THE REAL URBAN EMISSIONS INITIATIVE

TECHNICAL NOTE
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Evaluation of real-world vehicle emissions in Abu Dhabi

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INTRODUCTION

In 2021, the Emirate of Abu Dhabi had average air concentrations of fine particles ($PM_{2.5}$) and nitrogen dioxide (NO_2) that were around eight times higher and over three times higher, respectively, than the latest World Health Organization (WHO) Air Quality Guidelines.[1] Vehicle emissions from the road transport sector are a major contributor to urban air pollution and resulting health problems in many regions, including Abu Dhabi. According to the 2018 air emissions inventory conducted by the Environmental Agency of Abu Dhabi (EAD), road transport was the source of 34% of nitrogen oxides (NO_X) emissions, 17% of $PM_{2.5}$ emissions, and 74% of carbon monoxide (CO) emissions in 2015.[2]

Recognizing the significant contribution of road transport to air pollution, the United Arab Emirates (UAE) has introduced a range of federal policies to reduce emissions from the sector. Euro 4 was introduced as a minimum emission standard requirement for new cars, trucks, and buses sold from 2018 onward.[3] Additionally, in 2021, the government introduced a new fuel standard to ensure that petrol fuel sold within the country has no more than 10 ppm sulfur content, and this complemented the existing low-sulfur standard for diesel fuel.[4] The availability of low-sulfur fuels has reduced the pollutant emissions from the existing fleet and marked a crucial step necessary to introduce the most advanced emission control technologies, such as Euro 6.[5]

In early 2023, the EAD partnered with emissions remote sensing system provider Hager Environmental and Atmospheric Technologies (HEAT), 4 Earth Intelligence (4EI), and the International Council on Clean Transportation (ICCT) under The Real Urban Emissions (TRUE) Initiative to conduct an emissions testing campaign in Abu Dhabi. Emission data collected with remote sensing technology provide insight into the real-world performance of a city's fleet because vehicles are measured in real driving conditions.

This technical note assesses real-world NO_X and particulate matter (PM) emissions from light-duty and heavy-duty vehicles, including taxis and city buses, operating in Abu Dhabi.[6] It also compares the emission levels of these vehicles with similar data collected in Europe. The note concludes with policy recommendations to curb vehicle emissions in Abu Dhabi.

1 Environmental Agency of Abu Dhabi, "Air Quality Annual Summary Report Abu Dhabi 2021," (2021), https://www.ead.gov.ae/-/media/Project/EAD/EAD/Documents/Resources/AIR-QUALITY-ANNUAL-2021-ENG.pdf, p. 7 and p. 9. The average annual concentration of $PM_{2.5}$ in Abu Dhabi was of 38.5 μg/m³ against the 5 μg/m³ WHO guideline. The average annual concentration of NO_2 in Abu Dhabi was of 33 μg/m³ against the 10 μg/m³ WHO guideline.

2 NO_X here includes nitric oxide (NO) and nitrogen dioxide (NO_2). NO reacts with oxygen or ozone in the air to form NO_2; Environmental Agency of Abu Dhabi, "Abu Dhabi Air Emissions Inventory 2018," (2018), https://www.ead.gov.ae/-/media/Project/EAD/EAD/Documents/Resources/Abu-Dhabi-Air-Emission-Inventory-2018.pdf, p. 20.

3 Neha Bhatia, "Higher Emission Standards Reshaping UAE Vehicle Fleets," Construction Week Online, May 4, 2018, https://www.constructionweekonline.com/news/article-49209-higher-emission-standards-reshaping-uae-vehicle-fleets.

4 Anas Abdoun, "The Middle East Continues to Anticipate Implementation of Low-Sulfur Fuels through 2025 | Stratas Advisors," Stratas Advisors, March 30, 2023, https://www.stratasadvisors.com/insights/the-middle-east-continues-to-anticipate-implementation-of-low-sulfur-fuels-through-2025/2023-03-30t151600-0400; "Cleaner Fuels," Government of the UAE, accessed October 24, 2023, https://u.ae/en/information-and-services/environment-and-energy/the-green-economy-initiative/efforts-to-achieve-green-economy-/cleaner-fuels.

5 Katherine Blumberg, Michael Walsh, and Charlotte Pera, "Low-Sulfur Gasoline and Diesel: The Key to Lower Vehicle Emissions," (Washington, D.C.: International Council on Clean Transportation, 2003), https://theicct.org/publication/low-sulfur-gasoline-and-diesel-the-key-to-lower-vehicle-emissions/.

6 PM emissions include both $PM_{2.5}$ and PM_{10} emissions. PM emissions from the HEAT remote sensing device are derived using a light absorption technique. The absolute levels might not reflect the mass that other laboratory techniques may produce and are here used to reveal relative trends.

Acknowledgments: The authors are grateful for the significant contributions from project Lead Hussein I. Hamed, and reviewers Meera M. Harara, Rashed M. Ekaabi, Hazem H. Qawasmeh and Ruqaya M. Mohamed of the Environmental Agency of Abu Dhabi, Yolla Hager from Hager Environmental and Atmospheric Technologies, and Francisco Posada and Ana Beatriz Rebouças from the International Council on Clean Transportation.

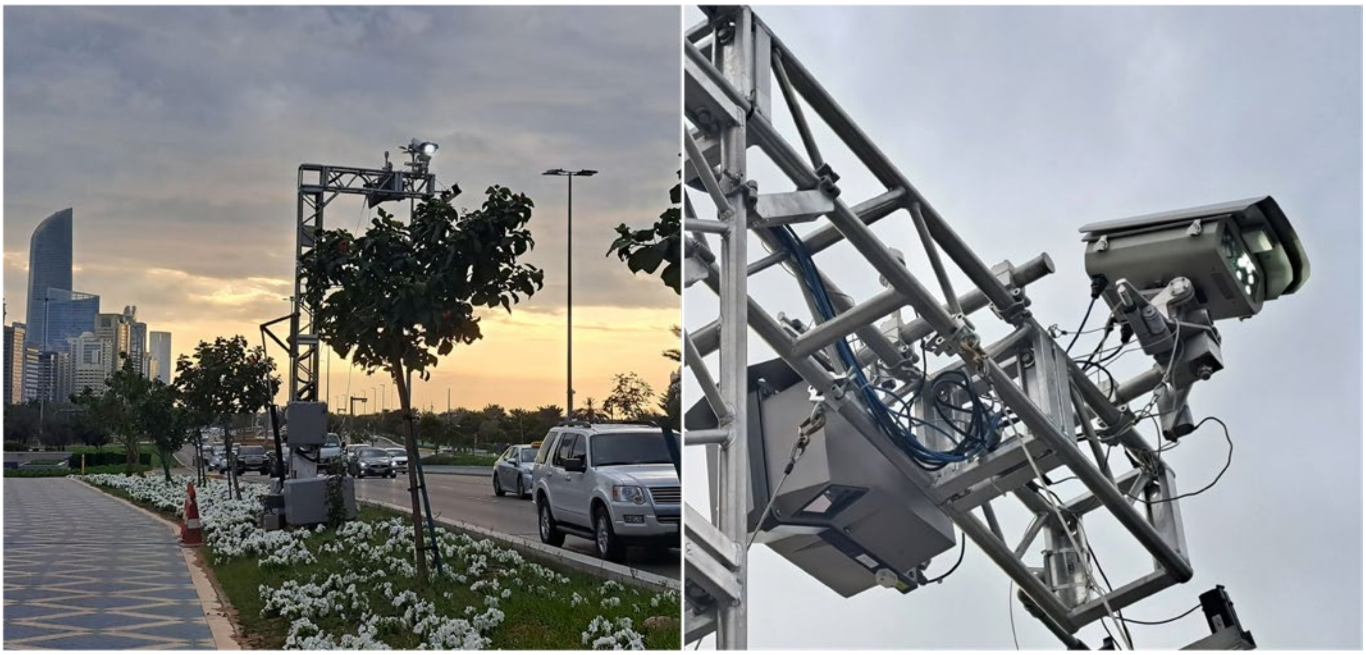

Figure 1. HEAT EDAR remote sensing device measuring emissions from passing vehicles in Abu Dhabi. *Source:* Oriol Teixidó, former project lead at EAD.

DATA COLLECTION AND PROCESSING

The emissions testing campaign was conducted from January 24 to February 6, 2023 in six sites in Abu Dhabi emirate: five in the city of Abu Dhabi and one in the city of Al Ain.[7] Figure 1 shows one of the measurement sites and demonstrates how HEAT's Emission Detecting and Reporting (EDAR) remote sensing device measured the exhaust emissions from vehicles in Abu Dhabi. HEAT's technology uses laser sources and detectors that are placed above a roadway and exhaust emissions are measured via spectroscopy as vehicles pass by the measurement location. Vehicle speed and acceleration are measured at the same time, and a camera captures an image of the vehicle's number plate to obtain its (non-personal) information.[8]

During the 15 days of testing, 108,957 measurements with valid emissions and license plate readings were collected.[9] After data processing and validation following methods described in prior TRUE Initiative publications, 82,797 usable measurements were retrieved.[10] Vehicle specification data from the Abu Dhabi police were used to distinguish vehicles' essential attributes such as their type (e.g., bus or passenger car), fuel, and model year.

This technical note focuses on the most common vehicle types in the dataset: light-duty vehicles, taxis, and buses. Others, such as two-wheelers and trucks, were underrepresented in the dataset and were therefore not included in the analysis. Real-world emissions from Abu Dhabi vehicles are compared with average real-world emissions data collected in various European cities for similar vehicles running on the same fuel.[11]

EMISSIONS RESULTS

LIGHT-DUTY VEHICLES (LDVs)

The LDV data consisted of passenger cars and light commercial vehicles measured in Abu Dhabi emirate. Figure 2 illustrates the average mass of NO_x emitted per kilogram of fuel burned by diesel and petrol vehicles by model year, and the timeline in which different emission standards were introduced in the UAE and Europe. Recall that the UAE introduced a minimum emission

7 Emirates News Agency, "Environment Agency - Abu Dhabi to remotely measure vehicle emissions in Abu Dhabi," February 2, 2023, https://wam.ae/en/details/1395303124586.

8 The vehicle number plate measured during the emissions testing campaign was shared by HEAT with the Abu Dhabi police to get access to vehicles characteristics such as type, fuel, engine power, curb weight, make, model, model year, and date of registration. No personal information was shared.

9 HEAT, internal report on EAD's remote sensing campaign (October 30, 2023), shared with the authors.

10 Duplicate vehicle specifications associated with unique plates in police data were also removed after the police confirmed that vehicles of different types (e.g., motorcycles and trailers) can use the same plate number. Vehicles registered in the police database after the campaign took place were also discarded. On data processing and validation methods, see Yoann Bernard et al., "Determination of Real-World Emissions from Passenger Vehicles Using Remote Sensing Data," (Washington, D.C.: International Council on Clean Transportation, 2018), https://theicct.org/publication/determination-of-real-world-emissions-from-passenger-vehicles-using-remote-sensing-data/.

11 The TRUE European dataset used for comparison includes Belgium, Czech Republic, France, Italy, Poland, Spain, Sweden, Switzerland, and the United Kingdom. A direct comparison of the Abu Dhabi results with previous TRUE European studies could be complicated by a number of factors, such as differences in instrumentation, site conditions, data quality, and date of measurements.

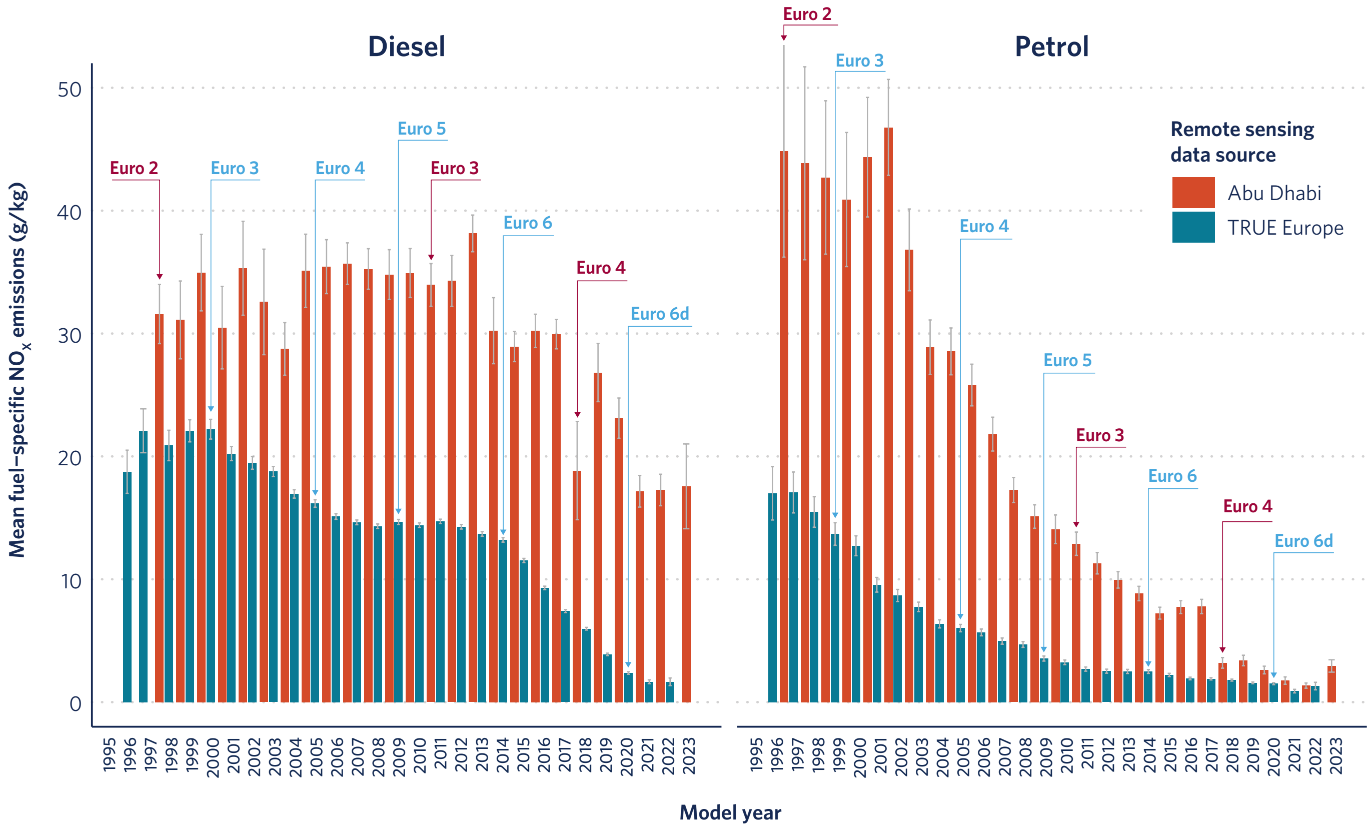

Figure 2. Average fuel-specific NO_x emissions of light-duty vehicles by fuel type and model year in Abu Dhabi and Europe. Whiskers indicate the 95% confidence interval of the mean. Blue and red labels represent the introduction of new emission standards in the European Union and Abu Dhabi, respectively. Only results with at least 30 measurements are shown; measurements do not include taxis.

standard requirement of Euro 4 for new cars in 2018. The notable decrease in the average fuel-specific NO_x emissions for both diesel and petrol vehicles of the 2018 model year seen in Figure 2 can be attributed to the adoption of the Euro 4 emission standard.

Despite the improvement in emission performance that Euro 4 vehicles demonstrated compared with vehicles of earlier model years, diesel Euro 4 vehicles in Abu Dhabi still showed high real-world NO_x emissions. Such levels are in line with extensive evidence from Europe showing that diesel Euro 4 vehicles emit NO_x at levels multiple times above the regulatory limit in real driving conditions.[12]

In addition, compared with diesel vehicles of the most recent (post-2019) model years in Europe, diesel vehicles' average NO_x emissions in Abu Dhabi were 10 to 15 times higher. In Europe, NO_x emissions from diesel vehicles have steadily decreased over the last decade, mainly due to the development of the Euro 6 regulation, which was introduced in late 2014.[13] Starting in late 2017, the Euro 6 regulation was further supplemented with on-road type-approval testing requirements; such testing was fully phased in with the Euro 6d standard in 2020, and it led to further NO_x reductions in real-world driving conditions.

Euro 4 petrol vehicles in Abu Dhabi, however, showed real-world NO_x emissions 44% lower than European vehicles certified to the same standard; their emissions were more comparable with those from European petrol vehicles certified to Euro 5. Emission measurements from European vehicles used for comparison likely show higher levels of NO_x emissions because of deterioration after more than 10 years of use.[14] This suggests that Euro 4 petrol vehicles in Abu Dhabi may also be prone to emission deterioration. Additional measures would be necessary to help ensure that new petrol cars introduced in Abu Dhabi are less vulnerable to emission degradation (e.g., by mandating the Euro 6 standard for new vehicles).

The data further demonstrate that the introduction of Euro 4 led to a substantial decrease in average PM emissions from diesel vehicles.[15] As shown in Figure 3, the introduction of Euro 4 in

12 International Council on Clean Transportation, "New ICCT Study Shows Real-World Exhaust Emissions From Modern Diesel Cars Seven Times Higher Than EU, US Regulatory Limits," October 11, 2014, https://theicct.org/press-release-new-icct-study-shows-real-world-exhaust-emissions-from-modern-diesel-cars-seven-times-higher-than-eu-us-regulatory-limits/.

13 The Euro 6 emission standard drove the use of NO_x aftertreatment technologies for diesel light-duty vehicles.

14 Jack Davison et al., "Gasoline and Diesel Passenger Car Emissions Deterioration Using On-Road Emission Measurements and Measured Mileage," *Atmospheric Environment: X*, no. 14 (April 2022): 100162, https://doi.org/10.1016/j.aeaoa.2022.100162.

15 PM emissions from petrol vehicles were below the detectable range of the remote sensing units and hence were excluded from the analysis.

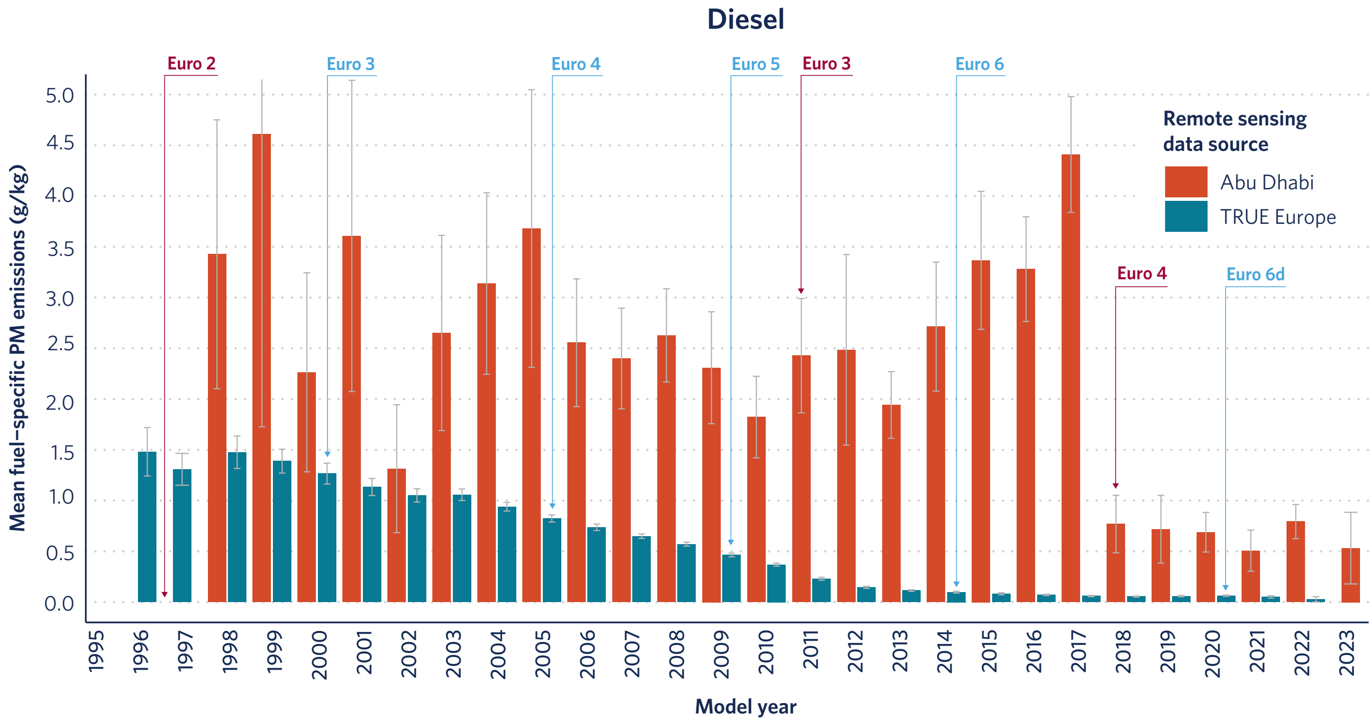

Figure 3. Average fuel-specific PM emissions of light-duty vehicles for diesel fuel type by model year in Abu Dhabi and Europe. Whiskers indicate the 95% confidence interval of the mean. Blue and red labels represent the introduction of new emission standards in the European Union and Abu Dhabi, respectively. Only results with at least 30 measurements are shown; measurements do not include taxis.

2018 brought down PM emissions from diesel LDVs by between 61% and 82% relative to Euro 3 LDVs of 2011–2017 model years. The resulting emission levels were in line with average PM emissions of Euro 4 diesel vehicles measured in Europe. Those levels are, however, still two to six times higher than those from Euro 5 and eight to 10 times higher than those from Euro 6 LDVs in Europe. Europe's large improvement in PM performance is attributable to diesel particular filters, which became compulsory for all diesel vehicles to meet the Euro 5 limit from 2009 onward.

The comparison with the European fleet indicates that while introducing the Euro 5 standard in Abu Dhabi would be expected to reduce PM emissions from new vehicles, it would fall short of curbing real-world NO_x emissions. Leapfrogging to the Euro 6 standard for new LDVs would be expected to bring emission benefits in terms of both PM and NO_x.

EMISSIONS FROM PRIVATE LDVs, PUBLIC LDVs, AND TAXIS

LDVs were further broken down into private, public, and taxis based on vehicle specifications. In Abu Dhabi, private LDVs are privately owned vehicles and public LDVs include vehicles used for garbage pickup, food transport, and fuel transport. Figure 4 compares the fleet average NO_x emissions from private, public, and taxi LDVs.

For private and public LDVs, diesel vehicles were the oldest and highest-emitting vehicles, emitting two to three times higher average NO_x emissions than their petrol counterparts. Hybrid LDVs used for private and taxi purposes had the lowest average age and the lowest average NO_x emissions among all fuels, with NO_x emissions 90% lower than those from diesel LDVs.

Petrol-powered public LDVs showed 50% higher average NO_x emissions than their petrol-powered private LDV counterparts, despite similar average age. Petrol taxis, by contrast, showed average NO_x emissions similar to those of petrol-powered private vehicles, despite being significantly younger. The emission gaps seen in petrol vehicles across different ownership types may be attributable to differences in mileage, as public LDVs and taxis are likely driven more per year than private LDVs.[16] Consistent with findings of past studies, higher NO_x emissions may reflect a deterioration of vehicle emissions control systems in higher-mileage vehicles.[17]

16 Environmental Agency of Abu Dhabi, "Abu Dhabi Air Emissions Inventory 2018," p. 90.

17 Jens Borken-Kleefeld and Yuche Chen, "New Emission Deterioration Rates for Gasoline Cars – Results from Long-Term Measurements," *Atmospheric Environment* vol. 101 (January 2015): 58–64, https://doi.org/10.1016/j. atmosenv.2014.11.013; Yoann Bernard et al., "TRUE U.S. Database Case Study: Emissions Deterioration of U.S. Gasoline Light-Duty Vehicles and Trucks," (Washington, D.C.: International Council on Clean Transportation, 2020), https://theicct.org/sites/default/files/publications/US-TRUE-emissions-deterioration-oct2020.pdf; Kaylin Lee et al., "Evaluation of Real-World Vehicle Emissions in Warsaw," (Washington, D.C.: International Council on Clean Transportation, 2022), https://www.trueinitiative.org/data/publications/evaluation-of-real-world-vehicle-emissions-in-warsaw.

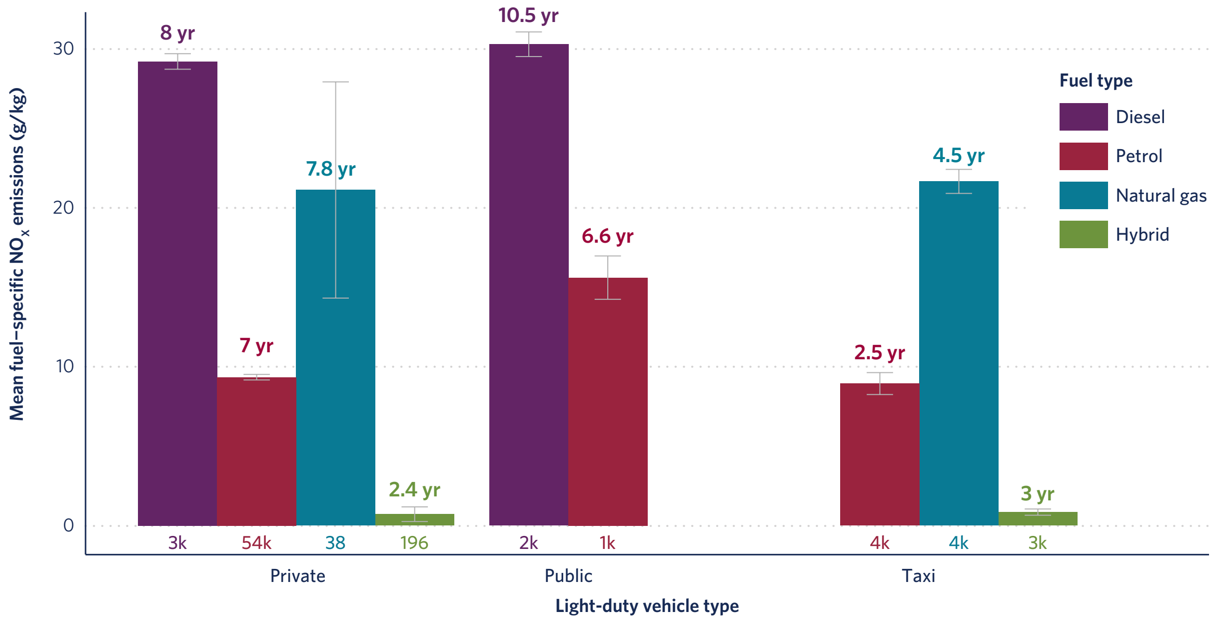

Figure 4. Average fuel-specific NO_x emissions of light-duty vehicles by plate and fuel type for different model years in Abu Dhabi. Whiskers indicate the 95% confidence interval of the mean. The number below each bar shows the number of measurements; the number above each bar indicates the average age of the vehicles assessed in each category. Only results with at least 30 measurements are shown.

TAXI EMISSIONS

Taxis made up 12% of the valid measurements recorded during the remote sensing campaign, and this highlights the significant share of taxis in the city's vehicle activities. Taxis in Abu Dhabi cover extensive distances, with an average annual mileage of around 150,000 km. Due to their higher mileage, the lifetime of taxis is typically shorter than other LDVs, which have average annual mileages of around 15,000 to 40,000 km per year.[18]

Taxis running on compressed natural gas (CNG) represented 36% of the taxi measurements. The government has promoted the conversion of petrol vehicles to CNG since 2012.[19] By fuel type, CNG taxis exhibited the highest level of NO_x emissions, two and a half times higher than petrol-powered taxis and 15 times higher than hybrids (Figure 4). This aligns with the findings of a study conducted in European cities which found that passenger cars powered by natural gas had higher average NO_x emissions than those powered by petrol.[20] Given that most of these CNG vehicles are likely converted from petrol vehicles, this raises concerns about a potential lack of NO_x emission verification at the time of the CNG conversion for vehicles that showed elevated NO_x emission levels. The difference may also be partially explained by the higher average age, and therefore likely higher mileage, of taxis running on natural gas, which are 1.5 and 2 years older than average hybrid and petrol taxis, respectively.

Toyota Camrys constituted 94% of the taxis measured and were therefore chosen for a more in-depth analysis. The methodology from a previous ICCT study was employed to combine real-world fuel economy estimates with fuel-specific NO_x emission values of Toyota Camry taxis to derive distance-specific emissions (g/km) for different fuel types.[21] The method was not applicable at the fleet level due to the lack of information on real-world fuel economy.

An assessment of mean NO_x emissions from taxis of different model years and fuel types is presented in Figure 5. The results show that petrol and natural gas taxis are largely responsible for NO_x emissions. A large share of petrol and CNG taxis are Euro 3 vehicles, or those of model years 2016–2017, and those vehicles

18 Environmental Agency of Abu Dhabi, "Abu Dhabi Air Emissions Inventory 2018," p. 90.

19 Anwar Ahmad, "Capital Switching to CNG Gradually," *Khaleej Times*, updated April 7, 2015, https://www.khaleejtimes.com/article/capital-switching-to-cng-gradually.

20 City Air Remote Emission Sensing (CARES), "Summary Report on Partner Cities' Measurement Campaigns," (April 2023), https://cares-project.eu/wp-content/uploads/2023/06/CARES-814966-D3.4-Summary-report-on-partner-cities-measurement-campaigns.pdf.

21 Bernard et al., "Determination of Real-World Emissions from Passenger Vehicles"; Yoann Bernard, Jan Dornoff, and David C. Carslaw, "Can Accurate Distance-Specific Emissions of Nitrogen Oxide Emissions from Cars Be Determined Using Remote Sensing without Measuring Exhaust Flowrate?," *Science of The Total Environment* vol. 816 (2022): 151500, https://doi.org/10.1016/j.scitotenv.2021.151500. Average fuel-economy was estimated based on type-approval information of the latest Euro 4 Toyota Camry models in Abu Dhabi and estimates of the gap between real-world and laboratory performance were based on studies from Europe on Euro 4 vehicles between 2005 and 2009. The approach assumes conservatively low fuel consumption that leads to conservative NO_x emission estimates, although the gap seen in Europe grew when Euro 5 and 6 were introduced. On the gap between real-world and laboratory performance, see Jan Dornoff et al., "On the Way to 'Real-World' CO_2 Values: The European Passenger Car Market in its First Year After Introducing the WLTP," (Washington, D.C.: International Council on Clean Transportation, 2020), https://theicct.org/publication/on-the-way-to-real-world-co2-values-the-european-passenger-car-market-in-its-first-year-after-introducing-the-wltp/. The following values for the fuel economy of Toyota Camry vehicles were considered: petrol: 8.0 L/100 km; hybrid: 4.6 L/100 km; and CNG, 5.5 kg/100 km. The lower fuel consumption of hybrid vehicles allows us to factor in the share in electric mode driving when converting the NO_x-to-fuel ratio per kilometer driven.

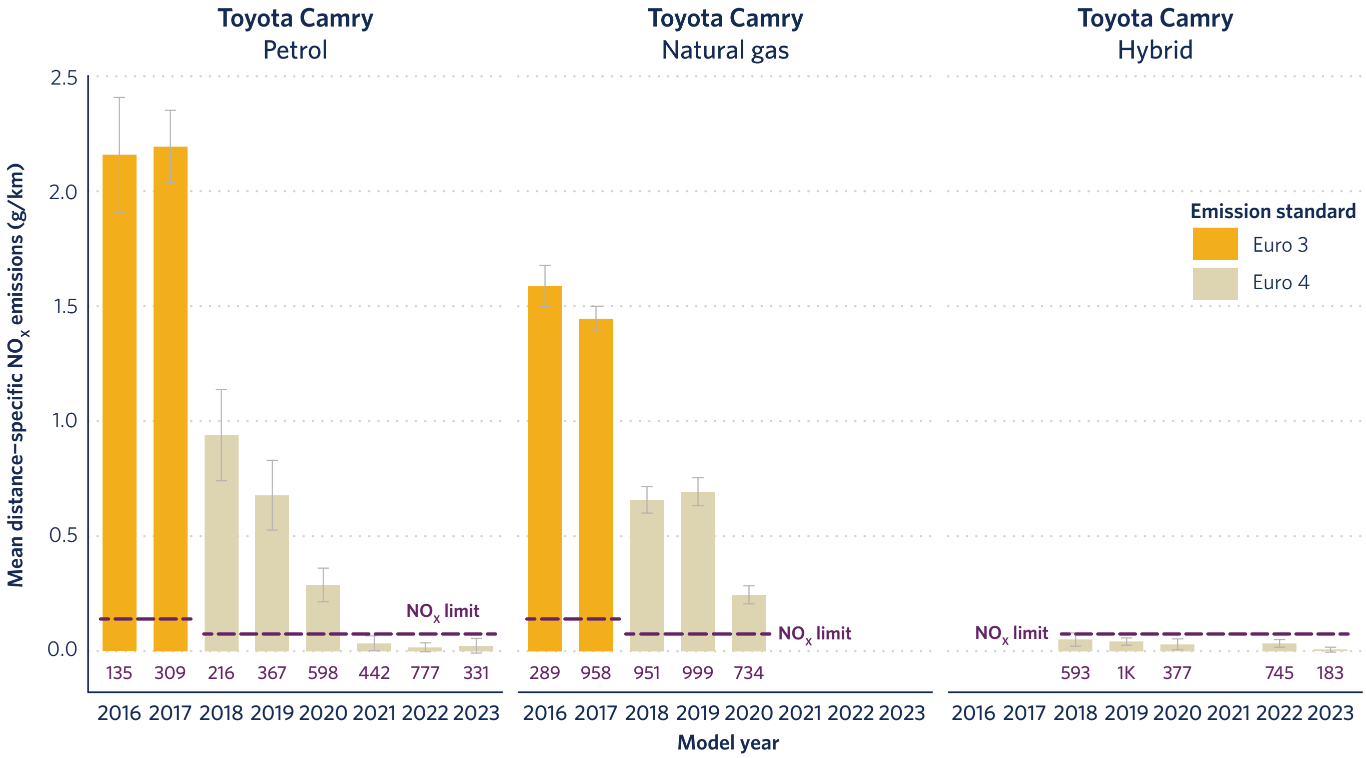

Figure 5. The estimated average distance-specific NO_x emissions of Toyota Camry taxis running in Abu Dhabi by fuel type for different model years and minimum emission standards. Whiskers indicate the 95% confidence interval of the mean. The number below each bar shows the number of measurements. Only results with at least 100 measurements are shown. Dotted lines represent the type-approval limit for the respective emission standards.

showed the highest NO_x emissions among taxis. Also, petrol and CNG taxis of model years 2018–2020 had real-world emissions eight to 19 times higher than their hybrid counterparts and three to 12 times higher than regulatory limits.

Newer Toyota Camry petrol taxis of 2021, 2022, and 2023 model years showed a notably improved emission performance and exhibited average NO_x emissions similar to their hybrid counterparts. All hybrid taxis showed real-world mean NO_x emissions in line with the regulatory limit.

The results further highlight that age and mileage could be key influencing factors for elevated NO_x emissions from non-hybrid taxis. Many taxis in Abu Dhabi emirate have likely accrued mileages beyond vehicle manufacturer emission durability requirements (e.g., 100,000 km for Euro 4 vehicles) in their first years of operation. Although Euro 4 brought a significant improvement in the emission performance of petrol and CNG taxis, vehicles of model years 2016–2020, which likely do not meet durability requirements, all showed NO_x emissions three to 15 times regulatory limits.[22] These high levels of NO_x emissions could also be attributable to unreported cases of petrol vehicles converted to CNG. That petrol taxis of model years 2021–2023 complied with the emission limits lends weight to this. There are fewer economic incentives for hybrid taxi owners to convert to CNG relative to petrol taxi owners, and that could explain why older hybrid models seem relatively unaffected.

Pre-2018 Toyota Camry taxis were responsible for 55% of total NO_x emissions from the taxi fleet, although they accounted for around 17% of taxi measurements recorded during the Abu Dhabi campaign.[23] Abu Dhabi has set a 5-year age limit for taxis, but measurements from pre-2018 models indicated that around 17% of taxis exceeded that age. Abu Dhabi emirate's Integrated Transport Center (ITC), which oversees taxi licensing, indicated that its agreement with franchise companies provides an option to extend the use of taxis awaiting franchise renewal. These results further highlight the emission benefits that would be expected from stricter application of the age limit.

BUS EMISSIONS

Multiple bus service lines operate in Abu Dhabi. Public city and intercity buses are operated mainly by ITC, while Emirates Transport, a federal government-owned entity, runs school buses throughout Abu Dhabi and surrounding emirates. Several private bus operators also run coaches to serve commuters in the region.

22 There were fewer private Toyota Camry LDV cars running on petrol fuel than taxis. Model year 2019 had the highest number of measurements across all other model years and showed 10 times lower NO_x emissions than 2019 Toyota Camry petrol taxis.

23 The share of remote sensing measurements is considered a crude proxy of vehicle-kilometers traveled by each group of vehicles, such as pre- and post-2018 models. The share of emissions is then calculated within each group as the product of the share of measurement by their estimated distance-specific emissions.

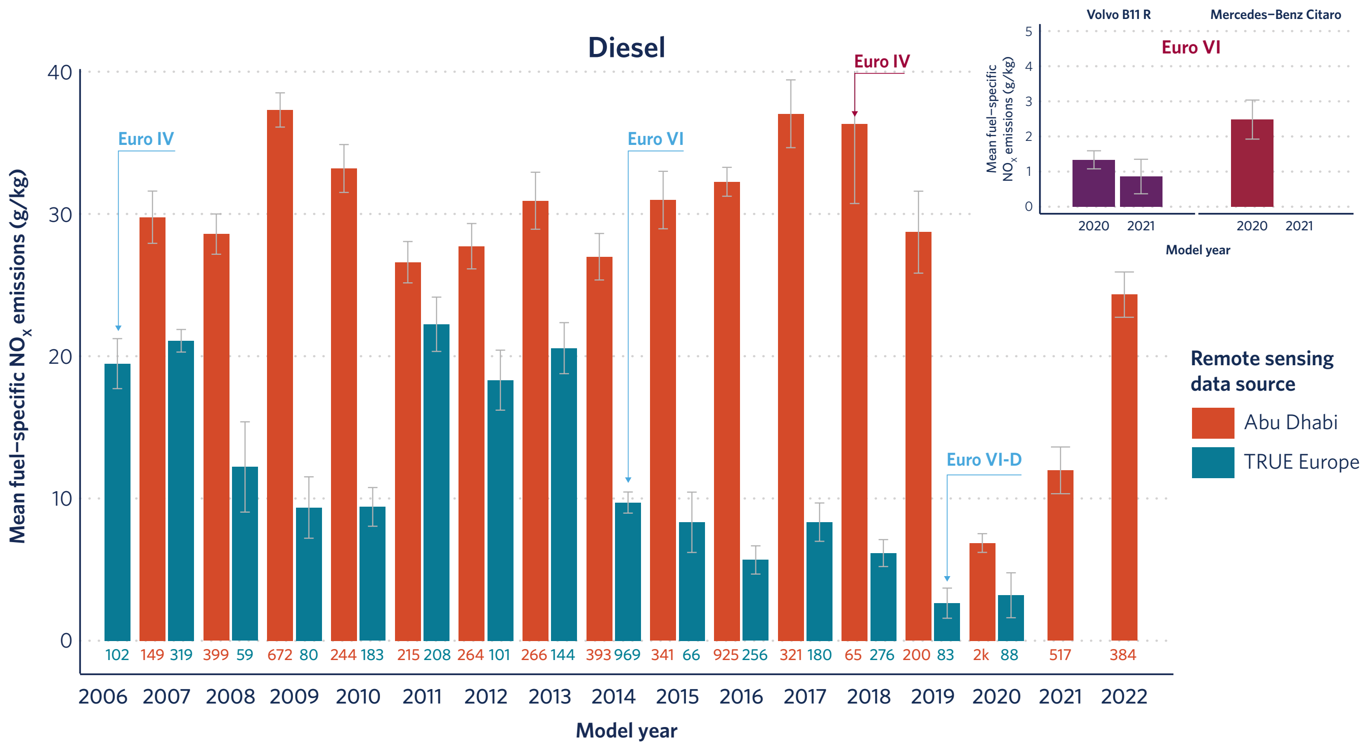

Figure 6. Average fuel-specific NO_x emissions of diesel buses by model year in Abu Dhabi. Whiskers indicate the 95% confidence interval of the mean. The number below each bar shows the number of measurements. Blue and red labels in the main figure represent the introduction of new emission standards in the European Union and Abu Dhabi, respectively. Only results with at least 50 measurements are shown. The right-hand figure shows the average fuel-specific NO_x emissions of new Euro VI buses operated by ITC in Abu Dhabi by model year.

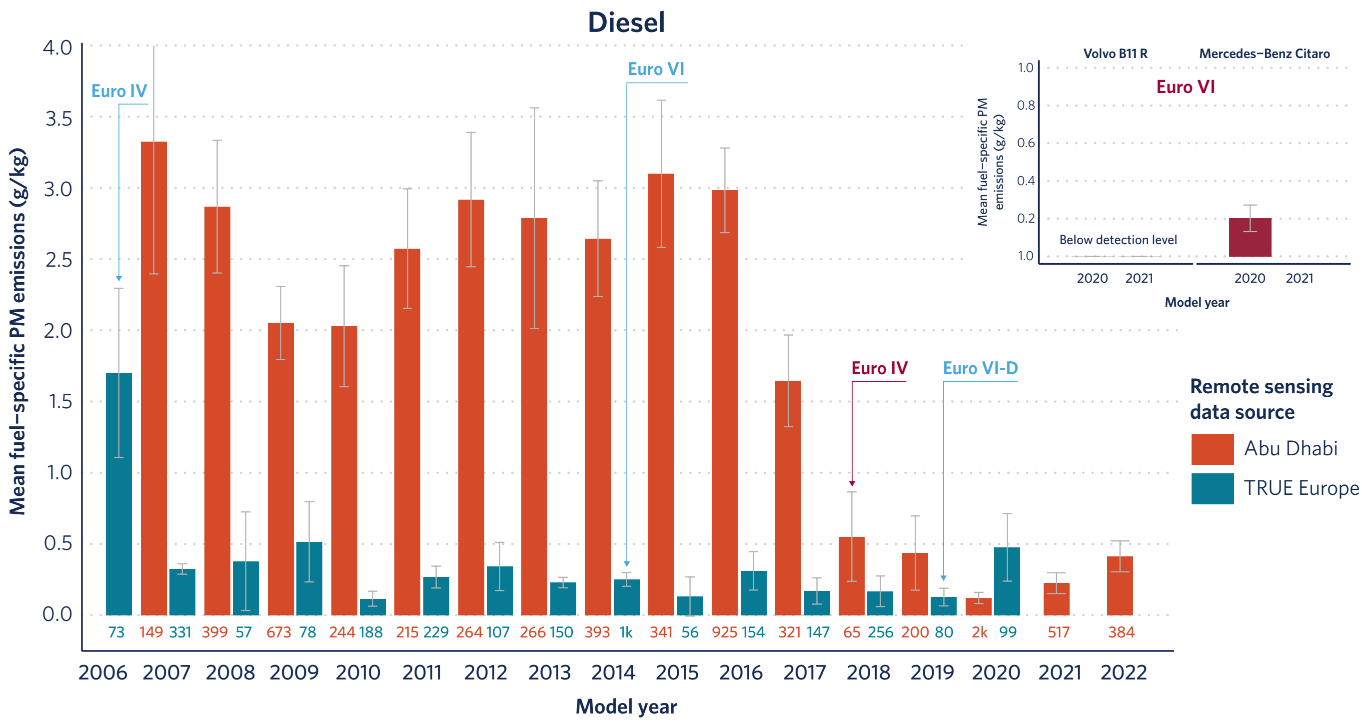

Figure 7. Average fuel-specific PM emissions of diesel buses by model year in Abu Dhabi. Whiskers indicate the 95% confidence interval of the mean. The number below each bar shows the number of measurements. Blue and red labels in the main figure represent the introduction of new emission standards in the European Union and Abu Dhabi, respectively. Only results with at least 50 measurements are shown. The right-hand figure shows the average fuel-specific PM emissions of new Euro VI buses operated by ITC in Abu Dhabi by model year.

Public and private buses were 29% and 71%, respectively, of buses measured in the Abu Dhabi campaign.

Figure 6 and Figure 7 show that average NO_x and PM emissions from diesel buses of model years before 2019 are two to eight times higher than those from buses of the same model year operating in Europe. Most of these are Euro II and Euro III buses without diesel NO_x exhaust aftertreatment systems. In 2018, with the introduction of Euro IV, average PM emissions from diesel buses were reduced by 75%, whereas NO_x emissions were unchanged.

We also found that average NO_x and PM emissions from buses of model year 2020 fell by 75% compared with those of model year 2019. The data revealed that 80% of buses of model year 2020 and 37% of buses of model year 2021 were certified to Euro VI. ITC ordered 168 new Volvo B11 R intercity coaches and 99 new Mercedes-Benz Citaro city buses with Euro VI diesel engines in 2019 and 2020, respectively.[24] These new buses came into operation in 2020 and show significantly lower NO_x and PM emissions than Euro IV buses.[25] For buses of model years 2021 and 2022, both average NO_x and PM emissions went up compared to model year 2020, as buses bought during those years were presumably certified to Euro IV or Euro V emission standards.[26]

POLICY RECOMMENDATIONS

The data collected during the Abu Dhabi vehicle emissions testing not only offered insight into the real-world emissions of the fleet currently on the road but also helped to assess the effectiveness of past and current vehicle policies in the emirate. The study findings provide evidence to support the following new policy actions that could help to reduce emissions from on-road vehicles.

ADOPTION OF EURO 6 STANDARDS FOR NEW LDVs

This study showed that the introduction of Euro 4 in 2018 significantly reduced NO_x and PM emissions from LDVs in Abu Dhabi, especially diesel-powered ones. Even so, these vehicles emit 10 to 15 times higher NO_x and PM emissions than average vehicles of the same model year in Europe. There is a vast evidence base from Europe indicating that the Euro 6 standard was able to ensure improved NO_x and PM emission performance from diesel vehicles that Euro 5 did not deliver. For diesel vehicles in the UAE, we recommend the implementation of the Euro 6 "d" stage or higher, which would support significantly lower real-world NO_x emission levels. In addition, for petrol vehicles, the Euro 6 standard sets higher requirements for emission durability to limit the deterioration seen from petrol Euro 4 and Euro 5 vehicles in Europe. By setting the minimum standard for new LDVs as Euro 6, the UAE could achieve a large reduction in pollutant emissions from new vehicles and set the stage for long-term reductions in emissions from the future fleet. The cost for manufacturers to meet the latest Euro 6 standard is expected to be below 1% and 4% of the retail price for petrol and diesel LDVs, respectively.[27] The UAE government could further consider an import ban on used or second-hand vehicles certified to below Euro 4 for petrol and below Euro 6 for diesel vehicles and, to accelerate fleet renewal, a scrappage program for the oldest vehicles.

PURCHASING BUSES CERTIFIED TO AT MINIMUM EURO VI OR EQUIVALENT EMISSION STANDARDS

The Euro IV minimum requirement for new buses introduced in 2018 delivered a substantial reduction in PM emissions from Abu Dhabi's fleet, but relatively minor NO_x emission benefits. A small number of Euro VI buses that Abu Dhabi introduced following procurement by ITC in 2019 and 2020 showed NO_x emissions 94% lower and PM emissions 86% lower than other buses in the emirate certified to the Euro IV minimum. We recommend that the Abu Dhabi government continue to acquire buses with minimum Euro VI standards, and preferably of the "D" stage or higher, because remote sensing data collected in Europe shows these buses generate around 66% lower NO_x emissions in urban conditions than Euro VI pre-D buses. Buses of model year 2017 and earlier, which are likely certified to Euro III and below and are responsible for a disproportionate share of emissions in Abu Dhabi, could also be replaced with Euro VI buses or, even better, electric buses. A study from the ICCT estimated that the cost of Euro VI for manufacturers would be under 1% of the retail price.[28]

STRENGTHENING THE APPLICATION OF THE 5-YEAR AGE LIMIT FOR TAXIS

This study found that taxis more than 5 years old accounted for a disproportionate share of emissions: despite comprising around 17% of the taxi fleet in Abu Dhabi, they were responsible for at least 55% of total NO_x taxi emissions. Taxis older than 5 years, driving under a derogation of their franchise awaiting renewal, were estimated to emit up to 15 times their type-approval limit.

24 Volvo Buses, "Abu Dhabi Orders 168 Volvo Intercity Coaches," July 11, 2019, https://www.volvobuses.com/en/news/2019/jul/abu-dhabi-orders-168-volvo-intercity-coaches.html; Mercedes-Benz, "99 Mercedes-Benz Citaro City Buses to Operate in Abu Dhabi's Public Transport Network," April 17, 2020, https://www.mercedes-benz-bus.com/en_CY/brand/news/2020/99-mercedes-benz-citaro-city-buses-to-operate-inpublic-transport-network-in-abu-dhabi.html.

25 Emirates News Agency, "ITC Operates New Buses, Offers 244 Additional Daily Trips during Peak Hours," October 13, 2021, https://www.wam.ae/en/details/1395302980250.

26 No evidence that other models could be type-approved to Euro VI was found, and their NO_x and PM emission performance suggests they would be Euro IV or at best Euro V.

27 Francisco Posada Sanchez, Anup Bandivadekar, and John German, "Estimated Cost of Emission Reduction Technologies for LDVs," (Washington, D.C.: International Council on Clean Transportation, 2012), https://theicct.org/publication/estimated-cost-of-emission-reduction-technologies-for-ldvs/. Cost estimate was updated in 2016 and therefore gives a ballpark estimate for 2023 prices. Current prices may be lower, as aftertreatment technology has improved and decreased in cost. The cost for Euro 6d gasoline is expected to be around 100 USD more than for early phase of the Euro 6 due to the need for a gasoline particulate filter.

28 Yihao Xie, Francisco Posada, and Arijit Sen, "Soot-Free Road Transport in South Africa: A Cost-Benefit Analysis of Euro VI Heavy-Duty Vehicle Standards," (Washington, D.C.: International Council on Clean Transportation, 2022), https://theicct.org/publication/africa-me-hvs-soot-south-africa-dec22/.

These findings reiterate the importance of an age limit and potential mileage cap for the taxi fleet. Among other measures, a stricter application of the rules limiting derogations combined with stringent enforcement for taxis (e.g., by using automatic number plate recognition cameras or remote sensing for vehicle emission monitoring), could significantly reduce this fleet's emission impact. Abu Dhabi could further promote the use of more fuel-efficient taxis, such as hybrid vehicles, which were shown to provide fuel and greenhouse gas emissions savings and which exhibited real-world NO_x emissions consistently below the limit across different model years.

ELECTRIFICATION OF THE VEHICLE FLEET

Electric vehicles emit zero tailpipe pollutant and greenhouse gas emissions and fleet electrification is the fastest way to reduce harmful emissions from motor vehicles. We recommend that Abu Dhabi accelerate the electrification of its public transport, government, and taxi fleet by setting zero-emission vehicle targets.[29] At the federal level, policies such as a zero-emission vehicle mandate or CO_2 standard for new vehicles would foster the uptake of electric vehicles and help individual emirates align with federal air quality and climate targets.

29 Based on the taxi fleet measured in this project, we estimate that a policy targeting an eight-percentage-point increase in new purchases of zero-emission taxies per year would lead to a fully electrified taxi fleet by 2035 and an increase in vehicle activity of 7% each year.

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