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## **HISTORY, CURRENT STATUS AND TRENDS FOR FURTHER INTRODUCTION OF ELECTRIC BUSES IN THE CITIES OF EUROPA AND WORLD**

### **Key Words:**

E-bus  
Development of  
E-bus  
subsystem  
Public urban  
transport

### **Abstract**

The electric bus (E-bus) is a new concept of environmentally friendly and energy-efficient bus subsystem of public urban transport, which is increasingly present in many cities around the world. The introduction of this type of bus has a steady upward trend and is a major alternative to conventionally powered buses. The paper presents a brief chronology of the most important events related to the application and introduction of electric buses around the world, the current situation in terms of the number of vehicles in operation, an overview of the electric bus market, and future directions of further implementation of this new concept in public transport systems, with special reference to Europe.

## **1. INTRODUCTION**

The transport sector occupies an important place in meeting the needs of society in the transport of goods and passenger transport, but at the same time, it is a source of emissions of harmful gases and carbon dioxide as a result of burning fossil fuels. The use of fossil fuels is directly proportional to the country, region, or city's industrial and economic development [1]. According to Borowik, currently, 75% of the population in Europe lives in cities, which will lead to a further increase in carbon dioxide emissions and traffic-related pollution [2]. Trends in the increase of the city's population also affect the increase in the number of vehicles, which imposes the growing importance of the application of alternative propulsion in vehicles (electric vehicles, hydrogen, natural gas, etc.) and the use of renewable energy sources. In the transport sector, the activity of passenger transport is very important. The bus subsystem of public urban transport in cities is one of the most important segments

of the city's urban life. The application of fully electric drive in buses for public urban transport should further reduce the level of emissions of harmful gases from traffic in cities, increase energy efficiency and contribute to the strategy of using zero-emission vehicles in cities, which is planned after 2050 [3,4 ]. The accelerated development of battery technology and charging systems has contributed to the electric bus concept since 2008 being increasingly present in many cities, primarily China, Europe, North and South America. It can be considered that the concept of the electric drive today has the greatest possibility and justification for use in buses used in the public transport system, given that the performance of electric buses in terms of operational requirements (autonomy, capacity, charging time) has reached such a level that can be a successful replacement for conventionally powered buses [5].

## 2. HISTORICAL OVERVIEW

The use of electricity to drive road vehicles has been a well-known concept since 1881 when Trouvé constructed the first electric road vehicle in France. The first commercial electric vehicle was Morris and Salom's Electrobat from 1901, which was used as a taxi vehicle in New York City. It can be considered that this taxi was the first vehicle intended for the public transport of passengers [7]. The concept of an electric public city bus was first introduced in Frankfurt in 1969 when Mercedes-Benz introduced the first hybrid, diesel-electric test bus. Until 1979, trial tests and continuous improvements of the hybrid concept of propulsion in public transport buses lasted, and in 1979 a total of 13 standard city diesel-electric buses Mercedes-Benz OE 305, were on a five-year test in regular traffic [8].

In 1982, the German bus manufacturer MAN produced the MAN SL-E200 bus, which was exclusively electric, which can be considered the first model of a bus with fully electric drive. This type of bus towed a trailer with batteries on it Figure 1 [9].



Figure 1. MAN SL-E300

The application of this concept was unsustainable due to the extremely large mass of the vehicle, low autonomy of movement, as a consequence of the small capacity of the batteries (accumulators), long charging time, and the necessary replacement of batteries (accumulators) at the terminals. The introduction of hybrid-powered

buses was the first phase of the application of electric propulsion. The first application of diesel-electric city buses in Japan began in 1991 when the manufacturer Hino delivered buses to eight cities. In the USA and Canada, there has been a significant use of diesel-electric buses since 1997, so that their number in 2010 was 6300, which made them leaders in the use of this type of bus [16]. In Europe, the significant introduction of hybrid buses has been recorded since 2006, when London procured 56 hybrid buses. Since then, other European cities have started introducing hybrid buses, so that in 2012, about 1191 buses were in operation [10].

The beginning of the use of fully electric buses, as a new concept in the system of public city transport, is considered to be August 28, 2006. year, when in Shanghai, China on line no. 11, started exploiting this concept of city buses [11]. Chinese bus manufacturer HIGER produced a standard city bus that used a supercapacitor to store electricity from manufacturer AOWEI (Figure 2). Recharging of the supercapacitor was performed at each station while the bus was standing. In this way, the autonomy of movement was limited to one inter distance (Figure 3).



*Figure 2. E-bus Higer*



*Figure 3. E-bus line no.11 (Shanghai)*

From then until today, the accelerated development of electricity storage technology using batteries and supercapacitors and the development of a fast-charging system has impacted that concept of the electric bus in the last few years to be in many cities all over the world.

## 2.1. Introduction of electric buses in China and Asia

China is a world leader in the production of electric buses and their implementation in many public urban transport systems. The demonstration of the operation of a fully electric bus in Beijing in 2008 during the Olympic Games opened a new chapter in the development of this drive concept. Already in 2010, there are fully electric buses on the Chinese market with a standard length of 12 meters, which can achieve autonomy of 250 ÷ 300 km, with a single charge. According to a report from 2017 by the IEA (Report – Global EV, Outlook 2017), there were about 345000 electric buses in use worldwide, of which 343500 vehicles or 99.5% were in use in China. Of that number, it is estimated that about 300000 are fully electric buses that use batteries as an electricity storage system [12]. The introduction of electric buses in Chinese cities is a state project, as one of the measures to reduce air pollution, especially in

large cities: Beijing, Shanghai, Shenzhen, etc. The city of Shenzhen is the first city in the world to have 16500 electric buses in operation since 2018, which makes the bus subsystem of public city transport 100% "electrified". The plan to introduce electric buses in Beijing is to reach 10000 E-buses in 2020. In 2018, the city of Guangzhou procured 4810 electric buses [13]. Production volume of New Energy Buses, which is the official name in China for electric buses, which include a battery, hybrid plug-in, and fuel cells, reached a record number of 135305 vehicles in 2016. [14] The largest producers are companies: Yutong, BYD, Zhongtong, Yinlong, whose percentage share in production for 2016 is 19%, 13%, 10%, 7%, respectively [14]. In 2018, the world's largest electric bus manufacturer, Yutong, sold 24,748 "New Energy Buses", of which 22744 were battery-powered fully electric buses [15].

India represents a large market for public city buses whose annual sales in 2017 are around 70000 buses of all types. In 2018, 932 electric buses were sold in this market and represent great potential in the Asian market [13]. Of other Asian countries and cities, there is greater use of electric buses in Singapore, where after a testing period conducted from November 2016 to May 2017 with an e-bus manufactured by BYD on three city lines, in 2019 the procurement of 60 BYD E-buses and 50 Volvo hybrid plug-in buses [13].

## 2.2. Introduction of electric buses in Europe

The beginning of the introduction of fully electric buses in Europe dates back to 2013, when in some cities: Rotterdam, Milan, Barcelona, Bremen, London, Copenhagen, Hamburg, etc., trial tests were performed, usually with one or two e-buses [16]. An important step in the greater use and affirmation of electric buses was the ZeEUS (Zero emission urban System) project, which was launched by the European Union in the period 2013/2017. years. The aim of the project was to test and consider the exploitation, environmental, economic, and social aspects of using the electric concept of city buses. 40 partners from different fields took part in the project [14]. In addition to the ZeEUS project as the most significant, many cities in Europe have launched their own projects to introduce electric buses: Amsterdam, Gothenburg, Berlin, Vienna, Sofia, Belgrade, which resulted in the official report of the ZeEUS project published in October 2017. In Europe, there were more than 800 electric buses in 90 cities, including fully electric, plug-in, and battery-powered trolleybuses. Increase in the number of electric buses in Europe by years for the period 2013/2017. year is shown in Figure 4 [17].

Of the total number of electric buses, 67% are fully electric buses that use batteries to store electricity, 2% are fully electric buses that use supercapacitors, 12% are hybrid with plug-in charging and 19% are trolleybuses that have batteries for autonomous movement [14]. The trend of increasing the number of fully electric buses continued in 2018 when 562 new battery buses were registered in the EU, which represented about 5% of annual sales of buses for PT in the EU [5].

Tenders for the procurement of new E-buses are started: Rome 200, Milan 150, Groningen 160, Wiesbaden 56, Venice 30, Berlin 30, Hamburg 30 [105]. Since

December 2019, the city of Nantes has started with the regular operation of 22 E-buses on a fully electric drive, 24.5 m long manufactured by Hess [5].

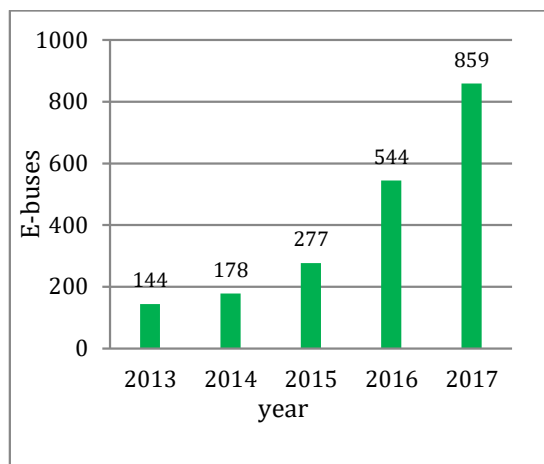


Figure 4. Number of E-buses in Europe

In Europe only until 2019 (as of September 30), 1123 new electric buses were registered [5]. In September 2018, the city of Moscow began regulating the operation of 15 fully electric buses. In 2019, the purchase of 285 electric buses from the manufacturers KAMAZ and GAZ was realized, which made Moscow one of the leading cities outside China in the number of electric buses. The trend of introducing electric buses in Moscow continued in 2020, and by the end of 2020, there were 600 E-buses on 24 city lines [18].

Since August 2020, the Norwegian city of Bergen has had 102 standard Yutong electric buses in regular operation. More than 150 fully electric buses have been in regular operation since July 2020 in Paris as well as in Gothenburg, where 145 electric buses from the Volvo manufacturer have been in operation since December 2020. From March 2021 In the EU, there are 2713 electric buses and 120 buses with fuel cell drive in operation [20].

### 2.3. Introduction of electric buses in North and South America

In the USA, the introduction of the first fully electric buses began in 2013 when 24 battery buses were first put into operation. These buses used are in intercity transport [21]. According to data from August 2018, published by the Calstart Institute-Pasadena, the total number of fully electric buses was 1650, of which 67 buses with a drive on fuel cells, and 1583 battery-electric buses. The largest number of 877 fully electric buses is registered in California, which makes 53% of the total number. There are 154 e-buses in operation in Washington state, 70 in Florida, 66 in Indiana, and 59 in Illinois. In Canada, the first test with a fully electric bus was

conducted during 2013/2014. by STL (Societe de Transport de Laval). It should be noted that STM has had 51 hybrid buses in operation since 2016, accounting for 12% of the buses inventory. [23] In 2018, the city of Toronto conducted a special test with 10 electric buses from different manufacturers: BYD, Proterra, New Flier, and based on the test results, 20 electric buses were bought.

In South America, the first test with two fully electric buses, the Chinese manufacturer BYD was conducted in the company Transantiago-Santiago de Chile in November 2017. Based on the positive test results in November 2018, the procurement of 100 standard BYD electric buses was contracted. At the proposal of the Government of Chile, in order to introduce new ecological buses with zero emissions and replace buses with diesel fuel, it was adopted as a state strategy [5]. At the end of March 2021, 776 electric buses were in operation in Santiago de Chile, [20]. Electric buses are widely used in Bogota 351, Mexico City 337, Medellin 69 [20].

In Argentina, since July 2019, 12 E-buses by BYD and 6 by Zhongtong are in regular traffic in the city of Mendoza. South American cities: Buenos Aires, Panama City, San Jose, plan to purchase electric buses in the near future [5]. As of May 28, 2020, 20 electric buses by manufacturer BYD are in regular operation in the Uruguayan capital, Montevideo.

### 3. ELECTRIC BUS MARKET

Electric buses as a relatively new technology, have a tendency to constantly improve and strain primarily electricity storage systems (batteries, capacity up to 400 kWh for 12m E-bus and supercapacitors 40 kWh), chargers "slow" with electric power 60÷80 kW, "fast" with power 400÷600 kW), traction control system, optimization of energy consumption, reduction of empty vehicle weight.

At the moment, all the world's bus manufacturers have electric buses of different lengths in their production program: midi (8÷9 m), standard (11÷13 m), articulated (18÷19 m) and double-articulated. 24÷27 m) and they become part of the standard offers on the bus market (Figures 5,6,7) [5].



Figure 5. E-bus BYD 12m



Figure 6. E-bus Solaris Urbino 18m



Figure 7. E-bus Hess, 24m

According to ZeEUS E-bus report # 2 from October 2017, 32 manufacturers of electric buses and 8 manufacturers of equipment and systems for charging electricity were registered on the European market [14]. The most represented manufacturers

of electric buses that are currently present on the European market are BYD, VDL, Solaris & bus, Volvo, Kamaz, GAZ, Yutong, Ebusco, Optare, Caetano, Skoda, Irizar, Van Hool. Leading manufacturers of equipment and systems for charging electric buses are ABB, Siemens, Shunk, Jema Energy, Bombardier Primove.

#### 4. FUTURE TREND INTRODUCTION OF E-BUSES IN EUROPE

It is a very important Directive 94/2014 / EC which refers to the application of alternative fuels to commercial vehicles in the public sector for the countries of the European Union [25]. The states are obliged to implement the prescribed participation of "clean vehicles" (electric, hybrid, with combined natural gas propulsion-CNG) in the public urban transport system by 2025, ie 2030 in the cities, as shown in Table 1.

*Table 1 Directive 2014/94 / EC, participation of "clean" buses in EU countries*

| EU country     | Target year<br>2025<br>Participation<br>"clean" buses<br>[%] | Target year<br>2030<br>Participation<br>"clean" buses<br>[%] |
|----------------|--------------------------------------------------------------|--------------------------------------------------------------|
| Luxembourg     | 50%                                                          | 75%                                                          |
| Sweden         | 50%                                                          | 75%                                                          |
| Denmark        | 50%                                                          | 75%                                                          |
| Germany        | 50%                                                          | 75%                                                          |
| Netherlands    | 50%                                                          | 75%                                                          |
| Austria        | 50%                                                          | 75%                                                          |
| Belgium        | 50%                                                          | 75%                                                          |
| Italy          | 50%                                                          | 75%                                                          |
| Ireland        | 50%                                                          | 75%                                                          |
| Spain          | 50%                                                          | 75%                                                          |
| Cyprus         | 50%                                                          | 75%                                                          |
| Malta          | 50%                                                          | 75%                                                          |
| France         | 48%                                                          | 71%                                                          |
| Lithuania      | 47%                                                          | 70%                                                          |
| Finland        | 46%                                                          | 69%                                                          |
| Czech Republic | 46%                                                          | 70%                                                          |
| Hungary        | 42%                                                          | 63%                                                          |
| Portugal       | 40%                                                          | 61%                                                          |
| Latvia         | 40%                                                          | 60%                                                          |
| Slovakia       | 39%                                                          | 58%                                                          |
| Bulgaria       | 39%                                                          | 58%                                                          |
| Greece         | 38%                                                          | 57%                                                          |
| Poland         | 37%                                                          | 56%                                                          |
| Estonia        | 36%                                                          | 53%                                                          |
| Slovenia       | 33%                                                          | 50%                                                          |
| Croatia        | 32%                                                          | 48%                                                          |
| Romania        | 29%                                                          | 43%                                                          |

The representation of electric buses in the total number of buses for public urban transport in the European Union, according to the estimate of the UITP from 2017, is shown in Figure 8 [17].

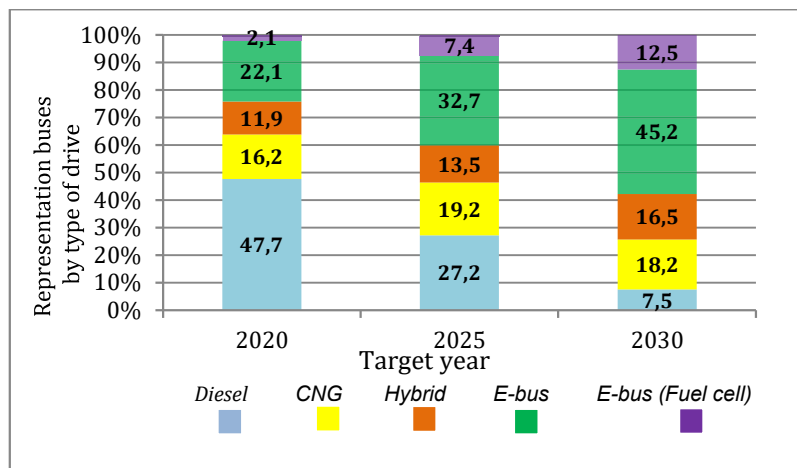


Figure 8. Representation of buses by type of drive

The forecast is that in 2025, the share of fully electric buses will be 40.1% and in 2030 it will reach 57.7%.

## 5. CONCLUSION

Based on the trends of increasing the number of electric buses in operation around the world, a large number of tender procedures around the world related to the purchase of electric buses, the growing supply on the market by almost all bus manufacturers, positive experiences in operation as well as legal regulations that prescribe the increasing participation of "clean" buses in the transport systems of cities, which is best seen in the example of EU member states (Directive 94/2014 / EC), it follows that in the coming years the presence of electric buses to be growing in the public transport systems of many cities in Europe and the world as the main alternative to conventional buses.

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