi-fuel CNG/gasoline vehicles.

Figure 6. Average NO_x , PM, HC, and CO distance-specific emissions by vehicle class and fuel

⁵⁵ CNG buses are not included in this figure due to a lack of fuel economy data. Fuel-specific results are shown in Figure A2 in the Appendix.

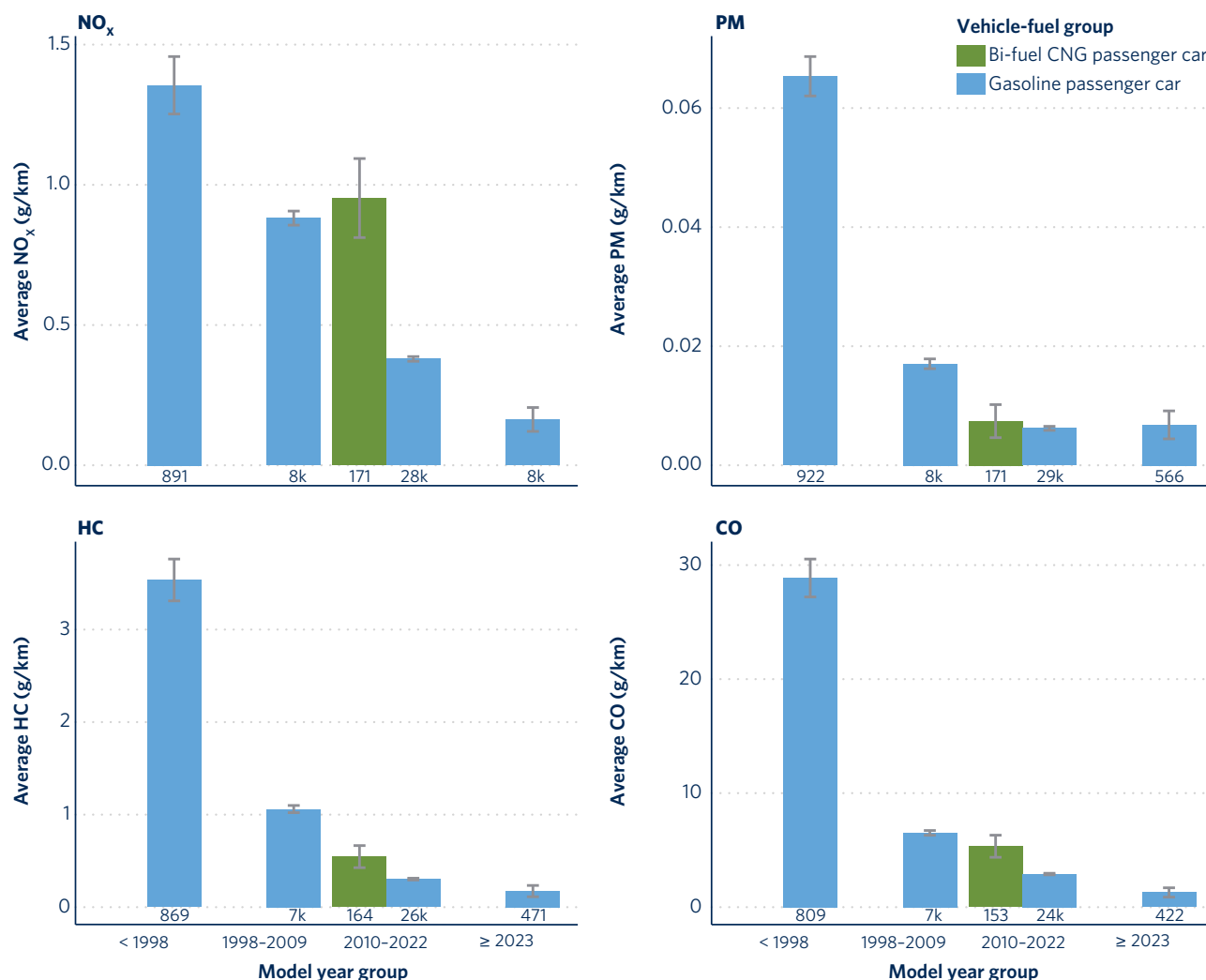
and subsequent elevated emissions.⁵⁶ Results for average fuel-specific emissions are available in Figure A2 in the Appendix.

PASSENGER CAR EMISSION TRENDS

Passenger cars of newer model year groups showed marked decreases across all real-world pollutant emissions, aligned with the implementation of more stringent vehicle emission standards in Colombia (Figure 7). Gasoline passenger cars manufactured since

2023—during the Euro 4 standard period—emitted 88%–96% lower average emissions across all pollutants compared with vehicles manufactured before 1998. The highest average emissions were among gasoline passenger cars of model years older than 1998, before Colombia introduced vehicle emission standards.

Figure 7 shows that bi-fuel CNG passenger cars showed especially elevated NO_x emissions compared with gasoline counterparts of the same model year group. Bi-fuel CNG passenger cars emitted 2.5 times higher



Note: Error bars represent the 95% confidence interval. Numbers below bars indicate number of measurements.

Figure 7. Average distance-specific emissions among gasoline and CNG-powered passenger cars over time

56 Yohén Cuéllar Álvarez, “Development of a New Integrated Assessment Methodology to Design and Select the Best Emission Reduction Strategies for Urban Passenger Transport” (PhD diss., Universidad Nacional De Colombia, 2023), https://www.researchgate.net/publication/370865140_Development_of_a_new_integrated_assessment_methodology_to_design_and_select_the_best_emission_reduction_strategies_for_urban_passenger_transport.

average NO_x emissions compared with their gasoline counterparts. Similarly, CNG-powered passenger cars showed 19%–84% higher HC, CO, and PM emissions compared with gasoline counterparts. A similar emissions trend can be observed among other light-duty vehicles: CNG light trucks exhibited higher average emissions across all pollutants compared with their gasoline counterparts, but especially for NO_x, which was 2.3 times higher than gasoline counterparts of model years 2010–2022 (see Figure A3 in the Appendix). It was not possible in this study to distinguish vehicles built to run on CNG from those retrofitted, and increased emissions among CNG vehicles may be attributable to vehicles retrofitted rather than

manufactured to use CNG.⁵⁷ Due to the smaller number of CNG passenger cars and light trucks in the sample, assessing emission trends against progressive emissions standard adoption was not possible.

Figure 8 shows that as the Bogotá gasoline passenger car fleet shifts to newer and lower-emitting vehicles, the oldest vehicles increasingly contribute to total fleet emissions despite making up a small portion of the fleet. Assuming that the vehicle fleet captured in Bogotá was representative of the gasoline passenger car activity, gasoline passenger cars manufactured before 1998 made up 2.5% of the measured gasoline passenger car fleet but contributed 6%–17% of cumulative NO_x,

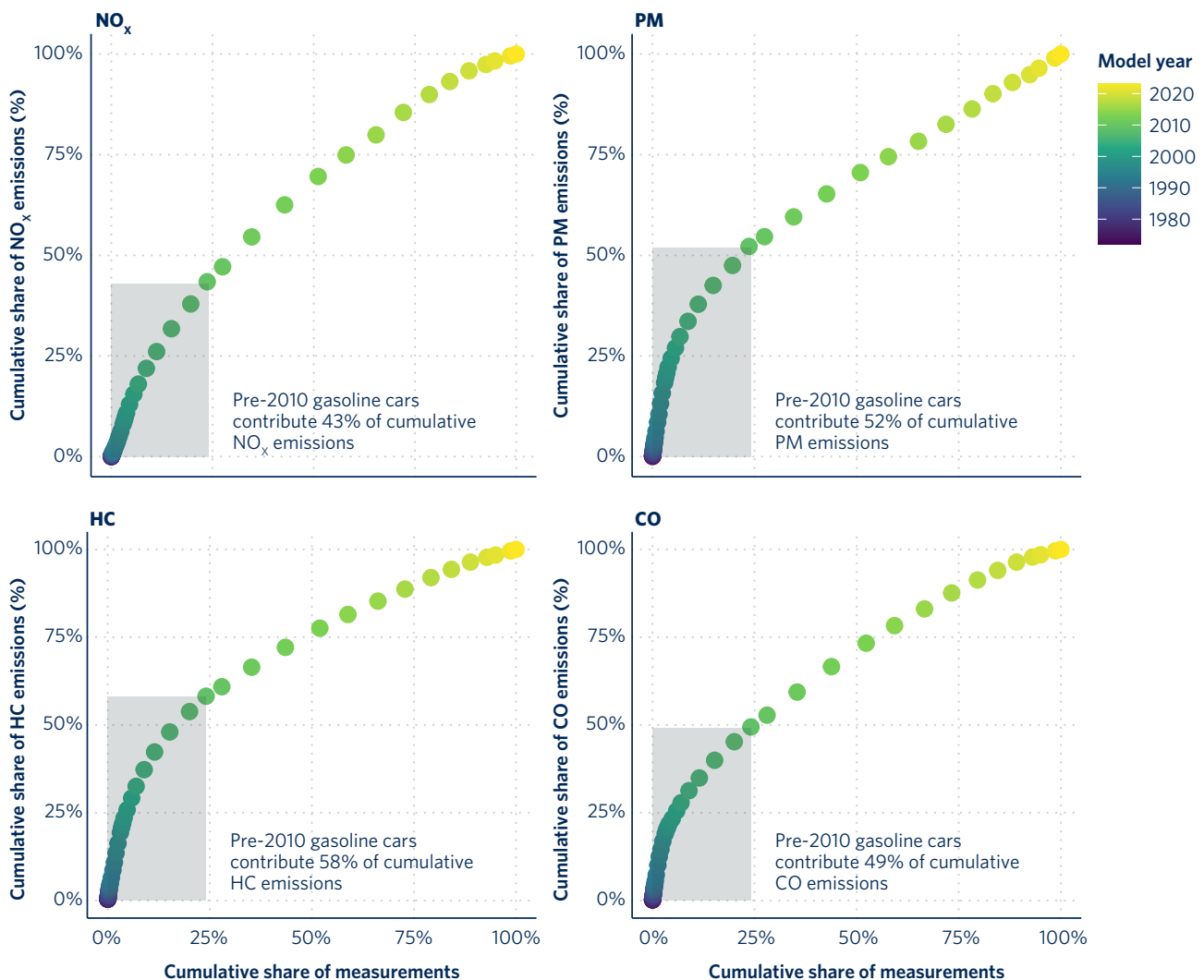


Figure 8. Cumulative share of emissions by cumulative share of gasoline passenger car measurements by model year

57 M. J. Bradley & Associates, *Natural Gas as a Transportation Fuel* (International Council on Clean Transportation, 2005), <https://theicct.org/publication/natural-gas-as-a-transportation-fuel/>.

PM, HC, and CO distance-specific emissions. Similarly, gasoline passenger cars manufactured before 2010 (pre-Euro 2 standards in Colombia) made up 24% of the measured gasoline passenger car fleet but contributed 43%–58% of cumulative emissions, as indicated in the shaded grey boxes in Figure 8. These results highlight the importance of targeting the oldest, highest-emitting portion of the gasoline passenger car fleet in Bogotá for replacement or traffic restrictions.

TAXI EMISSION TRENDS

Taxis in Bogotá showed elevated real-world emissions compared with private passenger cars. For model years 2004–2023, gasoline/CNG taxis showed up to 3.8 times higher average NO_x emissions, up to 4.7 times higher PM emissions, up to 5.2 times higher HC emissions, and up to 3.1 times higher CO emissions compared with private passenger cars of the same model year (Figure 9).

Elevated emissions among taxis may be attributable to the fuel powering them as well as accelerated fleet deterioration. On average, CNG vehicles in Bogotá showed elevated emissions compared with gasoline vehicles. As already described, it is likely that most taxis in Bogotá run on CNG due to the lower relative cost of the fuel and widespread retrofitting among taxis. In addition, the trend shown in Figure 9 may suggest accelerated emissions control deterioration among taxis compared with passenger cars, likely due to the high mileage of taxis.⁵⁸ Figure 9 shows the largest emissions difference between taxis and passenger cars of model years 2010–2018, and this difference decreases for newer taxis. Future data collection

covering more recent model years could help distinguish whether taxis of model years 2023 and later show sustained improvements and therefore lower rates of deterioration. Improved documentation on CNG retrofits among taxis in the RUNT database would also enhance understanding of emission trends.

Figure 9 also illustrates that there has been little improvement in average real-world PM emissions among gasoline passenger cars since model year 2010 and taxis since model year 2020. Similar trends among light-duty vehicles in the United States have been attributed to a shift toward gasoline direct injection (GDI) technology, which shows higher real-world PM emissions compared with other injection technologies.⁵⁹ Similar to the United States, Colombia has experienced growth in the use of GDI technology in the vehicle market.⁶⁰

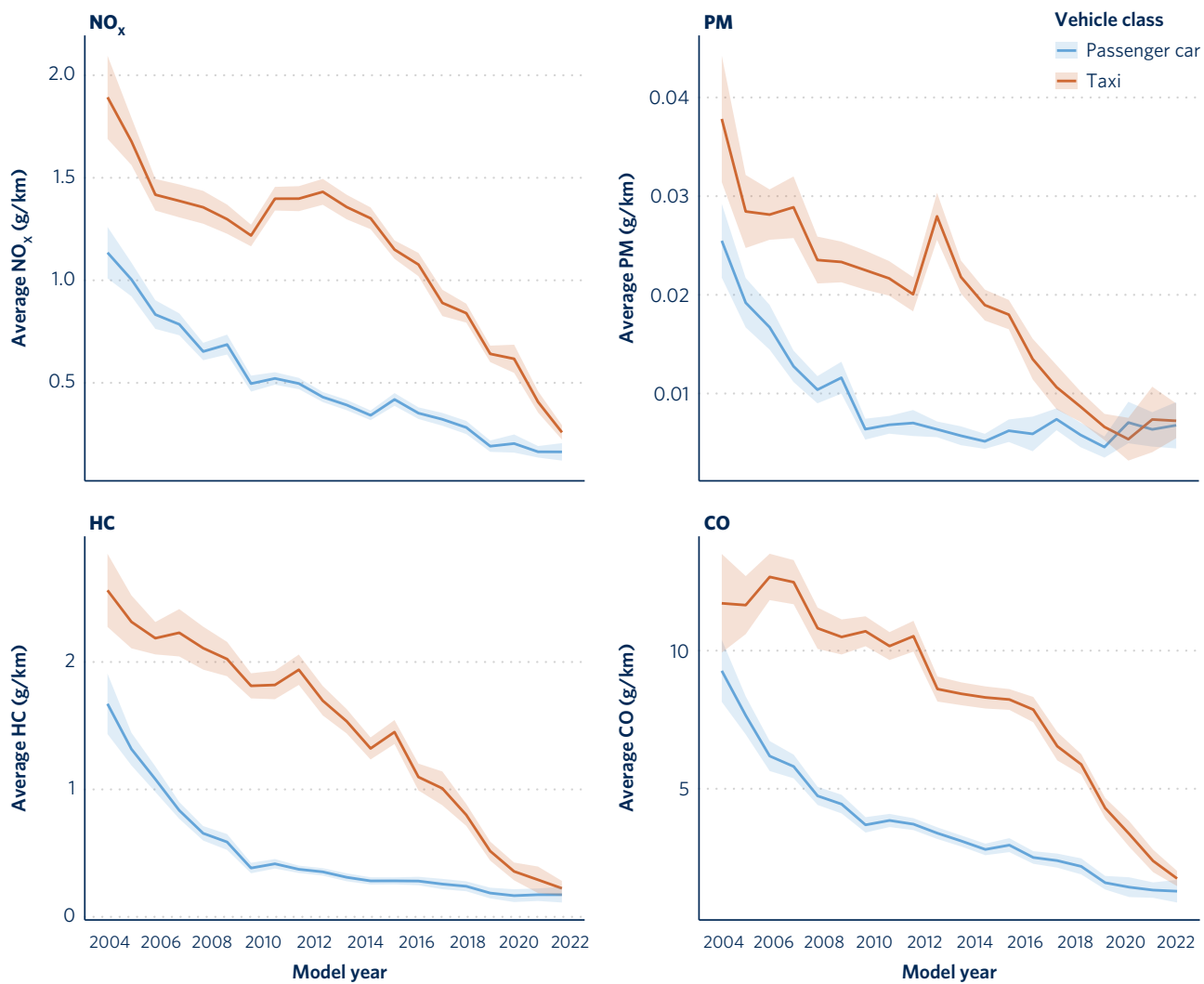
A comparison of common taxi models with private passenger cars of the same model year group (Figure 10) provides additional evidence for elevated emissions among taxis in Bogotá. As shown, the Hyundai Accent, Hyundai i10gl, and Kia Rio taxis showed 1.4–3.3 times higher NO_x emissions, 1.8–3.4 times higher PM emissions, 3.2–4.1 times higher HC emissions, and 1.6–2.3 times higher CO emissions than private gasoline passenger cars.

The results in Figures 9 and 10 highlight the importance of targeting the taxi fleet for vehicle inspection and maintenance or renewal. Similar trends of elevated taxi emissions were observed in the TRUE Mexico City analysis, which is explored in greater detail in a later section.

58 Cuéllar Álvarez, “Development.”

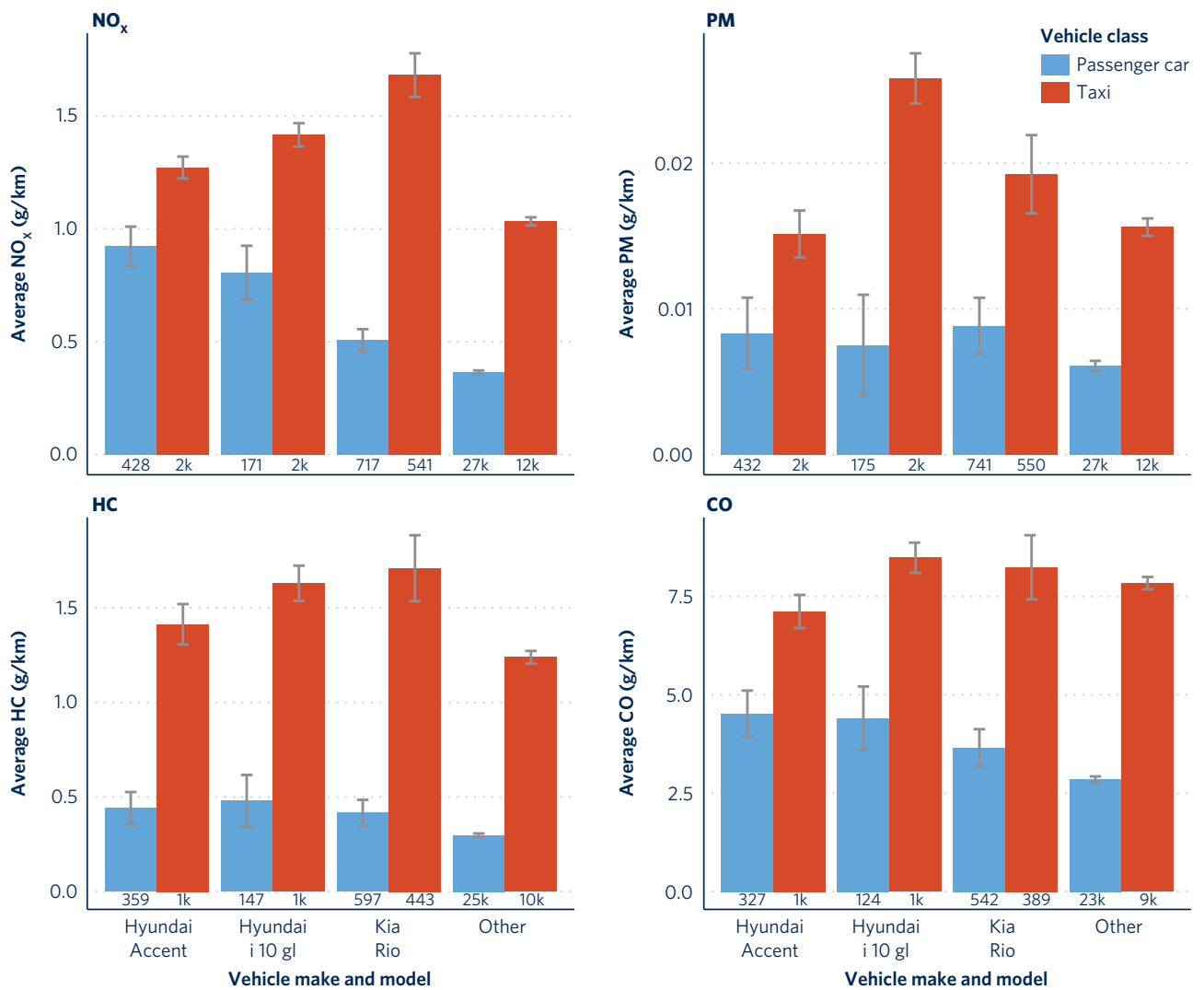
59 Meyer et al., *Particulate Matter*.

60 Supriya Yadav, *Gasoline Direct Injection GDI System Market Analysis*, Cognitive Market Research, October 2025, <https://www.cognitivemarketresearch.com/gasoline-direct-injection-gdi-system-market-report>.



Note: Shaded regions represent the 95% confidence interval.

Figure 9. Average distance-specific emissions by model year for private gasoline passenger cars compared with gasoline/CNG taxis in Bogotá



Note: The figure compares taxis and passenger cars of model year group 2010–2022, aligned with Euro 2 standards in Colombia. Error bars represent the 95% confidence interval. Numbers below bars indicate number of measurements.

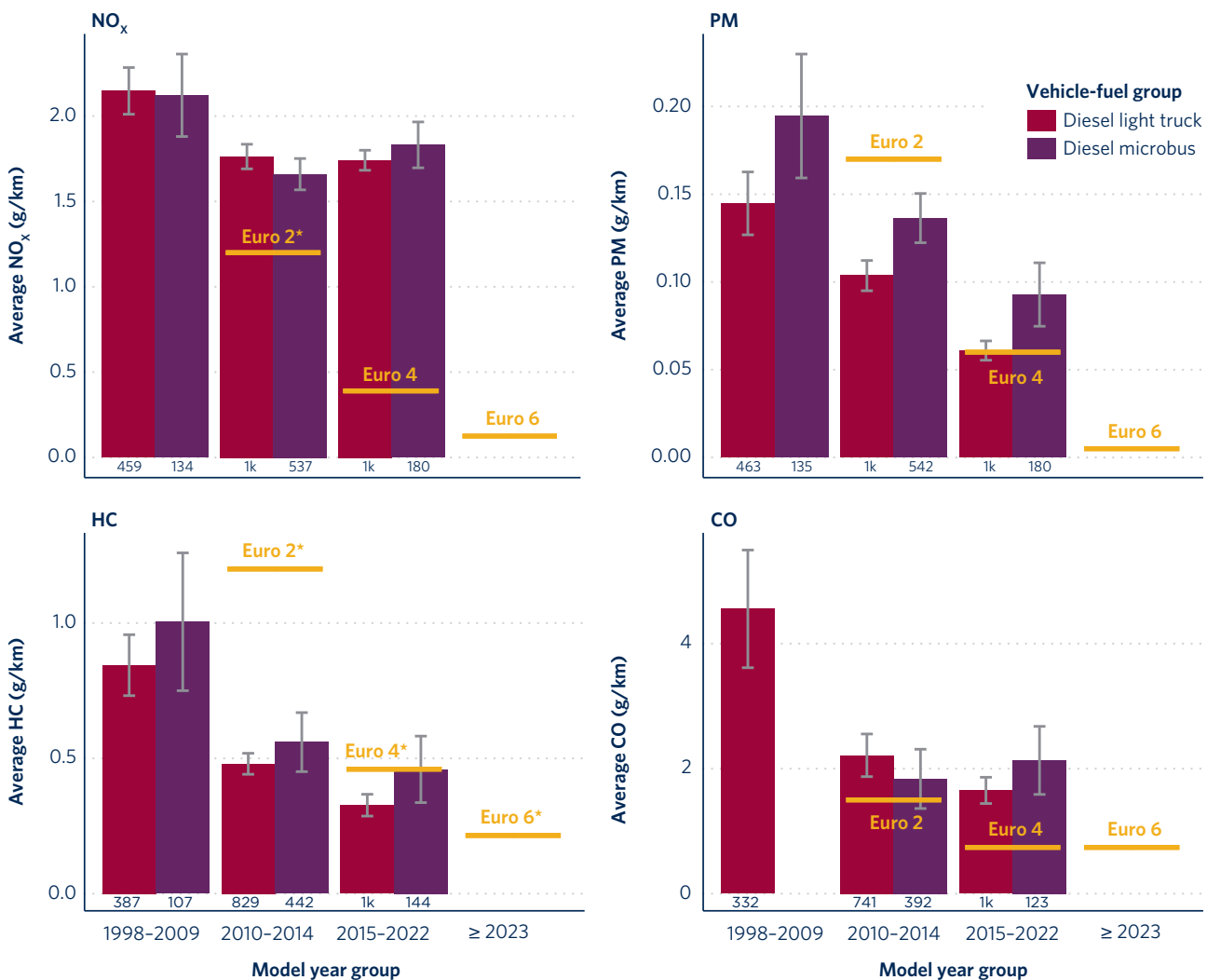
Figure 10. Average distance-specific emissions among common taxi models compared with private passenger cars

DIESEL VEHICLE EMISSION TRENDS

LIGHT TRUCKS AND MICROBUSES

Diesel light trucks and microbuses showed limited NO_x emission improvements over time, with real-world emissions above Euro standard type-approval limits.⁶¹ Corresponding to when Euro 4 standards were in effect, diesel light trucks and microbuses of model years 2015–2022 showed real-world NO_x emissions over 4 times higher than the Euro 4 type-approval limit (Figure 11). This is consistent with past TRUE research

finding that meaningful real-world NO_x emissions improvement is typically not observed until compliance with Euro 6 and later standards (i.e., beginning in 2023 in Colombia).⁶² Among diesel passenger cars of model years 2015–2022, we also observed a trend of real-world NO_x emissions that were 6 times higher than the Euro 4 type-approval limit (Figure A4). Progressive strengthening of emission standards is especially important for reducing NO_x emissions from diesel vehicles.



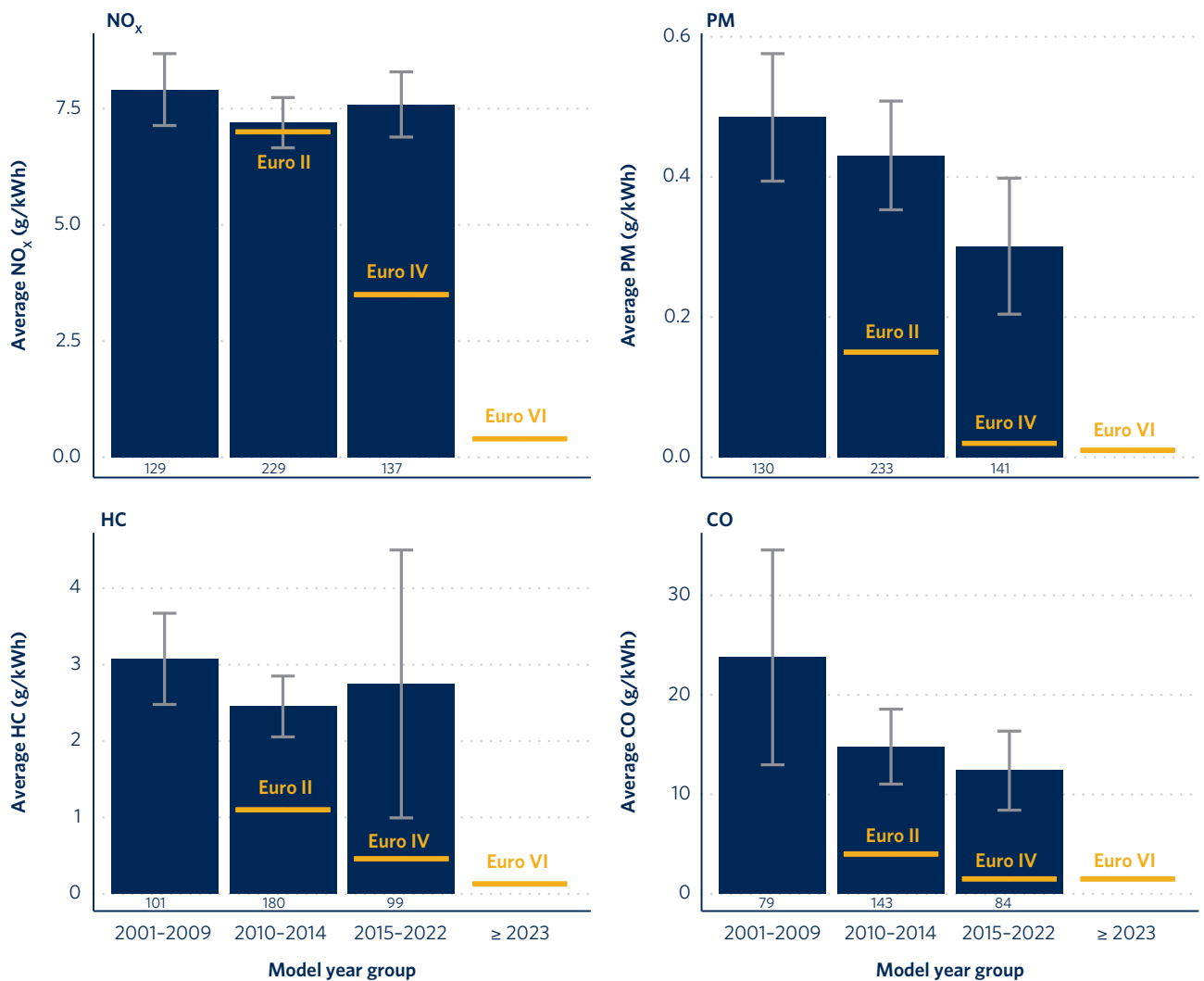
Note: Error bars represent the 95% confidence interval. Numbers below bars indicate number of measurements. Euro emissions limits shown are for N1 class III (over 1,700 kg) vehicles. Euro limits are shown for reference only. There were insufficient measurements from model year 2023 vehicles to analyze vehicles certified to the newest Euro 6 standards, but the limit is shown for reference.

*Indicates HC+ NO_x limit.

Figure 11. Average distance-specific emissions among diesel light trucks and microbuses over time

61 Comparisons are not intended to determine compliance with regulatory standards, as testing conditions and measurement methods differ between laboratory and real-world measurements.

62 Kaylin Lee et al., *Evaluation of Real-World Vehicle Emissions in Warsaw* (TRUE Initiative, 2022), <https://trueinitiative.org/research/evaluation-of-real-world-vehicle-emissions-in-warsaw/>.



Note: Error bars represent the 95% confidence interval. Numbers below bars indicate number of measurements. Euro limits are shown for reference only.

Figure 12. Average energy-specific emissions among diesel heavy-duty vehicles over time

Diesel light trucks and minibuses generally exhibited lower average PM, HC, and CO emissions, with newer model year groups aligned with increasing emissions limit stringency in Colombia. Diesel light trucks of model years 2010–2022 showed PM emissions within Euro 2 and Euro 4 limits; however, diesel minibuses of model years 2015–2022 showed emissions 1.5 times higher than the Euro 4 limit.

HEAVY-DUTY VEHICLES

Aligned with results for other diesel vehicles, diesel heavy-duty vehicles exhibited consistently high real-world NO_x emissions, showing no measurable improvement in emissions performance over time. Heavy-duty vehicles between model years 2015 and

2022 showed particularly elevated real-world PM emissions, at 15 times Euro IV type-approval limits (Figure 12). In the same model year group, real-world emissions for other pollutants were also above Euro IV type-approval limits, at 2 times for NO_x, 6 times for HC, and 8 times for CO.

The distribution of PM emissions for diesel heavy-duty vehicles was positively skewed, with the average exceeding the median by 0.2 g/kWh, indicative of high-emitting vehicles within the diesel heavy-duty fleet (Figure 13). The top 10 percentile of PM emitters showed emissions above 1 g/kWh, which is approximately 7 times the Euro II type-approval type-approval limit and 50 times the Euro IV type-approval limit. A similar distribution of model year groups was

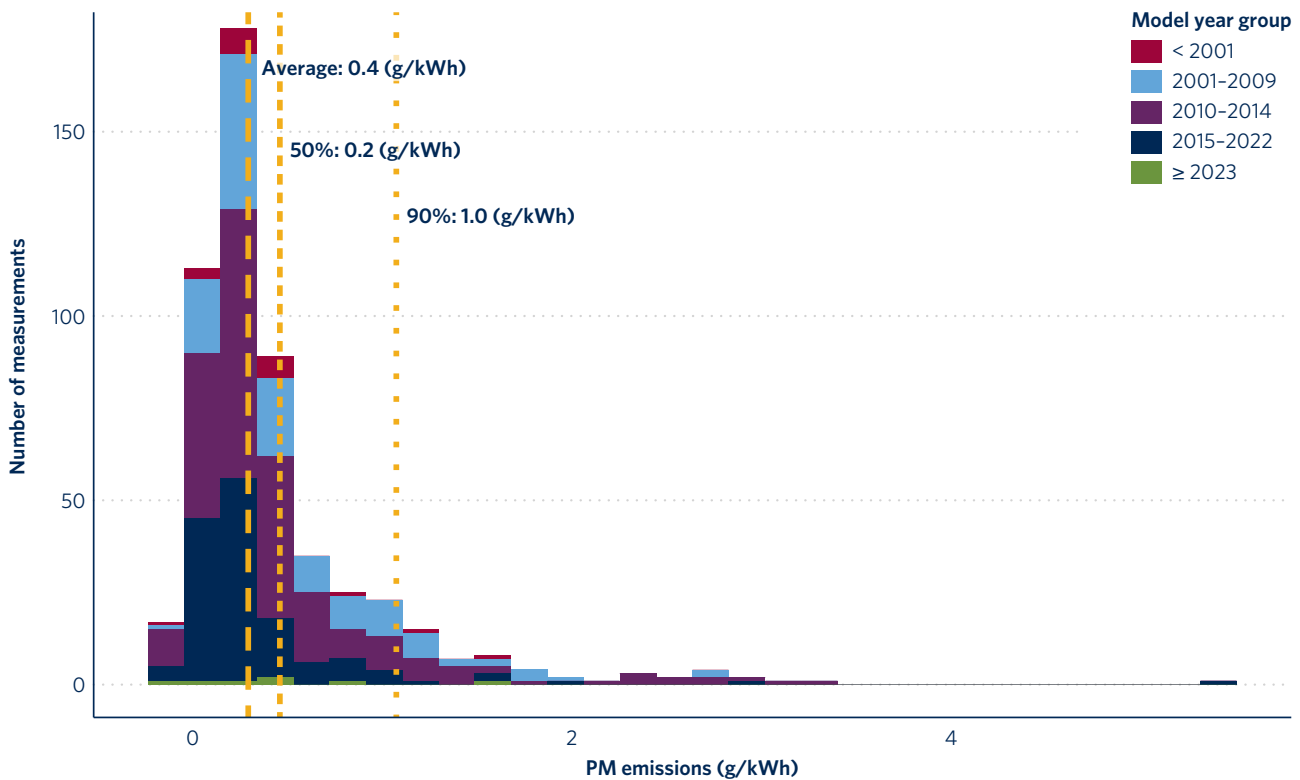


Figure 13. Diesel heavy-duty vehicle PM energy-specific emissions spread by model year group

reflected among the top 10% of emitters compared with the rest of the fleet, revealing that emission standards were not the only predictor for high-emitting diesel heavy-duty vehicles in Bogotá. While Bogotá’s heavy-duty trucks do skew older—the oldest measured was 77 years of age—these results suggest that fleet modernization and vehicle turnover alone likely would not address high real-world emissions. Therefore, further investigation into the reasons for these elevated emissions among this vehicle-fuel group is warranted. Additionally, measuring the real-world emissions of heavy-duty vehicles of model years 2023 and later would provide useful information to determine whether high emissions persist among the newest vehicles.

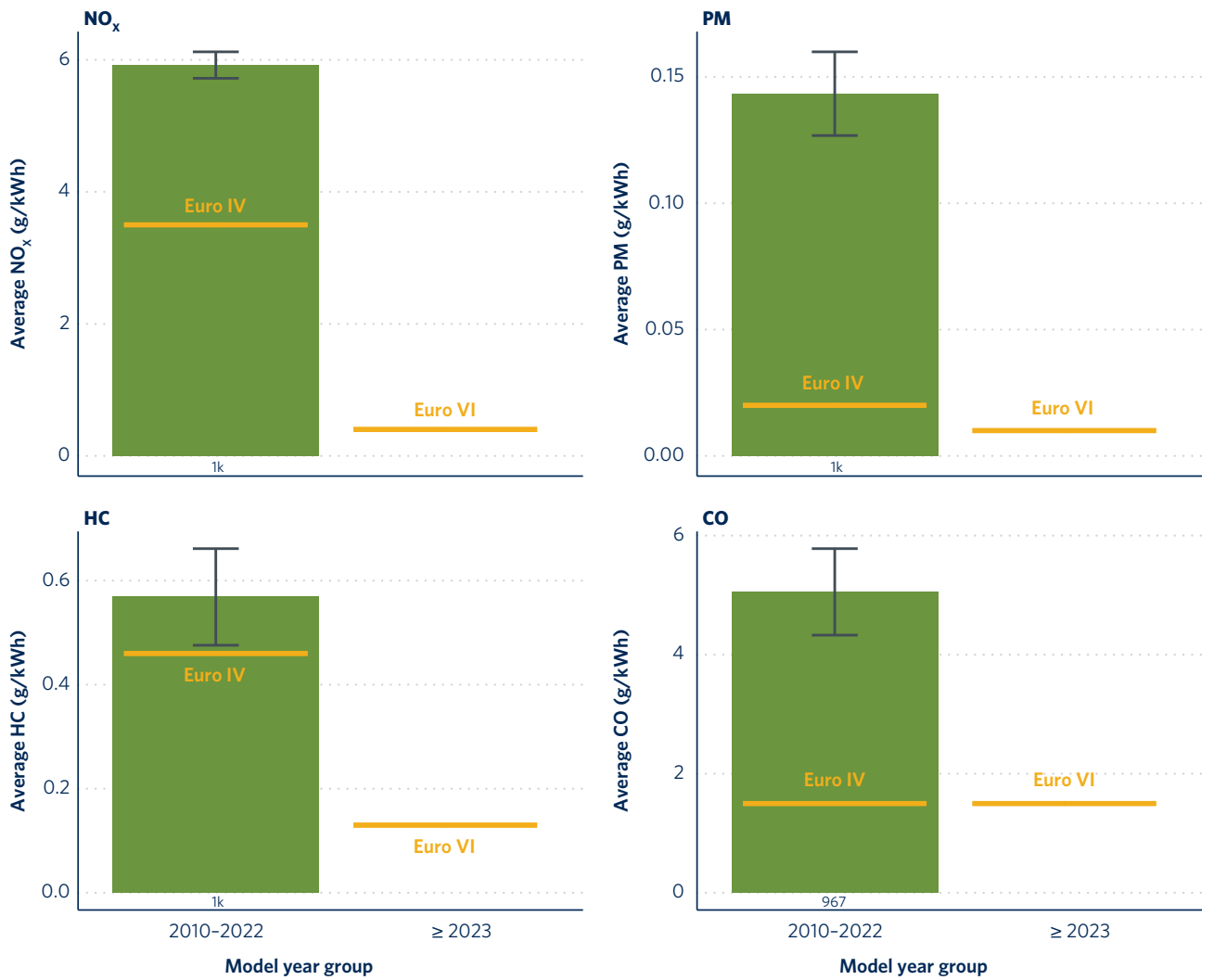
BUS EMISSION TRENDS

Diesel buses in Bogotá exhibited particularly elevated real-world PM emissions compared with the Euro IV emissions standard limits. Diesel buses of model years 2010–2022 showed average PM emissions 7 times above the Euro IV type-approval limit, a similar trend to diesel heavy-duty vehicles in Bogotá (Figure 14). In the same model year group, real-world emissions for other pollutants were also above Euro IV type-approval limits, at 1.7 times for NO_x , 1.2 times for HC, and 3.4 times

for CO. These results underscore the importance of Bogotá’s ongoing efforts to phase out diesel buses from the fleet in favor of lower- or zero-emission models. Similar to other diesel vehicles in Bogotá, average real-world PM emissions far above assumed emission limits warrant further investigation or targeted inspection and maintenance.

Diesel buses, which comprised the majority of buses measured, were 7 years of age on average, with 98% belonging to model years 2010–2022, corresponding to when Euro IV emission standards for urban diesel buses went into effect. CNG-powered buses were mostly of model year 2021 and were likely certified to Euro VI standards, as the city has been introducing Euro VI CNG-powered buses into the TransMilenio and SITP zonal fleets since 2019.⁶³ Model year 2021 CNG buses showed real-world emissions below Euro VI type-approval limits. Our analysis of model year 2010–2022 diesel buses included measurements of both TransMilenio BRT buses as well as other, non-BRT buses. Because both types of buses showed similar emission trends, we aggregated the results.

⁶³ Cuevas, “Con 320 Buses Zonales”; Suache, “Empiezan a Rodar los Primeros 140 Buses.”



Note: Error bars represent the 95% confidence interval. Numbers below bars indicate number of measurements. Euro limits are shown for reference only. There were insufficient measurements from model year 2023 vehicles to analyze vehicles certified to the newest Euro 6 standards, but limit is shown for reference.

Figure 14. Average energy-specific emissions among diesel buses

EMISSIONS CASE STUDY: BOGOTÁ VERSUS MEXICO CITY

A comparison with the TRUE remote sensing study in Mexico City reveals important differences in real-world emissions performance that may inform policy priorities for Bogotá. Results indicated that policies beyond national vehicle emission standards have likely contributed to sustained emission reductions in Mexico City. Most notably, Bogotá could consider the inclusion of NO_x emission limits in its routine vehicle inspection program and use of remote sensing to monitor real-world emissions.

VEHICLE AND EMISSION TRENDS

The Mexico City study, conducted in 2022, involved measurements at 21 locations in Mexico City, the State of Mexico, and Puebla.⁶⁴ Nearly 75,000 measurements were collected with valid pollutant readings, resulting in 44,731 measurements after filtering for vehicle speed and matching vehicle information. The Mexico City study focused on gasoline light-duty vehicles, including

passenger cars and taxis.⁶⁵ Both taxi and passenger car fleets trended slightly newer in Mexico City compared with Bogotá (Figure 15). Passenger cars and taxis in Mexico were on average 1 and 2 years younger than those in Bogotá, respectively. Nevertheless, vehicles in both cities were concentrated in model years 2010–2018. Mexico City has a very small share of taxis that were manufactured in 2008 or earlier, likely due to a 10-year operation restriction.

Results from both regions showed that newer vehicles emitted demonstrably lower emissions compared with the oldest vehicles in the fleet, and taxis in both cities showed substantially higher emissions compared with equivalent passenger cars, indicating emission control system deterioration in taxis due to high mileage (Figure 16). Despite similarities in overall trends, important differences emerged between the two cities regarding emission levels.

The two regions showed similar average NO_x and PM emissions for passenger cars manufactured before 2010. However, Bogotá’s newer passenger cars (model year 2010 and later) showed higher NO_x and PM emissions than passenger cars in Mexico City. Of these vehicles, Bogotá’s passenger cars had 2 times higher NO_x emissions on average compared with passenger

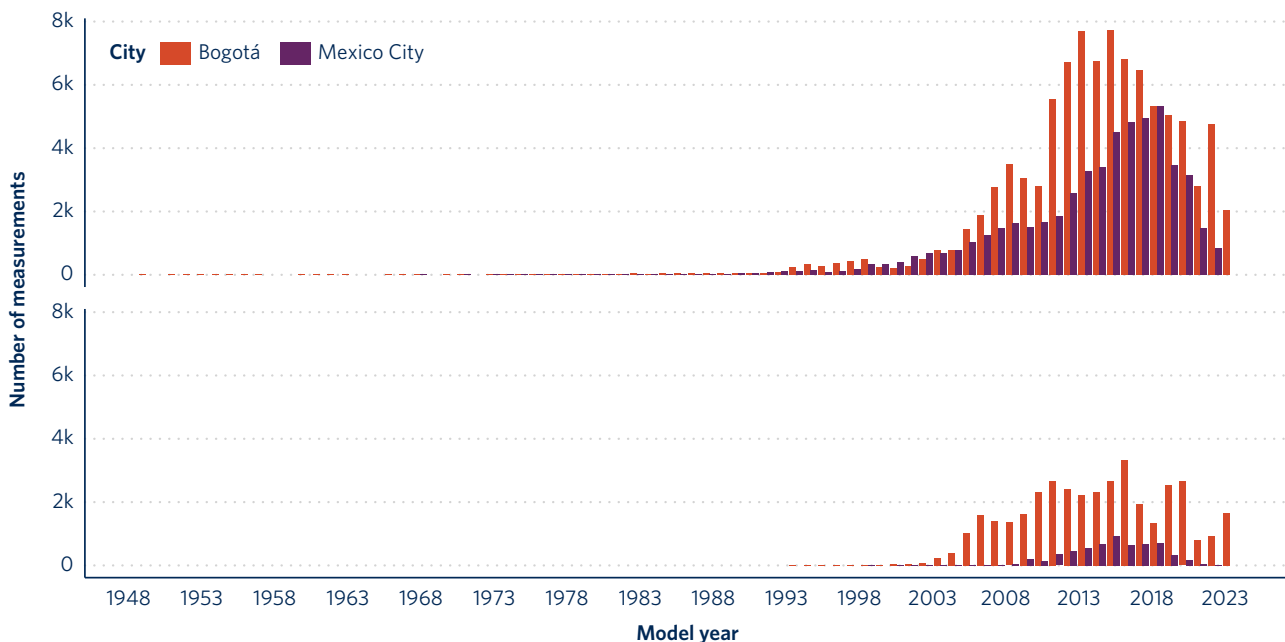
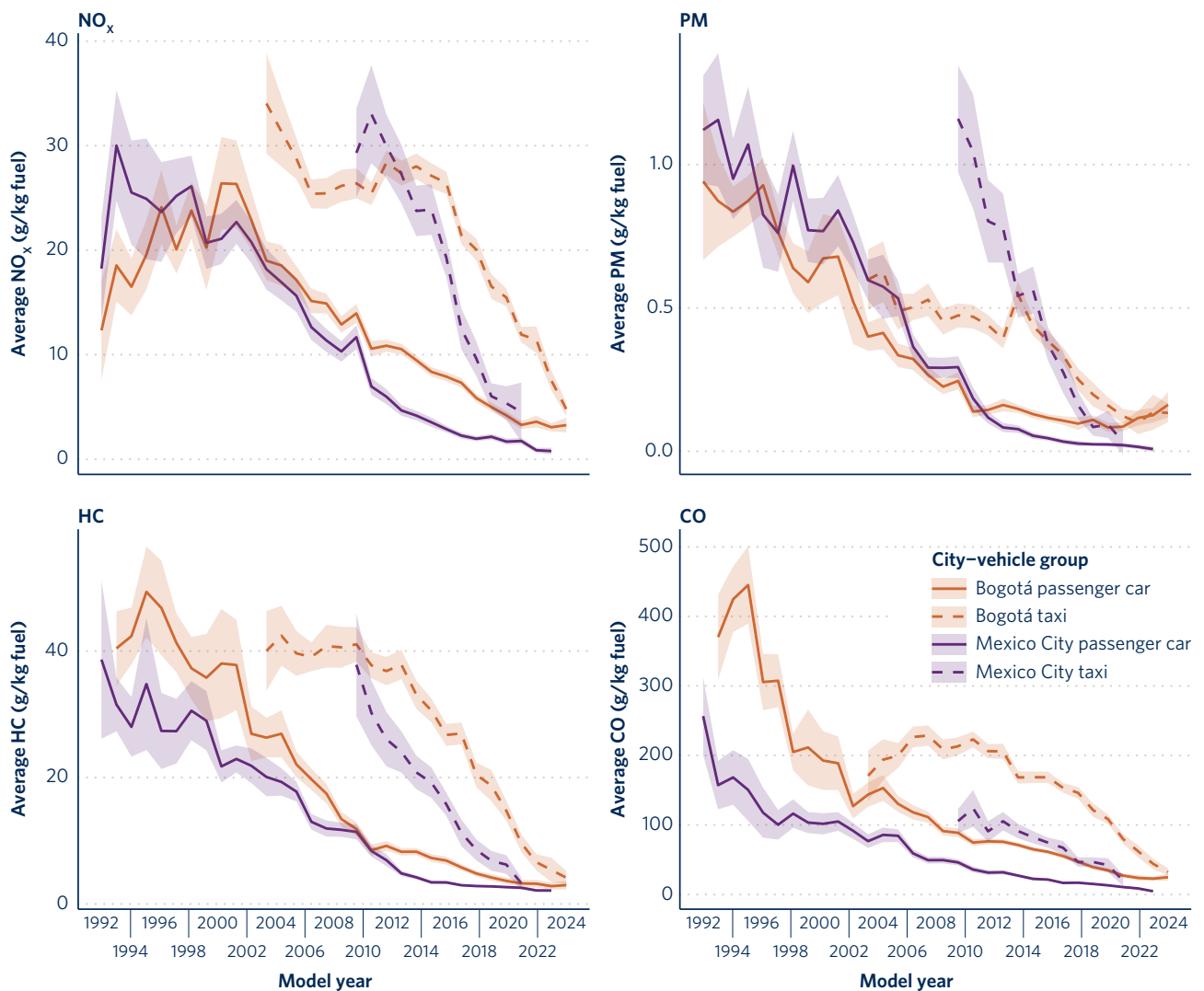


Figure 15. Measurements of passenger cars and taxis in Bogotá and Mexico City by model year

64 Meyer et al., *Passenger Vehicle and Taxi Emissions in Mexico City*.

65 Throughout this section of the analysis, passenger cars and light trucks in Bogotá were re-categorized as passenger cars to enable a better comparison with the Mexico dataset.



Note: Shaded areas indicate the 95% confidence interval of average estimate. Dotted lines indicate taxi emissions and solid lines indicate passenger car emissions.

Figure 16. Fuel-specific NO_x, PM, HC, and CO emissions by model year for passenger cars and taxis in Bogotá and Mexico City

cars in Mexico City; while PM emissions steadily declined with newer model years in Mexico City, they roughly stayed the same for vehicles in Bogotá. For model years 1992-2022, Bogotá's cars had 1.4-4.8 times higher CO emissions, and 1.1-2.0 times higher HC emissions compared with Mexico City cars. Taxis in Bogotá also showed consistently higher relative CO and HC emissions compared with taxis in Mexico City.

REGIONAL DIFFERENCES

Several differences likely contributed to the gap in emissions between regions, including differences in fuel sulfur content, national emission standards, regional regulations of in-use vehicle emissions, and geography. An analysis of these factors alongside emission results

provides useful insight into Bogotá's successes in addressing vehicle emissions as well as potential policy gaps. Although relatively comparable between regions, differences in fleet composition, driving conditions, and ambient temperature may have contributed to the disparities in average real-world emissions.⁶⁶

Fuel sulfur content. Historically higher sulfur levels in gasoline fuel in Bogotá provides one explanation for the emissions gap between the two fleets, because persistent use of higher sulfur fuel degrades vehicle emission control systems, including catalytic converters

⁶⁶ Median values for the Bogotá and Mexico City, respectively, are as follows: 24km/h and 23 km/h for speed, 0.35 m/s² and 0.47 m/s² for acceleration, 4 kW/t and 5.9 kW/t for VSP, and 24 °C and 31 °C for ambient temperature.

and particulate filters.⁶⁷ Mexico’s national standard for gasoline sulfur content is 30 ppm as an annual average and 80 ppm as a per-batch maximum since 2016, although Mexico City began phasing in 30 ppm sulfur fuel as early as 2007.⁶⁸ Gasoline sulfur fuel in Colombia was previously 300 ppm before being reduced to 100 ppm in 2021 and 50 ppm as of 2022.⁶⁹

National emission standards. Mexico’s light-duty emission standards were last updated in 2005, with the introduction of a standard that combined U.S. Tier 1 and Euro 3 standards (Table 4).⁷⁰ Colombia’s 2008 Resolution No. 910 introduced a standard with similar CO limits but with key differences in HC and NO_x limits.⁷¹ The Colombian emissions standard offered a combined limit for HC and NO_x emissions when certifying to Euro standards. Though Colombia’s NO_x limit when certifying to U.S. standards is equivalent to Mexico’s, the option for certifying to the less stringent Euro standard may provide one explanation for the elevated HC and NO_x emissions from Bogotá’s vehicles.

The continued decline in emissions of Mexico City’s vehicles despite unchanged national emission standards points to other policy drivers of these

reductions. Though differences in emission limits may explain some of the gap between the two regions, it is likely that other regional policy measures may be contributing to reducing real-world emissions in Mexico City. This highlights the importance of developing a comprehensive policy approach that is not limited to national emission standards.

Regional regulations. Mexico City’s inspection and maintenance program is one likely contributor to lower average emissions among newer passenger cars. While Bogotá’s mandatory periodic testing does not include any limit for NO_x, Mexico City’s periodic testing does, with the greatest stringency for newer vehicles meeting the cleanest certificates. Passenger cars in Mexico City that meet the two cleanest certificates during in-use testing averaged 1–5 g/kg fuel for NO_x in remote sensing testing, which is at or below levels for even the newest cars in Bogotá. These results suggest that Mexico City has an effective inspection and maintenance program in place and that Bogotá may be able to reduce real-world emissions by adding NO_x limits. Besides including NO_x limits, Mexico City’s program also exempts cars certified to U.S. Tier 2 Bin 5 or Euro 5 standards from periodic testing for 2–4 years,

Table 4. Emission standards for new gasoline vehicles in Bogotá and Mexico since 2010

Country	Standard	Applicable years	Cycle	CO (g/km)	NMHC ^a (mg/km)	NO _x (mg/km)	Equivalent standard
Mexico	NOM-042	2005–present	FTP (U.S.)	2.11	99	249	Tier 1+/Euro 3
Colombia	Resolución 910 de 2008	2010–2022	FTP (U.S.)	2.11	160	250	Tier 1
			NEDC (Euro)	2.20	500 (HC + NO _x)		Euro 2
	Resolución 0762 de 2022	2023–present	NEDC (Euro)	1.00	100	80	Euro 4

^a NMHC indicates non-methane hydrocarbons.

67 Zhaohui He et al., “Recent Advances in Sulfur Poisoning of Selective Catalytic Reduction (SCR) Denitration Catalysts,” *Fuel* 365 (June 2024): 131126, <https://doi.org/10.1016/j.fuel.2024.131126>.

68 Comisión Reguladora de Energía, *Acuerdo por el que la Comisión Reguladora de Energía Expide la Norma Oficial Mexicana NOM-016-CRE-2016, Especificaciones de Calidad de los Petrolíferos*, [Agreement by which the Energy Regulatory Commission issues the Official Mexican Standard NOM-016-CRE-2016, Quality specifications of oil], October 31, 2016, https://www.dof.gob.mx/nota_detalle.php?codigo=5450011&fecha=29/08/2016#gsc.tab=0; U.S. Agency for International Development and Instituto Nacional de Ecología y Cambio Climático, *Adaptation of the Vehicle Emission Model MOVES to Mexico* (AID-523-C-11-00001), 2022, <https://www.epa.gov/sites/default/files/2021-03/documents/usaaid-inecc-2016-01-31.pdf>.

69 Resolución Número 40444 de 2023.

70 Norma Oficial Mexicana NOM-042-SEMARNAT-2003, Secretaría de Medio Ambiente y Recursos Naturales, September 7, 2005, https://dof.gob.mx/nota_detalle.php?codigo=2091196&fecha=07/09/2005#gsc.tab=0.

71 Resolución 910 de 2008.

which is another mechanism Bogotá could consider to incentivize the adoption of cleaner vehicles.⁷²

Within Mexico City, differences in emissions performance by registration location also demonstrate the impact of periodic testing. The regulation requires that vehicles in Mexico's megalopolis, which includes Mexico City and six surrounding states, undergo periodic testing.⁷³ Previous remote sensing analysis found that older passenger vehicles registered in the State of Mexico emitted much higher pollutant levels compared with their Mexico City counterparts, suggesting that inspection and maintenance procedures may not be uniform across regions.⁷⁴ Regional coordination and homogenization of procedures may therefore be vital for achieving the greatest emissions reduction, an important consideration for Bogotá, surrounding jurisdictions, and the Colombia national government.

Another notable initiative in Mexico is remote sensing, which serves as informal market surveillance. National and regional environmental agencies in Mexico regularly conduct remote sensing testing campaigns to monitor fleet emission trends, collecting over 500,000 vehicle emission measurements since 2008.⁷⁵ Although this program is not part of official compliance structures, it provides oversight that may deter manufacturers from designing emissions control systems that lead to higher real-world emissions.⁷⁶

Taxis. Both regions showed elevated emissions among taxis, indicating that this vehicle segment is an important pollutant source to target. Mexico City has several programs to address taxi emissions. For instance, taxis

are limited to 10 years of operation, although there is no age requirement associated with taxi registration. Additionally, Mexico City has a taxi renewal program that provides rebates for taxi owners who scrap their older vehicle in favor of a newer, lower-emitting vehicle.⁷⁷ While these programs were designed to promote fleet renewal, the number of vehicles replaced has been limited in recent years.⁷⁸ Because taxis are prone to rapid emission control system deterioration, age limits or operation restrictions alone are insufficient to achieve sustained emission reductions. Transitioning to cleaner, more durable vehicle models and technologies and implementing stringent inspection and maintenance requirements are among the solutions to maximize taxi emission reductions.

Geography. Lastly, the higher levels of CO and HC among both passenger cars and taxis in Bogotá could be the result of high elevation, as the city's elevation is approximately 400 meters above Mexico City's.⁷⁹ Incomplete fuel combustion due to high elevation may contribute to higher real-world CO and HC emissions among Bogotá's vehicles.⁸⁰

IMPORTANCE OF MONITORING REAL WORLD EMISSIONS

Results by vehicle manufacturer indicated that Bogotá could benefit from additional efforts to monitor and address high real-world emissions. Figure 17 shows the average NO_x emissions for the most popular vehicle brands in Bogotá, in order from most to least number of measurements. Most vehicle brands showed significantly higher real-world NO_x emissions in Bogotá compared with Mexico City (95% confidence level). Some manufacturers had particularly large differences between the two cities. For example, Hyundai and Kia vehicles measured in Bogotá showed approximately 9 times higher real-

72 Secretaría del Medio Ambiente de la Ciudad de México, "Verificación Vehicular" [Vehicle verification], accessed December 16, 2025, <https://sedema.cdmx.gob.mx/programas/programa/verificacion-vehicular>.

73 Secretaría de Medio Ambiente y Recursos Naturales, *Norma Oficial Mexicana NOM-167-SEMARNAT-2017* [Official Mexican standard NOM-167-SEMARNAT-2017], September 5, 2017, https://www.dof.gob.mx/nota_detalle.php?codigo=5496105&fecha=05/09/2017#gsc.tab=0.

74 Meyer et al., *Passenger Vehicle and Taxi Emissions in Mexico City*.

75 U.S. Agency for International Development and Instituto Nacional de Ecología y Cambio Climático, *Adaptation of the Vehicle Emission Model MOVES to Mexico*; Gerencia de Eficiencia Energética y Sustentabilidad, *Aplicación de la NOM-167-SEMARNAT-2016, Mediante Campañas de Medición de Emisiones con Sensor Remoto en la Megalópolis* [Implementation of NOM-167-SEMARNAT-2016, through emission measurement campaigns with Remote Sensor in the Megalopolis], November 29, 2017, https://www.gob.mx/cms/uploads/attachment/file/555003/10.Informe_Final_Campan_a_Medicio_n_Emisiones_Sensor_Remoto_Megalo_polis_Noviembre_2017_.pdf; Junta de Gobierno del INECC, *Informe de Autoevaluación* [Self-assessment report], December 31, 2019, https://www.inecc.gob.mx/transparencia/transparencia/2019_inf_autoevaluacion.pdf.

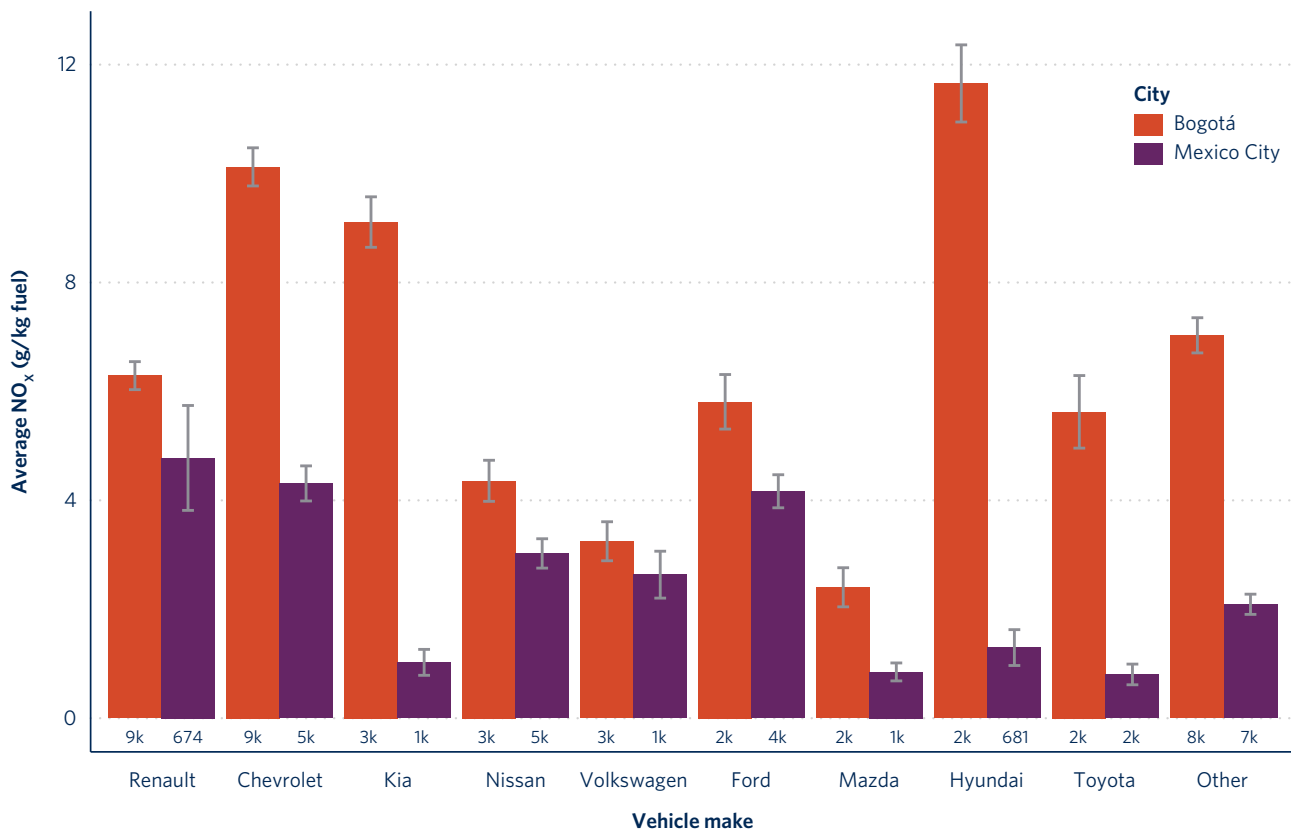
76 Yoann Bernard et al., *Worldwide Use of Remote Sensing to Measure Motor Vehicle Emissions* (International Council on Clean Transportation, 2019), <https://theicct.org/publication/worldwide-use-of-remote-sensing-to-measure-motor-vehicle-emissions/>.

77 Secretaría de Movilidad de la Ciudad de México, "Aviso por el que se dan a Conocer los Lineamientos de Operación de la Acción Social Programa de Sustitución para el Transporte Público Individual Sostenible, 2025" [Notice announcing the operational guidelines of the taxi substitution program, 2025 Social Action], 2025, https://data.consejeria.cdmx.gob.mx/portal_old/uploads/gacetas/d271b15455d24059f599e650c2cd3eaf.pdf.

78 Secretaría de Movilidad de la Ciudad de México, "Aviso."

79 Alcaldía Mayor de Bogotá D.C., *Manual de Uso de Marca Ciudad "Bogotá"* [City brand usage manual "Bogotá"], 2021, <https://bogota.gov.co/bog/manual-de-marca-bogota.pdf>; "Acerca de la Ciudad de México" [About Mexico City], Ciudad de México, accessed October 28, 2025, <https://mexicocity.cdmx.gob.mx/e/about/about-mexico-city/>.

80 Yanxu Ren et al., "Effects of Altitude on Light Gasoline Vehicles: Fuel Consumption and Air Pollution," *Atmospheric Pollution Research* 16, no. 11 (2025), <https://doi.org/10.1016/j.apr.2025.102652>.



Note: Error bars represent the 95% confidence interval. Numbers below bars indicate number of measurements. Vehicle makes with at least 1,500 measurements in Bogotá are included in the plot.

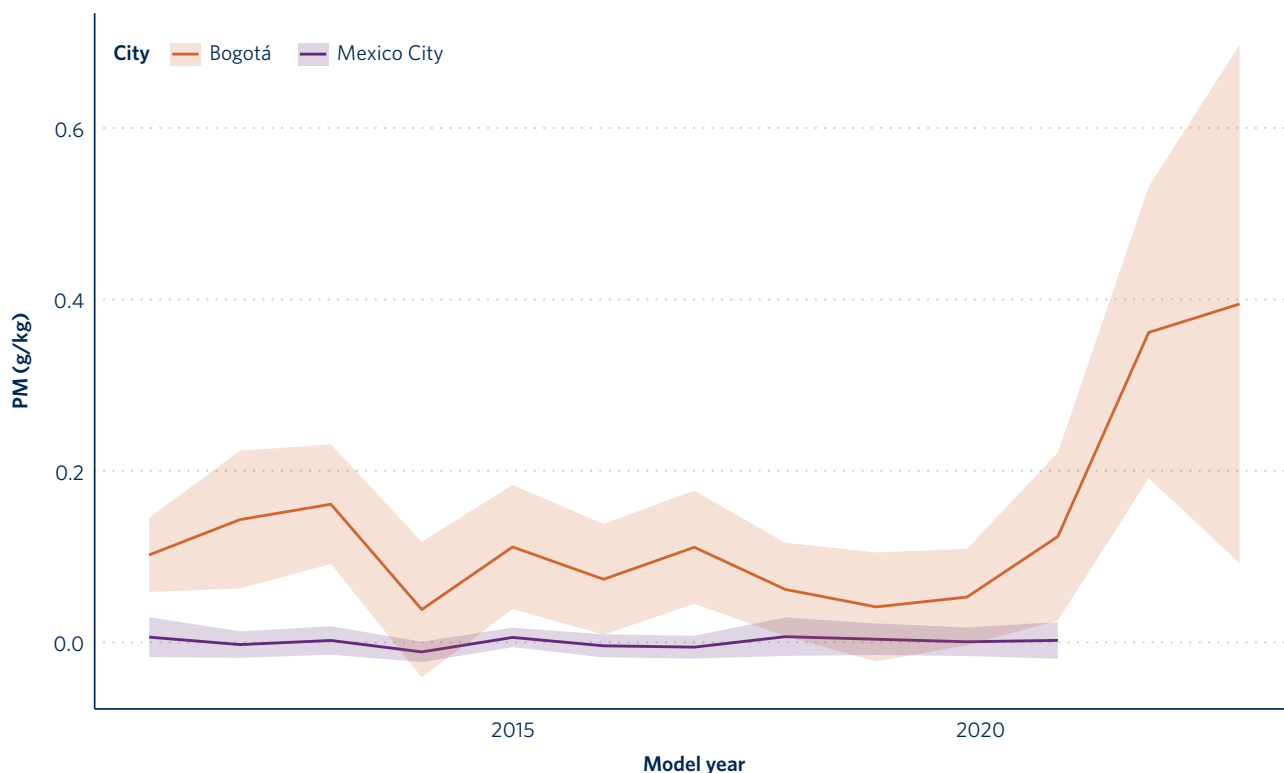
Figure 17. Average NO_x fuel-specific emissions by vehicle make from passenger cars in Bogotá and Mexico City manufactured after model year 2011

world NO_x emissions than those measured in Mexico City. One cause could be increased deterioration among these vehicles in Bogotá due to years of operation using fuel with a higher sulfur content.

There are also notable trends in PM emissions by vehicle brand. As highlighted, passenger car PM emissions have steadily declined in Mexico; meanwhile, they have plateaued in Bogotá, showing a similar trend as gasoline light-duty vehicles in the United States, where the increase in PM emissions has been linked to GDI technology. Further investigation by vehicle brand in Bogotá revealed that one brand, Toyota, showed substantially higher emissions among newer model years. Figure 18 shows the sharp increase in Toyota passenger car PM emissions measured in Bogotá around model year 2021. It is unclear whether these

Toyota vehicles use GDI engines. Toyota vehicles measured in Mexico City do not display the same trend; however, data beyond model year 2021 were limited. This finding suggests that continued monitoring of real-world gasoline PM emissions may be beneficial for both regions to determine whether this trend is evident among other vehicle brands.

The relatively large gap between Bogotá and Mexico City emission measurements among select vehicle brands suggests further investigation may be warranted. Bogotá may consider implementing an official market surveillance program, using remote sensing for fleet monitoring, and adding an NO_x emissions limit for periodic testing to help reduce excess real-world emissions.



Note: Shaded regions represent the 95% confidence interval.

Figure 18. Average PM fuel-specific emissions from Toyota gasoline passenger car by model year in Bogotá and Mexico City

CONCLUSIONS AND POLICY CONSIDERATIONS

This report presented the results of a 2023 remote sensing study in Bogotá, Colombia, comparing the passenger car and taxi emissions with Mexico City remote sensing data. Through the analysis of real-world NO_x , PM, HC, and CO measurements, this study found that the progression of emission standards in Colombia has led to emission reductions in Bogotá. Nevertheless, certain vehicle segments showed real-world emissions above expected levels and their assumed emission limits. Evidence-based policies to target the highest-emitting vehicle groups in Bogotá could help reduce vehicle-related emissions.

This section summarizes the key findings across vehicle segments in Bogotá and highlights policy options to reduce vehicle-related emissions across five key themes.

Diesel vehicles showed NO_x and PM emissions above type-approval limits, highlighting the importance of prioritizing these segments for inspection,

maintenance, and market surveillance. Diesel heavy-duty vehicles and buses exhibited the highest average NO_x and PM emissions among the vehicle fuel groups measured in this study, consistently above estimated Euro type-approval limits. All diesel vehicle groups showed minimal improvement in real-world NO_x emissions performance over time. Diesel light trucks and minibuses had NO_x emissions over 4 times the Euro 4 type-approval limit. Additionally, diesel buses and heavy-duty vehicles likely certified to Euro IV standards showed real-world PM emissions 7 and 15 times above the type-approval limit, respectively. Our results show that there were high PM-emitting diesel heavy-duty vehicles across all model year groups, indicating that further investigation is warranted and action is needed to address excess emissions among the current diesel vehicle fleet.

Elevated emissions may also be the result of auxiliary emission control strategies. An auxiliary emission control strategy refers to a deviation from the vehicle's base emissions control strategy in response to certain operating conditions, which is permitted at high altitudes even under Euro 7 standards. To address any

excess emissions associated with altitude, Colombia could consider including in future emission standards a minimum emissions performance for vehicles operating at Bogotá's altitude.

Diesel vehicles are an important focus for Colombia's existing roadside emissions testing program, and remote sensing could be employed to more comprehensively monitor the vehicle fleet for high emitters. Remote sensing may be favorable over existing roadside testing, which causes disruptions to city traffic and is estimated to cost over COL\$1.75 billion to test no more than 3,000 vehicles per year.⁸¹

Remote sensing can also serve as a tool for market surveillance to verify that vehicles meet emission standards under real-world operating conditions, even when no malfunctions are present. Mexico City's remote sensing programs may be contributing to lower gasoline passenger car emissions compared with Bogotá. Other remote sensing techniques may offer similar benefits, such as plume chasing, which has been trialed successfully in Slovakia.⁸²

These results highlight the importance of an accelerated phaseout of diesel buses to expedite the adoption of electric buses in Bogotá. Alongside continued electrification, adopting Euro 6 standards—with considerations for emissions at altitude—and eventually Euro 7 standards can help to further reduce real-world emissions.

Gasoline vehicle emissions in Colombia have decreased through progressive emission standards, and adopting Euro 6 requirements could yield further reductions. Gasoline passenger cars manufactured since 2023 produced 88%–96% less average NO_x, PM, HC, and CO emissions compared with pre-1998 vehicles made before emission standards were established in Colombia. Adopting Euro 6 emission standards for gasoline light-duty vehicles in Colombia would allow continued emission reductions. Evidence from other cities show that transitioning to Euro 6 requirements—with stricter NO_x emission limits and on-road testing—

can help reduce emissions and close the gap between real-world emissions and regulatory limits.⁸³

Pre-2010 gasoline passenger cars contribute disproportionately to emissions, indicating that restrictions on their operation could effectively reduce emissions. Although gasoline passenger cars manufactured before 2010 (before Euro 2 emission standards in Colombia) made up 24% of the gasoline passenger car fleet measured, they contributed between 43% and 58% of cumulative NO_x, PM, HC, and CO distance-specific emissions. These results are aligned with a 2025 study that found accelerated retirement of pre-Euro and Euro 1 passenger cars in Bogotá could lower fleet-wide CO emissions by about 60%.⁸⁴

Policies that could progressively limit the operation of pre-2010 vehicles include the *pico y placa* policy and the ZUMA initiative. Alongside existing plans to promote electric vehicles to reduce vehicle-related air pollution, the first ZUMA in the Bosa Apogeo region could also limit the operation of the oldest, highest emitting vehicles. These results can inform Bogotá's Environmental Vehicle Labeling system, which classifies vehicles based on their environmental impact to support policies that incentivize cleaner technologies.⁸⁵

These restrictions could be paired with incentives to support vehicle owners in transitioning to newer, lower-emitting models. Well-designed scrappage incentives, reinforced with registration or circulation restrictions where necessary, could provide the quickest route to such emission reductions.

CNG light-duty vehicles emitted over double the real-world emissions of their gasoline counterparts. CNG passenger cars and light trucks emitted higher average emissions across all pollutants compared with their gasoline-powered counterparts of comparable model year groups. CNG-powered passenger cars and light trucks emitted particularly elevated NO_x emissions, at over double that of gasoline vehicles in comparable

81 Helmer Acevedo and Oscar Delgado, *Mecanismos de Bajo Costo Para La Verificación y Control de Emisiones Vehiculares En Colombia* [Low-cost mechanisms for vehicle emission verification and control in Colombia], (International Council on Clean Transportation, 2023), <https://theicct.org/publication/heavy-vehicles-colombia-costs-may23/>.

82 Christina Schmidt et al., "Identification of High Emitting Heavy Duty Vehicles Using Plume Chasing: European Case Study for Enforcement," *Science of The Total Environment* 994 (September 2025): 179844, <https://doi.org/10.1016/j.scitotenv.2025.179844>.

83 Lee et al., *Vehicle Emissions in Warsaw*.

84 Jaime and Mangones, "Benefits of Transportation Strategies."

85 Cielo Fierro, "Así son las Etiquetas con las que el Distrito Medirá Contaminación de Vehículos" [These are the labels that the District will use to measure vehicle pollution], September 9, 2023, <https://bogota.gov.co/mi-ciudad/seguridad/asi-son-las-etiquetas-con-las-que-el-distrito-medira-contaminacion>; Ambiente Bogotá, "Planes, Proyectos y Estrategias para Mejorar la Calidad del Aire de Bogotá" [Plans, projects and strategies to improve air quality in Bogotá], accessed October 24, 2025, https://www.ambientebogota.gov.co/historial-de-noticias/-/asset_publisher/VqEYxdh9mhVF/content/estrategias-para-mejorar-la-calidad-del-aire-de-bogota.

model year groups. The higher emissions among CNG vehicles may be attributable to vehicles retrofitted to use CNG rather than manufactured to use CNG, as these groups were not distinguishable in this study.

Presently, owners of certain dedicated CNG-powered vehicles receive multiple benefits, including exemption from the *pico y placa* traffic restrictions, a discounted annual vehicle tax, and annual mandatory *Seguro Obligatorio de Accidentes de Tránsito* insurance. Focusing existing policies solely on incentivizing electric light-duty vehicles over internal combustion engines would ensure that the purchase and operation of only the lowest-emitting vehicles are encouraged.

Additionally, our findings demonstrated the need for improved data on CNG retrofits in Bogotá to better understand their emissions performance. Currently, the RUNT government dataset does not indicate whether vehicles are manufactured for CNG fuel or retrofitted, and there is a lack of reliable data on the number of retrofitted vehicles, particularly taxis. Additional emissions testing of both types of CNG vehicles would allow for more effective understanding and regulation of CNG vehicles in Colombia.

Policies to address the highest emitting taxis through maintenance and scrappage would help to reduce their elevated real-world emissions. Taxis in Bogotá showed up to 5 times higher real-world emissions compared with private passenger cars of the same model year. We observed similar trends when comparing taxis and passenger cars of the same vehicle model. Widespread CNG retrofitting of taxis in Bogotá likely influenced these elevated emissions. The magnitude and trend of taxi emissions also indicated accelerated emission

control deterioration compared with Bogotá's passenger cars, likely due to higher relative mileage among taxis.

Improved inspection and maintenance procedures can help mitigate the effects of accelerated emission control system deterioration on fleet-wide emissions. Periodic testing currently only includes CO and HC limits; the addition of an NO_x limit, as in Mexico, could help to reduce real-world NO_x emissions from taxis.

Additionally, programs can incentivize taxi owners in Bogotá to replace older taxis with newer models to reduce emissions. This could be achieved through a rebate program that incentivizes owners of the oldest 25% of taxis (i.e., taxis that are 13 years or older) to scrap their old vehicle and receive a rebate to purchase a lower- or zero-emission vehicle (i.e., vehicles compliant with Euro 4 standards or higher), similar to the rebate program in Mexico City.⁸⁶ In addition, Bogotá could introduce Euro 5 and 6 standard requirements for newly registered taxis before other gasoline light-duty vehicles. Policymakers could establish a maximum operating age for all non-electric taxis to help limit the effect of emissions deterioration, similar to programs in Delhi and London.⁸⁷ A maximum operating age of 13 years by 2030, for example, would help ensure the phaseout of Euro 1 and pre-Euro certified taxis from the fleet in Bogotá.

While Bogotá has achieved vehicle emission reductions over time, this report illustrates that continued progress requires targeted policy intervention. Adoption of the evidence-based recommendations presented in this report could support further emission reduction and improved air quality in the city.

⁸⁶ Meyer et al., *Passenger Vehicle and Taxi Emissions in Mexico City*.

⁸⁷ Government of NCT of Delhi Transport Department, *Validity of Contract Carriage (Delhi NCR) Taxis Permit Up to 15 Years*, June 20, 2023, https://transport.delhi.gov.in/sites/default/files/Transport/circulars-orders/government_of_national_capital_territory_of_delhi.pdf; Transport for London, *Taxi Age Limits and Exemptions – Additional Information*, accessed October 24, 2025, <https://content.tfl.gov.uk/taxi-age-limits-additional-information.pdf>.

APPENDIX

Table A1. Spanish-language vehicle class from the vehicle specification data and corresponding English-language vehicle class categorization in this report

Report vehicle class	Spanish-language vehicle classes	Examples
Bus	Bus	Single-body bus, articulated bus, bi-articulated bus
Heavy-duty vehicle	Camion, volqueta	Cargo truck, dump truck
Light truck	Camioneta	SUV, cargo van, light commercial truck
Motorcycle	Motocarro, motocicleta	Motorcycles, scooters
Passenger car and Taxi	Automovil, campero	Sedan, hatchback, SUV
Microbus	Microbus	Passenger van ^a

^a Most common models included Hyundai H1, Kia Pregio GS, Nissan Urvan, and Volkswagen Transporter T5.

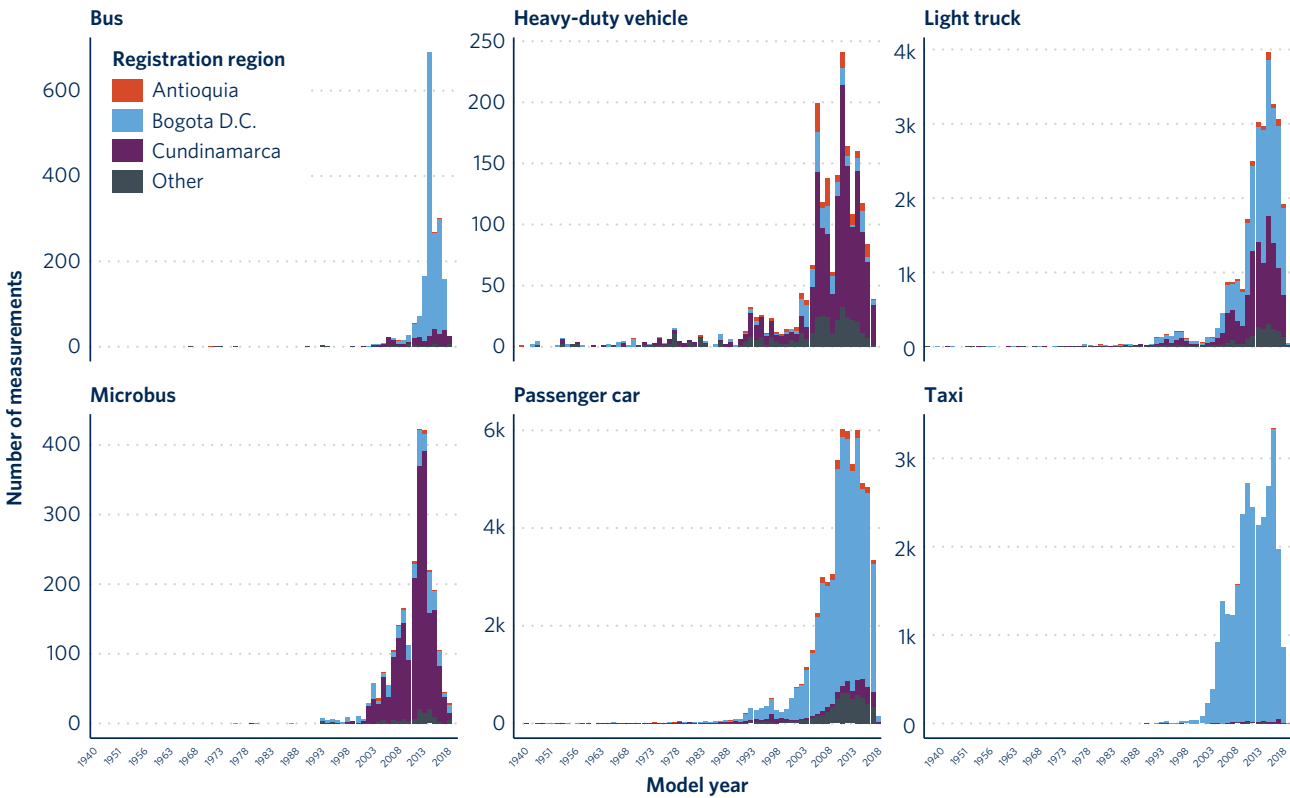
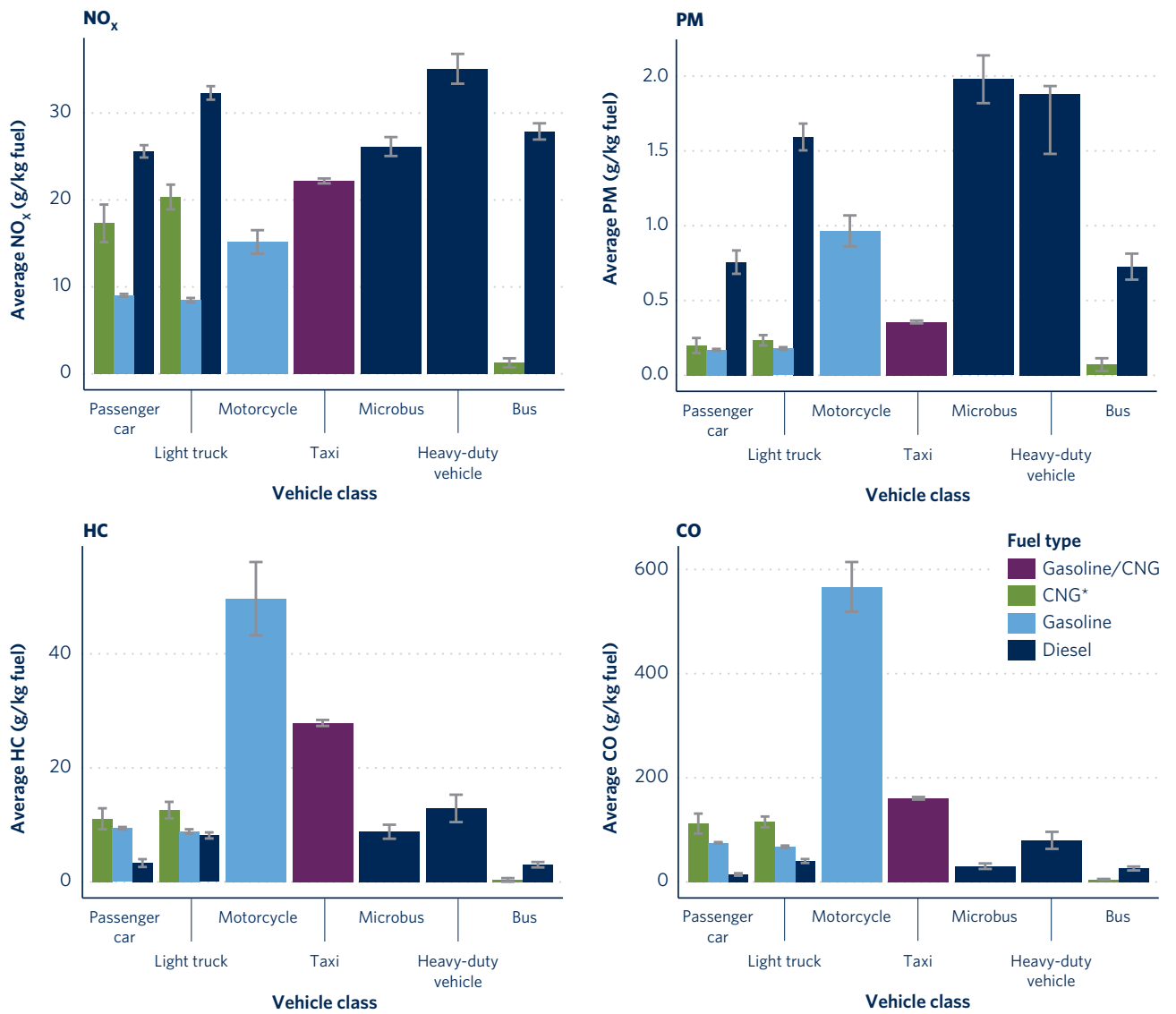


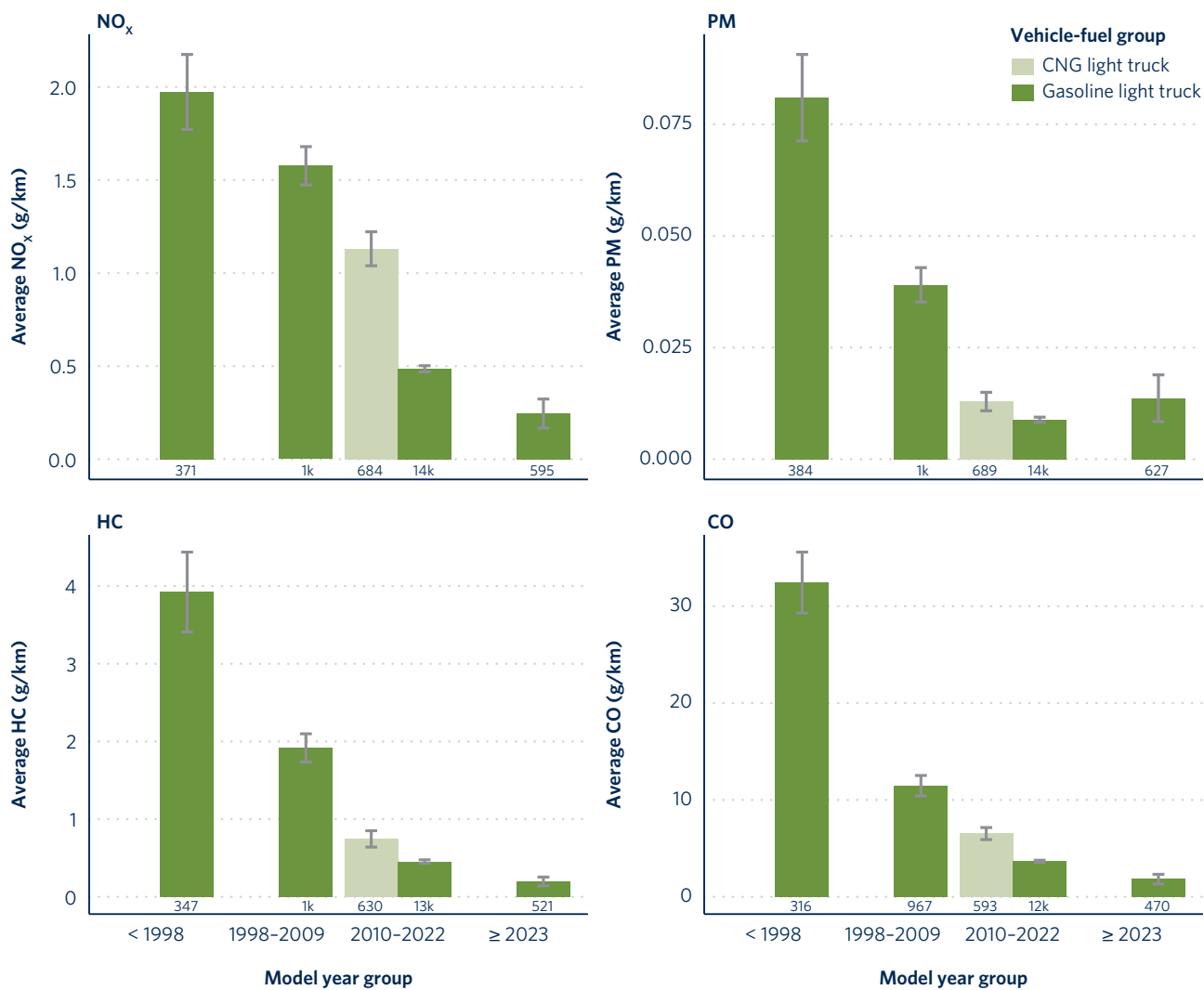
Figure A1. Measurements by vehicle registration regions among vehicle classes with registration data



Note: Error bars represent the 95% confidence interval.

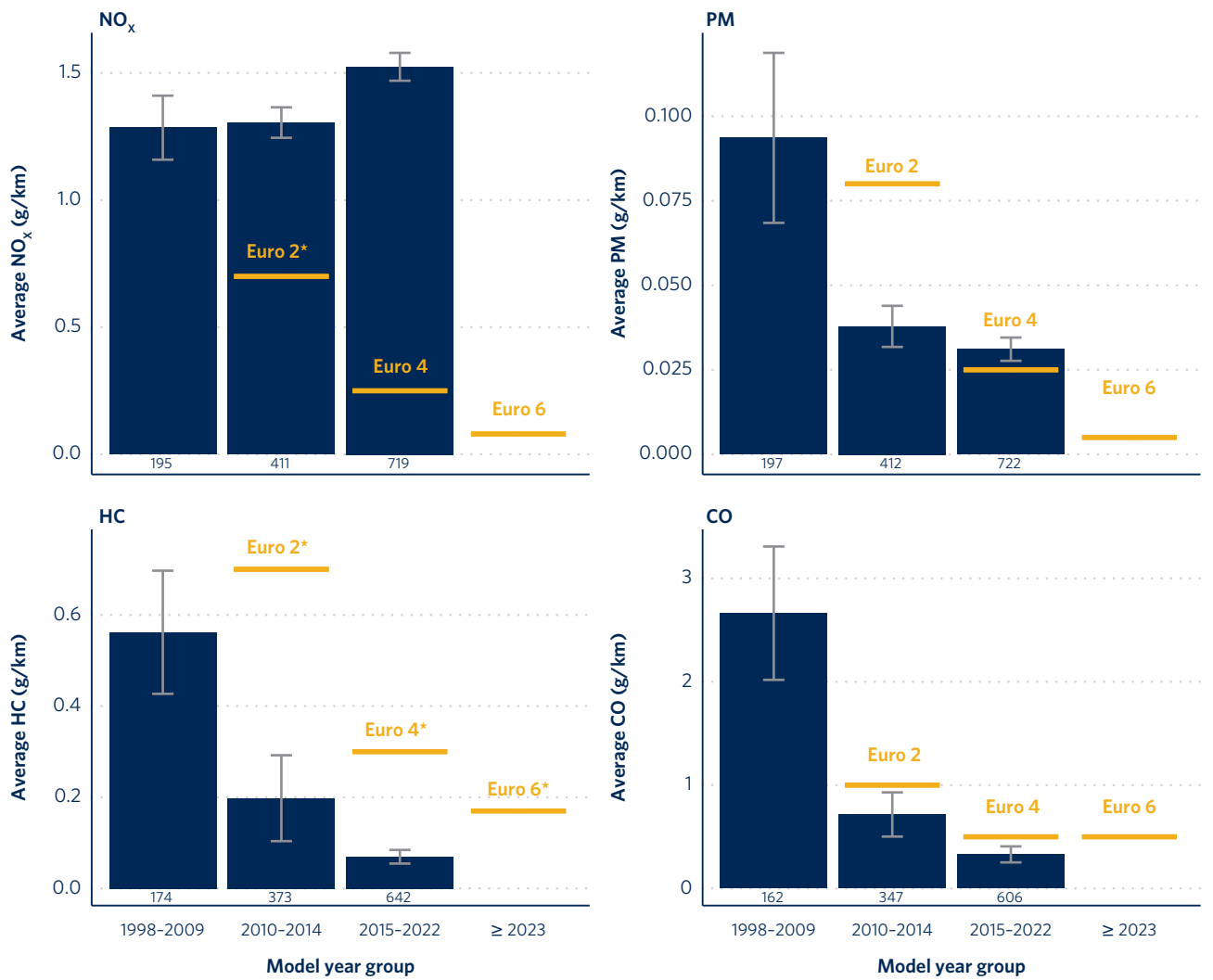
* CNG passenger cars are likely primarily retrofitted bi-fuel CNG/gasoline vehicles.

Figure A2. Average real-world NO_x, PM, HC, and CO fuel-specific emissions by vehicle class and fuel type



Note: Error bars represent the 95% confidence interval. Numbers below bars indicate number of measurements.

Figure A3. Average distance-specific emissions among CNG- and gasoline-powered light trucks over time



Note: Error bars represent the 95% confidence interval. Numbers below bars indicate number of measurements. Euro limits are shown for reference only. There were insufficient measurements from model year 2023 vehicles to analyze vehicles certified to the newest Euro 6 standards, but limit is shown for reference.

*Indicates HC+NO_x limit.

Figure A4. Average distance-specific emissions among diesel passenger cars over time

