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B&H Electrical Engineering, Volume 17, Special Issue, 2023:33-43
ISSN:2566-3143, eISSN:2566-3151, DOI: 10.2478/bhee-2023-0016

Professional paper

Submitted: August 29, 2023

Accepted: November 21, 2023

ELECTROMOBILITY IN BiH

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Abstract: In this paper an overview of the current state of electromobility in Bosnia and Herzegovina (BiH) and a prediction of the future state of electromobility in BiH according to models from the European Union (EU) and the state expected in the future is given. Based on the reference state, an analysis of energy consumption and energy savings due to the increase in the number of EVs in the future was performed. The main goal of this paper is to provide predictable data on the number of EVs expected in the future, according to models from the EU. These data can be used when planning the development of the network for electric cars, mainly charging stations. An analysis of the current state of the number and locations of charging stations for electric vehicles (EVs) was made.

Keywords: electric vehicles, electromobility, electrical power network, subsidies, influence

INTRODUCTION

In BiH, there is no large number of EVs and no charging stations for EVs. There is also little incentive for buying and using them, and only in 2022 the Government of Federation of BiH (FBiH) adopted the Program which subsidizes the purchase of electric and hybrid vehicles. Nor has a regulatory framework that would function in the direction of the development of electromobility been established. The first charging station for EVs in BiH was installed in 2016, and the first new EVs were sold in 2017, so it can be stated that the beginning of the development of electromobility in BiH is 7-8 years behind the developed countries of Europe and the world. The first charging station for EVs in BiH was installed by the Residence Inn Marriott hotel in Sarajevo (two Mode 3 Type 2 connectors are installed on the charging station).

When talking about the technical limitations of the distribution and transmission network, it is necessary to make an analysis of the impact of increasing the load on each of their individual segments by an authorized organization that has all the information about them. PE EPBiH in the document "Electromobility in PE EPBiH d.d.- Sarajevo" discussed one high-voltage, one medium-voltage and one low-voltage network. Scenarios for 2025 and 2030 were analysed, which take into account the annual increase in peak load of 3% in this period and the penetration of electric vehicles of 5% and 10%, respectively, in the total number of vehicles. The analysis showed that for all scenarios the voltage stability of the system will not be threatened [1]. If tariffs or other various market positions would achieve the result that the peak loads caused by the operation of filling stations are distributed in time periods that otherwise do not fall into the intervals of the existing peak loads of the transmission network (the current load diagram of individual transmission lines in terms of electric power), in the first phase implementation of charging stations for electric vehicles, it would not be necessary to reconstruct the transmission network.

Such an analysis is required for each part of the distribution and transmission network, in order to determine the limitations and necessary reconstructions thereof.

1. THE CURRENT STATE OF E-MOBILITY IN BIH

In BiH, there is currently not a lot of EVs and not a lot of charging stations for EVs. Also, until recently, there were no incentives for the purchase and use of EVs.

In 2017, PE Elektroprivreda BiH (EPBiH) d.d. Sarajevo installed the first charging station for EVs in front of the EPBiH PTZ Directorate in Sarajevo. In the same year, two purely EVs (Mitsubishi i-MiEV and Volkswagen e-Golf) were also purchased for the needs of EPBiH, which also represent the first two new passenger EVs purchased in BiH. JP EP BiH installed a total of 7 charging stations for EVs in the following locations: Bihać, Goražde, Mostar, Sarajevo, Travnik, Zenica and Tuzla. All charging stations are equipped with two AC Mode 3 Type 2 connectors for charging EVs with a power of 22 kW individually.

At the beginning of 2022., EPBiH put into operation a charging station for EVs on the section of the Mostar-Sarajevo highway, at the Lepenica rest stop, the first of its kind in BiH that was built on the VC Corridor. The direct current (DC) charging station at the Lepenica rest

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area can simultaneously charge two EVs, with three different connections. The use of the charging station is available to all electric car users free of charge. It is a typical charging station that was built as an independent and separate unit with complete necessary equipment for filling and its control. The charging station has two Combo 2 and Chademo DC ports, and one Type 2 alternating current (AC) port for charging EVs, which takes about half an hour on the DC charger for standard cars, and several hours on the AC side, depending on the rectifier in the car.

At the beginning of March 2022, the most powerful charger for electric cars in BiH, which was installed and put into operation on the grounds of the Porsche Sarajevo company, was presented. The charger in question is the "MOON Power Charger 75-300 DC" charger, the specificity of which is the possibility of varying the total power. The heart of the charging station is made up of powerful 75 kW charging inserts.

According to data from July 2023, 200 electric car charging stations were installed in BiH [2]. However, most of these charging stations are so-called slow charging stations and also privately owned (within restaurants, hotels, shopping centres, etc.). Most charging stations were built in Sarajevo, Banja Luka, Mostar and Tuzla.

Figure 1 shows a map with charging stations in BiH, but it should be emphasized that the map does not show all currently installed charging stations in BiH. There is visible room for significant progress, especially when it comes to charging stations located outside the settled areas. In the picture, the green pin indicates public and yellow private charging stations.

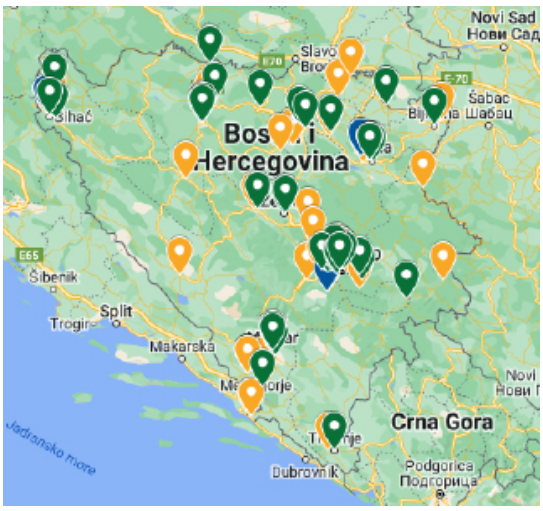


Figure 1: Locations of EV's charging stations [3]

According to the latest data, there are currently 1,677 hybrid-powered cars registered in BiH, and 243 EVs, shown in Table I. According to information from the BiH Indirect Taxation Administration, 70 electric and 610 hybrid vehicles were imported into BiH in 2022.

Table I: Registered road vehicles in BiH in the period January - December 2022

Year	Number of registered EVs	Number of registered Hybrid vehicles
2022	243	1,677
2021	133	1,211
2020	98	823
2019	60	652
2018	38	436

*Source: „Information on registered road vehicles in BiH in the period January - December 2022", BIHAMK, March 2023

When it comes to the offer on the market, authorized dealers and car dealers such as, for example, Porsche BH, Kia Corporation BH, Renault BH, Peugeot BH, etc., offer certain models of EVs, but the offer is significantly smaller compared to e.g., Croatia or Slovenia.

1.1. Current state of registred vehicles in BiH

During the past year, 2022, a total of 1,184,758 road vehicles were registered in BiH, which compared to 2021 (1,152,743) represents an increase of 32,015 vehicles, or 2.78%. According to the Euro standard, out of the total number of registered vehicles in 2022, EV occupy only 0.13%. Table II shows comparative data. of the total number of registered road vehicles for 2019, 2020, 2021 and 2022 [4].

Table II: Total number of registered vehicles

Year	Total number of registered vehicles
2022	1,184,758
2021	1,152,743
2020	1,108,711
2019	1,175,731

*Source: "Information on registered road vehicles in BiH in the period January - December 2022", BIHAMK, March 2023

2. SUBSIDY FOR PURCHASE OF ELECTRIC CARS

As already stated, there were no incentives for the purchase and use of EVs in BiH until recently.

The Council of Ministers of BiH, at the proposal of the Ministry of Foreign Trade and Economic Relations, on 28 July 2022 adopted the Decision on the temporary suspension and temporary reduction of customs rates for the import of new electric and hybrid cars until December 31, 2022. By the end of the year, this Decision abolishes the customs duty on the import of electric cars and significantly reduces the customs rate for the import of hybrid cars from the previous 15% to 5%.

B&H Electrical Engineering, Volume 17, Special Issue, 2023:33-43
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In addition, the Government of the FBiH on 14 June 2023 decided on allocating one million convertible marks for subsidizing citizens who buy electric and hybrid cars. The Federal Ministry of Energy, Mining and Industry has drawn up a Program on granting subsidies to individuals for the purchase of new cars in 2022, which have an exclusively electric drive and cars that, in addition to an internal combustion engine, also run an electric drive (hybrid cars). The amount awarded as a financial incentive to individuals is 10,000 KM for EVs, and 5,000 KM for hybrid electric "plug-in" and hybrid "full hybrid" vehicles.

Furthermore, in July 2022, the Fund for Environmental Protection of the FBiH announced a public competition for the allocation of funds for the implementation of programs, projects and similar activities in the field of environmental protection for 2022. LOT 2.2 was announced as part of the aforementioned Public Call. with an available budget of 1,000,000 KM, which includes electromobility projects.

2.1. Existing regulatory framework for filling facilities, financial and fiscal incentives

Until now, no special laws that would transpose the requirements of Directive 2014/94/EU on the establishment of infrastructure for alternative fuels and create legal prerequisites for defining the initial framework of measures for market development regarding alternative fuels in the transport sector and for setting up the appropriate infrastructure have been adopted. Policies and planning documents adopted at the level of BiH and entity and county laws from individual administrative areas (with the exception of power engineering in the RS and BD) only touch on certain aspects of e-mobility, and there is no systematic and harmonized legal regulation that would represent an adequate basis for development and introduction of e-mobility in BiH.

The adopted strategic planning documents emphasize the sustainable development of the BiH economy as a whole, including individual sectors, and promoting the introduction of environmentally friendly vehicles. Below is a brief overview of their basic specifications.

"Framework transport policy of BiH for the period 2015-2030" is a framework and fundamental document of the transport sector in BiH, on the basis of which, in the process of development and improvement of the sector, strategies, plans and other strategic documents are adopted. An important goal of the Policy is the sustainable development of the sector while taking care of environmental conditions, within which competent institutions will try to minimize the harmful effects of traffic, among other things, by procuring environmentally friendly vehicles.

The "Framework Strategy of BiH Transport" is a guideline for the development of the transport sector in BiH for the period from 2015 to 2030. In this document, e-mobility is viewed in the context of environmental protection, and competent institutions are committed to measures that stimulate the import of new and ecological vehicles and contribute to the reduction of harmful emissions and harmonization with EU laws and standards. This includes the revision of existing fees (e.g., import, registration, tolls, etc.)

The key document of BiH's energy policy "Framework Energy Strategy of BiH until 2035" provides an analysis and overview of the strategic priorities of BiH's energy policy in its key segments, through several scenarios, including one that predicts stronger growth and incentives for the purchase of EVs.

The "Energy Efficiency Action Plan for BiH" contains an overview of existing and planned energy efficiency measures in transport. The importance of e-mobility is recognized and the introduction of EVs, which will result in a reduction in pollutant emissions, greater use of public transport, noise reduction, etc is proposed. In the future, cities should increase alternative modes of transport and transport and modernize the existing infrastructure. Within the framework of the proposed measure, it should be possible to subsidize the purchase of EVs as environmentally friendly vehicles. The described measures would be implemented continuously, and the Ministry of Foreign Trade and Economic Relations (MVTEO) of BiH and the Chamber of Foreign Trade of BiH are designated as institutions responsible for the implementation of the measure.

The "Action Plan for Renewable Energy Sources (RES) for BiH" states that in the transport sector measures will be considered to encourage the use of hybrid vehicles and vehicles that use alternative fuels through investment subsidies, but also by providing free parking spaces, the right to use yellow lanes, etc.

Regarding the legislative transport and infrastructural aspects of e-mobility, it should be noted that the use, financing, construction and maintenance of public road infrastructure are regulated at the level of the entity and Brčko District (BD), by the Law on Public Roads of the Republic of Srpska (RS) ("Official Gazette of the RS", No. 89/13 and 83/19), the Law on Roads of FBiH ("Official Gazette of FBiH", No. 12/10, 16/10 correction and 16/13) and the Law on Roads BD ("Official Gazette of BD of BiH" No. 22/18) and entrusted to the management of competent public companies. The legal provisions do not give special treatment to charging stations for EVs, nor do they consider them part of a public road (roads) as a structure that serves to provide special services such as charging EVs. A special fee is required for the use of road land for ancillary services such as gas stations and similar services.

The planning and development of e-mobility is also influenced by regulations governing spatial planning and construction. Competence for spatial planning and construction of buildings is divided between the entities and the BD, and thus there are the Law on Spatial Planning and Construction at the level of the RS ("Official Gazette of the RS", no. 40/13, 106/15 and 84/19), the Law on spatial planning and land use at the FBiH level ("Official Gazette of the FBiH", number 2/06, 72/07, 32/08, 4/10, 13/10, 45/10, 85/21 and 92/21) and the Law on spatial planning and construction for BD ("Official Gazette of BD BiH", no. 29/08, 18/17, 48/18, 54/18, 10/20, 29/20 and 40/20). In addition, in FBiH, Laws on spatial planning of Cantons in FBiH are in force that govern the process of building charging stations for electric vehicles. Certain cantons, such as ZDK, have already passed a new spatial planning law that simplified the procedures for building charging stations for electric cars, and other cantons are planning similarly.

The field of energy, apart from transmission activities and foreign energy policy, is under the jurisdiction of the entity and BD of BiH. In the RS, the legal framework of the electric power sector is represented by the Law on Energy ("Official Gazette of the RS", No. 49/09), the Law on Electric Energy ("Official Gazette of the RS", No. 68/20) and the Law on RES ("Official Gazette of RS", No. 16/22). The Law on Energy is a key legal act for the RS that defines the adoption of an energy development strategy, the basic issues of regulating and performing energy activities, the use of RES and the conditions for achieving energy efficiency.

However, an important contribution to the introduction of e-mobility in the territory of the RS is represented by the new Law on Electric Energy which, as a special law for the electric power sector, defines an EV (a motor vehicle equipped with a power transmission system, which contains at least one non-peripheral electrical energy storage device with the possibility of recharging that can be charged externally) and the definition of places for charging EVs, differentiating them by power and availability to the public.

The new Law on Electricity of BD ("Official Gazette of the BD of BiH", No. 27/21) contains provisions that represent the basis for the introduction of e-mobility in the territory of the BD. The law defines EVs, their charging points, the obligations of the distribution system operator, the issuance of electric power approvals for EV charging stations, the conditions and method of providing electricity supply services to EV charging points, the content and scope of the EV charging service, and the technical requirements for chargers. EVs.

In this sense, the amendment of the legal framework of the electricity sector of the FBiH, i.e., the Law on Electricity in the FBiH ("Official Gazette of the FBIH", no. 66/13, 94/15, 54/19 and 1/22) and the Law on the use of RES and efficient cogeneration ("Official newspaper FBIH", no. 70/13 and 5/14), at the moment give little importance to e-mobility.

Customs policy

Customs tariffs for electric and hybrid vehicles are currently prescribed by the Decision on Establishing the Customs Tariff for 2022 ("Official Gazette of BiH", No. 80/21). However, the encouraging regulatory framework for the introduction of e-mobility implies the introduction of reduced tariffs for the purchase of EVs. Based on the initiative of the Association for Electromobility and the Association of Authorized Representatives and Car Dealers operating under the Chamber of Commerce/Economics of the FBiH, MVTEO BiH prepared a proposal for a decision of the Council of Ministers of BiH on the temporary suspension and temporary reduction of customs rates for the import of new electric and hybrid cars. This proposal proposes to reduce the import rate of hybrids and EVs to 5% and 0%, respectively. The proposal was sent to the competent institutions for opinions and the decision was adopted and the customs rate is 5% on the import of hybrid vehicles, or 0% on the import of EVs. The adoption of the proposed decision stimulates the import of this group of vehicles and contributes to the reduction of air pollution, environmental protection and increased traffic safety.

3. ANALYSIS OF THE EFFECT OF THE INTRODUCTION OF E-MOBILITY AT THE MACRO LEVEL

As a candidate country for joining the EU, BiH demonstrates its readiness for entry by strengthening e-mobility at the macro level, using the example of the transport and energy sectors. In addition, national e-mobility policies will strengthen intra-state cohesion and ensure balanced energy and transport development, as well as the status of a country where EV owners can safely access the infrastructure of charging stations.

On the economic and energy level, the strengthening of e-mobility will lead to new jobs and opportunities to strengthen production and development capacities through investments in that sector. Furthermore, the impact of e-mobility will also be important for the education sector, enabling the training of experts in the field of e-mobility, from technical to marketing aspects.

The assessment of the macroeconomic effects of capital investments was carried out using an analytical tool based on the so-called input-output tables specified for BiH. Table III describe the flow of goods and services between all sectors of the economy during a certain period. The analysis quantified the direct and indirect (multi-application) effects on the economy that are expected in the period up to 2050.

B&H Electrical Engineering, Volume 17, Special Issue, 2023:33-43
ISSN:2566-3143, eISSN:2566-3151, DOI: 10.2478/bhee-2023-0016

The assessment of macroeconomic effects was carried out for the defined development scenario of the construction of infrastructure for charging EVs. Capital investment in the construction of the relevant infrastructure in the period until 2050 amounts to 2.1 billion KM [5].

The macroeconomic effects of investments for each individual scenario are grouped by five-year periods, and are shown in the tables below.

In the entire analysed period, the average annual investment is 71 million KM. It is to be expected that the investments in question will lead to an increase in the number of new employees (on an annual average by 951 persons compared to the initial year of the analysis). Gross domestic product (GDP) would increase by 51 million KM annually on average, while the added value would amount to 43 million KM annually on average [5].

Table III: Macroeconomic effects of capital investments in EV charging infrastructure

Period	Capital investment required	Average annual investment	Average annual added value	Average annual GDP	Average annual employment
Year	million KM/year	million KM/year	million KM/ year	million KM/ year	Number of employees/ years
2022 - 2025	24	5	3	3	62
2025 - 2030	199	40	23	28	516
2030 - 2035	459	92	56	67	1,256
2035 - 2040	513	103	63	75	1,404
2040 - 2045	469	94	57	68	1,275
2045 - 2050	450	90	54	65	1,224
	2,119 (total)	71 (average)	43 (average)	51 (average)	951 (average)

In the context of the chapter in question, it is important to mention the potential savings for end users of EVs in the event of the revised system of trading greenhouse gas emission units coming into force in the future.

The introduction of this new system will certainly have an impact on the end users in the road transport sector, because there is a certain increase in the costs of using energy sources, which until now have not been burdened by the carbon price. This impact is foreseen in the proposal to amend Directive 2003/87/EC, and to mitigate these consequences, it is envisaged to use funds that will be collected through auctions of emission units through the Innovation Fund and the Social Fund for Climate Actions.

Accordingly, in the event of such a system being implemented in BiH, users of EVs would achieve additional operational savings in the form of lower costs for fuel compared to users of conventional vehicles.

4. ADDITIONAL DEMAND FOR ELECTRICAL ENERGY DUE TO ELECTRIFICATION OF TRAFFIC

In open market conditions, with the restructuring of vertically integrated systems and the deregulation of the electricity production sector, the need to increase the efficiency of the electric power system (EPS) in such a way as to reduce fluctuations in energy consumption to a minimum is becoming increasingly pronounced. The balance between the consumption and production of electricity in real time is the basis of the stability of the electricity system, and the operator of the transmission system is responsible for its maintenance. This is a demanding task since changes and oscillations can occur suddenly and unexpectedly, both on the production side and on the consumption side. Investments in electric power infrastructure are capital intensive, therefore consumption management is imposed as one of the options.

Given that an average daily distance travelled by an individual resident is the basic parameter that determines passenger activity, it is necessary to define the factor of car ownership as the dominant means of mobility in city and intercity traffic. In other words, for the purposes of modelling the number of cars in the future, it is necessary to consistently determine the number of inhabitants and registered cars in BiH, which is expected in parallel with the growth of GDP per inhabitant.

According to models from the EU [6], the number of electric cars will increase to 50% of the total number of cars by 2050. The number of electric cars in 2022. According to BIHAMK data is 243, while the total number of cars is 1,175,731, and a prediction was made that the number of electric cars in 2050 will be 577,751. In the period from 2023 to 2050, the number of electric cars will grow exponentially. Figure 2 shows several key years that show the expected increase in the number of electric cars

According to the Table IV, in 2025 it is expected that there will be 559 electric cars in Bosnia and Herzegovina, or 2.3 times more than in 2022. In 2035, the number of electric cars is expected to be 8,976, which is almost 40 times more than in 2022.

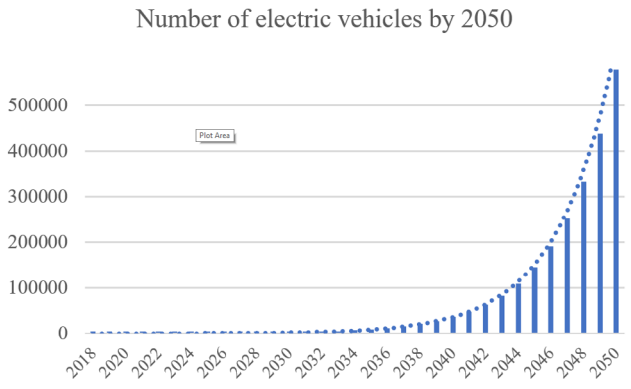


Figure 2: Number of electric vehicles by 2050 [6]

Table IV: The number of cars in BiH according by used fuel

Year	2023	2025	2030	2035	2040	2045	2050
No. Electric vehicles	321	559	2240	8976	35,973	144,165	577,751
No.Diesel vehicles/1000	866	866	864	859	839	758	462,189
No.Gasoline vehicles /1000	288	288	288	286	279	252	144434
No.LPG vehicles/1000	57	57	57	57	55	50	28887
No. Total/1000	1,213	1,213	1,213	1,212	1,211	1,206	1,213,260

In BiH, there is no trend of increasing the number of cars, because there is no noticeable trend of population growth, and the total number of cars is mostly constant during the analysed period. In 2050, the number of electric cars is expected to increase so that they would make up a total of about 50% of registered cars in Bosnia and Herzegovina. Taking all the above into account, the number of cars using diesel fuel and gasoline will decrease. Figure 3 shows the trend of increasing the number of electric cars and decreasing the number of diesel, gasoline and LPG cars on a logarithmic scale.

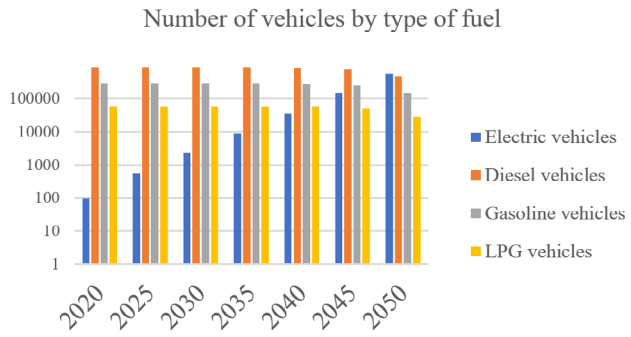


Figure 3: Number of vehicles by type of fuel

The energy consumption in kWh was analysed by using the reference data for the Audi Q7 vehicle, which has a diesel version, gasoline as well as an electric vehicle (Audi e-tron 50). Table V shows the basic characteristics of the mentioned vehicle, which were used in further analyses of vehicle energy consumption in Bosnia and Herzegovina.

Table V also shows that electric vehicles consume much less energy than diesel and gasoline vehicles.

Table V: Characteristics of vehicles that were used as a reference for analyses

	Diesel	Gasoline	EV
Fuel consumption	5.4-6.2 l/100km	6,8-9,4 l/100km	/
Direct CO2 emissions	149 g/km	179 g/km	0 g/km
Average fuel consumption	5.8l/100km	8,1l/100km	21.9 kWh/100 km
Energy consumption	58 kWh	72,1 kWh	21,9 kWh

For the analysis below, the data from Table V were used. The actual data differ from the reference data, but for easier analysis, the data were reduced to the reference data. Using energy consumption and compared to the number of cars expected in the coming period until 2050, the data shown in Table VI were obtained.

Table VI: Energy consumption for typical vehicle categories in kWh

Year	EV [kWh]	Diesel [kWh]	Gasoline [kWh]
2022.	5,321.7	50,253,060	20,823,251
2025.	12,239.94	50,239,318	20,817,556
2030.	49,052.4	50,166,197	20,787,258
2035.	196,580.9	49,873,161	20,665,833
2040.	787,811.7	48,698,799	20,179,215
2045.	3,157,210	43,992,459	18,229,059
2050.	12,652,741	26,806,951	10,413,674

The increase in the number of electric cars also causes a decrease in energy consumption for cars. Until 2035, there is no significant energy consumption for EVs compared to other vehicles.

Figure 4 shows a decrease in energy consumption for vehicles that use diesel fuel and vehicles that use

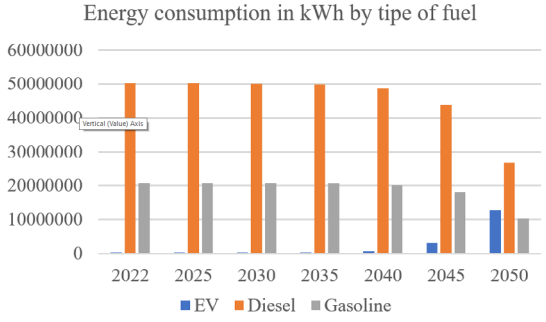


Figure 4: Energy consumption in kWh by type of fuel

B&H Electrical Engineering, Volume 17, Special Issue, 2023:33-43
ISSN:2566-3143, eISSN:2566-3151, DOI: 10.2478/bhee-2023-0016

gasoline, and an increase in energy consumption for electric vehicles.

Figure 5 shows the energy consumption trend in kWh for cars in Bosnia and Herzegovina until 2050. In the initial state, i.e., in 2018, according to the reference state, it is 71,089,755 kWh, while the energy consumption in 2050, according to the reference state, is 49,873,365.7, which means that in the specified period, energy savings of 21,216,389.32 kWh were achieved, which is directly related to the increase in the number of electric cars.

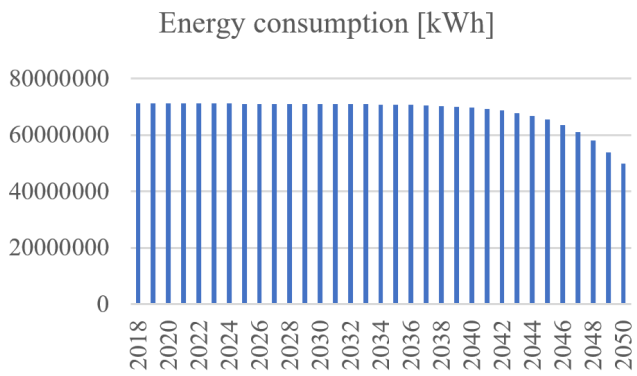


Figure 5: Energy consumption for all cars in Bosnia and Herzegovina until 2050

4.1. Potential impacts on the electricity transmission and distribution network

Due to the increase in peak load caused by the installation of infrastructure for charging EVs, there will be negative impacts on the distribution network in terms of increasing losses in the network and deterioration of voltage and frequency quality.

The aforementioned increase in the load of the distribution network will have the greatest negative impact in the time period of peak load (from 10 a.m. to 2 p.m. and from 6 p.m. to 8 p.m.). For this reason, it will be necessary to introduce the planned mode of charging connected EVs outside this time frame, that is, to integrate other solutions that are currently in the development and testing phase, such as smart networks. Other solutions refer to the increase in the tariffs of the calculation unit of electricity during periods of unfavourable conditions in the network. In addition to the negative impacts on the distribution network, the increase in peak load caused by the installation of charging infrastructure will also have a similar impact on the transmission network.

The development of EVs and their chargers is aimed at eliminating the aforementioned negative impacts on EPS, and we can also talk about positive impacts on the network in terms of storing electricity and returning it to the network. By storing such a large amount of electricity, the issues of balancing (imbalance) and secondary and tertiary frequencies can be solved. Thermal power plants and imports are currently used for that, which would consequently mean more production from production facilities that use undesirable sources for their electricity production. The result of such a measure would be a reduction in emissions of harmful gases, primarily carbon dioxide and sulphur dioxide.

Connecting the charging infrastructure to the distribution/transmission network

The way to connect the EV charging infrastructure to the grid is determined by the capacity of the charging station. They are generally divided into three power levels: 2.3 kW (so-called wall chargers), 2x22 kW and fast DC/AC power of 43 kW and more.

The first power level of 2.3 kW is located in private buildings, therefore, for their connection to the network, it is only necessary to ensure a sufficient section of the installation cables in the building and, if necessary, correct the building's connection power [7].

The second level of 2x22 kW power is public AC charging stations, for which a request for connection cannot be submitted by a natural person. After submitting a request from a legal entity for connection according to the valid regulations on connection in BiH, it is the responsibility of the competent institution to provide an infrastructure solution to that place. It is important to emphasize that with these and stronger AC chargers, the charging power will depend on the power of the AC/DC converter inside the EV. Currently, the converter power in vehicles is around 7.5 kW, so charging will take place at that power, regardless of the higher power of the charger.

The third power level is divided into DC chargers with a power of 50 kW and more and AC chargers with a power of 43 kW and more. In the case of these chargers, it is also true that the competent institutions must provide infrastructure solutions, as in the case of the above-mentioned forces. In addition, the same limitations exist with these AC chargers, while for DC chargers that do not use converters inside the vehicle for the charging process, they can charge with the full power of the charger.

Certain distribution consumption areas where the installation of a larger number of fast charging stations (higher power) is expected, that is, where a higher density of implementation of higher power charging stations is expected, may require the planning and construction of new medium-voltage facilities (lines and facilities), and transformer-switching facilities in order to the infrastructural requirements for powering the charging stations in question have been met.

It is important to emphasize that for all issues related to the impact of the charging infrastructure on the transmission and distribution network, as well as for issues of connection to the same, it is necessary to prepare a special comprehensive study.

5. FEASIBILITY OF EVS PROVIDING ADDITIONAL ANCILLARY NETWORK SERVICES

5.1. Charging methods for EVs

Balancing the power system through the provision of auxiliary services through EVs depends first of all on the performance of charging stations, i.e., EVs, then on the method of charging EVs, but also on the possibilities provided by the platform for mutual communication between the charging station, the EV and the network, but also on other non-technical aspects of the provision of auxiliary services in the EPS of BiH. Three EV charging concepts are explained below with a conclusion on the (im)possibility of implementing auxiliary services for each individual EV charging concept.

Scheduled (smart) charging

The positive contribution of planned (smart) charging to voltage conditions and power flows, i.e., EPS balancing, is evident only after a significant increase in the number of charging stations and EVs. Although some consumers (owners of EVs) still use a certain type of smart charging, which implies charging during the cheaper night electricity tariff, for a more efficient application of this type of consumption response technology, a structural reform of the electricity market is necessary. In that case, electricity producers would have more flexibility when planning production and determining the price of electricity, while consumers would have the option of contracting dynamic tariffs that follow the prices on the electricity market. To realize such a market, it is necessary to build an online platform for communication between participants in the energy network. Through this platform, the purchase and sale of electricity would be contracted a day in advance or intraday, when the climatic conditions are known with great certainty, so the production of electricity from variable RES can be estimated with high certainty. The upgrade of the communication network, as well as the installation of smart meters, is the basis of the development of all consumption response technologies. Planned (smart) charging does not require extremely high charging power, and therefore does not require an expensive infrastructure of charging stations. However, the ratio of charging stations to the number of EVs should be as high as possible so that most vehicles can be connected to the grid while they are parked. With a certain software infrastructure, this charging method could be used for the partial provision of auxiliary services in the classical sense.

A similar but much more advanced idea is controlled charging, in which the energy supplied to the vehicle can not only be turned on or off at certain periods of time but also increased or decreased in real time to account for e.g., supply from renewable sources, market prices and grid stability. This more advanced practice is known as V1G and although its wider use has not yet begun and will require more sophisticated communication protocols, it requires only minimal additional hardware and would not put additional strain on the vehicle's battery.

Vehicle to grid (V2G) – (V2X) technology

Vehicle to grid technology represents the technology of balancing the power system and is actually an upgrade of smart charging, and also requires infrastructural changes. In addition, it is necessary to equip charging stations and EVs for a two-way flow of electricity, while considering efficiency so that as much of the electricity as possible when charging the battery can later be returned to the grid. In an EPS with a high proportion of variable RES, where fluctuations in electricity prices are large, the financial profitability of vehicle to grid technology is increasing. On the other hand, battery loads due to a large number of charges and discharges, which may result in degradation of battery cells, could keep EV owners away from the application of this technology. If the vehicle is in charge of balancing the system with vehicle to grid technology, the degradation of the batteries in the vehicle can take place up to 50% faster. In that case, the quality of the batteries and the manufacturer's guarantees could have a major impact on the mass use of vehicle to grid technology. In order to optimize the balancing of the system, there are various algorithms that determine when and with what power each individual vehicle should be charged or return energy back to the network in order to achieve the set goals. Some of the objectives may be to minimize imported electricity and/or critical surplus of generated energy. For the best effect of reducing the critical surplus of produced energy, it is necessary to optimize the trade in electricity for charging EVs in order to encourage the consumption of electricity from variable sources during the peak production period.

5.2. The possibility of balancing EPS BiH using EVs

For the functioning of a system in which EVs represent a distributed energy storage for intermittent energy sources, and then the potential for providing flexibility services, it is necessary to meet certain prerequisites that can be divided into technical, legal, regulatory and economic. In a technical sense, the basic prerequisite for ensuring flexibility is the existence of infrastructure, vehicles and other parts of the system that support the two-way flow of electricity and data exchange, whereby all elements are integrated into the smart grid concept. From a legal and regulatory point of view, it is necessary to recognize the elements

B&H Electrical Engineering, Volume 17, Special Issue, 2023:33-43
ISSN:2566-3143, eISSN:2566-3151, DOI: 10.2478/bhee-2023-0016

of the concept of e-mobility in terms of providing new services, including the possibility of providing flexibility to the power system, and defining them in the legal framework. Finally, the need to manage the entire process of providing flexibility services opens up space for the creation of new business models in which different stakeholders will find their interests, and one of the basic conditions is the existence of a sufficient number of EVs and adequate infrastructure.

5.3. Necessary amounts of balance energy reserve capacity in EPS BiH

According to the Report on auxiliary services and operation of the balancing market in BiH in 2021, created by the Independent System Operator in BiH (NOS BiH), the average required capacity of secondary regulation in the off-peak period (00:00 – 06:00) was 26.9 MW, while in the peak period (06:00 - 24:00) the average required secondary regulation capacity was 44.3 MW. The required capacity of tertiary upward regulation (which is activated in case of energy shortage in EPS BiH) was 196 MW, while the required capacity of tertiary downward regulation (which is activated in case of excess energy in EPS BiH) was 68 MW.

An overview of the required secondary regulation capacity reserves by month in 2021 is shown in Table VII:

Table VII: Required secondary regulation capacity reserve for EPS BiH by month for 2021

Month	1	2	3	4	5	6	7	8	9	10	11	12
Peak period (MW)	32	29	27	25	24	24	26	25	25	27	28	31
Off-peak period (MW)	51	47	45	42	38	40	44	41	41	45	46	51

The amount of capacity reserves for secondary regulation is calculated on a monthly basis, especially for periods of peak and off-peak load. The calculation of monthly reserves is carried out at the beginning of November of the current year based on the official data of NOS BiH on hourly consumption in BiH in the previous 12 months. The required capacity reserve is calculated for all months of the following calendar year. Considering the above, the required secondary regulation capacity reserves change every year, but these changes are not significant.

In accordance with the Grid Code, the total required capacity reserve of tertiary upregulation is equal to the "stable" maximum available power of the largest production unit in BiH at the transmission threshold. This value is corrected in accordance with the Agreement on the joint regulation reserve in the SHB Control Block, and currently, in accordance with that agreement, the required tertiary regulation capacity reserve in BiH is 196 MW, constant throughout the year.

The number of registered EVs in BiH is given in Table VIII, and according to the public annual reports on registered EVs (BIHAMK):

Table VIII: The number of registered EVs in BiH according to BIHAMK reports

Year	Number of EVs
2018	38
2019	60
2020	98
2021	133
2025*	559

*Assumption of the number of registered EVs considering the trend of increasing the number of EVs during the previous years

Considering the assumption about the number of registered EVs in BiH to be correct and optimistically assuming that the average battery capacity of EVs is 50 kWh, we arrive at the total maximum capacity of EVs:

$$E_C = 133 * 50\ kWh = 6.65\ MWh$$

Based on the previous expression, the total current capacity, i.e., the energy available for eventual balancing of the EPS contained in the batteries of EVs in BiH is approximately 6,65 MWh, according to the data on the number of registered EVs in BiH that are available in the public annual reports on vehicles registered in BiH (BIHAMK).

The previously mentioned, currently maximum available amount of energy contained in the batteries of EVs can be supplied to the power system via charging stations for EVs. For the purposes of this study, we will consider four cases of electricity delivery from EV batteries to the power system:

1. All EVs deliver electricity to the power system via home charging stations with a power of 2.3 kW. In this case, the power of electricity delivery amounts to:

$$P_i = 133 * 2.3\ kW = 0.306 MW \quad (1)$$

2. Approximately 2.890 EVs are needed to achieve delivery power in the amount of 6.65 MW through home charging stations with a power of 2.3 kW.
3. EVs deliver electricity to the power system, combined, through home charging stations with a power of 2.3 kW and through AC charging stations for which we assume an average power of 11 kW (average individual delivery power is between 2.3 kW and 11

kW). In this case, the total power of electricity delivery amounts to:

$$P_i = 133 * (2.3\text{-}11)\ kW = (0.306\text{-}1.46)\ MW \quad (2)$$

To achieve delivery power in the amount of 8 MW through home charging stations with a power of 2.3 kW and AC charging stations with an average power of 11 kW, approx. 605 - 2890 EVs are needed.

4. All EVs deliver electricity to the power system via AC charging stations with an average power of 11 kW

$$P_i = 133 * 11\ kW = 1.46\ MW \quad (3)$$

To achieve the delivery power in the amount of 8 MW through AC charging stations with an average power of 11 kW, approx. 605 EVs are needed.
All EVs deliver electricity to the power system via DC chargers with a power of 50 kW (the selected amount of DC charger power in this case is 50 kW due to the previously introduced assumption that the current average battery capacity of EVs is 50 kWh)

$$P_i = 133 * 50\ kW = 6.65\ MW \quad (4)$$

In this case, with the existing number of EVs, we can ensure delivery power in the amount of 6.65 MW.

5. EVs deliver electricity to the power system, combined, through home chargers with a power of 2.3 kW, through AC chargers for which we assume an average power of 11 kW, and through DC chargers of different power. The maximum power of electricity delivery in this case depends on the average power of the installed DC chargers.

The ideal case from the aspect of the current number of EVs and the available energy in the batteries of EVs is case number 4), while the realistic case, which will be more pronounced in the future, is case number 5).

By realizing the ideal scenario from the fourth case, the most significant support for the balancing of the EPS is achieved within the current state from the aspect of the number of EVs and the maximum available energy for eventual balancing of the EPS. In view of this, the scenario from the fourth case will be considered in comparison with the actual needs of the EPS of BiH for balance energy, that is, the necessary capacities of secondary and tertiary regulation (primary regulation will not be considered since the charging of primary regulation energy is realized only from January 1, 2022, and it is necessary to meet special technical conditions for the provision of this type of auxiliary services, which is impossible from the point of view of EVs). All other cases and/or their combinations have a smaller contribution to the balancing of the power system.

Considering the stated capacity of EVs, i.e., the energy contained in the batteries of EVs, and with the assumption of the power of delivering electricity in the amount of 8 MW, Table IX shows a comparison of the stated values in relation to the actual needs of the power system. In addition to the analysis of the current situation, a predictive analysis for the year 2025 was also performed:

Table IX: The ratio of the maximum battery capacity of existing EVs and the needs of EPS BiH for the capacity of balance energy

EPS BiH	Required capacity	EV battery capacity (2021)	EV battery capacity (2025*)	Possible share of required capacity (2021/2025)
Secondary regulation capacity (non-peak load)	26.9 MW	6.65 MW	27.95 MW	25 %/100%
Secondary regulation capacity (peak load)	44.3 MW	6.65MW	27.95 MW	15%//63%
Tertiary regulation capacity (upward) – energy shortage in EPS BiH	196 MW	6.65 MW	27.95 MW	3%/14%
Tertiary regulation capacity (down) – excess energy in EPS BiH	68 MW	6.65 MW	27.95 MW	10%/41%

*Assumption of the number of registered EVs considering the trend of increasing the number of EVs during the previous years

From the previous table, which shows the ideal case in which, in addition to the two-way flow of electricity between EVs and EPS, the total capacity of EV batteries is fully available at all times, it can be concluded that the maximum capacity currently available in EVs is still insufficient for a significant positive contribution to the balancing of EPS BiH. However, the actual available capacity at a given moment differs significantly from the maximum capacity of EV batteries and depends on several factors, such as the proportion of vehicles that are connected to the power system at a given moment via slow chargers, the battery charge status and the vehicle owner's default settings.

However, if the current trend of increasing the number of EVs in BiH continues, during the next 4-5 years the capacity contained in the batteries of EVs may reach the amount of 80-90 MWh, which represents a significant source of electricity, i.e., a significant consumer of electricity (especially in case of unplanned, stock and intermittent interaction with EPS BiH). In addition to the expected increase in the number of EVs in BiH, an increase in the production capacity of RES is expected, which, given the variable production of RES, and consequently the dynamic interaction with the EPS, will cause an increase

B&H Electrical Engineering, Volume 17, Special Issue, 2023:33-43
ISSN:2566-3143, eISSN:2566-3151, DOI: 10.2478/bhee-2023-0016

in the need for balance energy, i.e., an increase in the required capacity of secondary and tertiary regulation EPS BiH. The significant capacity of EVs that is expected in the coming years can partly compensate for the increased needs for balancing energy of EPS BiH due to the increased integration of RES, acting as a decentralized producer/consumer that contributes to the balancing of EPS BiH at various favourable tariffs.

The assumption of balancing for 2025, when the number of EVs is expected to be 559, was also made. The necessary balancing conditions were used the same as in 2021, since no more recent data is available.

Given that there is currently no possibility of a two-way flow of energy when it comes to EVs that interact with the power system through charging stations, the provision of auxiliary services is significantly limited from that aspect. In EPS BiH, there is no possibility of providing auxiliary services through the interaction of EVs with the power system due to the lack of a platform for communication between EVs and the power system, which enables the contracting and implementation of auxiliary services, as well as the implementation of all procedures involved in the implementation of auxiliary services. These (technological) shortcomings have the consequence that the current contribution of EVs to the balancing of the power system in real time, apart from being positive, can often be unfavourable from the aspect of balancing the system, i.e., frequency maintenance.

6. CONCLUSION

In this paper, special attention is paid to the prediction of the increase in the number of EVs according to models from the EU. In the coming period, an increase in the number of EVs is expected in Bosnia and Herzegovina, and therefore the infrastructure needed for EVs. Based on this, a prediction of electricity consumption for charging EVs was also given. Until now, the number of EVs grew very slowly, since there was no kind of co-financing for the purchase of electric vehicles, and there were very few public charging stations for EVs. EVs are also very convenient from the point of view of environmental protection because they do not emit CO2 emissions into the air. From the point of view of electric power infrastructure, BiH is a country rich in energy sources (hydropower, wind, solar energy) and if it is done in a systematized manner, there will be no problems from the aspect of energy demand for EVs. The contribution of this paper is reflected in the fact that it provides an analysis of the use of EVs for secondary regulation of the power grid. This method of regulation can be considered and integrated into the development plans of electrical distribution networks.

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