ANALYSIS OF THE INTEGRATION POSSIBILITY OF THE ELECTRIC VEHICLES ON BATTERY AND FUEL-CELLS BASE IN TRANSPORT SECTOR OF THE SLOVAK REPUBLIC

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DOI: 10.17973/MMSJ.2021_11_2021098

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The total world energy consumption is permanently growing during last 30 years. Alternative energy sources are one of the best ways to save the environment polluted by the combustion products of gasoline, diesel fuel, and even methane or propane. The main idea of the article is to analyse the possibility and it influence of integration of the electric vehicles on battery and fuel-cells base in the transport sector of the Slovak Republic. This paper highlighted the main challenges associated with usage of battery-based and fuel-available technologies in a transport sector of Slovak Republic.

KEYWORDS

Electric vehicles, fuel-cells, hydrogen, transport

1 INTRODUCTION

The total world energy consumption is permanently growing during last 30 years. The industrial sector (excluding the non-combusted use of fuels) consumed around 45% of global energy in 2018, with the non-combusted use of fuels accounting for an additional approximately 5%. The remainder was used within residential and commercial buildings (29%) and transport (21%) [BP 2020].

Alternative energy sources are one of the best ways to save the environment polluted by the combustion products of gasoline, diesel fuel, and even methane or propane [Smeringai 2018]. Nowadays electricity is one of the main alternative to the fossil fuels. But there is still no consensus on which electric vehicles the world will switch to [Krenicky 2018, Trefilov 2020, Nikitin 2020]. Traditional battery-powered electric cars have already achieved some popularity. But these devices have many drawbacks: batteries lose their charge in cold weather, and their average service life is 1–1.5 thousand cycles, that is, when recharged twice a day, the battery will last only about 3–5 years [Randall 2020, Alasward 2016, Lekomtsev 2020, Bozek 2021].

The fuel cell is one of the most promising products of the 21st Century as it continues to compete with batteries, the internal combustion engine and power grid in terms of high efficiency [Murcinkova 2013]. The cost of a fuel cell is influence by three factors: material and components costs, labour for design and fabrication, and capital cost of the manufacturing equipment and facilities [Wilderforce 2017].

The main idea of the present article is to assess and compare the possible influence of the replacement of the fossil fuels cars by battery-powered and fuel cells electric, in the Slovak Republic conditions.

2 MATERIALS AND METHODS

An input data for the research are the statistical data of the Slovak Republic and the technical data of the existing transport. All assumptions which are represented in the article were based on evaluation of the statistics data and market aspects of Slovak Republic.

According to the statistics of the Ministry of the Interior of the Slovak Republic, the total number of vehicles registered till 31.10.2020 is 3 337 851 [MVSR 2020].

Table 1 shows the distribution of all registered vehicles in Slovakia by categories according to the Consolidated Resolution on the Construction of Vehicles (R.E.3) [Economic Commission for Europe 2017].

Within the scope of article and structure of the Slovak transport sector the possible influence of the replacement of the fossil fuels cars by battery-powered and fuel cells electric were compared only at category of vehicles used for the carriage of passengers and comprising not more than eight seats in addition to the driver's seat, as they are representing approximately 73% of all registered vehicles in SR.

	31.12.2018	*31.12.2019*	*31.10.2020*
Motor vehicles with less than four wheels	*152 049*	*159 934*	*167 935*
Vehicles having at least four wheels and used for the carriage of passengers (e.g., standard car with 2, 3, 4 doors).	*2 330 674*	*2 402 551*	*2 437 682*
Power-driven vehicles having at least four wheels and used for the carriage of goods	*348 344*	*350 658*	*351 693*
Agricultural and Forestry tractors and Non-road mobile machinery	*66 657*	*60 494*	*59 260*
Others (bicycles, semi-trailers, trailers, self-propelled work machines)	*305 717*	*312 654*	*321 281*
Total	***3 203 441***	***3 286 291***	***3 337 851***
*Vehicles used for carriage of passengers, comprising not more than eight seats**	*2 321 608**	*2 393 577**	*2 429 526**

Table 1. Total number of vehicles in 2018-2020 [MVSR 2018, MVSR 2019, MVSR 2020]. * *Vehicles which are used for carriage of passengers, comprising up to* ***eight seats***

To unify the calculation conditions, the fuels prices (Table 2) which are presented at the article are average annual prices in 2020. The price of hydrogen is proposed as the average price of hydrogen at service stations in Central and Eastern Europe.

The expected average consumption of liquid fuels in the city is 7.6 l / 100 km, outside the city 5.4 l / 100 km, combined 6.2 l / 100 km, high 10.3 l / 100 km, medium 7.2 l / 100 km, low 6.1 l / 100 km and combined 7.2 l / 100 km.

Fuel	Price €/l	Price €/kg
Gasoline 95 Octane	1.147	1.43
Diesel	1.007	1.2
Hydrogen	-	9

Table 2. Fuel prices for 04.2021

The proposed consumption of a hydrogen (fuel-cells) car represents the average value of the consumption of hydrogen cars currently available on the market based on their declared consumption.

3 DISCUSSION

Despite on increasing number of vehicles powered by alternative fuels in last years, gasoline and diesel powered passenger cars are in preference. The highest share is the gasoline powered cars among all vehicles used for carriage of passengers. At the Figure 1 is reflected the share of the passenger cars by types of engine fuels in Slovak Republic.

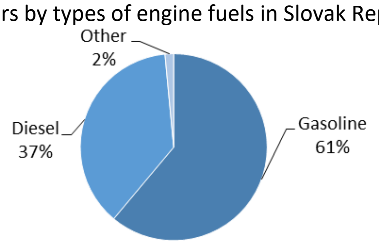

Figure 1. Passenger cars by types of engine fuels in Slovak Republic

Based on the structure and physical parameters of the represented fuels, the comparison of energy consumption in case of difference types of vehicles was made in kWh (Table 3).

From the technical characteristics of electric (battery-based) cars, which are currently available on the market, the declared consumption of a car is 62 kWh with a range of 450 km. Thus, the energy consumption per 100 km of road is 13.7 kWh.

Fuel	Consumption kg/100 km	Costs €/100 km	Energy consumption kWh/100 km
Gasoline 95 Octane	5.76	8.23	87.19
Diesel	5.04	6.05	71.04
Hydrogen	0.8	9	26.56
Electric	-	1.37	13.7

Table 3. Fuel consumption and costs of the vehicles per 100 km

According to the data the consumption of hydrogen per 100 km is about five times lower than the consumption of conventional fuel, but the price per hydrogen per 100 km will be the highest (Figure 2).

A prerequisite in determining the annual energy consumption of the different types of cars was annual mileage of 10000 km (Figure 3).

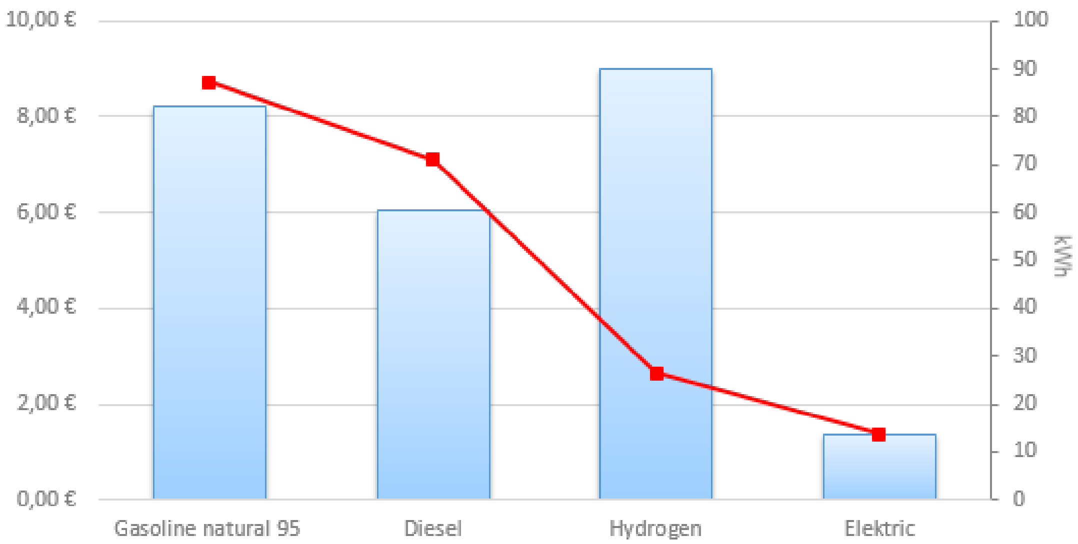

Figure 2. Costs and energy consumption per 100 km

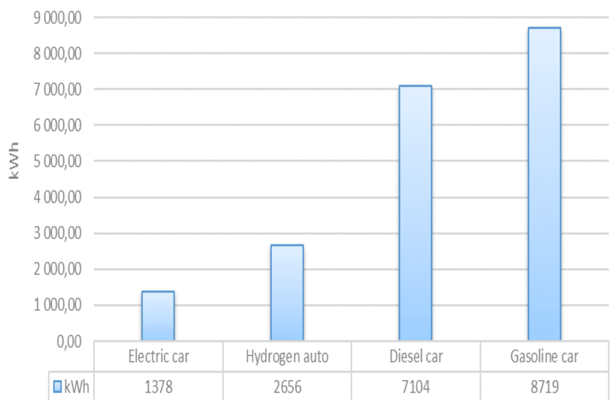

Figure 3. Energy consumption in kWh per 10 000 km

number of personal cars		10 000 km	15 000 km	20 000 km
		total energy consumption GWh/year		
10%	242 204	334.7	502.1	669.5
25%	607 584	836.8	1 255.3	1 673.7
50%	1 211 021	1 673.7	2 510.5	3 347.3
75%	1 816 531	2 510.5	3 765.8	5 021.0
100%	2 422 041	3 347.3	5 021.0	6 694.0

Table 4. Total annual electricity consumption for electrolysis in case of changing a certain number of personal cars for electric cars

Assuming the production of green hydrogen (by electrolysis), production of 1 m^3 of H_2 currently requires about 5.2 kWh of electricity, i.e. about 57 kWh / kg. Table 4 shows the total annual electricity consumption depending on mileage and the expected number of electric cars.

number of personal cars		10 000 km	15 000 km	20 000 km
		total energy consumption for hydrogen production GWh/year		
10%	**242 204**	**1 107.9**	**1 661.8**	**2 215.7**
25%	**607 584**	**2 769.7**	**4 154.5**	**5 539.3**
50%	**1 211 021**	**5 539.3**	**8 309.0**	**11 078.6**
75%	**1 816 531**	**8 309.0**	**12 463.5**	**16 615.0**
100%	**2 422 041**	**11 078.6**	**16 615.0**	**22 157.3**

Table 5. Total annual electricity consumption for electrolysis in case of changing a certain number of personal cars for hydrogen powered cars

Table 5 shows the total annual electricity consumption for hydrogen electrolysis in GWh depending on mileage and the expected number of hydrogen cars [Doucek 2010].

Based on the above data, the theoretical primary electricity consumption by hydrogen and electric car was compared, assuming a 50% change in the type of car and 10,000 km annual mileage (Figure 4).

The required power of the electricity source to cover the necessary energy consumption for the production of hydrogen by electrolysis, assuming the operation of the source by 8000 hours per year, assuming a 50% change in the type of car and 10,000 km annual mileage is 690 MW, comparing to 300 MW for the production of el. energy for battery-based cars.

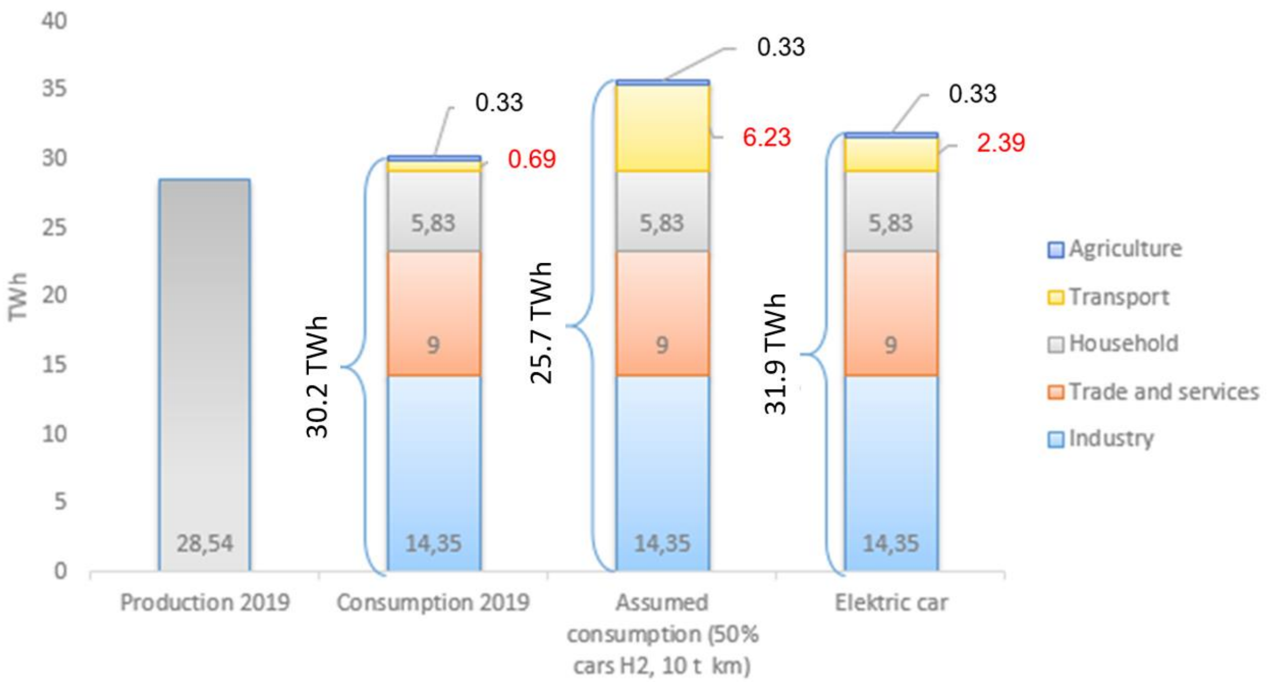

Figure 4. Expected increase in annual electricity consumption with a 50% conversion of passenger cars to hydrogen compared to electric

4 CONCLUSIONS

The call for fuel cells to be introduced into the transport industry is gradually gaining attention by the automobile industry. The advantages of PEM type fuel cell devices over the traditional ICE continue to make them a better choice for the automobile industry due to their high efficiency and low emissions [Wilderforce 2017].

Nevertheless, immediate replacement the fossil fuels cars by the hydrogen should be a great challenge for the electricity system of the country comparing even to battery-based electric cars [Panda 2021, Patsch 2020].

The other main challenge that limits the widespread usage of the fuel-cells technology is a higher price of green energy comparing to the existing fossil and nuclear alternatives.

This paper highlighted the main challenges associated with usage of battery-based and fuel-available technologies in a transport sector of Slovak Republic.

ACKNOWLEDGMENTS

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-16-0192

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