Seminar paper

City buses

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1. Abstract

This paper analyses the market for city buses in the European Union, with a focus on the transition from traditional diesel-powered buses to alternative energy sources. With the help of literature research, the most important trends and developments will be identified and analysed, focussing on Austria and the Czech Republic. It will also outline the policy measures influencing these trends and the market dynamics in these countries. Based on these informations reasons for this trends and development will be explained.

2. Introduction

In a rapidly changing world, urban mobility is evolving towards more demand for greener mobility solutions, especially in urban areas. This change can also be seen in the choice of drive systems for city buses. This document looks at the key developments in bus propulsion systems, focussing on the shift from traditional diesel engines to more sustainable alternatives. Cities around the world are facing challenges such as air quality and climate change. The transition to electric and alternative fuelled buses is therefore emerging not only as a practicable alternative, but also as a necessary development in public transport.[1][2]

This shift is being driven by several factors, including the tough climate targets set by European cities, progress in battery technology and the economic benefits this offers. Together, these factors have increased the pressure on new technologies to increase production and reduce costs, leading to an increase in registrations of battery electric vehicles.[3][1]

The document also analyses how the regulatory and political framework in the European Union, with a focus on Austria and the Czech Republic, is encouraging this transition. In addition, the paper reviews the geographical distribution of new buses by power source in this two countries and how they are adapting to EU-wide goals. For example, the European Commission's proposal to sell only zero-emission city buses by 2030 emphasises the EU's commitment to reducing carbon emissions and tackling climate change. Financial instruments such as the European Investment Bank and initiatives such as the NextGenerationEU project facilitate this transition by alleviating the financial burdens associated with the purchase of greener, state-of-the-art buses.[1][4]

The transition to greener bus propulsion systems is not just a reflection of technological opportunity, but a coordinated response to the current environmental, health and po-

litical challenges of our time. By exploring these trends, this paper aims to provide a comprehensive overview of how the bus market dynamics are adapting to the future of urban mobility - a future that promotes sustainability and resilience.[4][5]

3. Propulsion Options for City Buses

City buses play a crucial role in public transport and make urban areas more accessible. They are an important part of the transport sector, with the entire bus fleet in the European Union consisting of around 750 000 vehicles in 2023. Around 535 000 of these vehicles are used for long-distance transport and 215 000 are city buses.[1]

First of all, it is important to understand the different drive types for city buses. The following is a brief introduction to the different types. Focusing on the most commonly used types before discussing their use in practice.

3.1. Diesel Engines

In many countries, diesel is still widely used as dominant fuel for city buses. Diesel Engines have been the traditional choice for city buses for a long time due to their robustness and fuel efficiency, particularly suitable for the heavy loads and frequent stops of urban public transport. However, diesel motors are now under criticism for their higher emissions of nitrogen oxides and particulates, which contribute to air pollution in city environments.[6]

3.2. Sustainable Propulsion Technologies

With growing environmental concerns and an increasing focus on sustainability, various propulsion technologies for city buses are being developed and implemented to reduce emissions and enhance efficiency. The alternatives currently in use will be discussed briefly below.

CNG (Compressed Natural Gas) is mainly methane stored at high pressure. It is known for emitting fewer greenhouse gases compared to conventional fuels. However, it requires high-pressure storage tanks and has a fuel economy similar to petrol.[7]

LPG (Liquefied Petroleum Gas) consists mostly of propane and butane. LPG is widely used due to its high octane rating and ability to reduce emissions of hydrocarbons and carbon monoxide compared to diesel and petrol. It is also easier to find than CNG.[8]

LNG (Liquefied Natural Gas) is essentially the same as natural gas but super cooled to a liquid state, making it denser and more suitable for long range vehicles like heavy trucks due to its energy density. However, it requires cryogenic storage and has a more complex infrastructure.[9]

H2 (Hydrogen) can be used in fuel cells to power electric motors in buses, offering a zero-emission alternative. Hydrogen fuel cell vehicles emit only water vapor as a byproduct.[10]

PHEV (Plug-in Hybrid Electric Vehicle) combines a conventional internal combustion engine system with an electric propulsion system, providing the flexibility of using either or both to power the vehicle.[11]

BEV (Battery Electric Vehicle) is fully electric, powered by a battery and electric motors. These vehicles produce zero emissions at the point of use and are an important part of the shift towards sustainable urban mobility.[11]

While the majority of EU buses still operate on diesel, recent years have seen a significant shift towards alternative propulsion systems. Notably electric buses have experienced a substantial increase, nearly doubling their numbers from 2022 with an addition of around 11 000 units, which can be seen in figure 1. Hydrogen-powered buses also had an immense growth since 2021, compared to the years from 2015 to 2021.[1]

Looking at CNG buses a moderate growth from 2015 to 2021 is evident. However, the rate plateaued since. Reasons for that are that the previous advantage of CNG buses, such as reduced emissions, is diminishing due to stricter diesel engine emission controls introduced with the Euro 6 norm. In combination with their lower efficiency compared to diesel engines these types are becoming less attractive.[1]

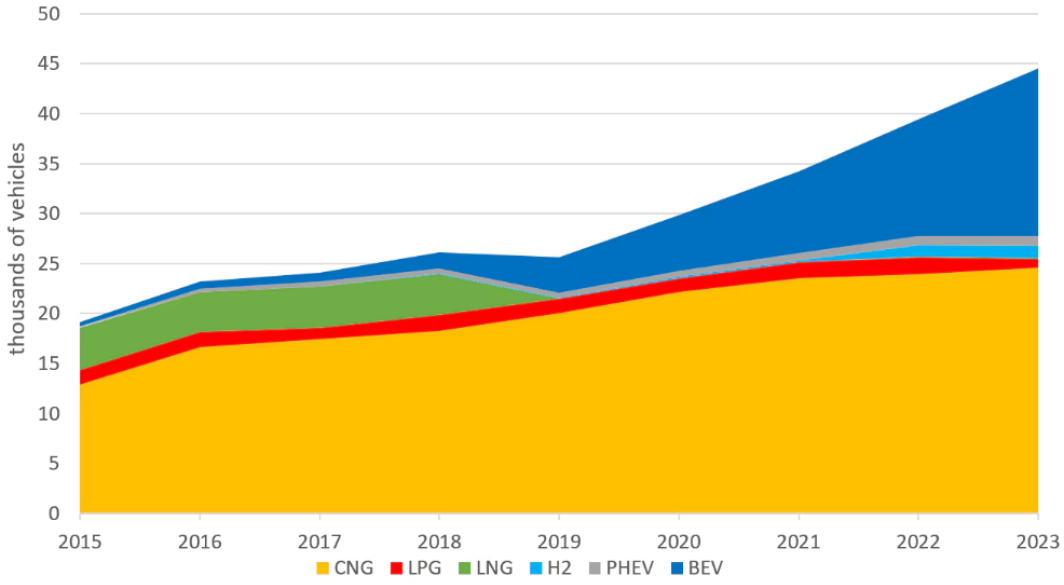

Figure 1: Trends in Alternative Fuel Use for City Buses (2015-2023)

As already explained, there were around 750 000 buses in the EU in 2023, of which an estimated 215 000 were city buses. Only around 2% of the total fleet are BEV or PHEV buses and hydrogen-powered vehicles. Low-emission fuels, including LNG, CNG and LPG, account for around 3% of the total fleet. These figures clearly show that even if every alternatively fuelled bus were a city bus, only a quarter of the city buses could be alternatively powered. So there is still a long way to go before the majority of city buses are operated alternatively [1]

3.3. Electrification Rate of City Busses across the EU

If we take a closer look at the different EU countries it is evident that the electrification differs strongly within the EU. When looking at figure 2 the first thing that is clearly noticeable is the large proportion of electric vehicles in Luxembourg, at around 43%. Followed by the Netherlands, which have the second largest proportion of electric buses in its fleet, at around 27%. It is clear that the northern countries are in the lead here with an average share of 10 to 24 % of the total city bus fleet in the respective countries. Although Germany has a lower electrification quote of its total city bus fleet, it has the highest number of electric buses of all countries in the EU. France also does not have such a high electrification rate in their country, but they have the second highest absolute number of electric buses.[12]

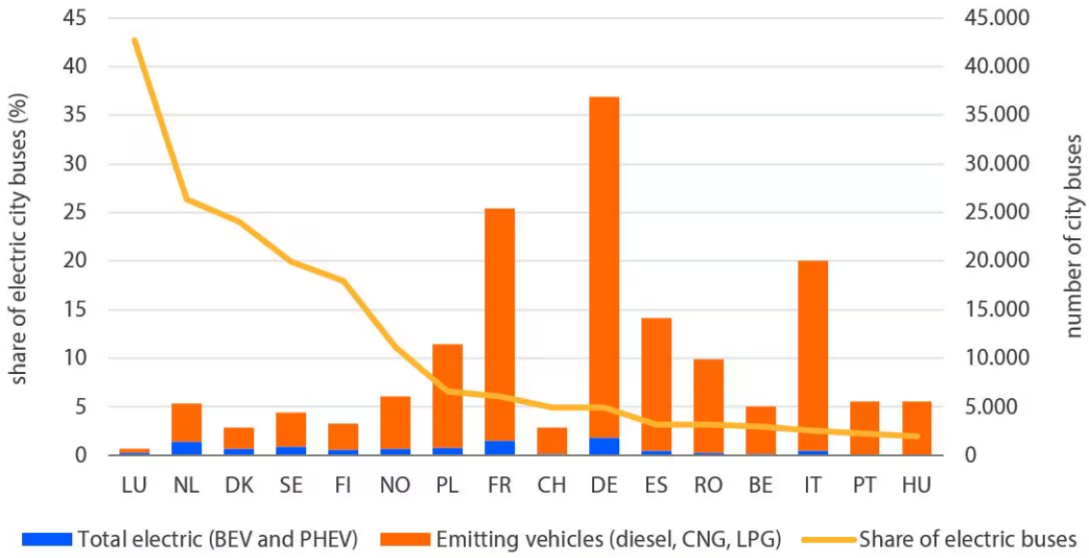

Figure 2: Share of Electric and Emission-producing City Buses Across EU Countries

3.4. Comparing Costs - Electric vs. Diesel Buses

When comparing the acquisition costs of electrical-powered buses and a diesel bus, since the electric bus is the biggest competitor for diesel buses on the market, you realise that electric buses are more expensive to purchase than diesel buses. An average diesel transit bus costs around 500 000 dollars, while an electric bus costs 750 000 dollars. Although the acquisition costs of a diesel bus are significantly lower, the long-term savings in fuel and maintenance costs can outweigh these initial costs. Over the life of an electric bus, up to $400 000 can be saved in fuel costs and $125 000 in avoided maintenance costs. This is due to the fact that electric buses have significantly fewer parts than their fossil-fuelled counterparts, no oil changes are required and the braking systems have a longer lifespan.[13]

4. Geographical Distribution of City buses

4.1. Situation in the EU in general

4.1.1. Policies

Members of the European Parliament are advocating for robust CO2 emissions reduction goals for medium and large trucks, including specialized vehicles like refuse collectors, dump trucks, or concrete mixers, as well as buses. The reduction targets they propose are set at 45% between 2030 to 2034, 65% for the years 2035 to 2039, and 90% starting from 2040 onwards.[16][4]

They concur with the Commission's proposal that starting in 2030, only zero-emission new urban buses should be permitted for registration. Additionally, they suggest a provisional exemption (valid until 2035) for urban buses powered by biomethane, provided they meet stringent criteria.[16][4]

4.1.2. Buses by propulsion: Share and purchase

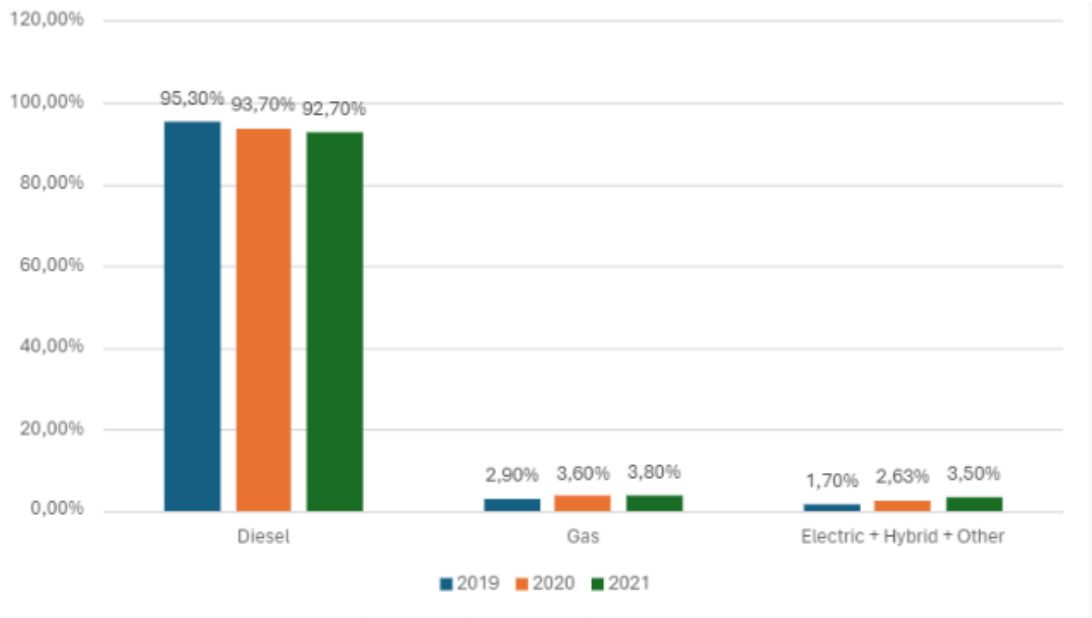

Figure 3: Progression of buses by their fuel in European Union

As we can see in the figure 3, in 2019, diesel buses dominated the EU bus market with a share of 95,3%. Their dominance slightly decreased in the following years, reaching 93,7% in 2020 and 92,7% in 2021. In contrast, gas-powered buses experienced a slight increase in share from 2,9% to 3,6% in 2020, and then slight increase to 3,8% in 2021. The electric + hybrid + other category saw a increase in popularity, with their share rising from 1,7%

in 2019 to 2,63% in 2020 and then another increase to 3,5% in 2021.[17][18][19]

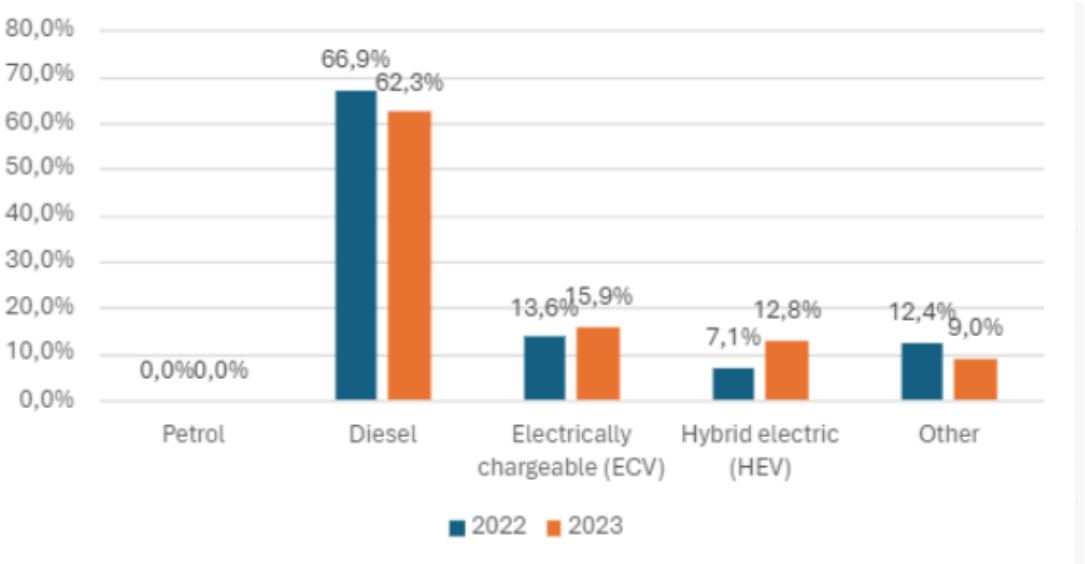

Figure 4: New buses by power source in European Union

The graph 4 shows, that in EU diesel buses constituted 66.9% of purchases in 2022, but their share decreased to 62.3% in 2023. Electric buses increased from 13.6% in 2022 to 15.9% in 2023. The share of hybrid electric buses rose from 7.1% in 2022 to 12.8% in 2023. Category "other" recorded a decrease from 12.4% in 2022 to 9% in 2023.[20]

4.2. Situation in Austria

4.2.1. Policies

The Recovery and Resilience Plan of Austria, funded by the EU to address the economic impacts of the Covid-19 pandemic, is designed to promote initiatives that support the green and digital shift, aligning with the EU's ecological targets. A principal element of the plan dedicates approximately $960 million to projects advancing zero-emission transportation.[21]

The initial funding segment will cover the costs of roughly 600 zero-emission buses for public transportation and their necessary infrastructure, amounting to $285 million, with $160 million of that earmarked for 2022. The Austrian government will distribute public funds for the procurement of fully electric buses, hydrogen fuel cell electric buses, and trolleybuses, based on submissions from qualified Austrian parties, which include bus service providers, transport infrastructure firms, and public transportation agencies.[21]

These financial commitments stem from Austria's implementation of the EU Clean Vehicle Directive (CVD). As per the national regulations enforcing this EU Directive, starting from 2021, 45% of all public transit buses purchased publicly must be classified as "clean buses," which encompasses vehicles powered by electricity, hydrogen, biofuels, synthetic fuels, natural gas, or LPG, with a stipulation that half of these should be zero-emission. From the second quarter of 2026, the obligation for acquiring "clean buses" increases to 65%, maintaining the requirement that at least half be zero-emission. The mandate dictates that by the start of Q2 in 2026, at least 650 emission-free buses should be operational.[21]

4.2.2. Buses by propulsion: Share and purchase

In the graph 5 we can see, that in Austria, the share of diesel buses has decreased from 96.20% in 2019 to 90.00% in 2021. The gas-powered buses didn't change between years 2019 and 2020 and stayed at 1.60%, but their share decreased to 1.20% in 2021. The electric + hybrid + other category (which includes fuel cell electric vehicles (FCEVs) and other fuels) saw a significant increase in popularity, with their share rising from 2.20% in 2019 to 3% in 2020 and 3.70% in 2021.[17][18][19]

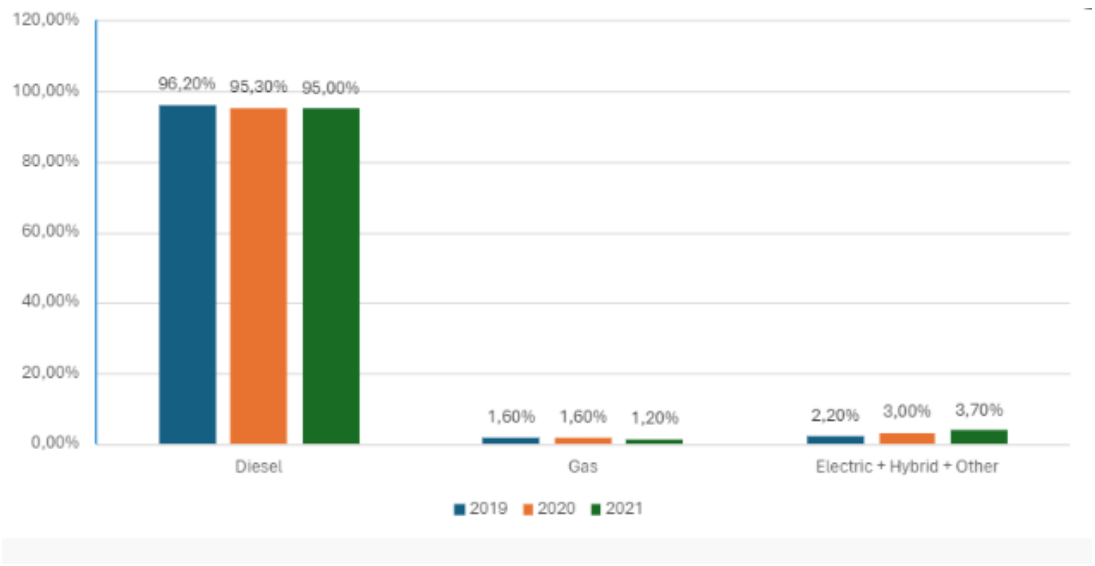

Figure 5: Progression of buses by their fuel in Austria

The graph 6 shows the distribution of bus purchases in Austria by type of propulsion for the years 2022 and 2023. Diesel buses had the largest share in both years, with 89.3% in 2022 and an increase to 93% in 2023. Electric buses recorded growth from 2.8% in 2022 to 5% in 2023. Conversely, hybrid electric buses saw a decrease from 7.7% in 2022 to 2.1% in 2023.[20]

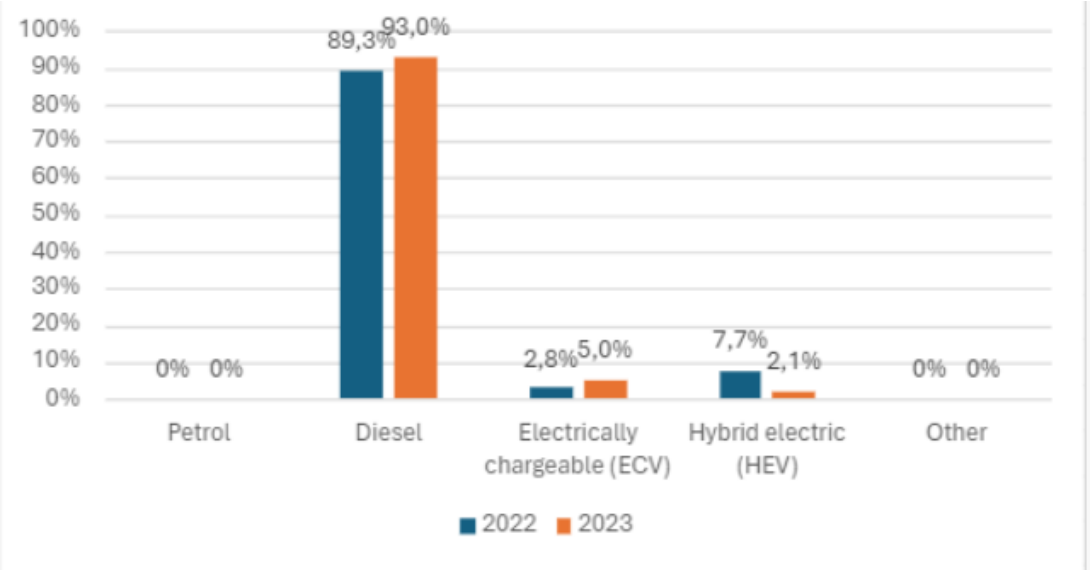

Figure 6: New buses by power source in Austria

4.3. Situation in Czechia

4.3.1. Policies

The long-term vision for the Czech Republic's transport system envisions a system that caters to both passenger and freight transport needs, supports sustainable economic growth, and includes policies targeted at supporting structurally disadvantaged regions and their residents.[22]

Simultaneously, this transport system is designed to comply with sustainability criteria, signifying its neutral effect on both global climate and other changes, including mitigation and adaptation. It will minimize its effect on public health, exert the smallest possible impact on biodiversity, nature, and landscapes, and employ a judicious use of renewable-based natural resources to avoid burdening future generations with ecological debt.[22]

The objective is to evolve transport rather than constrain it. The goal is to move away from the current model, which heavily relies on the intensive use of energy, particularly fossil fuels, towards a more energy-efficient and eco-friendly approach. Consequently, the

societal challenge lies in enhancing the energy efficiency of the transportation sector, which involves decreasing the specific energy usage (the ratio of energy consumed to transport work completed).[22]

4.3.2. Buses by propulsion: Share and purchase

As we can see in the graph 7, in 2019, diesel buses dominated the Czech bus market with a share of 89.20%. Their dominance slightly decreased in the following years, reaching 86.10% in 2020 and 87.50% in 2021. In contrast, gas-powered buses experienced a slight increase in share from 6.70% to 9.30% in 2020, but their share slightly decreased to 9.00% in 2021. The electric + hybrid + other category saw a slight increase in popularity, with their share rising from 4.20% in 2019 to 4.60% in 2020 and significant decrease to 3,40 in 2021.[17][18][19]

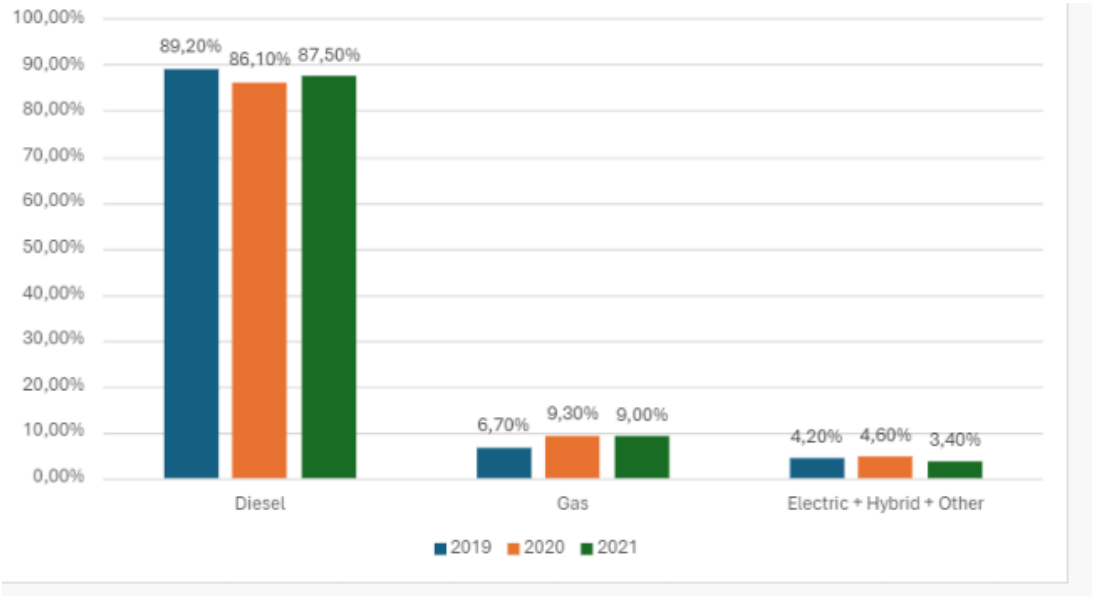

Figure 7: Progression of buses by their fuel in Czech Republic

The graph 8 shows, that in 2022, diesel buses were the most common, with a share of 88.1%, while in 2023, this share dropped to 75.7%. Electric buses made up 3.3% of purchases in 2022, but fell to 0.6% in 2023. Hybrid electric buses decreased from 2.1% in 2022 to 0.9% in 2023. The "Other" category, which includes fuel cell electric vehicles (FCEVs) and vehicles powered by natural gas, liquefied petroleum gas (LPG), E85/ethanol, and other fuels, increased from 6.6% in 2022 to a significant 22.8% in 2023.[20]

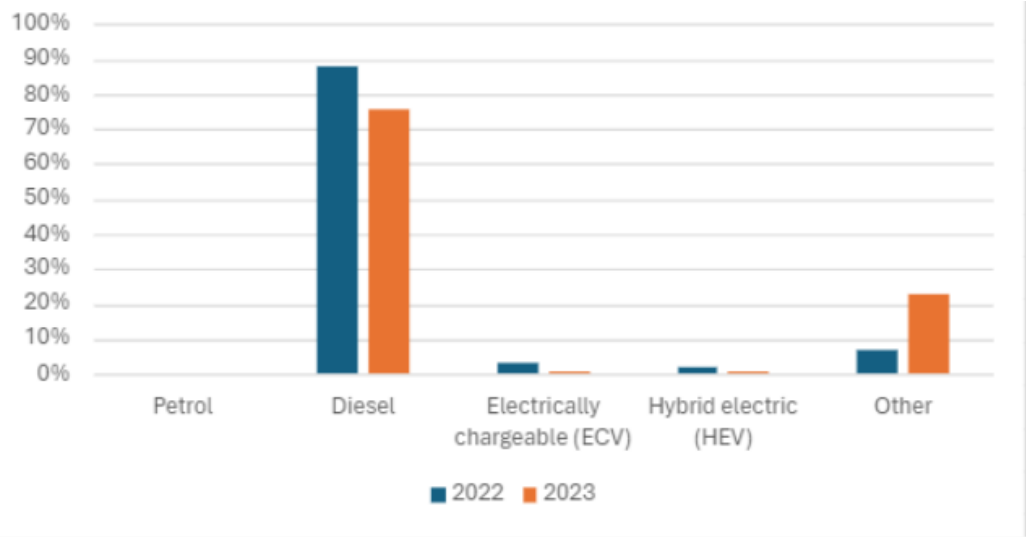

Figure 8: New buses by power source in Czech Republic

5. Transition to Alternative-Powered Buses in the EU

5.1. Trends in bus propulsion systems over time

If we look at the sales shares of drive systems between 2015 and 2023, as shown in Figure 9, we see a significant increase in alternative drive systems and also a drastic reduction in diesel engines. As a result, the largest share of new city buses in 2023 are BEV buses. Diesel buses take the second place, followed by PHEV and CNG buses. If you compare these figures with just four years earlier, diesel buses reached the largest share in 2019 with around 8 000 units sold, while PHEV, BEV and CNG buses each accounted for around 2 000 units of new buses.[1]

Looking at the development of recent years, a steady decline in the share of diesel buses can be seen, while a continuous increase in the share of more sustainable drive types is noticeable overall. BEV buses have shown the greatest increase among the alternative drive types since 2015. CNG buses, like BEV buses, initially rose, but have fallen slightly again since 2020. The situation is similar for PHEV buses, which have also shown a reverse trend since 2019 compared to the previous years.[1]

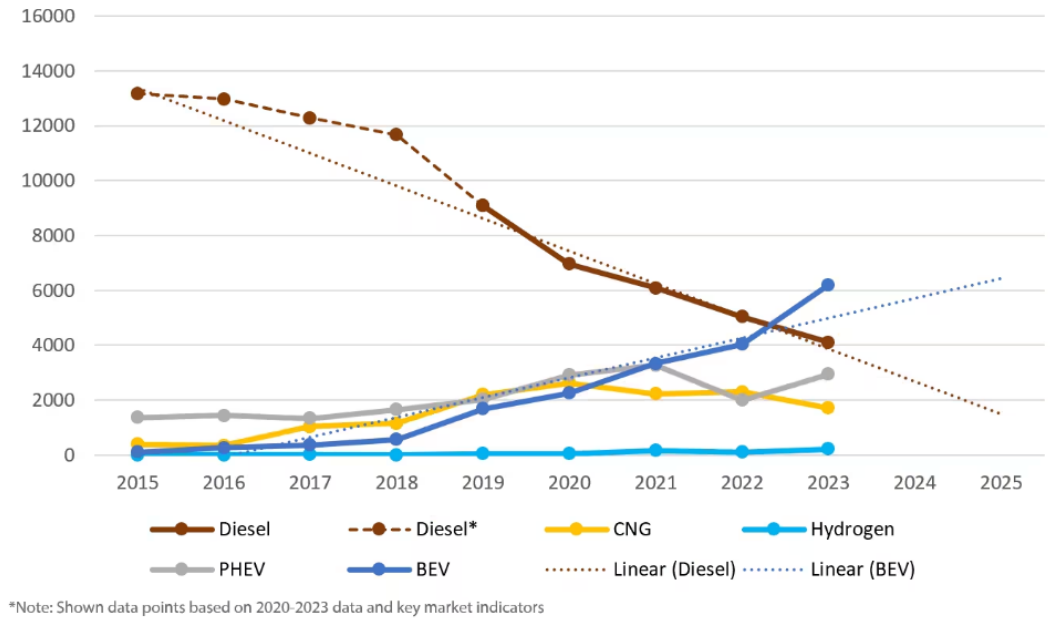

Figure 9: Evolution of yearly sales of City Bus Propulsion Types between 2015 and 2023 with Projections up to 2025

So a significant portion of the city bus registrations in 2023, approximately 75%, is served by zero-emission buses. This development shows a substantial move away from traditional

diesel-powered buses, underlining the market's readiness for cleaner, more sustainable urban mobility solutions.[1][2]

Regarding the sales of hybrid electric buses, we can see that they increased by 160.5% and their market share more than doubled in the first half of 2023 from 6.2% compared to the first half of 2022 to 14%. This immense increase was mainly caused by significant sales increases in France and Spain with growth rates of 886% and 180.3%. Despite the remarkable increase in the introduction of electric and hybrid models, diesel buses continue to dominate the market with a 63% share.[2]

5.2. Cost Benefits of Buses with Alternative Drive Systems

In 2023 the usage of alternative-powered buses not only promoted sustainable transport, but also led to a significant reduction in diesel consumption, saving 400 million litres over the year. This amount is roughly equivalent to the diesel consumption of 29 days of road transport in the Netherlands over the same period. These developments are a remarkable step towards reducing the carbon footprint and transitioning to more environmentally friendly transport alternatives.[1]

In addition, diesel prices have been very uncertain over the past two years, with price fluctuations across the EU increasing by almost 30%. Such instability, especially when prices are trending upwards, has an negative impact on consumers. Where alternative buses were used early on, a lot of money was saved.[1]

Projecting the entire fleet of 215 000 city buses in the EU to electric buses, the savings in diesel could amount to 5.6 billion liters. This amount corresponds to the diesel consumption of an entire year in the Netherlands. The potential that lies in a change in this transport sector is therefore very large.[1]

5.3. Europe's Bus Manufacturing and Green Transition

With 71 bus assembly plants across Europe, the bus industry represents a significant segment of the European manufacturing landscape. The demand for and production of city buses has a direct and indirect economic impact on the transport sector, including job creation, and promotes technological progress. The demand for greener solutions and the resulting competition in this industry is driving manufacturers to find ever more innovative and better solutions. As a result, manufacturers are a crucial part of the green transition in the public transport sector.[14]

If you take a closer look at the big players in this industry, three companies stand out in particular. Solaris, MAN, and BYD-ADL are leading the transition to a more sustainable bus infrastructure, with Solaris leading the electric bus market with the highest number of registrations.[15]

5.4. Reasons for the Shift to Eco-Friendly Buses

The recent increase in BEV bus sales can be attributed to a combination of factors. Firstly, the push to meet the climate targets set by various European cities has played an important role, as outlined in our previous discussions. In addition, advances in battery technology combined with the benefits of economies of scale have improved battery performance leading to reduced costs. These advances in the market have had a positive impact on the increase in BEV bus registrations and support the realistic goal of eliminating diesel-powered city buses by 2027, as shown in Figure 9. This optimistic outlook suggests that the adjustments to diesel vehicle sales targets previously considered necessary by organisations such as 'Transport & Environment' might not be necessary.[1]

This shift towards electric and fuel cell buses not only reflects the EU's commitment to reducing carbon emissions and combating climate change but also aligns with broader legislative and policy frameworks aimed at fostering zero-emission public transport. For instance, proposals by the European Commission to mandate the sale of only zero-emission city buses by 2030 exemplify the ambitious targets set to achieve a more sustainable and environmentally friendly transport sector.[3]

The dynamics of the city bus market are largely influenced by the political agenda of city councils, which are often responsible for the procurement of urban mobility services. However, the financial pressure on these cities means that initiatives at EU level play a crucial role in helping to reduce the additional purchase costs associated with electric buses, enabling technological progress. An illustrative example is Madrid's utilisation of the NextGenerationEU project, which will provide 41.2 euros million for the purchase of 150 electric city buses - a significant proportion of the €81 million required. In addition, the European Investment Bank is proving to be a key financier in the transition to greener public transport. A notable example of this support was in 2019, when the EIB provided a EUR 115 million loan to the Rotterdamse Electrische Tram in Rotterdam to support the electrification of its fleet.[3][1]

These developments in the electric and fuel cell bus market represent a key moment in

the evolution of public transport in the EU and mark a shift away from more than a century of dominance by buses with internal combustion engines. As European cities and Member States continue to embrace zero-emission vehicles, the transition to greener and cleaner urban mobility solutions is likely to accelerate, as shown in figure 9.[3]

6. Conclusion and Future Outlook

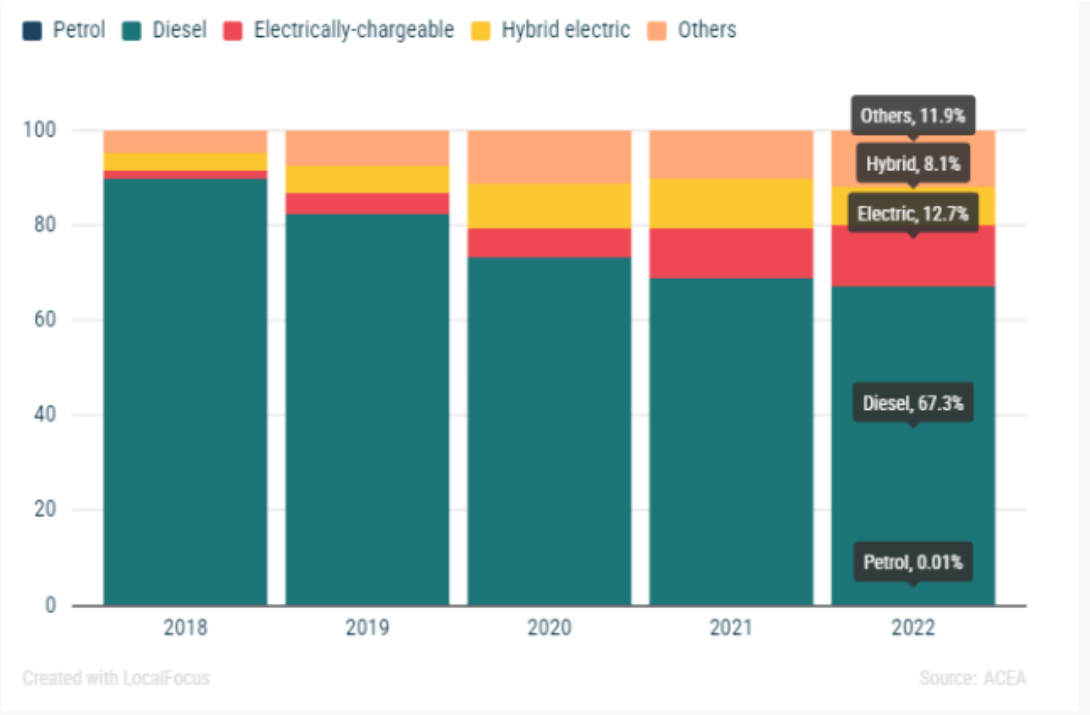

Figure 10: New EU buses by power source since 2018 to 2022

Diesel's grip on the EU bus market loosens as cleaner options gain ground. Graph 10 shows that while diesel remains the dominant fuel source for buses in the European Union, accounting for 67.3% of new sales in 2022, its market share is shrinking. There's a clear shift towards cleaner alternatives: 12.7% of new buses are now electrically-chargeable, 8.1% are hybrid electric, and 11.9% run on alternative fuels. This interactive chart visualizes the trend in bus fuel types across the EU from 2018 to 2022.[23]

The uptake of electric city buses has surged in the past year. In 2023, registrations expanded by 2000 vehicles over the prior year, marking a 54% growth on top of the 21% rise seen the year before (refer to 11). Previously, we projected a consistent annual growth rate of at least 18% to reach complete zero-emission (electric and hydrogen) city bus registrations by 2030. At present, the market's expansion rate is exceeding double this anticipated 18% growth requirement. Maintaining the current growth rate of 54% could lead to a market composed entirely of zero-emission city bus sales by as early as 2025.[4]

Nonetheless, anticipating a continuous 54% annual growth rate might be overly optimistic over an extended period. Yet, by applying a more conservative average growth rate of 40%—the mean rate from the past three years—we could see all new bus registrations be-

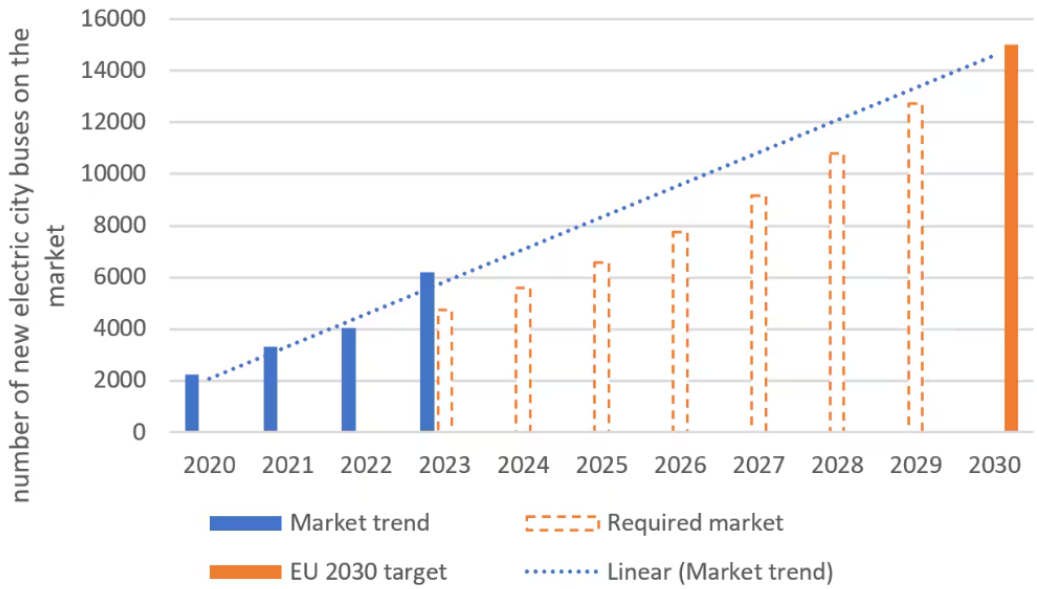

Figure 11: EU 2030 target for city bus market vs. the 2020-2022 market trend

ing zero-emission by 2026, and the entire European city bus fleet of 215,000 could achieve zero emissions by 2031.[4]

Since the introduction of the European Green Deal in 2019, comprehensive legislation has been established to reduce carbon emissions in the EU's transport sector. The Sustainable and Smart Mobility Strategy consolidates various initiatives aimed at achieving this goal. Moreover, in its recent update of CO2 emission standards for heavy-duty vehicles, the European Commission has set a goal for all new city buses to be zero-emission by 2030.[1] [12]

The strategy also includes the EU's objective to establish "100 climate-neutral and smart cities by 2030," recognizing the crucial role that cities play in driving the desired technological shift in their regions. Demonstrating local governments' dedication to meeting climate objectives, the initiative attracted 362 applications, from which 100 pilot cities were chosen. In the Netherlands, cities such as Amsterdam, Eindhoven, Helmond, Groningen, Rotterdam, The Hague, and Utrecht were among those selected.[1] [12]

While Europe has made significant strides with zero-emission buses, it is not the frontrunner; for many years, China has led the way, where zero-emission buses accounted for an astounding 91% of sales in 2022. Nonetheless, this represents a landmark achievement for Europe, marking the first time in more than a century that fossil fuel-powered buses are no longer the main focus. Over the next decade, it is expected that the remainder of the passenger transport sector will follow this trend, potentially establishing zero-emission

vehicles as the dominant force for the foreseeable future.[5]

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