BRIEFING

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The rapid deployment of zero-emission buses in Europe

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INTRODUCTION: A SNAPSHOT OF THE MARKET

The sales of zero-emission buses (ZEBs) have been rapidly increasing in the European Union (EU-27).[1] Over the last five years, the sale of ZEBs has increased over six-fold from 400 in 2016 to 2,500 in 2021. In 2021, fully electric powertrains represented 10% of new bus sales (see Figure 1),[2] exceeding the same share in passenger cars.[3] While the pace of the transition away from diesel outpaces the passenger car market, the technology transition is more diverse. Shares of natural gas buses have sharply been on the rise, increasing from a 5% share of sales in 2016 to 12% in 2021, although plateauing since 2020. By the end of 2021, the bus fleet of nearly 700,000 in the EU-27[4] was comprised of over 9,000 electric and 20,000 natural gas buses.[5]

1 Only battery-electric and fuel-cell electric buses are considered to be zero-emission in this paper. The scope covers buses and coaches with a maximum mass greater than 5t, i.e., M3 vehicles.

2 All data related to Member State-wide bus sales are derived from IHS Global SA; Copyright © IHS Global SA, 2022.

3 Peter Mock, Uwe Tietge, Sandra Wappelhorst, Georg Bieker, Jan Dornoff, and Marie Rajon Bernard "Market Monitor: European Passenger Car and Light Commercial Vehicle Registrations, January–December 2021," (Washington, D.C.: ICCT, February 7, 2022), https://theicct.org/publication/market-monitor-eu-jan-to-dec-feb22/.

4 ACEA, "Vehicles in Use, Europe 2022," January 2022, https://www.acea.auto/publication/report-vehicles-in-use-europe-2022/.

5 Estimated by applying survival profiles derived from ICCT stock modelling to historic sales data.

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THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

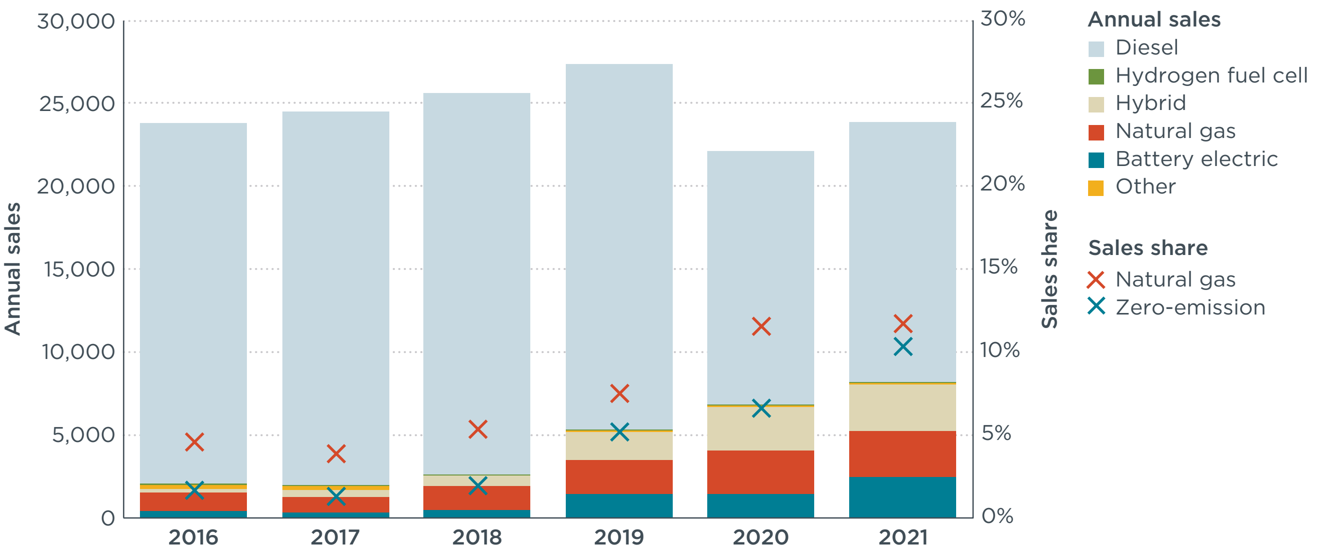

Figure 1. Annual sales (bars, left axis) and sale shares (crosses, right axis) of buses by fuel type in the EU-27 2016-2021.

While the overall trends are promising, a different picture is evident at the country level (see Figure 2). Some Member States had little to no deployment of electric buses in 2021, such as Greece, Portugal, and Ireland, each of which had a share of ZEBs below 1%. Meanwhile, ZEBs have already achieved, or are close to achieving, market dominance in several other countries, most notably in Finland (78% sales share), the Netherlands (59%), and Denmark (46%). The Netherlands was the only country to have a significant share of hydrogen fuel cell vehicles representing 11% of total buses sold. Driving the rapid transition in both the Netherlands and Denmark are ambitious phase-out targets for the sale of fossil-fueled buses by 2025, while no national plans are in place for Finland, despite its leading role.

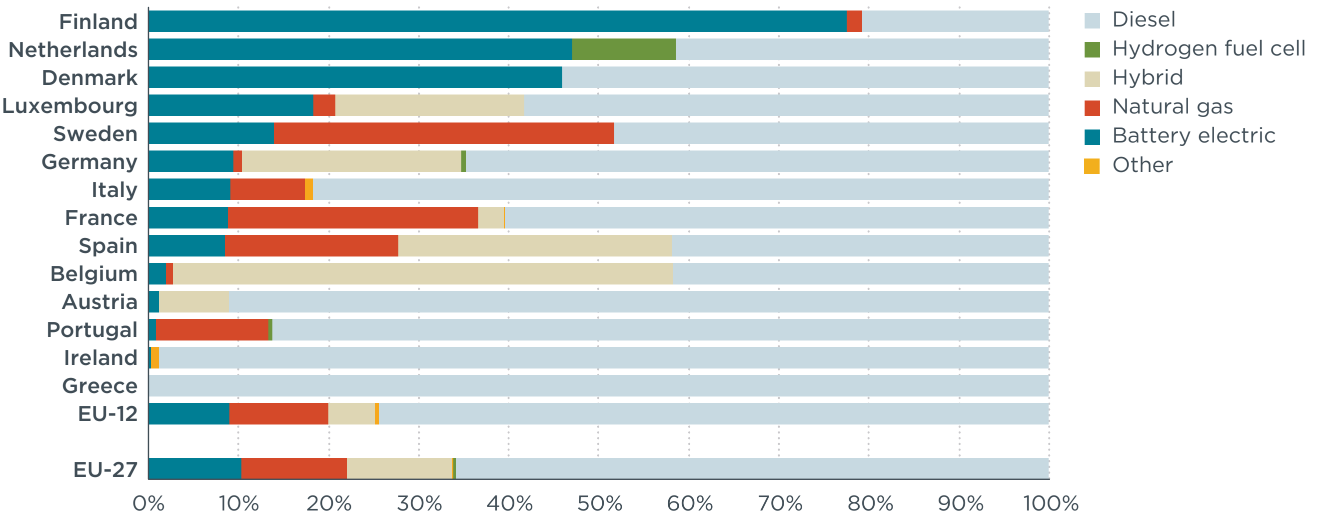

Figure 2. Share of buses by fuel type in EU-27 by Member State. EU-12 represents CY, CZ, EE, HR, HU, LT, LV, MT, PL, RO, SI, and SK. Other fuels include ethanol, gasoline, plug-in hybrids, and liquified petroleum gas. Data for BG is not included.

An equally diverse picture is evident in the movement towards natural gas buses, with a small but significant number of countries driving the transition. France, Spain, Sweden, and Portugal, which combined comprise a third of bus sales in the EU-27, are particularly ramping up their investments in the technology, with sales of natural gas buses increasing nearly three-fold from 750 buses in 2017 to 2,100 in 2021. While the sales growth of natural gas buses briefly stagnated over 2020–2021, they still held a higher overall share of the bus market compared to electric vehicles. While ZEBs provide irrefutable emission reductions and associated health benefits, natural gas buses provide little-to-no real benefit, as we detail further in this paper, and its misguided perception as a clean technology threatens the lock-in of an unsustainable fuel.

To better understand the driving force behind the growing diversity of the European bus market and its rapidly changing nature, this briefing paper summarizes the role of supply-side actors, i.e., manufacturers, and the demand-side actors at the national and city levels in this transition. We discuss the current market for alternative-fueled buses by these actors, provide an insight into the evolution of various technologies based on long-term trends and deployment targets, and propose policy levers to accelerate the full deployment of zero-emission buses in Europe.

THE SUPPLY SIDE: DEVELOPMENTS IN BUS TECHNOLOGIES

Despite the rapid growth in alternative-fueled buses, buses newly registered in Europe continue to be dominantly powered by diesel engines. This section discusses the emissions benefits of the emerging technologies that are challenging diesel's hegemony, as well as the industry players behind them.

ENVIRONMENTAL PERFORMANCE OF POWERTRAIN TECHNOLOGIES

Thanks to the introduction of increasingly stringent pollutant emission standards, the air pollutant emissions of buses have decreased in recent years. Analysis from remote sensing campaigns has shown that diesel buses compliant with Euro VI emission standards produce 80% lower nitrogen oxides (NO_x) emissions and particulate matter (PM) emissions than buses compliant with previous standards.[6] Despite these improvements, modern diesel buses still contribute to the poor air quality experienced in many urban centers. Recent testing contracted by ICCT shows that modern Euro VI buses emit substantial amounts of pollutants during urban operation, as these low-speed conditions typically fall outside of the scope of the current Euro standards.[7]

Natural gas powertrains have increased their market penetration in urban buses over the past five years, as shown in Figure 1. Compared to Euro V and older diesel technologies, natural gas buses once offered better NO_x and PM emissions performance, earning them a reputation for clean combustion. However, the introduction of Euro VI standards, which set much more stringent NO_x and PM limits for diesel engines, led to the wide deployment of diesel emission control technologies that closed the emissions performance gap between the two powertrains.[8] Real-world vehicle testing indicates that the NO_x emissions range of heavy-duty natural gas and diesel engines are closely aligned, and that natural gas powertrains have similar PM emissions as diesel engines equipped with particulate filters. In addition, unfiltered

6 Sina Kazemi Bakhshmand et al., "Remote Sensing of Heavy-Duty Vehicle Emissions in Europe," (Wahsington, D.C.: International Council on Clean Transportation, 2022), https://theicct.org/publication/remote-sensing-of-heavy-duty-vehicle-emissions-in-europe/; Yoann Bernard, Tim Dallmann, Kaylin Lee, Isabel Rintanen, and Uwe Tietge, "Evaluation of Real-World Vehicle Emissions in Brussels" (Washington, D.C.: TRUE Initiative, 2021), https://theicct.org/publication/evaluation-of-real-world-vehicle-emissions-in-brussels/.

7 Nikiforos Zacharof, Sina Kazemi Bakhshmand, Tianlin Niu, Felipe Rodriguez, Sheng Su, Tao Lu, Petri Soderena, Rasmus Pettinen, and Konstantin Weller "Pollutant Emissions from the Latest Generation of Heavy-Duty Vehicles in Europe and China," SAE Technical Paper (Warrendale, PA: SAE International, 2022), https://www.sae.org/publications/technical-papers/content/2022-01-1024/.

8 Fredy Rosero, Natalia Fonseca, José-María López, and Jesús Casanovaac, "Effects of Passenger Load, Road Grade, and Congestion Level on Real-World Fuel Consumption and Emissions from Compressed Natural Gas and Diesel Urban Buses," *Applied Energy* 282 (January 2021): 116195, https://doi.org/10.1016/j.apenergy.2020.116195; L. Deville Cavellin, A. Arfire, F. Joly, A. Mahnaoui, and C. Joly "Bus Emissions Measurement in Operational Conditions Using PEMS: Comparison between Different Euro Technologies and Fuels," in *Transport and Air Pollution (TAP) Conference*, 2022, 48, https://publications.jrc.ec.europa.eu/repository/handle/JRC126978.

exhaust from natural gas engines contains significantly larger numbers of very small particles—deemed the most damaging type due to the ease of deposit within the human body—than the filtered exhaust from diesel engines.[9] The rhetoric that natural gas engines are cleaner than diesel is no longer valid in the current technology landscape, and there is no health benefit to be gained from natural gas relative to a modern-day diesel engine.

Natural gas buses also fail to deliver climate benefits. As a fuel, natural gas has a carbon dioxide (CO_2) content nearly 30% lower than diesel. However, the energy consumption per kilometer of a natural gas bus is 24%–50% higher,[10] which largely, if not wholly, offsets the emission reduction benefits from the lower carbon content. From a well-to-wheel perspective, the potential environmental benefits of natural gas as a transport fuel are further reduced through fugitive emissions of methane into the atmosphere due to unintended leakages during the extraction and transport processes.[11] Literature suggests a wide range of methane leakage rates, between 0.4% and 11.7% of the natural gas produced, with an average rate of 2.5%.[12] There are significant environmental concerns over such leakages, as methane is a particularly potent greenhouse gas with a global warming potential over 80 times higher than CO_2 over a 20-year period.[13]

In contrast to internal combustion engines, zero-emission buses do not produce any air pollutant emissions, delivering considerable health benefits, especially in an urban environment. The life-cycle greenhouse gas emissions are also lower, providing additional climate benefits. The emissions associated with the extraction and processing of raw materials and powertrain component manufacturing are 40%–55% higher for a battery electric vehicle and 50%–65% higher for a hydrogen fuel cell vehicle relative to a diesel or natural gas counterpart.[14] However, the bulk of a bus's life-cycle emissions are produced in the operation phase. Here, higher powertrain efficiency of battery electric and hydrogen fuel cell buses delivers a CO_2 reduction over the lifetime of the vehicle relative to a combustion engine vehicle. This is particularly evident in electric powertrains, which emit 73% less CO_2 equivalent than their diesel counterparts when powered off the current grid electricity.[15] These emissions reduction benefits are further amplified as renewable electricity is deployed to the grid. If powered off 100% renewable electricity, a battery electric bus would emit 90% less CO_2 equivalent emissions than its diesel counterpart.[16]

The emission reduction benefits of hydrogen fuel cell buses are less pronounced, at a 33% CO_2 equivalent reduction relative to diesel, as the vast majority of hydrogen in the

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9 U.S. Environmental Protection Agency, "Particle Pollution Exposure," Collections and Lists, September 15, 2014, https://www.epa.gov/pmcourse/particle-pollution-exposure.

10 Samuel Rodman Oprešnik, Tine Seljak, Rok Vihar, Marko Gerbec, and Tomaž Katrašnik, "Real-World Fuel Consumption, Fuel Cost and Exhaust Emissions of Different Bus Powertrain Technologies," *Energies* 11, no. 8 (August 18, 2018): 2160, https://doi.org/10.3390/en11082160; Rosero, Fonseca, López, and Casanovaac, "Effects of Passenger Load, Road Grade, and Congestion Level on Real-World Fuel Consumption and Emissions from Compressed Natural Gas and Diesel Urban Buses"; Cavellin, Arfire, Joly, Mahnaoui, and Joly "2.5 Bus Emissions Measurement in Operational Conditions Using PEMS."

11 Georg Bieker, "A Global Comparison of the Life-Cycle Greenhouse Gas Emissions of Combustion Engine and Electric Passenger Cars" (Washington, D.C.: ICCT, 2021), https://theicct.org/publication/a-global-comparison-of-the-life-cycle-greenhouse-gas-emissions-of-combustion-engine-and-electric-passenger-cars/.

12 Moritz Mottschall, Peter Kasten, and Felipe Rodríguez, "Decarbonization of On-Road Freight Transport and the Role of LNG from a German Perspective" (Washington, D.C.: Institute for Applied Ecology (Öko-Institut e.V.), The International Council on Clean Transportation, May 12, 2020), https://theicct.org/publications/on-road-freight-lgn-germany.

13 Intergovernmental Panel on Climate Change, "Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change," 2022, https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/.

14 Adrian O'Connell et al., "A Life-Cycle Analysis of the GHG Emissions of Heavy Duty Vehicles in the EU" (Washington, DC: ICCT, 2022).

15 O'Connell et al.

16 O'Connell et al.

EU-27 is still produced through steam methane reforming. If hydrogen was produced entirely from renewable electricity and used in a fuel cell bus, the emission reduction benefits are further increased to 87%.[14]

MANUFACTURERS: A STORY OF GROWING DIVERSITY

The bus market in Europe is less consolidated than the truck market. In the truck sector, seven manufacturers comprised 97% of sales in 2021, while the top seven bus manufacturers were responsible for 74% of the sales.[17] To simplify, we group manufacturers by their parent companies and report values for the highest-selling four groups—Daimler Truck, Traton Group, Iveco N.V., and CAF—who combined were responsible for 75% of all bus sales in 2021. We group the remaining manufacturers under the "Other" classification (see Figure 3).

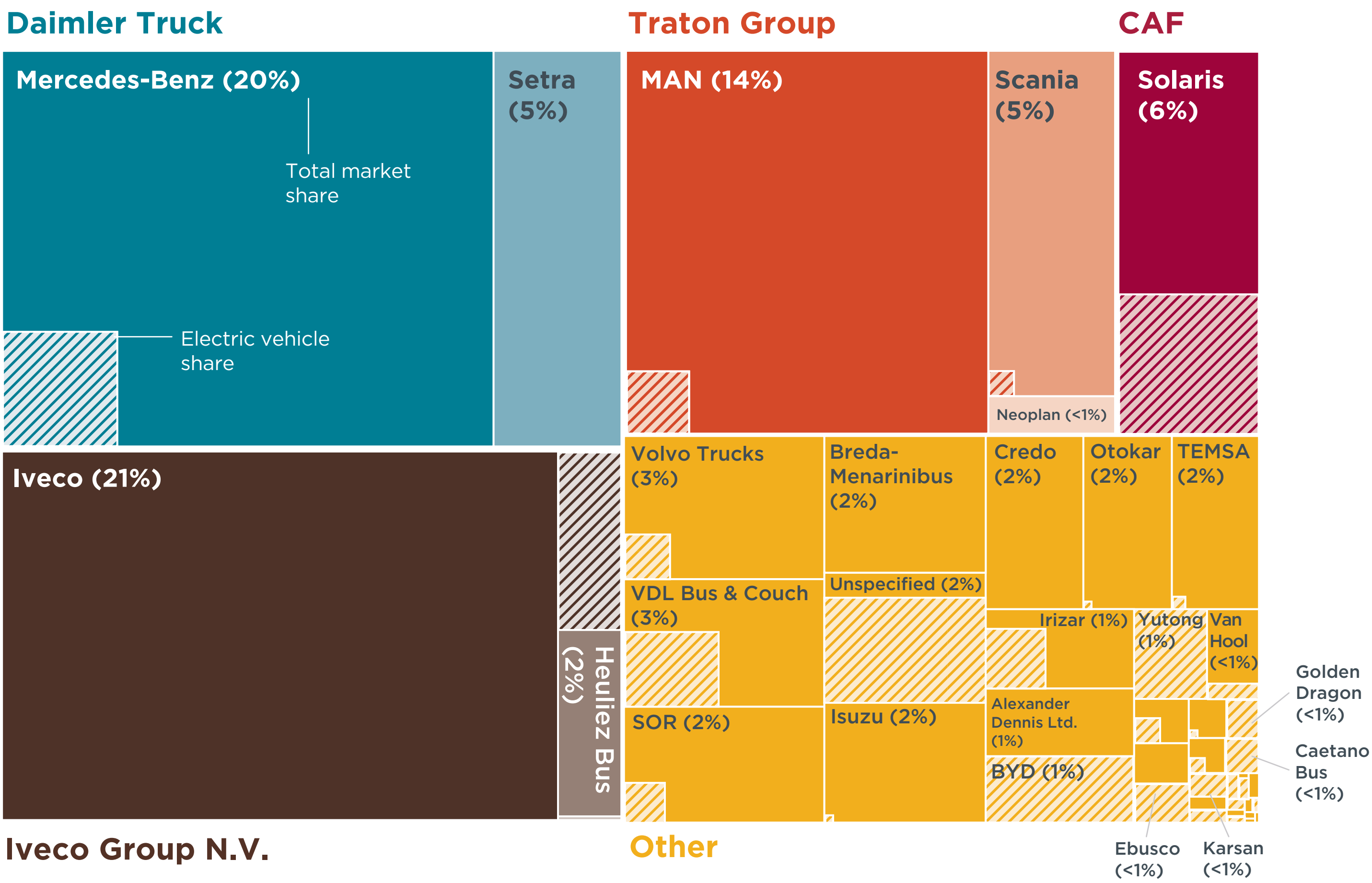

Figure 3. Market share of bus sales by manufacturer in 2021. Overall market share shown in brackets. Cross hatched areas represent share of sales which are ZEBs. "Unspecified" represents manufacturers who were undefined by our data provider.

Despite the 75% market share of all buses sold held by legacy manufacturers, they were only responsible for 45% of electric bus sales in 2021. Meanwhile, a significant share of the electric bus market in the EU-27 is being driven by the emergence of historically less-dominant manufacturers, particularly Chinese manufacturers.

Of the 2,500 electric buses sold in the EU-27 in 2021, Chinese manufacturers were responsible for 17%, most notably Yutong, BYD, and Golden Dragon. The remaining 38% of bus sales were made up of smaller manufacturers (in descending order of total sales): VDL Bus & Coach, Irizar, Volvo trucks, Ebusco, SOR, Caetano Bus, Karsan, and Autosan.

17 IHS Global SA; Copyright © IHS Global SA, 2022.

BYD, the fourth largest manufacturer of ZEBs in the EU-27, has been ramping up their deployment of ZEBs in Europe. In 2019, they opened a manufacturing plant in Hungary and announced plans to expand this year.[18] Since 2015, BYD has also been engaged with the UK-based Alexander Dennis Ltd. which has been steadily providing ZEBs to the British market.[19] While CAF, Iveco Group N.V., and Daimler Truck, are still the top three ranked manufacturers of electric buses in terms of total sales, the increasing demand for ZEBs combined with the growing number of smaller manufacturers focusing solely on ZEB production risk these major manufacturers losing their foot-hold in the market.

Where smaller manufacturers have been ramping up their production of ZEBs, the major bus manufacturers in the EU-27 have been increasing investments into natural gas vehicles, accounting for 92% of all natural gas buses sold in 2021. Notably, Iveco Group N.V. and Traton Group were market leaders in natural gas sales, accounting for 71% of the market in the same year. Manufacturers falling outside these four major parent organizations were responsible for just 8% of total natural gas bus sales in 2021, over half of which came from the Italian based manufacturer, BredaMenarinibus (see Figure 4).

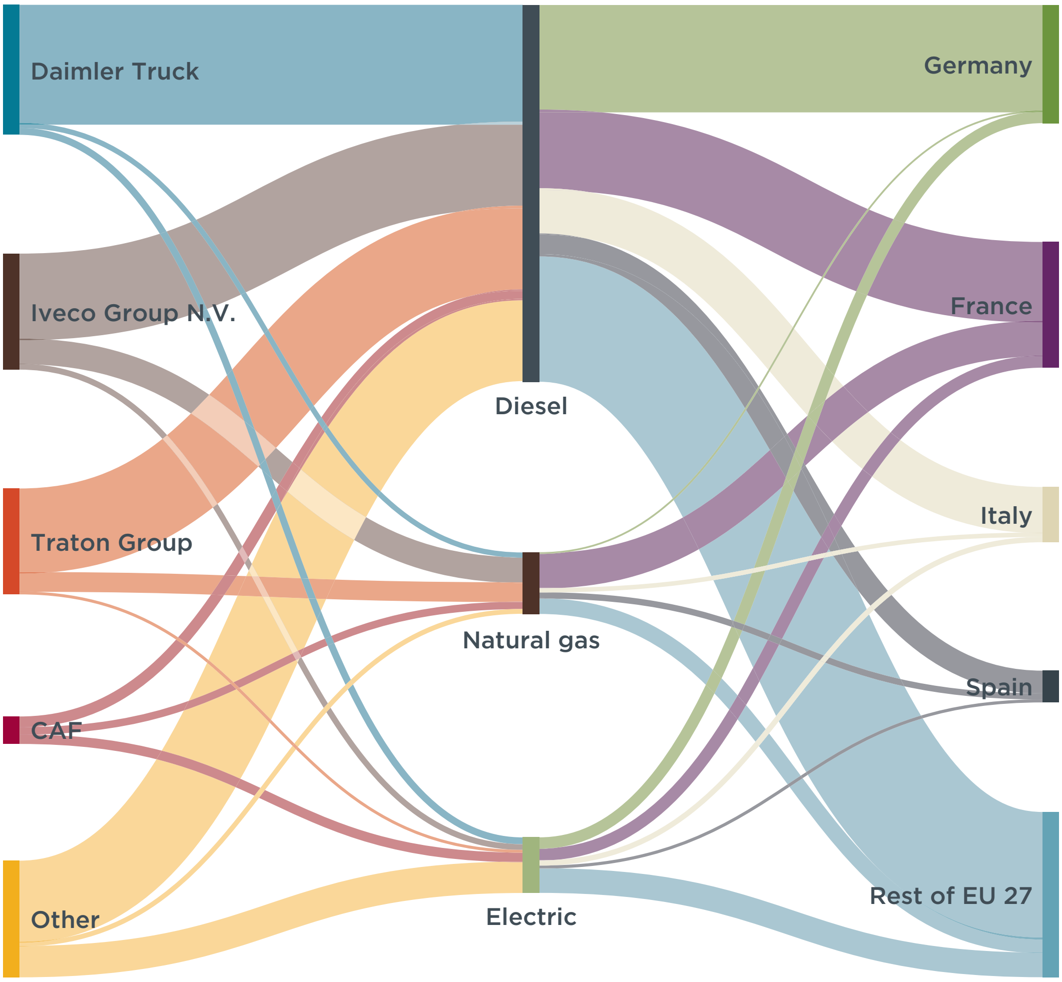

Figure 4. Vehicle sales in 2021 by manufacturer, fuel type, and country. Data for Bulgaria is not included. The left side of the figure represents vehicle sales by manufacturer, with the fuel breakdown in the center, and the flow to the major Member States shown on the right.

18 Sustainable Bus, "70,000 e-Buses Delivered by BYD Worldwide (2.5% of Them in Europe). 5.5 Billion Km Covered," 2022, https://www.sustainable-bus.com/electric-bus/byd-70000-electric-buses/.

19 Alexander Dennis Ltd., "BYD and ADL Leading the Charge with Pure Electric Vehicles," (May, 2019), https://www.alexander-dennis.com/media/84563/byd-and-adl-leading-the-charge-may-2019.pdf.

While the current market performance of ZEBs from legacy bus manufacturers is still nascent, there are a number of notable targets for the rollout of zero-emission buses. In the Traton Group, MAN plans for half of their buses sold to be equipped with an electric drive by 2025 (which may include hybrid or hydrogen fuel cell vehicles), while Scania intends for electric vehicles to make up around 10% of their sales in the same year, albeit including trucks.[20] Daimler aims to phase out the sale of internal combustion engine city buses from 2030 and plans to only offer a battery or hydrogen technology in every bus segment by then. As such, they do not plan to invest in technologies for buses to comply with the upcoming Euro VII emission standards for heavy-duty vehicles.[21] Iveco has plans to release a range of fully electric buses by 2023.[22]

A number of manufacturers in the "Other" category in Figure 4 have also pledged to increase ZEB sales. Volvo Group intends to reduce the CO_2 emissions of its fleet by 40% by 2030 relative to 2019, although it is unclear the portion that will be met through electrification or efficiency improvements to its internal combustion engine.[23] Isuzu has pledged to strengthen their efforts to electrify buses to achieve carbon neutrality by 2050.[24] TEMSA intends for half of their buses sold to be electric by 2025.[25] Figure 5 summarizes the major commitments from manufacturers and their respective sales share in 2021.

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20 Traton Group, "Traton Group Boosts Investment in Electric Mobility," (2021), https://traton.com/en/newsroom/press-releases/press-release-22032021.html.

21 Daimler Truck, "Daimler Buses to Offer CO2-Neutral Vehicles in Every Segment by 2030 – Dual-Track Strategy Based on Batteries and Hydrogen," (2022), https://media.daimlertruck.com/marsMediaSite/en/instance/ko/Daimler-Buses-to-offer-CO2-neutral-vehicles-in-every-segment-by-2030--dual-track-strategy-based-on-batteries-and-hydrogen.xhtml?oid=51925779.

22 Nick Carey and Valentina Za, "Iveco Eyes Drive into Zero Emission Trucks after Spin-Off," *Reuters*, (November 11, 2021), sec. Autos & Transportation, https://www.reuters.com/business/autos-transportation/cnhs-iveco-targets-up-175-bln-euros-industrial-revenues-2026-2021-11-18/.

23 Volvo Group, "Reducing Carbon Emissions," n.d., https://www.volvogroup.com/en/sustainability/climate-goals-strategy/reducing-carbon-emissions.html.

24 Earl Lee, "Hino, Toyota, and Isuzu Pledge to Accelerate Bus Electrification," *TruckDeal*, (2022), https://www.truckdeal.com.ph/articles/truck-news-philippines/hino-toyota-and-isuzu-pledge-accelerate-bus-electrification.

25 Handan Sema Ceylan, "One of Every Two Buses TEMSA Sells Will Be Electric by 2025," *TR MONITOR* (blog), (2021), https://www.trmonitor.net/one-of-every-two-buses-temsa-sells-will-be-electric-by-2025/.

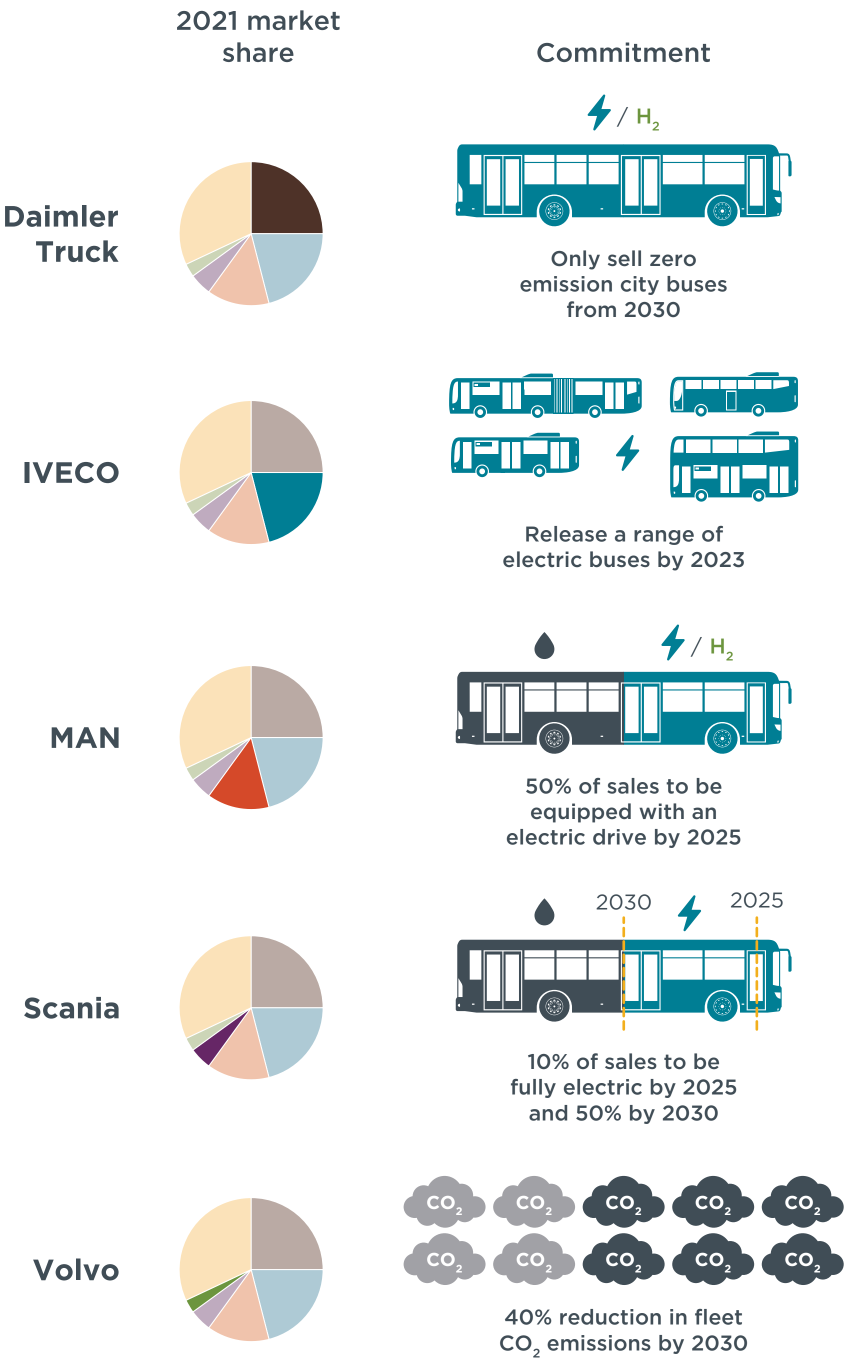

Figure 5. Summary of the major zero-emission commitments from bus manufacturers.

THE DEMAND SIDE: POLICY MAKERS IN ACTION

Unlike passenger cars and heavy trucks, bus manufacturers in the EU-27 are not currently subject to CO_2 emission standards.[26] As there is no regulatory obligation on manufacturers to yet limit their CO_2 emissions, the technology transition is primarily driven by demand-side measures from public institutions to improve the air quality of urban areas, tackle climate change, or comply with the EU's Clean Vehicles Directive.

26 The CO_2 standard for heavy-duty vehicles will be reviewed in late 2022. With this review, it will be possible to extend its scope to include buses and coaches.

CLEAN VEHICLES DIRECTIVE

All EU Member States have targets for the public procurement of alternatively fueled buses through the Clean Vehicles Directive.[27] This directive was adopted in 2019 and requires a portion of all publicly procured buses to be fueled by either zero-emission technologies (such as hydrogen or battery-electric powertrains), low carbon fuels (such as liquid biofuels and e-fuels), or through alternative fossil fuels (such as natural gas or liquified petroleum gas).[28]

For the first phase, from August 2021 to December 2025, the procurement targets for alternatively fueled buses range from 24% to 45% of new purchases. In the second phase, from January 2026 to December 2030, the targets range from 33% to 65%. The targets vary by Member State, with eastern European countries generally subject to lower targets. Critically, at least half of the procurement target must be achieved through ZEBs. A summary of these targets by Member State is presented in Figure 6.

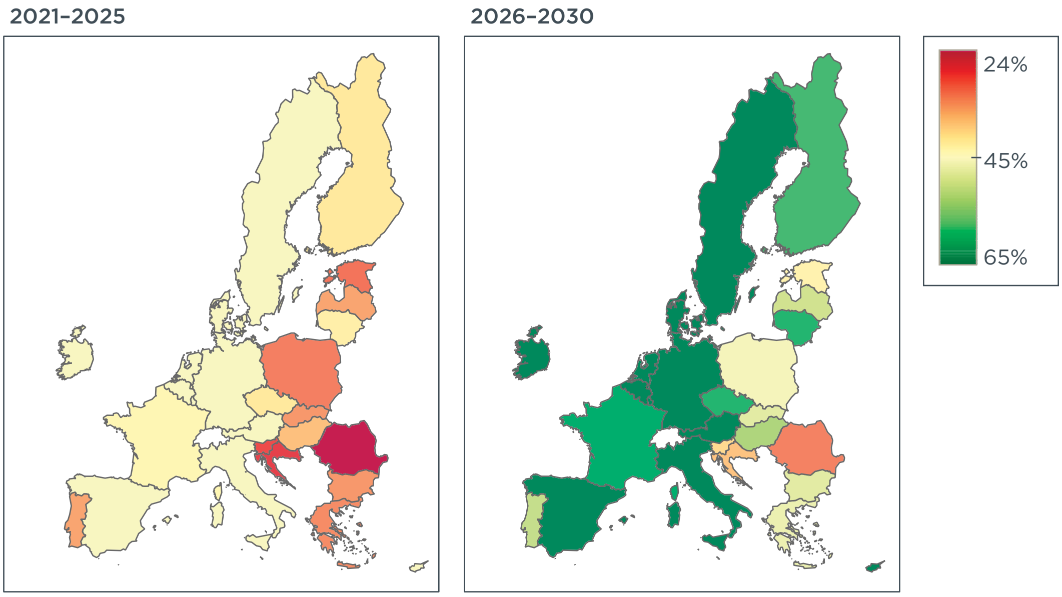

Figure 6. Targets for the public procurement of clean vehicles under the Clean Vehicles Directive by Member State

NATIONAL INTERNAL COMBUSTION ENGINE PHASE-OUT TARGETS

To date, five Member States have phase-out targets for conventionally fueled buses in the EU-27—The Netherlands, Denmark, Austria, France, and Ireland.

The Netherlands currently has one of the most ambitious national targets in the world for the phase-out of internal combustion engine buses. In 2016, all transport authorities signed an administrative agreement in cooperation with the central government committing to only register zero-emission buses from 2025 onward and to convert the entire bus fleet to zero-emission by 2030.[29] They have already made significant progress towards achieving this target, with 59% of bus sales in 2021 comprised of ZEBs.

27 European Commission, "Directive (EU) 2019/1161 of the European Parliament and of the Council of 20 June 2019 Amending Directive 2009/33/EC on the Promotion of Clean and Energy-Efficient Road Transport Vehicles," *Official Journal of the European Union* L 188 (June 20, 2019), http://data.europa.eu/eli/dir/2019/1161/oj.

28 Applies to M3 buses only, or passenger vehicles with more than 8 seats and with a maximum mass greater than 5 tonnes. Vehicles with a maximum mass less than this, i.e., M1 and M2 buses, are subject to a different set of targets.

29 RVO, "Mission Zero - Powered by Holland," (2019), https://www.rvo.nl/sites/default/files/2019/06/Misson%20Zero%20Powered%20by%20Holland.pdf.

Denmark holds a similar target, albeit only applicable to urban buses. In 2018, Its Ministry of Energy, Supply and Climate Change established targets through its climate and air initiative, which stipulates that in 2020 new buses must be CO_2 neutral,[30] in 2025, new buses in cities must be zero-emission, and from 2030, all city buses in operation must be zero-emission.[31] Beyond this, six of the country's municipalities, representative of approximately one-quarter of the Danish bus fleet, have signed the Climate Cooperation Agreement with the Danish Ministry of Transport committing to only procuring zero-emission city buses from 2021.[32]

Austria has set a goal of all registrations of new buses to be zero-emission from 2032 to contribute toward its target of achieving climate neutrality in 2040.[33] Austria has the youngest bus fleet in all of Europe, at an average age of 4.9 years in 2020 compared to the EU average of 12.8.[34] However, the average retirement age of a bus is generally longer than its average age,[35] and in 2021 just 2% of new buses in Austria were zero-emission. To achieve its climate neutrality target by 2040, it will require either a rapid ramp-up of zero-emission buses in the short-term or conventionally fueled buses will need to be retired before the end of their useful life.

Ireland has set the target through its Climate Action Plan to sell only low- or zero-emission buses from 2030 (although low emission is not clearly defined) and to have a fully electric fleet by 2035.[36] In 2021, Ireland had one of the lowest shares of ZEB sales in Europe. It also aims to have 300 electric buses in circulation by 2025 and 1,500 by 2030, representing 3% and 15% of its current fleet, respectively.

France adopted the Energy Transition for the Green Growth Act in 2015, establishing that only low- and zero-emission buses can be procured for public transport services from 2025 onwards.[37] However, the definition of low emission is not defined within this act, and could potentially include natural gas as a low-emission vehicle.

In additional to these individual targets, a number of countries signed a Global Memorandum of Understanding in 2021, pledging for 30% of sales of passenger and freight vehicles with a GVW greater than 3.5t to be zero-emission by 2030 and 100% by 2040. Of the 14 signatories, six were EU Member States: **Austria, Denmark, Finland, Luxembourg, Netherlands, and Portugal**, which represented 9% of all EU-27 bus sales in 2021.[38]

30 A fuel is usually be considered to be CO_2 neutral if the CO_2 emissions generated from the fuel's combustion are offset from the production of the fuel. For example, the feedstock used to produce biofuels absorb CO_2 from the atmosphere, which is mostly equivalent to the quantity released into the atmosphere upon combustion. However, due to potential indirect land use change, biofuels are not always strictly carbon neutral.

31 Energi-, Forsynings- og Klimaministeriet, "Sammen Om En Grønnere Fremtid - Klima- Og Lufudspil [Together for a Greener Future - Climate and Air Quality]," (2018), https://kefm.dk/media/6728/klimaministeriet_klimaogluftudspil_digital.pdf.

32 DR, "Hver fjerde nye bybus skal være grøn i 2021 [One-in-four new city bus must be green by 2021]," DR, (2020), https://www.dr.dk/nyheder/politik/hver-fjerde-nye-bybus-skal-vaere-gron-i-2021.

33 The goal only applies to buses with a technically permissible maximum laden mass above 3.5t. Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology, "Austria's 2030 Mobility Master Plan" (Vienna, 2021), https://www.bmk.gv.at/dam/jcr:eaf9808b-b7f9-43d0-9faf-df28c202ce31/BMK_Mobilitaetsmasterplan2030_EN_UA.pdf.

34 ACEA, "Vehicles in Use, Europe 2022."

35 Eamonn Mulholland, Joshua Miller, Caleb Braun, Arijit Sen, Pierre-Louis Ragon, and Felipe Rodríguez, "The CO2 Standards Required by Trucks and Buses for Europe to Meet Its Climate Targets," (Washington, D.C.: ICCT, 2022), https://theicct.org/publication/hdv-co2standards-recs-mar22/.

36 Rialtas na hEireann, "Climate Action Plan 2021: Securing Our Future" (Dublin, 2021), https://assets.gov.ie/203575/bb143644-a33a-4f18-b2bd-04ab32ca8e2e.pdf.

37 Ministères Écologie Énergie Territoires, "Loi de transition énergétique pour la croissance verte [Energy transition law for green growth]," (2017), https://www.ecologie.gouv.fr/loi-transition-energetique-croissance-verte.

38 Dutch Ministry for the Environment and CALSTART, "Global Memorandum of Understanding (MOU) for Zero-Emission Medium- and Heavy-Duty Vehicles," (November 10, 2021), https://globaldrivetozero.org/MOU/.

ZERO-EMISSION BUS TARGETS IN EUROPEAN CAPITAL CITIES

The procurement of public vehicles is generally conducted by local transport authorities rather than at the national level. As such, the rate of technology transition for bus fleets is usually most apparent by considering what's happening in major cities. To identify the areas experiencing the fastest transition away from conventionally fueled buses in Europe, we have compiled an overview of the bus market for all capital cities in the EU-27, extending it to include the capitals of the UK, Switzerland, Iceland, and Norway. Where possible, we derived these data directly from official publications from the respective fleet operator or local governments. In the cases where this information was unavailable, we referred to local or international news briefings. As this section draws off a high volume of sources, all numbers related to fleet size, zero-emission targets, and fuel composition of battery electric, hydrogen, and natural gas buses are documented in the Appendix. A summary is provided in Table 1.

Table 1. Fleet composition of capital cities in Europe and planned targets for the phase-in of fully electric fleets.

Capital city	Fleet size	Electric	Natural gas	Hydrogen	Zero-emission fleet targets	Green and Healthy Streets Declaration
Vienna, Austria	400	12	0	5	100% by 2040[b]	
Brussels, Belgium	800	37	0	1	100% by 2035	
Sofia, Bulgaria	712 (+118 trolley buses)	45	334	0	100% by 2030[c]	
Cyprus (country-wide)	200	-	0	0	No targets	
Prague, Czech Republic	1241 (+1 trolley bus)	14	0	0	33% by 2030	
Berlin, Germany	1500	139	0	0	100% by 2030	Yes
Copenhagen, Denmark	1185 (estimate)	119	41	1	100% by 2025	Yes
Tallinn, Estonia	546 (+49 trolley buses)	1	97	0	100% by 2035[d]	
Athens, Greece	1611 (+286 trolley buses)	0	301	0	No targets	
Madrid, Spain	2100	85	1723	0	33% by 2027	Yes
Helsinki, Finland	1400	164	22	0	30% by 2025	
Paris, France	4700	500	500	0	66% by 2025[e]	Yes
Zagreb, Croatia	475	0	91	0	No targets	
Budapest, Hungary	1500 (+140 trolley buses)	180	75	0	No targets	
Dublin, Ireland	994	14 (PHEVs)	0	3	100% by 2035[f]	
Rome, Italy	2036 (+75 trolley buses)	0	51	0	25% by 2026; 50% by 2030[g]	Yes
Vilnius, Lithuania	396 (+255 trolley buses)	5	107	0	No targets	
Luxembourg (country-wide)	1200	180	53	5	100% by 2030	
Riga, Latvia	500 (+250 trolley buses)	9	0	10 (trolley buses)	100% by 2030	
Malta (country-wide)	420	8	0	0	No targets	
Amsterdam, Netherlands	233	44[a]	0	0	100% by 2025	Yes
Warsaw, Poland	1823	160	180	0	No targets	Yes
Lisbon, Portugal	724	15	70	0	100% by 2040	
Bucharest, Romania	1534 (+265 trolley buses)	0	0	0	No targets	

Capital city	Fleet size	Electric	Natural gas	Hydrogen	Zero-emission fleet targets	Green and Healthy Streets Declaration
Stolkholm, Sweden	2200	14	330 (bio-CNG)	0	100% by 2035	
Ljubljana, Slovenia	217	0	87	0	No targets	
Bratislava, Slovakia	356 (+98 trolley buses)	18	71	0	No targets	
London, United Kingdom	9068	485	0	2	100% by 2034	Yes
Bern, Switzerland	145 (+14 trolley buses)	5	72	0	100% by 2035	
Reykjavik, Iceland	85	15	3	0	No targets	
Oslo, Norway	1200	99	110 (bio-CNG)	0	60% by 2025 100% by 2028	Yes

[a] 206 electric buses are also in operation for transit from Schiphol airport, which are not reflected in the city's fleet values

[b] National target, may be satisfied with climate-neutral fuels

[c] The target for Sofia was vague, aiming for city logistics to be "essentially free of carbon dioxide" by 2030

[d] The target for Tallinn is to have 650 electric buses in its fleet by 2035. The current bus fleet is 546, so we take this to mean a 100% zero-emission phase-in target by 2035.

[e] Target stipulates that it may be satisfied through PHEVs

[f] National target, the target established by the fleet operator, Dublin Bus, is less ambitious, at 100% by 2050

[g] The target for Rome is to have 500 electric buses by 2026, and 1000 by 2030. Rome currently has approximately 2000 buses in its fleet, which is how we arrived at these targets.

There are a growing number of phase-out targets for conventionally fueled buses across these capital cities. Most of them intend to convert either the entire fleet or a significant portion to zero-emission vehicles within the next 15 years; 17 of the 31 cities we considered have plans for a 100% ZEB fleet to operate by 2040 at the latest. Six of these have an earlier phase-out date of 2035,[39] seven set a date of 2030,[40] and two set a date of 2025.

Such a phase-out is challenging and will require a rapid cessation of public procurement of fossil-fueled buses. To this end, nine of these cities have signed up to the Green and Healthy Streets Declaration, pledging to procure only zero-emission buses from 2025 and ensuring a major area of the city is zero-emission by 2030.

PROGRESS IN THE TRANSITION TO ZERO-EMISSION BUSES: EXAMPLE CASES

Zero-emission buses comprise over 6% of the bus fleet stock across all 31 capital cities considered, significantly higher than the 1.5% country-wide average across the EU-27. Capital cities representing 60% of the total bus stock of all cities considered in this analysis have plans to only operate ZEBs in their fleet by 2035. More have targets to convert a sizeable portion of their fleet by the same date. If these targets are adhered to, over 30,000 zero-emission buses will be in operation across capital cities by 2035, three times the current zero-emission fleet across the entire EU-27.[41] For earlier years, this translates to a 15% share of the bus fleet across all cities analyzed by 2025, rising to 37% in 2030, and 70% in 2035 (see Figure 7).

39 Including London, which is 2034

40 Including Oslo, which is 2028

41 Calculated based on current fleet statistics, and not assuming any change in the stock of buses.

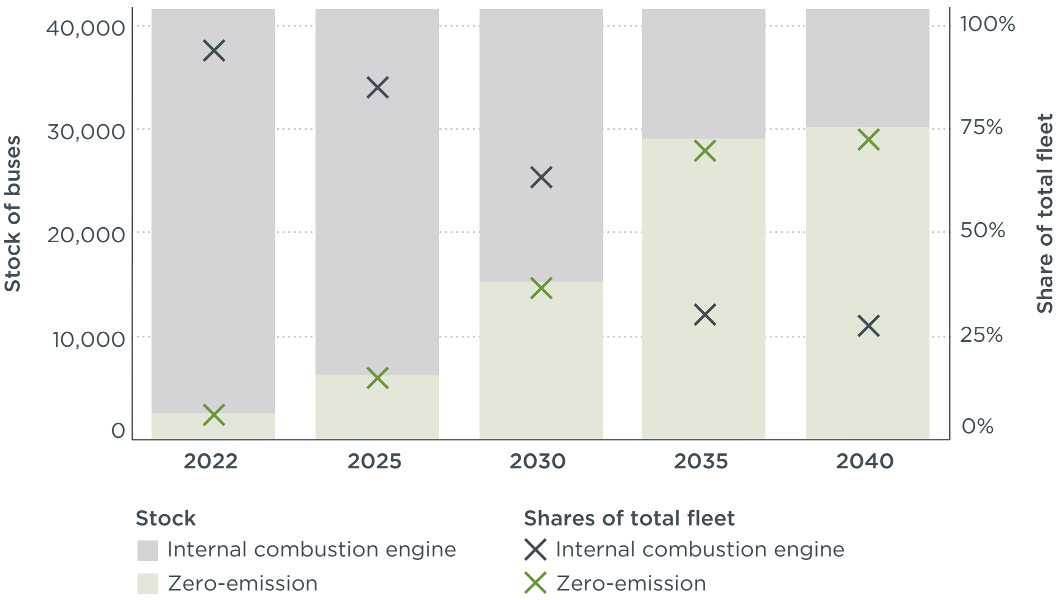

Figure 7. Projected stock (bars, left-axis) and share of fleet (crosses, right-axis) of zero-emission buses in European capital cities based on city targets.

This section presents examples of the ongoing and planned technology transition to zero-emission buses in selected cities.

THE VERY AMBITIOUS TWO

Amsterdam, Netherlands has one of the most ambitious targets for ZEBs in the world. They intend to have a fully zero-emission bus fleet by 2025. Currently, 44 buses representing 20% of the Amsterdam bus fleet are ZEBs, not including an additional 206 transit ZEBs in operation for Schiphol airport.

Copenhagen, Denmark matches this ambition by also planning for a fully ZEB fleet by 2025. This contributes to the city's plan to become carbon neutral by the same year. There are currently 199 electric buses in Copenhagen representing 10% of the bus fleet.

THE IMPORTANT BIG THREE

Three of the largest EU-27 capitals have ambitious plans for scaling up ZEBs—Berlin, Madrid, and Paris. Combined, they represent 20% of the bus stock in all capital cities.

Berlin, Germany plans for a fully ZEB fleet to be in place by 2030. Currently they have a fleet of 139 electric buses, representative of 9% of its entire fleet, with plans to expand to 228 by the end of 2022. Included in its fleet are 17 articulated 18-metre buses, introduced as part of its E-MetroBus project funded by €5.6m provided by the Federal Ministry of Transport and Digital Infrastructure. The same ministry recently granted funding for 1,200 low- and zero-emission buses to a total of 41 public transport authorities.[42]

Madrid, Spain only has 85 of its 2,100 buses fully powered by electricity, representing just 4% of its fleet. The vast majority of the Madrid bus fleet is fueled by natural gas, as discussed further below. The city plans for one third of its fleet, or 700 buses, to be ZEBs by 2027, and for a major area of the city to be zero-emission under the Green and Healthy Streets Declaration.

42 Carrie Hampel, "Funding Granted for 1,200 Low- and Zero-Emission Buses in Germany," *electrive.com*, (July 13, 2022), https://www.electrive.com/2022/07/13/funding-granted-for-1200-low-and-zero-emission-buses-in-germany/.

Paris, France launched its Bus2025 project in 2014, under which it intends for two thirds of its 4,700 buses to be electric by 2025, and for the remainder to be biogas powered. The city has the most electric buses of any capital city analyzed, standing at 500 vehicles. Its fleet operator, RATP, expects the project to cost €600m in total. As a signatory of the Green and Healthy Streets Declaration, the city also intends for a major area to be zero-emission by 2030.

MOVEMENTS ON THE EASTERN FRONT

While most of the eastern European cities we considered have been slow to commit to ZEBs, there are a few promising examples. ***Warsaw, Poland*** has a 10% share of ZEBs in their existing fleet, most of which were purchased through a €95 million loan provided by the European Investment Bank to support the purchase of 130 electric buses. The city also has begun to invest in hydrogen fuel cell vehicles. They have already built one hydrogen refueling station, while a national plan exists to build 32 hydrogen filling stations to service between 100 and 250 buses across the country by 2025.

Hydrogen has also been gaining traction in other eastern European cities. ***Sofia, Bulgaria*** is involved in a €20 million project to procure 30 hydrogen buses and trolley buses and provide supporting infrastructure for the city, with no clear timeline presented. ***Bratislava, Slovakia*** plans to invest €24.4 million to purchase 40 hydrogen buses that may come into operation in 2023.

Tallinn, Estonia sent a proposal to the EU's innovation fund intending to launch 200 hydrogen buses to be put into operation "in a few years". Tallinn also plans to introduce 650 electric buses to its fleet by 2035, which is more than its current bus fleet of 546 vehicles.

Lastly, ***Riga, Latvia*** has ambitions to scale up its number of ZEBs. Currently 58% of its fleet are made up of ZEBs and hybrid vehicles, and the city has laid out funds to shift towards 100% ZEBs by 2030.

BEYOND THE CAPITALS

Although the analysis above exclusively examines capital cities, there are several noteworthy European cities that have made strides in ZEB deployment. Coventry in the United Kingdom intends to adopt a fully ZEB fleet by 2025.[43] It has recently ordered 130 double-decker electric buses and intends to convert the remining 170 buses in the next three years. Hamburg, Germany recently placed an order for 500 ZEBs to be delivered in the next two years and intends for a fully electric fleet by 2030.[44] The bus fleet operator in Flanders in the Netherlands initially had a target for a fully ZEB fleet by 2025, but later pushed this back to 2035, as it was seen as unrealistic for their fleet of over 2,500 buses.[45]

A RETROGRADE APPROACH: CITIES INVESTING IN NATURAL GAS BUSES

Natural gas offers no environmental or health benefits relative to a modern diesel engine. However, there is still considerable interest across European cities in investments in compressed natural gas (CNG) buses. The following provides a synopsis

43 Morgan Johnson, "Coventry Set to Be UK's First All-Electric Bus City," *CoventryLive,* (January 22, 2022), https://www.coventrytelegraph.net/news/coventry-news/coventry-set-become-uks-first-22826422.

44 Hochbahn, "E-Buses: Clean Public Transport for Hamburg," accessed July 19, 2022, https://www.hochbahn.de/en/projects/e-buses-.

45 Alan Hope, "Target of 100% Emissions-Free Buses by 2025 'Unrealistic' Says De Lijn Boss," *The Brussels Times*, (March 12, 2021), https://www.brusselstimes.com/159624/target-of-100-emissions-free-buses-by-2025-unrealistic-says-de-lijn-boss.

of some of these key cities that have a significant share of CNG buses in their fleet, or that have plans to invest in the technology in the near future.

Madrid, Spain stands as the single largest operator of CNG buses across all capital cities. Currently over 1,700, or 80% of their bus fleet, run on natural gas. They plan to replace the remaining diesel buses in their fleet with CNG by the end of 2022. However, they also plan to gradually divest from CNG vehicles in the next decade, with the target of one third of buses to be zero-emission by 2027 (the remaining two thirds will be CNG), and all buses to be zero-emission by 2030. Madrid is not the exception in Spain; In Seville, 74% of the fleet is fueled by CNG, and 32% in Barcelona.

Paris, France also has plans to further invest in CNG fueled buses. Approximately 11% of the 4,700 buses in the fleet is currently powered by CNG, and the city plans to increase this share to 33% by 2025. Eight of the 25 depots in Paris will be adapted to bio-CNG operations as part of the Bus2025 project. At a national level, France is by far the largest market for natural gas vehicles in Europe, responsible for 38% of all EU-27 natural gas bus sales in 2021, the majority of which were purchased from Iveco Bus. The market has also been rapidly expanding, with natural gas bus sales increasing over five-fold over the last five-year period.

The entire fleet of 110 CNG buses in ***Oslo, Norway,*** representing 9% of their fleet, is currently run on biomethane. Oslo plans to increase its share of CNG buses to 40% by 2025 but has also adopted the plan for all buses to be zero emission by 2028.

Tallinn, Estonia is also ramping up its dependence on CNG buses. Out of the city's 546 buses, 97 are currently powered by natural gas. The public fleet operator, TLT, recently placed an order for 250 CNG buses, which when in operation will have CNG buses making up a 70% share of the fleet. Tallinn has the goal to have a diesel-free bus fleet by 2025, and to be zero-emission by 2035.

Warsaw, Poland has a 10% share of CNG buses in its fleet with plans to nearly double this share later this year. The €95m received from the European Investment Bank was used to purchase 130 ZEBs and 270 CNG buses. The taxonomy of natural gas as a low-emissions fuel is enabling significant funds to be used to invest in a technology which offers little climate or health benefits relative to a new diesel vehicle. Warsaw is not alone in Poland in these recent investments. The city of Suwałki purchased 12 CNG buses through a project co-financed by European funding.[46] Rzeszòw have also been ramping up their share of CNG recently, with half of their 221 vehicle bus fleet now CNG fueled.[47]

THE OUTLOOK FOR ZERO-EMISSION BUSES IN EUROPE

The deployment of electric buses has increased rapidly, rising from a 5% sales share in 2016 to 10% in 2021. This trend looks likely to accelerate, driven by both increased supply from manufacturers and demand from city and national governments.

On the demand side, internal combustion engine phase-out targets are continuously being set by the Member States and major cities of Europe. Entire national zero-emission fleets are expected by as early as 2030, as is the case in the Netherlands. More ambitious targets are evident at the local level, with Amsterdam and Copenhagen planning for a fully zero-emission fleet by as early as 2025, and over half of all

46 Centrum Informacji o Rynku Energii, "Suwałki zakupią autobusy napędzane gazem CNG [Suwałki to buy CNG buses]," (February 18, 2020), https://rynek-gazu.cire.pl/artykuly/serwis-informacyjny-cire-24/155684-suwalki-zakupia-autobusy-napedzane-gazem-cng.

47 Global Gas Mobility, "Delivery of 60 CNG Buses Completed for Public Transport in Rzeszów, Poland," (April 26, 2021), https://www.globalgasmobility.com/delivery-of-60-cng-buses-completed-for-public-transport-in-rzeszow-poland/.

European capital cities planning for a fully-zero emission fleet by 2040. However, a clear divide exists—most of the ambition is driven by high-income Western Europe countries, with less of a transition evident from lower-income Eastern European countries.

On the supply side, there has been an emergence of several smaller manufacturers entering the market early and gaining a considerable foothold. Several major bus manufacturers have also committed to increasing their production of zero-emission buses but have, in parallel, been focusing significant resources on natural gas technology. While there is still a clear demand for natural gas buses, despite the insignificant climate or health benefits over a modern-day diesel bus, the cities that plan on investing in the technology see it as a short-term investment and plan to eventually shift to fully zero-emission vehicles. By delaying investments into zero-emission technologies, legacy manufacturers may risk losing their share in the market to emerging manufacturers of zero-emission buses.

POLICY RECOMMENDATIONS

The acceleration of zero-emission bus deployment may be solidified through upcoming directives and regulations. The introduction of the Clean Vehicles Directive, which establishes zero-emission targets for the public procurement of vehicles for each Member State, will play a significant role in further driving the increase in zero-emission buses in the near future. In the absence of CO_2 regulation, there has already been a clear rise in the deployment of zero-emission buses, which will likely accelerate over the next decade due to this Directive. The Directive will be reviewed in 2027 to set new targets for the post-2030 period and to consider the life-cycle CO_2 emissions when setting targets. Accurately representing the full life-cycle emissions of natural gas is a crucial step in removing the fuel from the clean taxonomy.

The CO_2 standards for heavy-duty vehicles will also be reviewed by the end of 2022. The intention of this review is to set heavy-duty vehicles on a pathway to contribute to Europe's legal obligation of climate neutrality by 2050. Our previous analysis has shown that to fully decarbonize Europe's bus fleet by 2050, 90% of new buses in 2030 need to be zero-emission and 100% in 2035.[48] Such a target aligns well with signals sent by both demand and supply side actors: five Member States and half of all European capital cities have already set phase-out targets for conventional buses before 2035, while Daimler Truck, who sold a quarter of all buses in Europe in 2021, aims to only sell zero-emission city buses from 2030 onward.

Finally, lower income regions may lack the capital to overcome the financial hurdles associated with investing in zero-emission vehicles. Some financial support is already available. The European Bank for Reconstruction and Development and The European Investment Bank both provides loans and equity investments towards the provision of sustainable transport systems.[49] Such initiatives may play a critical role in unlocking the zero-emission transition of public fleets in lower income countries. However, caution should be exercised that the provision of these funds is not used to fund further investment into unsustainable practices such as natural gas vehicles.

48 Mulholland, Miller, Braun, Sen, Ragon, and Rodríguez "The CO_2 Standards Required by Trucks and Buses for Europe to Meet Its Climate Targets."

49 European Investment Bank, "Sustainable Transport: Overview," (2021), https://www.eib.org/attachments/publications/sustainable_transport_overview_2021_en.pdf; "EBRD Sector Profiles: Transport," accessed July 19, 2022, https://www.ebrd.com/transport.html.

APPENDIX: SOURCES

The sources for city fleet sizes, emission targets, and hydrogen, electric, and natural gas fleets and plans are listed in the tables below.

Table A1. Sources for city zero-emission targets

Capital city	Zero-emission targets
Vienna, Austria	Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology, "Austria's 2030 Mobility Master Plan," (Vienna, 2001), https://www.bmk.gv.at/dam/jcr:eaf9808b-b7f9-43d0-9faf-df28c202ce31/BMK_Mobilitaetsmasterplan2030_EN_UA.pdf.
Brussels, Belgium	Renilde Craps et al., "Low Emission Mobility Brussels – En Route Vers Une Mobilité Basses Émissions [The Road to Low Emission Mobility]," (The New Drive; Vrije Universiteit Brussel VUB – MOBI; Bruxelles Environnement, 2021), https://environnement.brussels/sites/default/files/user_files/roadmap1.4_lowemissionmobility_fr_final_clean.pdf.
Sofia, Bulgaria	Ministry of Transport, Information Technology and Communications, "Integrated Transport Strategy for the Period until 2030," (2017), https://www.mtc.government.bg/sites/default/files/integrated_transport_strategy_2030_eng.pdf.
Cyprus	
Prague, Czech Republic	Maurits Kuypers, "Prague Goes All in for Modern and Green Public Transport," Innovation Origins, (2022), https://innovationorigins.com/en/prague-goes-all-in-for-modern-and-green-public-transport/.
Berlin, Germany	BVG, "Electromobility," (2022), https://unternehmen.bvg.de/electromobility/.
Copenhagen, Denmark	Copenhagen Capacity, "Copenhagen City Buses Will Be Electric by 2025," (2019), https://www.copcap.com/news/copenhagen-city-buses-will-be-electric-by-2025.
Tallin, Estonia	Tallinn City Administration, "Tallinn 2035 Development Strategy" (Tallinn, 2020), https://www.tallinn.ee/en/media/313030.
Athens, Greece	
Madrid, Spain	Pablo R. Roces, "Madrid eliminará todos sus autobuses ah Ei en 2022: toda la flota serán híbridos, eléctricos o de gas natural [Madrid will eliminate all its diesel buses by 2022: the entire fleet will be hybrid, electric or natural gas buses.]," El Mundo, 2020, https://www.elmundo.es/madrid/2020/12/10/5fd10521fc6c83dc798b4627.html.; Fan Bus, "España: En 2027 Un Tercio de La Flota de EMT Será Eléctrica [Spain: By 2027 One Third of EMT Fleet to Be Electric]," (2020), https://www.fanbus.cl/2020/03/espana-en-2027-un-tercio-de-la-flota-de.html.; C40, "Mayor of Madrid, José Luis Martínez-Almeida Commits to C40 Green and Healthy Streets Declaration," C40 Cities, (2019), https://www.c40.org/news/madrid-green-healthy-streets/.
Helsinki, Finland	HSL, "Helsinki's First Fully Electric Bus to Hit the Road in January," (2017), https://www.hsl.fi/en/hsl/news/news/2017/01/helsinkis-first-fully-electric-bus-to-hit-the-road-in-january.
Paris, France	"RATP on the Way to a 2025 Clean Fleet in Paris. Interview with Nicolas Cartier," *Sustainable Bus*, (September 24, 2019), https://www.sustainable-bus.com/news/ratp-on-the-way-to-a-2025-clean-fleet-in-paris-interview-with-nicolas-cartier/.
Zagreb, Croatia	
Budapest, Hungary	
Dublin, Ireland	Rialtas ah Eireann, "Climate Action Plan 2021: Securing Our Future" (Dublin, 2021), https://assets.gov.ie/203575/bb143644-a33a-4f18-b2bd-04ab32ca8e2e.pdf.
Rome, Italy	"Rome to Phase out Most Polluting Buses by 2022. 100 Mild Hybrid Buses Just Received from Daimler," *Sustainable Bus*, (December 27, 2021), https://www.sustainable-bus.com/news/rome-atac-hybrid-buses/.; "Roma, 1000 Bus Elettrici Grazie a Un Accordo Fra Atac, Atm e Anm [Rome, 1000 Electric Buses Thanks to an Agreement Between Atac, Atm and Anm]," *AUTOBUS Web*, (August 27, 2021), https://www.autobusweb.com/roma-1000-bus-elettrici-grazie-a-un-accordo-fra-atac-atm-e-anm/.
Vilnius, Lithuania	
Luxembourg	Christophe Hochard, "Public Transport: RGTR Bus Fleet to Be Entirely Electric by 2030,"*RTL Today*, (November 9, 2019), https://today.rtl.lu/news/luxembourg/a/1402059.html.
Riga, Latvia	GreenSAM, "City of Riga: Towards Green, Inclusive and Digitally Open Urban Mobility," *GreenSAM* (blog), 2021, https://greensam.eu/city-of-riga-towards-green-inclusive-and-digitally-open-urban-mobility/.
Malta	
Amsterdam, Netherlands	I "Amsterdam More than Doubles Its Electric Bus Fleet to Meet Carbon Neutral Goal," *I Amsterdam*," (July 20, 2021), https://www.iamsterdam.com:443/en/business/news-and-insights/news/2021/amsterdam-more-than-doubles-its-electric-bus-fleet-to-meet-carbon-neutral-goal.
Warsaw, Poland	
Lisbon, Portugal	Carris, "The New Electric Buses Have Arrived," accessed July 15, 2022, https://www.carris.pt/en/discover-lisbon/news/the-new-electric-buses-have-arrived/.
Bucharest, Romania	
Stockholm, Sweden	Dagens Industri, "Stockholm köper in ytterligare 200 nya elbussar – "det nya normala" [Stockholm buys another 200 new electric buses – "the new normal"]," Dagens ah Eire, 2022, https://www.di.se/nyheter/stockholm-koper-in-ytterligare-200-nya-elbussar-det-nya-normala/.
Ljubljana, Slovenia	
Bratislava, Slovakia	
London, United Kingdom	Mayor of London, "Mayor Announces That All New London Buses Will Be Zero-Emission," London City Hall, 2021, https://www.london.gov.uk//press-releases/mayoral/mayor-host-zero-emission-bus-summit-at-city-hall.
Bern, Switzerland	Siemens, "Siemens and Bernmobil Drive Sustainable Bus Transport in Bern," (July 21, 2021), https://press.siemens.com/global/en/pressrelease/siemens-and-bernmobil-drive-sustainable-bus-transport-bern.
Reykjavik, Iceland	
Oslo, Norway	Ruter, "Sporveien Årsrapport 2020 [Sporveien Annual Report 2020]," (2020), https://epub.artbox.no/sporveien/ar2020/.; Ruter, "Plan Ready for Transition to Running Exclusively on Renewable Energy in 2020," accessed July 15, 2022, https://ruter.no/en/about-ruter/reports-projects-plans/fossilfree2020/plan-ready-for-transition-to-running-exclusively-on-renewable-energy-in-2020/.

Table A2. Sources for city hydrogen fleet and plans

Capital city	Hydrogen fleet and plans
Vienna, Austria	Carrie Hampel, "Solaris Signs New Agreement for Buses in Austria," *Electrive*, (March 7, 2022), https://www.electrive.com/2022/03/07/solaris-signs-new-agreement-for-buses-in-austria/.; Hyundai, "Hyundai Motor to Hand over ELEC CITY Fuel Cell Bus to City Bus Operator in Austria," (2021), https://www.hyundai.news/eu/articles/press-releases/hyundai-motor-to-hand-over-elec-city-fuel-cell-bus-to-city-bus-operator-in-austria.html. "The First Hydrogen Bus on the Streets in Vienna from December," *Tek Deeps* (blog), (September 9, 2021), https://tekdeeps.com/the-first-hydrogen-bus-on-the-streets-in-vienna-from-december/.
Brussels, Belgium	FuelCellsWorks, "Van Hool Delivers First Hydrogen Bus For STIB-MIVB In Brussels," (2021), https://fuelcellsworks.com/news/van-hool-delivers-first-hydrogen-bus-for-stib-mivb-in-brussels/.
Sofia, Bulgaria	The Mayor, "Bulgaria Is Slowly but Surely Embracing Hydrogen in Public Transport," (2021), https://www.themayor.eu/en/a/view/bulgaria-is-slowly-but-surely-embracing-hydrogen-in-public-transport-9166.
Cyprus	
Prague, Czech Republic	Dopravní podnik hlavního mesta Prahy, "Hydrogen-Powered Bus Testing," (2022), https://www.dpp.cz/en/company/news-and-events/detail/342_1594-hydrogen-powered-bus-testing.
Berlin, Germany	
Copenhagen, Denmark	Jakob Engelund Vistisen, "Hovedstadsområdet får sin første brintbus: Tager kun ni minutter at tanke [Capital region gets its first hydrogen bus: takes just nine minutes to refuel]," *Ingeniøren*, (January 11, 2022), https://ing.dk/artikel/hovedstadsomraadet-faar-sin-foerste-brintbus-tager-kun-ni-minutter-at-tanke-253391.
Tallin, Estonia	ERR, "Hydrogen Buses Set to Drive on Tallinn Routes in near Future," (2021), https://news.err.ee/1608344201/hydrogen-buses-set-to-drive-on-tallinn-routes-in-near-future.
Athens, Greece	
Madrid, Spain	
Helsinki, Finland	
Paris, France	
Zagreb, Croatia	The Mayor, "Zagreb Signed Agreements to Begin Using Hydrogen for City Buses," (2021), https://www.themayor.eu/en/a/view/zagreb-is-planning-the-use-of-hydrogen-for-public-transport-7340.
Budapest, Hungary	"Hungary Launches First Hydrogen Bus Route in Budapest," *Hydrogen Central*, (February 10, 2022), https://hydrogen-central.com/hungary-first-hydrogen-bus-route-budapest/.
Dublin, Ireland	Rialtas ah Eireann, "Ireland Takes next Step in Testing Hydrogen Buses in Transport Fleet," (2021), https://www.gov.ie/en/press-release/fb42f-ireland-takes-next-step-in-testing-hydrogen-buses-in-transport-fleet/.
Rome, Italy	
Vilnius, Lithuania	
Luxembourg	European Alternative Fuels Observatory, "Vehicles and Fleet: Luxembourg," (2022), https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road/luxembourg/vehicles-and-fleet.
Riga, Latvia	"Riga Rolls out 10 Trolleybuses with Fuel Cell Range Extender. Solaris Trollino FC on the Road," *Sustainable Bus*, (March 28, 2020), https://www.sustainable-bus.com/news/riga-rolls-out-10-trolleybuses-with-fuel-cell-range-extender-solaris-trollino-fc-on-the-road/.
Malta	
Amsterdam, Netherlands	
Warsaw, Poland	Osborne Clarke, "Decarbonising Technologies for Cities: Warsaw Case Study," (2022), https://www.osborneclarke.com/insights/decarbonising-technologies-cities-warsaw-case-study.
Lisbon, Portugal	
Bucharest, Romania	
Stockholm, Sweden	
Ljubljana, Slovenia	
Bratislava, Slovakia	News Beezer, "In the First Slovak City You Will Travel with 40 Hydrogen Buses. The Eco Novelty Will Cost Tens of Millions of Euros," 2021, https://newsbeezer.com/slovakiaeng/in-the-first-slovak-city-you-will-travel-with-40-hydrogen-buses-the-eco-novelty-will-cost-tens-of-millions-of-euros/.
London, United Kingdom	TfL, "Bus Fleet Audit" (London, 2020), https://content.tfl.gov.uk/fleet-annual-audit-report-31-march-2021.pdf.
Bern, Switzerland	
Reykjavik, Iceland	
Oslo, Norway	

Table A3. Sources for city electric fleet and plans

Capital city	Electric fleet and plans
Vienna, Austria	Weiner Linien, "Factsheet: E-Mobilität (Factsheet: Emobility)" (Vienna, n.d.), https://www.wienerlinien.at/media/files/2019/factsheet_e-mobilit%C3%A4t_web_315122.pdf.
Brussels, Belgium	Renilde Craps et al., "Low Emission Mobility Brussels – En Route Vers Une Mobilité Basses Émissions (The Road to Low Emission Mobility)" (The New Drive; Vrije Universiteit Brussel VUB – MOBI; Bruxelles Environnement, 2021), https://environnement.brussels/sites/default/files/user_files/roadmap1.4_lowemissionmobility_fr_final_clean.pdf.; STIB, "The Network and Vehicles," STIB-MIVB, accessed July 15, 2022, https://www.stib-mivb.be/article.html?l=en&_guid=8086313c-3883-3410-f894-ec3da5b1280e.
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Cyprus	
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Table A4. Sources for city natural gas fleet and plans

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Table A5. Sources for city fleet numbers

Capital city	Fleet size
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