International Congress Motor Vehicles & Motors 2014

Kragujevac, October 09rd-10th, 2014

MVM2014-NNN

Zoran Nikolic[1]
Zlatomir Zivanovic[2]

STATE OF DEVELOPMENT AND PERSPECTIVE OF THE ELECTRIC VEHICLES

ABSTRACT: First EV has been made in in 1837. This type of motor vehicles has dominated throughout the whole 19th century. In the early 20th century the faster and more robust vehicles with ICE overcame them until late 20th century, when ecological and economic problems of further application of these vehicles have emerged. The interest in EV has risen sharply.

Researches are working in several directions in order to reduce the need for oil derivatives considering that the EV's are weak primarily due to inferior "reservoir of energy" to fully meet the current driving habits. Savings can be achieved in two ways, by making more economic motor vehicles or by the use of alternative fuels. Combining an electric propulsion and IC engine drives a hybrid vehicle is obtained, with a greater amount of batteries and "plug in" that is to some extent possible to reduce fossil fuel consumption and exhaust emissions. Intensive research work on exploring new battery is still to come. Today promising results with Li - air batteries, fuel cells and super capacitors, as well as the efforts of major car manufacturers indicate that the EV could soon appear massive in the streets of cities.

This paper deals with the development of EV, following the development of powertrain and can conclude the fact that in the near future this type of drive could return.

KEYWORDS: EV, EV development, Hybrid EV, EV History, EV perspective.

ABBREVIATIONS:

AC	Alternating current
ACEA	European Automobile Manufacturer's Association
BEV	Battery electric vehicle
BP	British Petroleum
CNG	Compressed natural gas
DC	Direct current
EIA	Energy Information Administration
EU	European Union
EV	Electric vehicle
FCV	Fuel cell vehicle
GHG	Greenhouse gas
HEV	Hybrid electric vehicle
HV	Hybrid vehicle
IC	Internal combustion
ICE	Internal combustion engine
Li-air	Litium air
Li-ion	Litium ion
LNG	Liquefied natural gas
OICA	International Organization of Motor Vehicle Manufacturers
OPEC	Organization of the Petroleum Exporting Countries
PHV	Plug-in hybrid vehicle

[1] *Zoran Nikolic PhD, BSc, Institute of Technical Sciences of the SASA, Belgrade, E-mail: zoran.nikolic@itn.sanu.ac.rs*

[2] *Zlatomir Zivanovic, PhD, BSc, Institute of Nuclear Sciences "VINČA", Department for I.C. Engines and Vehicles, 11001 Belgrade, PO Box 522, E-mail: zzivanovic@vinca.rs*

UN	United Nations
ZEV	Zero-emissions vehicle

1. SOME PROBLEMS WITH ICE VEHICLE

Usage and application of the electric motor vehicle started long before usage of motor vehicles with ICE and that marked the entire nineteenth century. Nevertheless, the EV could not withstand the competition with ICE vehicles, which were faster, stronger and more robust. The main reason for leaving the electric propulsion at the beginning of the twentieth century lies in the fact that the weight of 1 kg of batteries could accumulate around 25Wh of energy, and liquid fuels around 12.000Wh, and that meant that the reservoir of classic cars with ICE, which has weight about 50kg could store approximately 600kWh of energy, and a lead battery pack only about 2 - 10kWh [01] of electricity, which again in the early 20th century was much less.

In the seventies of last century, begins EV renaissance. Permanent increase in the price of oil, which reserves are dropping, and problems related to its production, transport and use, lead to renewed interest in EV. Simultaneously with the crisis and shortage of oil, ecology and environmental protection are gaining on importance. At that time, it seemed that the reserves of coal and oil wear out quickly, as predicted for the beginning of the third millennium, which lead people to start thinking about the "conservation of energy". Especially at the turn of this century, the need of making clean vehicles or vehicles of "zero emissions" was stressed. In addition, steady technical progress gave the quality and cost-effective solutions, speed control motors, lighter batteries and lighter materials for the body.

Large car manufacturers are starting to invest in the development of EV, as well as improving the components of the propulsion equipment. The decisive criterion for EV success is their price, a criterion that is still very vague. EV retails in small-series production between 30,000 and 75,000$, which mainly depends on the kind and type of battery. One can not say how much EV will cost when mass produced. Historically, comparing the prices of other products, including classic cars, hinted that full production will significantly reduce their cost (expected even at half the current values).

As a transient solution to the pure EV, today HEV is intensively develop. In urban areas these vehicles operate as an EV with poorer performances and out of town they are using built-in IC engine power for drive or recharge the batteries. In this way, the HEV contribute greatly to the ecology, affecting the economy of operation, and at the same time intensively developing the fuel cell as a promising energy reservoir for use in EV. In terms of retail, they gained increasing popularity. They are made of ICE vehicles with an increasing degree of usefulness or with lower fuel consumption per unit of road. While modern materials are used, the resistance movement is reduced and vehicles are made to be more effective.

Even in HEV vehicles is being experimented with different types of plant, from the type of ICE plant to fuel cells. Prices of cars with these drives are still high because of two types of driving machines, but to create the habits of drivers, public authorities and institutions usually significantly stimulate sales by reducing taxes when selling these vehicles.

The fuel cell generates the least pollution from all sources of electricity made to run motor vehicles. Hydrogen is an ideal fuel for fuel cells, in the technical and environmental terms. Hydrogen can be produced in many ways, but when fossil fuels are becoming scarce and expensive, hydrogen will be the most likely to be produced of the water using the solar cells and renewable sources. In scenario where solar hydrogen will be widely used, the whole system energy transport will be almost perfect and the energy will be completely renewable.

It can be concluded that as the main means of mass transportation, a car with SUS drive marked the twentieth century. However, the consequences of this form of mass transportation are a large amount of exhaust of harmful substances that pollutes the environment. Finding alternative energy sources that would power the vehicle could solve this problem. One of the possible solutions is EV.

In addition to the level of efficiency of EV significantly higher than the corresponding motor vehicles with ICE, one can not ignore the fact that the cars with fossil fuel store over 44 times more energy than the EV battery pack. Until today, this is the main reason why there has been no large scale production and use of EV.

2. A BRIEF HISTORY OF EV

First implemented electric motor drive was achieved by Moritz Jakobi [02], in 1838., when for a short time it propelled boat with 14 people on the River Neva in the presence of the Russian Emperor Nicholas I and his entourage. Still, the beginning of creation and use of EV can be marked with 1839. year when Robert Davidson [03] from Scotland made the first vehicle powered by electricity with the aim of replacing steam locomotives, which were noisy and dirty due to smoke and coal. That EV on the rails, that made trip from Edinburgh to Glasgow possible, which is about 130km with one wagon and with one more built-in primitive electric motor is used as the primary power source battery. The achieved speed was 6.5 km/h; and vehicle could not handle any kind of payload. Therefore, the use of this vehicle was very limited. Suitable battery pack was made by Plante in 1860. enabling the commercialization of EV.

The first small-scale production of EV began 1892. in Chicago. These vehicles were very clumsy but as such had very good sales. The vehicles had the appearance of carriages with large wheels, no roof, with a canopy that protected the passengers from rain and the sun. They were used for trips, to do a certain job, and even a taxi to transport more passengers. Passenger electric cars had engines up to several kilowatts which made it possible to develop a maximum speed of 20km/h while covering the distance over 100km on a single charge of the batteries. Usually EV used serial DC motors. Rechargeable batteries were with large capacity of up to 400Ah and voltage up to 100V. Share in battery weight, relative to the fully loaded vehicle with passengers, was over half, which enabled wide autonomous movement radius.

On the roads of America in 1900. were about 8,000 cars, and almost equally, one third of the total, at the time the vehicle was powered by electricity, steam vehicles and vehicles with ICE.

Figure 01. The main reason for leaving the development of EV in the early twentieth century lies in the fact that the accumulator batteries could accumulate around 25Wh/kg energy, and oil derivatives around 12.000Wh/kg

The fall of oil prices, discovery of oil wells had also impact on the wider application of EV. The invention of the muffler in the late 19th century reduced the noise of ICE vehicles and an electric starter at the beginning of the 20th century eliminated the need for manual operation. Further progress of the implementation of EV opposed by three obstacles: low top speed, limited radius of a single battery charge and the relatively high price compared to the mass production of Ford vehicles [04]. Car with a combustion engine was gaining increasing popularity due to their ease of refueling, mobility, speed and autonomy, although the EV is still kept. EV are especially favored by females, who considered gasoline-powered car dirty and difficult to drive, and in the same time those were the very characteristics that made it more preferred by men, driven by the passion of sports.

The main drawback of the EV back than was relatively short range between charging. At the end of the 19th century, the specific energy in the accumulator batteries was about 10Wh/kg. At the beginning of the 20th century, this value improved to the level of 18Wh/kg, that only a decade later stood at 25Wh/kg [05]. In addition, the charging stations were not enough branched, although the situation began to improve in the early 20th century. However, locating new sources of oil caused drop in price of gasoline and the advancement of technology in the production of ICE created the conditions for the rapid progress of these cars. Therefore, the development of EV,s remained on the sidelines.

3. FACTORS THAT CONTRIBUTE TO MORE INTENSIVE DEVELOPMENT OF EV

The growth of the gross national income of each nation, as well as general technical progress is determined by great needs for all types of energy. Annual percentage growth of energy need in the world is greater than the percentage of population growth.

Transport in cities today is based on oil derivatives. With the existing technical solutions EV today does not posses enough energy so that it can achieve performance and radius of competitive vehicles with combustion drive. On the other hand, the lack of emissions and low noise make the EV more attractive for some special purpose, such as short trips with frequent stops at which the vehicles with ICE,s have inefficient operation.

In addition to high economic dependence on oil and petroleum products, are a common problem and the problem of protecting the environment, reducing exhaust emissions and greenhouse gases. It is anticipated that, due to the development of technology, the energy consumption in the production systems and the addition of large-scale production in the coming years could largely stagnate.

There are several factors that influence the development of EV:

• **Population growth in the world**

Population growth in the world had a constant value from the beginning of a new era to the 19th century, when the population was about 1 billion. The world population has grown to more than 6 billion people in the 20th century. Today there are over 7 billion people in the world. Although the assessment of the UN [06], contains three possible scenarios of population growth in this century, the most probable is one that predicts that the world population will increase in 2050. on about 8.9 billion, and will then come to a slowdown in growth to by the end of the 21st century, while stagnating in the following centuries.

• **Transportation needs**

With the growth of population in the world there is a need to increase the transport of people, goods and raw materials as a prerequisite for the growth of production and consumption, including the standard of living. This steady growth is a natural and expected process of the development of civilization and one of the most important indicators of the development of society and humanity so that it is considered that the present life is unimaginable without road traffic.

In the world in 2012. according to OICA [07], was around 1143.231 million vehicles, of which 833.342 passenger cars and 309.888 commercial. That same year was produced a total of 87,249,845 new vehicles, an increase in respect to the previous year of 3.6%, of which 65,386,596 passenger cars and 21,863,249 commercial.

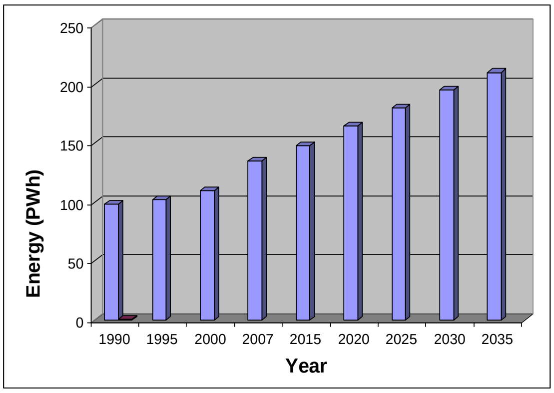

Figure 02. Consumption of total or primary energy in the world since 1990. year until now and forecast to 2035.

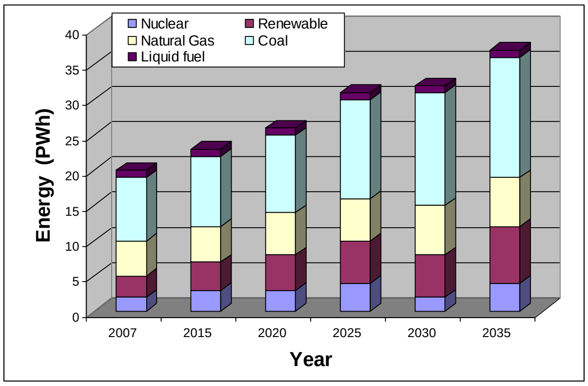

Figure 03. Share of energy sources in electricity generation in the world from 2007. until 2035. [09]

• **Energy needs**

The growth of population in the world and the general technical progress conditioned the growing needs of all types of energy. Percentage growth of energy needs in the world is greater than the percentage of population growth.

Statistical summary of total consumption and primary energy in the world since 1990. until today, and forecast to 2035. [08] estimates that due to the increasing demands of consumer and especially due to the increasing demands for the transportation of goods and people, the demand for energy could increase by approximately 1,5 to 2% per year. It is believed that in the period from 2000. to 2050. year, energy need will be more than doubled.

• Crude oil as an energy source

Although the share of oil in total production of primary energy percentually decreases, the production and consumption of oil is generally increasing. Efforts are made to find new sources and new evidence suggests that slowly this form of energy is reduced and scientists expect that for a certain time all sources of energy could dry up.

According to the BP Statistical Review (British Petroleum) [10], from 2011. Figure 04 shows the increase in prices of petroleum products in Rotterdam since 1993. expressed in U.S. $ per barrel.

Forecast of production of petroleum products in the world by 2035. according to the Energy Information Administration (EIA) [11], is shown in Figure 05. new oil fields are expected to be found, activation and depletion of existing ones, so that in the next 25 years, production of crude oil will retain most of the existing value. It is expected increase in natural gas consumption and non-conventional liquid fuels. At the same time this will make certain redistribution of consumption of liquid fuels. Increase in consumption of liquid fuels for transport is expected and to a lesser extent for other consumers.

Although people are still finding new sources of oil, the fact is that oil consumption is increasing and one day it will dry up so humanity will need to find other energy sources.

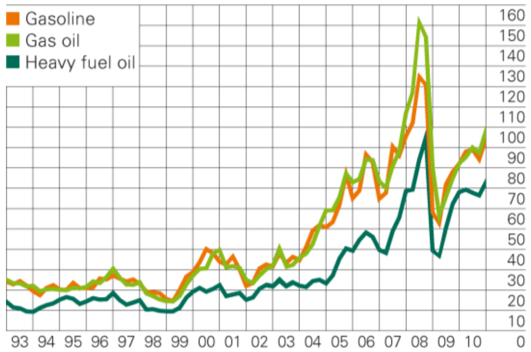

Figure 04. The prices of petroleum products on the market in Rotterdam from 1993. until 2010th year, expressed in U.S.$ per barrel

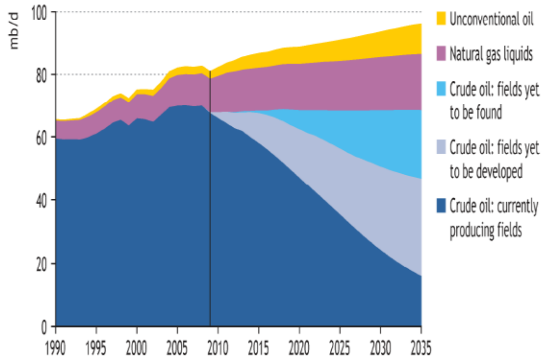

Figure 05. Forecast of the global production of liquid fuels by 2035.

Taking into account today discovered and researched fossil fuel reserves can be estimated that by mid-century, the transport sector and transport of energy resources could be generally supported, but certainly not after the 2050, if today's fuel reserves resulted in new energy crisis [12].

• **Environmental pollution and global warming**

Pollution of air fuel combustion in motor vehicles is becoming the most important global problem, especially in urban areas around the world. The emission of pollutants originating from motor vehicles is caused by the level of traffic, the possibility of roads as well as meteorological conditions. Pollutants from the exhaust system of motor vehicles can reach the atmosphere and dependent on the composition, inflammability and fuel volatility. In contrast to the natural greenhouse effect, the additional effect caused by human activity contributes to global warming and may have serious consequences for humanity. The average surface temperature of Earth has increased by about $0,6^{0}$C [13], only in the twentieth century. In addition, if humanity do not take any steps towards limiting emissions of greenhouse gases in the atmosphere, it can be expected that the concentration of carbon dioxide by 2100. reaches between 540 and 970 million particles of the volume. This concentration of carbon dioxide would lead to a global temperature increase between 1.4 and $5,8^{0}$C by the end of this century.

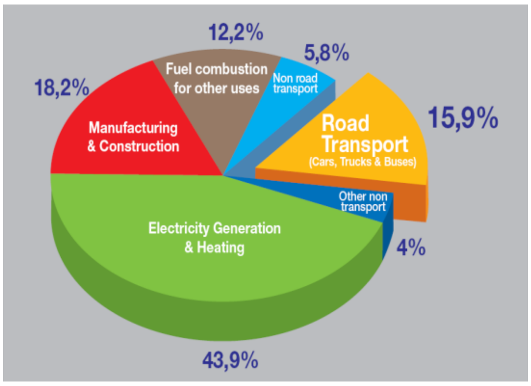

Figure 06. About 15.9% of global man-made CO2 emissions come from motor vehicles [14]. It is about 13% of total greenhouse gas

Temperature rise of this magnitude would also greatly affect the entire Earth's climate, and would be manifested as more frequent rainfall, more tropical cyclones and natural disasters every year in some regions, or on the other hand, in other regions such long periods of drought, which would have very bad effect on agriculture. Entire ecosystems could be seriously threatened with extinction species that could not quickly enough to adapt to climate change.

• Production and consumption of electricity

An essential prerequisite for economic growth and development of each country and the region is a safe and reliable supply of electricity. Electricity consumption per capita is the highest in the Nordic countries (with a maximum value of 24.677kWh, Iceland) and in North America. Almost half of the EU countries have nuclear power plants so that in France and Lithuania almost 75% of electricity generation is from nuclear power plants. Primary energy demand increases by 41% between 2012 and 2035 [15], with growth averaging 1.5% per annum (pa). Growth slows, from 2.2% pa for 2005-15, to 1.7% pa 2015-25 and just 1.1% pa in the final decade.

Energy consumption grows less rapidly than the global economy, with GDP growth averaging 3.5% p.a. 2012-35. As a result energy intensity, the amount of energy required per unit of GDP, declines by 36% (1.9% p.a.) between 2012 and 2035th The decline in energy intensity accelerates; The expected rate of decline post 2020 is more than double the decline rate achieved from 2000 to 2010.

Electricity generation is mainly the combustion of solid fuels 40% and natural gas 20%. About 16% of electricity is obtained from hydropower and slightly less, 15% from nuclear power plants. Less than 10% is obtained from oil. It is believed that in the near future to reach a substantial increase in electricity would come from production from nuclear power plants, to a lesser extent from natural gas, and later from renewable sources.

• **High energy efficiency of electric drive**

In order to analyze the energy level from the energy source to the wheels of the vehicle, it is necessary to bear in mind the following:

- The efficiency of operation of the mine of natural fuels (fossil fuels or nuclear energy), - The production of electricity and
- The network transport.

Efficiency of electricity generation varies widely. According to European measurements, ranges from 39% for plants with coal production to 44% of power plants with natural gas, or the mean value of 42%. Power plants with combined cycle natural gas can reach the efficiency level of over 58%. If the mean value of 42% multiplied by the efficiency of the transfer of 92% efficiency from source to reservoir of 38% is obtained. Battery charger, battery recharging, transmission and losses in the electric motor give the utility of the reservoir energy to the wheels from 65-80%. In this way, the overall usefulness of the source to the wheels is from 25 to 30%.

Exploitation of natural fuel and transport network depend on the type of energy but have an average efficiency of about 92%. Together with losses in transport and processing receives the total level of efficiency from the source to the reservoir by about 83%. But the internal combustion engine is only 15-20% of the energy converted into useful work. In this way, the overall usefulness of the source to the wheel is 12 to 17%.

Table 01. Existing level of utility vehicles with ICE and EV [16-17]

	ICE	EV
From the source to the reservoir	83%	38%
From the reservoir of energy to the wheels	15–20%	65-80%
Total: From the source to the wheels	12–17%	25-30%

Energy efficiency is a very important data, and is expressed as the electric energy consumption from the electric distribution grid to one kilometer of road. It is obtained as the ratio of distance traveled per unit of electricity consumed. Measurements made in our country [18] showed that the specific energy efficiency of the flat road is about 5,1 km/kWh, while in the city's hilly operation is about 4,5 km/kWh. Specific energy consumption, defined as the ratio of electricity consumed from the electric distribution grid per unit of distance traveled, or the reciprocal value of energy efficiency, is on the straight road below 0.2 km / kWh and in the hilly city driving about 0.22 km / kWh.

4. FURTHER DEVELOPMENT EV

The main problem that follows the EV is connected to the "reservoir of accumulated energy." Existing battery, despite the fact that has been developed specifically for this application, has a lot of flaws in service. The efforts of scientists are focused precisely because of the finding of an entirely new principle for energy storage.

• Hybrid vehicles

Not finding opportunities to the existing types of EV satisfy the habits of drivers of vehicles with conventional drive, as well as with vehicles with conventional drive meet certain environmental conditions, vehicle manufacturers have resorted to an interim solution, the so-called “hybrid power train”. As a combination of vehicles with ICEs and pure EV, hybrid vehicles reduce fossil fuel consumption by about 20% in the cities as well as emissions.

The general conclusion is that it performs a positive step towards the introduction of environmental drive vehicles. However, since there is no definite solution, experiments were conducted with pure electric and hybrid solutions, as well as various kinds of technical solutions drive. Despite the turbulent development of EV and HEV, some experts believe that vehicles with ICEs will dominate for another 15 years, but even after that, will not disappear [19]. Hybrid, a combination of electric motors and ICEs, is relatively simple and inexpensive solution that today meets the environmental requirements.

With the optimal allocation of functions between components of the hybrid drive can be achieved:
- Economical electric-powered cars, no combustion products and noise-free in city traffic;
- Cost-effective operation of ICEs with a nominal (generator) mode, high acceleration and high speed on the open road.

Due to the lack of rigid coupling ICE-drive wheels the transient regimes engine are eliminated and thus all the bad effects of these regimens on the increase in fuel consumption, emissions and noise. The ICE runs at a stationary regimes load and high efficiency of primary energy, just in time intervals when necessary to maintain the level of battery power within the given limits. With this variant of the HV performance are limited by the nominal capacity of the power plant and the radius of the reservoir tank of ICEs. Despite the turbulent development of EV and HV, some experts believe that vehicles with ICEs would dominate for another 15 years, but even after that will not disappear [20].

The main reason for the production and purchase of HVs is reduction in terms of the fuel economy in city driving, but commonly cited and displayed are information on saving energy and pollution reduction. Top selling hybrid Prius [21], has fuel-efficiency of 51mpg (21,7 km / l) in a city driving and 48mpg (20,4 km / l) on the open road. Typically in our presents data on consumption per 100km odometer, so that consumption in the city driving is 4,6 l/100km and on the open road is about 4,9 l/100km.

• Plug in EV

If the HV possess a larger capacity battery that can be recharged via connection to an external source, i.e. the distribution network, then such vehicles we can call as "plug in" hybrid vehicle (PHV). Although PHV will never become a "zero emission vehicle" (ZEV) for their internal combustion engine, the first

PHV which appeared on the market reduce emissions by one-third to half [22], and more modern models are expected to reduce emissions even more [23].

"Plug in" HV vehicles can cross a distance up to 120km with a charged battery and batteries, and then the batteries need to supplement from the power grid or by using the ICE. Often the onboard computer determines the most optimal conditions for recharging.

The primary difference between HV and "plug in" HV Prius becomes obvious if one looks at increasing the range or radius of the vehicle in electric mode, from about 2 km (Prius) to 23.4 km (PHV) [24]. In addition, specific fuel consumption in a hybrid mode is improved as well. Studies have shown that in Japan, 90% of drivers exceed the average daily distance below 50km, 60km and 75km in the EU and the U.S. respectively. In this case, the expected fuel economy greatly affects the price of electricity during the day, which in Japan is about 20 cents / kWh and late at night around 8 cents / kWh. It should be noted that the average price of electricity in Serbia is only about 5 EU cents / kWh.

The best-selling hybrid car in the U.S. "Toyota Prius", has the highest demand when the price of fuel rises. Country stimulates with $ 6.400 the cost of producers, so that the standard model sells for just U.S. $ 21.610. The fuel economy of this vehicle is 48mpg (4,9 l/100 km) in city driving and 45mpg (5,2 l/100km) on the open road. Compared to consumption of fuel per 100 km is 5,2 l/100km in city driving and 4.9 l/100km on the open road.

Large oil producers such as BP [25], are stipulating that in the next period until, 2030 PHV will dominate the market, mainly due to the reduction of fossil fuel consumption per kilometer distance.

• **EV fuel cell**

The fuel cell is an electrochemical device that is used to convert chemical energy into DC power. The principle of operation of this device is the opposite of the operation of the electrolyzer, and is composed of two electrodes between which is an electrolyte. The electrodes are separated by separators of the electrolyser, so in this space gasses are injected mainly hydrogen and oxygen. Oxidation takes place on anode and reduction of the fuel on cathode. Fuel cell system applied in autonomous electrical actuators is derived from the study of the space program [26].

The fuel cell has the potential to be more efficient than the engines for the following reasons [27]:

1. fuel cell produces little amount of collateral products;
2. has few moving parts (pumps for the chemical reaction and faucets);
3. during this conversion process converts the energy of fuel into heat;
4. the fuel is oxidized at a low temperature instead of burning in high temperature in the internal combustion engine;
5. shows a small components as a result of oxidation at low temperature;
6. In case of hydrogen (making the fluid), a side product is water.

Therefore, one can expect a wider application [28] of the "reservoir of energy" in the EV.

Based on the aforesaid, the following can be concluded - hydrogen plays a key role in the future clean energy, that is:

1. has the high energy content per unit weight of existing capacity;
2. when burned in the engine, hydrogen produces effectively zero emissions when powered by a fuel cell: only waste is water;
3. hydrogen can be produced from different national resources, including natural gas, coal, biomass, and even water;
4. Combined with other technologies such as carbon sequestration and storage, renewable energy and fusion energy, fuel cells can make future energy needs without harmful emissions.

The great hope is to be taken in the development and deployment of fuel cells, so that some researchers [29] believe that fuel cells are the only way to achieve true zero-emission transport. Company Vice President *Ballard* - Research and Development division [30], which develops and manufactures fuel cells, said that by 2020 or 2025th year will be about one million vehicles with fuel cells.

It is interesting to note that FCEV has a disadvantage that their quick-change loads are low, so their work has to be combined with Supercapacitors. Supercapacitors are electrochemical systems that store energy in a polarized liquid layer, the intermediate layer between the ion conducting electrolyte and conductive electrodes. The possibility of storing the energy increases with the surface area of the intermediate layer. They have a higher specific energy and power of electrolytic capacitors - devices that store energy as an electrostatic charge [31]. They were developed as primary energy equipment for extra power during acceleration and inclined driving as well as for recharging during braking [32].

They can be used as a secondary energy source in HEV, accumulating energy while the vehicle is stationary or during braking. Ongoing research and development tend to form ultracapacitors with the possibility of 50 Wh/kg specific energy and specific power of 1,000 W/kg. However, ultracapacitors have certain disadvantages. The additional electronics needed to maintain certain parameters taking into account the characteristic of the capacitor to the voltage at the ends of the capacitor decreases linearly in accordance with the energy of the discharge.

Older solution for energy storage is the flywheel. A flywheel is a flat disk or cylinder that spins at very high speeds, storing kinetic (movement) energy. A flywheel can be combined with a device that operates either as an electric motor that accelerates the flywheel to store energy or as a generator that produces electricity from the energy stored in the flywheel. The faster the flywheel spins, the more energy it retains. Energy can be drawn off as needed by slowing the flywheel.

Modern flywheels use composite rotors made with carbon-fiber materials which have a very high strength-to-density ratio, and rotate in a vacuum chamber to minimize aerodynamic losses.

Flywheels can discharge their power either slowly or quickly, allowing them to serve as backup power systems for low-power applications or as short-term power quality support for high-power applications. They are little affected by temperature fluctuations, take up relatively little space, have lower maintenance requirements than batteries, and are very durable.

• Battery-powered EV

Development of motor vehicles is going in the direction of renewable fuel and power, and there in the first place we see electrical energy that can be obtained from various sources. As previously noted [16-17], EV has higher degree of energy utilization and generally the existing solutions of sufficient quality except "reservoir of electricity." Existing batteries are not able to meet the habits of today's drivers of motor vehicles. Today, the most promising potential source of energy is the Li-air system.

The energy density of gasoline is 13,000 Wh/kg, which is shown as "a theoretical energy density" (Figure 07). The average utilization rate of passenger cars with IC engine, from the fuel tank to the wheels, is about 13% in US, so that "useful energy density" of gasoline for vehicles use is around 1.700 Wh/kg. It is shown as "practical" energy density of gasoline. The efficiency of autonomous electric propulsion system (battery-wheels) is about 85%.

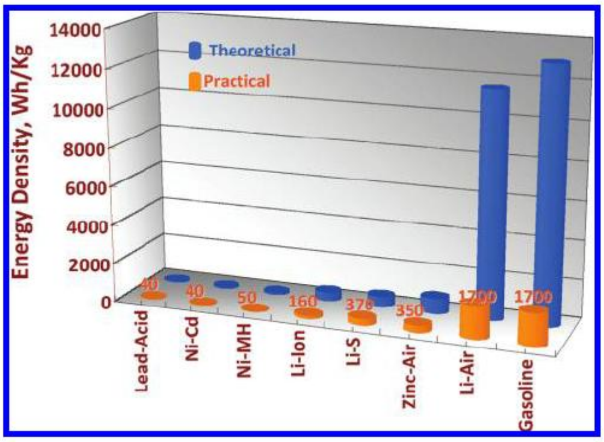

Figure *07. Image Energy density of different types of batteries and gasoline* [33]

Significantly improvement of current Li-ion energy density of batteries is about 10 times, which today is between 100 and 200 Wh/kg (at the cellular level), could make that electric propulsion system be equated with a gasoline powered, at least, to specific useful energy. However, there is no expectation that the existing batteries, as Li-ion, have ever come close to the target of 1,700 Wh/kg.

The latest researches are conducted in the field of graphene [34]. Graphene's good electrical conductivity and large surface area per unit mass make it an exciting material for energy storage applications such as advanced batteries and supercapacitors.

• **Comparison of the main characteristics of EV**

Comparison of basic characteristics of the EVs is shown in Table 02.

Table 02. Major characteristics of HEV, PEV, FCEV and BEV [35].

Type's of EVs	Hybrid EVs	PEVs	Fuel cell EVs	Battery EVs
Propulsion	Electric motor drives Internal combustion engine	Electric motor drives Internal combustion engine	Electric motor drives	Electric motor drives
Energy system	Battery Supercapacitor ICE generating unit Integrated starter generator	Battery Supercapacitor ICE generating unit Integrated starter generator	Fuel cells Need battery/ supercapacitor to enhance power density for starting	Battery Supercapacitor
Energy sources and infrastructure	Gasoline stations	Gasoline stations Electric grid charging facilities	Hydrogen Hydrogen production and transportation infrastructure	Electric grid charging facilities
Characteristics	Very low emission Long driving range Higher fuel economy as compared with ICE vehicles Dependence of crude oils Complex Commercially available	Very very low emission Long driving range Higher fuel economy as compared with ICE vehicles Dependence of crude oils Complex Commercially available	Zero emission or ultra low emission High energy efficiency Independence on crude oils Satisfied driving range High cost Under development	Zero emission Independence on crude oils High energy efficiency High initial cost Commercially available Relatively short range
Major issues	Managing multiple energy sources Dependent on the driving cycle Battery sizing and management	Managing multiple energy sources Dependent on the driving cycle Battery sizing and management	Fuel cell cost Hydrogen infrastructure Fueling system	Battery and battery management High performance propulsion Charging facilities

5. CONCLUSION

Although the EV appeared before the IEC vehicles, they could not withstand the competition more robust and more powerful IEC vehicles, which have marked the entire 20th century. Beginning of the 21st century, noted that it was necessary to develop a vehicle with new properties to transport people. The vehicle must be powered by renewable energy and be environmentally friendly. Bearing in mind that there are still no quality solutions, today vehicles are developed in two directions, to save fossil or non-renewable energy sources and to be environmentally friendly.

Vehicles that use alternative fuels, as well HV, significantly reduce the need for petroleum products. In addition, motor vehicles are becoming faster, environmentally cleaner, safer and more energy efficient.

If renewable electricity gets developed significantly in the next period, it will allow the possibility of its cheap production. This means that, in addition to environmental, economic conditions will be met for the broader application of EV. Almost all the problems related to the technology of production EV are sufficiently well resolved, except for storage of energy. Fuel cells, electrochemical or new resources that could be made cheap enough and compact would allow in the near future, pass from the vehicles that use liquid fuel to EV. Price of the batteries today seems EV to be more expensive than buying appropriate vehicles with conventional drive. Accordingly, the price of EV, according to the mileage compared to cars with internal combustion-powered, would be the same. Fuel for EV's is cheap, maintenance is minimal, and the duration of the electric motor is significantly longer than the internal combustion engine. Taking into consideration the cost of air pollution, gas emissions that cause the effect of "greenhouse gases" and other market conditions, the factors that the company has to pay, it is believed that the golden era of EV is coming.

It is likely, however, there won't be a quick transition from internal combustion vehicles to EV. Still EV's are considered to be inferior and can not meet the needs of potential buyers under all circumstances. The development of batteries has made great progress, but still not enough. In addition, if the battery problem is to be solved, there are still plenty of problems that need to be better addressed. Some of these problems will be solved on its own, such as drop in price of the components due to the increased production, but others, in support of the introduction of new vehicles in the traffic will be much harder to resolve spontaneously.

Set targets for electric-drive vehicle sales. To achieve the roadmap's vision, industry and government must work together to attain a combined EV / PHEV sales share of at least 50% of LDV sales worldwide by 2050th By 2020, global sales should achieve at least 5 million EVs and PHEVs (combined) per year [38]. Achieving these milestones will require that national governments lead strategic planning efforts by working with "early adopter" metropolitan areas, targeting fleet markets, and supporting education programs and demonstration projects via government-industry partnerships. Additionally, EV / PHEV sales and the development of supporting infrastructure should first occur in selected urban areas of regions with available, low GHG emission electricity generation.

It is believed that the future and the past belong to the EV. This is a positive step towards the introduction of environmental drive vehicles. However, since there is no definitive solution, experiments are conducted with pure electric and hybrid solutions. Despite the turbulent development of EV and HV, some experts believe that vehicles with internal combustion engines will dominate for another 15 years, but even after that will not disappear [36-37], primarily due to a reduction in fuel consumption per kilometer of distance. At the meeting of the Competitiveness Council in San Sebastian, in 2010, ACEA President Dieter Zetsche [38] made clear statement: “The question is not whether the diesel and petrol will be replaced by electricity and hydrogen as the dominant means of tank cars. The only question is when? “

ACKNOWLEDGEMENT

This work was financially supported by the Ministry of Education, Science and Technological Developments Republic of Serbia (Projects No. TR 36035, TR 35041 and TR 35042).

REFERENCES

[1] Nikolić Z., Živanović Z., Kragić R., Development and prospects of electric vehicles in the country, Proceedings of the First Conference on OIEE, Belgrade, SMEITS 2011, p.177-190.
[2] Fredzon, I.R., Sudovbie elektromehanizmbi, Gosudarsvenoe soioznoe izdetelbstvo sudostroitelbnoi promibišlennosti, Leningrad, 1958, p. 5.
[3] Kordesch K., The electric automobile, Union Carbide Corporation Battery Product Division, Ohio, (1978).
[4] Chan C. C., The Rise & Fall Of Electric Vehicles In 1828–1930: Lessons Learned, Proceedings of the IEEE, Vol. 101, No. 1, January 2013, p.206-212.
[5] Larminie J, Lowry J., Electric Vehicle Technology Explained, John Wiley & Sons Ltd, England, 2003, p.4.
[6] -, World Population to 2300, UN Department of Economic and Social Affairs, New York, (2004), 240, ST/ESA/SER.A/236
[7] -, International Organization of Motor Vehicle Manufacturers. via NationMaster http://www.nationmaster.com/graph/ind_car_pro-industry-car-production
[8] -, World energy Outlook 2010, International Energy Agency, Key Graphs, OECD/IEA 2010, http://www.iea.org/statist/index.htm
[9] -, BP Statistical Review of World Energy, June 2011, http://www.bp.com/statisticalreview
[10] -, BP Energy Outlook 2030, London, January 2011, http://www.imf.org/external/np/res/commod/pdf/ppt/BP0113.pdf

[11] -, Annual Energy Outlook 2011 with projections to 2035, EIA, U.S. Energy Information Administration, DOE/EIA-0383 (2011)

[12] -, Medium-term markets 2011 Overview, International Energy Agency, OECD/IEA 2011, www.iea.org

[13] Metz B., Davidson O., Bosch P., Dave R., Meyer L., Climate Change 2007 Mitigation, Cambridge University Press, New York, USA

[14] CO2, International Organization of Motor Vehicle Manufacturers, OICA, World Resources Institute, Climate Analysis Indicators Tool, Transportation&stockbyte, p. 6.

[15] - , BP Energy Outlook 2035, January 2014, bp.com/energyoutlook, #BPstats

[16] -, International Organization of Motor Vehicle Manufacturers. via NationMaster http://www.nationmaster.com/graph/ind_car_pro-industry-car-production

[17] Bilen B., Nikolić Z., Mogućnosti i perspektive električnih vozila, Zbornik radova sa XVI međunarodnog skupa NMV 97, Beograd, (1997), p.49-52.

[18] Nikolić Z., Marjanović S., Dakić P., Neki rezultati ispitivanja električnog vozila YUGO-E, Zbornik radova sa XVI međunarodnog skupa NMV 97, Beograd, (1997), p.53-56.

[19] Higgins A., Profile of Ralf Schuermans, Electric & Hybrid Vehicle Technology International, July 2009, p.120.

[20] Akihira W., The Automobile of Tomorrow: Toyota,s Approach, A Toyota quaterly rewiew, No. 100, 1997, p.30-37.

[21] www.uscar.org/freedomcar

[22] -, Kampman B., Leguijt C., Bennink D., Wielders L., Rijkee X., De Buck A., Braat W., Green Power for Electric Cars, Development of policy recommendations to harvest the potential of electric vehicles, Delft, CE Delft, January 2010, page 20.

[23] Bagot N., It,s good, but is it enough?, Electric & Hybrid Vehicle Technology 97, 1997, p.22-23.

[24] Abe S., Development of Toyota Plug-in Hybrid Vehicle, Journal of Asian Electric Vehicles 2010; 8: p.1399-1404 . Journal of Asian Electric Vehicles, Volume 8, Number 2, December 2010, p.1399-1404.

[25] -, Annual Energy Outlook 2011 with projections to 2035, EIA, U.S. Energy Information Administration, DOE/EIA-0383 (2011)

[26] Panik F., Fuel cell for vehicle applications in cars - bringing in future, Journal of Power Sources 71 (1998), p.36-38.

[27] Frederick Veit R., Fuel of the future, Electric & Hybrid Vehicle Technology 98, 1998, p.124-127.

[28] Joon K., Fuel cells - a 21 st century power system, Journal of Power Sources 71 (1998), 12-18, Lamy C., Leger J.M., Fuell Cells - Aplication to Electric Vehicles, Journal de Physique IV, vol 4, 1994, p. 253 - 281,

[29] Nnji N., Fuel cells, Electric & Hybrid Vehicle Technology International, annual 2008, p.30-36.

[30] – Fuel cell future, Electric & Hybrid Vehicle Technology International, annual review 2005, p.96.

[31] Harrison R., Create a super car, Electric & Hybrid Vehicle Technology, annual review 2000, p.144-145.

[32] Baudry P., Marquet A., Application of Solid-State Electrolite Generators for Electric Utilities, Electrochemica Acta, vol 37, Iss. 9, 1992, p. 1627 – 1629.

[33] Girishkumar, L.G.G., McCloskey, B., Luntz, A. C., Swanson, S., and Wilcke, W., (2010), Lithium-Air Battery: Promise and Challenges, J. Phys. Chem. Lett. 2010, 1, 2193-2203, doi: 10.1021/jz1005384 |

[34] Jari Kinaret, Vladimir Falko, Andrea Ferrari, Jani Kivioja, Tomas Löfwander, Daniel Neumaier, Konstantin Novoselov, Vincenzo Palermo, Stephan Roche, GRAPHENE-CA, Coordination Action for Graphene-Driven Revolutions in ICT and Beyond Coordination and support action WP3 Defining the Research Agenda, Deliverable 3.2 “Research agenda for the GRAPHENE flagship”, Project funded by the European Commission under grant agreement n°284558

[35] Kamil Çagˇatay Bayindir, Mehmet Ali Gözüküçük, Ahmet Teke, A comprehensive overview of hybrid electric vehicle: Powertrain configurations, powertrain control techniques and electronic control units, Energy Conversion and Management 52 (2011) p.1305–1313.

[36] - International Energy Agency (IEA), Technology Roadmap, Electric and plug-in hybrid electric vehicles, June 2011, p.4.

[37] Higgins A., Profile of Ralf Schuermans, Electric & Hybrid Vehicle Technology International, July 2009, p.120.

[38] Dieter Zetsche, The Future of Electric Cars - The Automotive Industry Perspective, San Sebastian, 9 February 2010, http://www.acea.be/images/uploads/files/20100211_Speech_Dieter_Zetsche.pdf