Provisional chapter

The Contribution and Prospects of the Technical Development on Implementation of Electric and Hybrid Vehicles

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Additional information is available at the end of the chapter

1. Introduction

Population growth in the world had a constant value since the beginning of a new era to the 19th century when the population was 1 billion. The technological revolution is largely influenced by that in this century, the population increase by 68%. The population in the world increased by about 270%, or over 6 billion people just in the 20 century. Although the UN in [1], estimates three possible scenarios of population growth in this century, the **Figure 1**, is the most possible one that predicts that the world population will increase by 2050 to about 8,9 billion, and afterwards it will be a slowdown so that by the end of the 21st century, and in the next few, does not expect the growth of population in the country. In any case, in the near future over the next four decades strong growth of the population is expected. With the growth of population in the world there is a need to increase transportation of people, goods and raw materials as a prerequisite for the growth of production and consumption and the standards of living.

The 19th century was the age of industrial revolution. Thee more factors enabled the industrial revolution. The first was the new steam and textile technology and then the new agriculture and population growth crating both the labor force for the new industrial factories and the markets to buy their manufactured goods [2]. Development of a superior transportation system for getting raw materials was basis that colonials provided raw materials for the factories as well as more markets for their goods.

The result of all this was an industrial revolution of vast importance in a number of ways. For one thing, it would spawn the steam powered locomotive and railroads which would

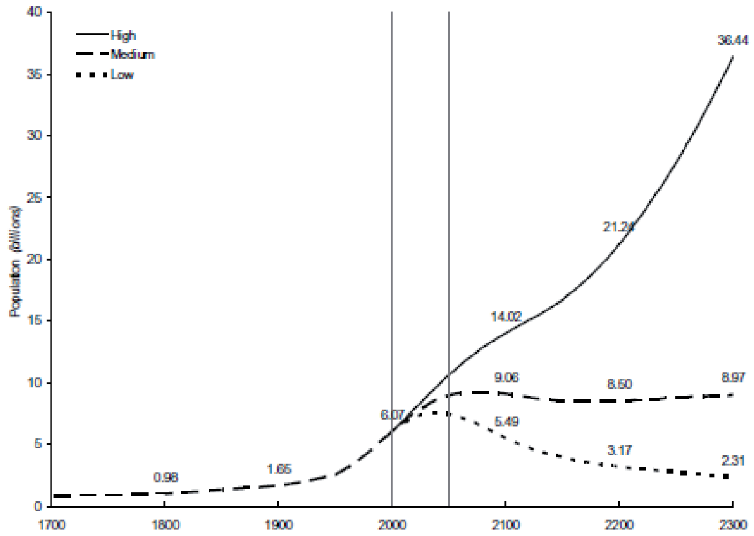

Figure 1. World population estimation and prediction 1700th – 2300th, in ref. [1].

revolutionize land transportation and tie the interiors of continents together to a degree never before imagined. It would trigger massive changes in people's living and working conditions as well as the structures of family and society. No invention of the 1800's played a more vital role in the Industrial Revolution than the steam locomotive and railroad, triggering the biggest leap in transportation technology in history. Railroads cut travel time by 90% and dramatically reduced freight costs, see [3].

With factories more closely connected to markets and the larger population of potential consumers, many more people could afford consumer goods. This stimulated sales, providing more jobs, increased production, and lower prices. With business booming, companies developed new products, triggering a virtual explosion of new technological advances, inventions, and consumer products in the latter 1800's. All these advances led to a higher standard of living, which further increased the consumer market, starting the process all over again [2].

The first step most countries took to industrialize was to build railroads to link coal to iron deposits and factories to markets. Once a transportation system was in place, factory building and production could proceed. By 1900, railroads had virtually revolutionized overland transportation and travel, pulling whole continents tightly together (both economically and politically), helping create a higher standard of living, the modern consumer society, and a proliferation of new technologies [2].

From the start, industrialization meant the transformation of countries' populations from being predominantly rural to being predominantly urban. By 1850, Britain had become the first nation in history to have a larger urban than rural population, and London had become the largest town in the world.

These early industrial cities created problems in three areas: living conditions, working conditions, and the social structure. First of all, cities built so rapidly were also built shoddily. Tenement houses were crammed together along narrow streets, poorly built, and incredibly crowded.

But in second half of 19th century, the standard of living of the common people improved, they had money to buy goods. Sales and profits led to more production and jobs for more people, who also now had money to spend. This further improved the standard of living, leading to more sales, production, jobs, and so on, all of which generated the incentive to create new products to sell this growing consumer market. It was the age of progress [2].

Steam powered ships reduced travel time at sea much as the steam locomotives did on land since ships were no longer dependent on tail winds for smooth sailing.

By 1900, the automobile, powered by the internal combustion engine, was ushering in an age of fast personal travel that took individuals wherever and whenever they wanted independently of train schedules. In 1903, the internal combustion engine also allowed human beings to achieve their dream of powered flight. The sky was now the limit, and even that would not hold up, as the latter twentieth century would see flights to the moon and beyond [2].

Fuelling these new developments were new sources of energy. Petroleum powered the automobile, while natural gas was used extensively for lighting street lamps. Possibly most important of all was electricity, which could be transmitted over long distances and whose voltage could be adapted for use by small household appliances. Among these was Thomas Edison's light bulb, providing homes with cheaper, brighter, and more constant light than the candle ever could provide [2].

The 19th century was the age of electricity. For the development of electric vehicles is important 1800. when for the first time Allessandro **Volta** (Italian) produces an electrical power from a battery made of silver and zinc plates. After many other more or less successful attempts with relatively weak rotating and reciprocating apparatus the Moritz Jacobi created the **first real usable rotating electric motor** in May 1834 that actually developed a remarkable mechanical output power [4]. His motor set a world record which was improved only four years later. On 13 September 1838 Jacobi demonstrates on the river Neva an 8 m long electrically driven paddle wheel boat, in [5]. The zinc batteries of 320 pairs of plates weight 200 kg and are placed along the two side walls of the vessel. The motor has an output power of 1/5 to 1/4 hp. (300 W) [6]. The boat travels with 2,5 km/h over a 7,5 km long route, and can carry a dozen passengers. He drives his boat for days on the Neva. A contemporary newspaper reports states the zinc consumption after two to three months operating time was 24 pounds.

In 1887 Nikola **Tesla** (Serbian, naturalized US-American) files the first patents for a two-phase AC system with four electric power lines, which consists of a generator, a transmission system and a multi-phase motor. Presently he invention the **three-phase electric power system** which is the basis for modern electrical power transmission and advanced electric motors. The inventor for the three-phase power system was Nikola Tesla, see reference [7]. But, the highly successful **three-phase cage induction motor** was built first by Michael Dolivo-Dobrowolsky in 1889.

2. Beginning of the EV development

The first attempt of electric propulsion was made on railways in the first half of the 19th century. It was not about cars, but as a locomotive fed by batteries, it is reasonable that this is considered a forerunner of the current prototype electric vehicles.

Robert Davidson (Scottish) also developed electric motors since 1837th in [8]. He made several drives for a lathe and model vehicles. In 1839, Davidson manages the construction of the first electrically powered vehicle. In September 1842, he makes trial runs with a 5-ton, 4,8 m long locomotive on the railway line from Edinburgh to Glasgow. Its electromotor makes about 1 hp. (0,74 kW) and reaches a speed of 4 mph (6,4 km/h) [6], a vehicle could carry almost no payload. Therefore, the use of the vehicles was very limited. Gaston Plante found a suitable battery pack in 1860th year, enabling the commercialization of electric vehicles.

At the world exhibition in Berlin 1879th years, Siemens has demonstrated the first practical electric vehicle applicable for, for example, a small electric battery tractor on rails, which was able to pull three small carriages full of people. Motor has had almost all the characteristics of today's motors for electric traction.

Already in 1881st year after on the streets of Paris was driven tricycle powered from lead-acid batteries. A year later, a horse power-drawn tram with electric propulsion was rebuilt, so that up to 50 passengers could be driving these carriages without horses. Several years later, Thomas Edison had constructed a little better first electric vehicle with nickel-alkaline batteries that are powered electric vehicle with nominal power of 3,5 kW. Immediately afterwards, the electric bus was built as well.

In England J.K.Starley constructed in 1888th the small electric vehicle [9]. Several years later, on 1893. Bersey constructed a postal vehicle and a passenger vehicle with four seats using a battery brand Elwell - Parker.

Since then, efforts are continuing, especially in America. According to some sources, the first electric vehicle in the United States was constructed by Fred M. Kimball 1888th, from Boston. In commercial use, the vehicle began to produce the first company Electric Carriage and Wagon Co. of Philadelphia, which has produced a vehicle 1894th, and the 1897th New York City has delivered a number of electric taxis. Another company, Pope Manufacturing Co. from Hartford, began producing electric vehicles 1897th years and has evolved considerably. Company produced 2.000 taxis as well as busses and electric trucks. However, they did not have great commercial success.

The first small batch production of EV had began in 1892 in Chicago [10]. These vehicles had been very cumbersome but even so had a very good pass by customers also. They had carriages of look like (**Figure 2**), with large wheels, no roof, with eaves that protected passengers from rain and sun. They were used for trips, in order to perform some business, and even as a taxi to transport more passengers. Passenger's EV had the engine up to several kilowatts, which were allowed at the maximum speed of about 20 km/h, and cross a distance over a hundred kilometers on a single charge of batteries. Series DC electric motors were used, usually. Batteries have a high capacity, as far as 400 Ah, and voltages up to 100 V. Proportion of battery

Figure 2. First EV's were possible to cross up to 100 km, moving with speed below 20 km/h.

weight, compared to a fully loaded vehicle with passengers, was over half, which allowed so many autonomous movement radius.

In Europe, the first real electric vehicle was constructed by the French and Jeantaud Raffard in 1893rd. Electric motor power was 2,2 to 2,9 kW (3–4 hp), a battery capacity of 200 Ah was placed behind and had a weight of 420 kg.

In 1894, five electric vehicles participated in the first automobile race held from Paris to Rouen, a distance of 126 km. One steam vehicle won, from manufacturers De Dion.

The first race of motor vehicles was won by electric. Five vehicles with internal combustion engine and two cars with electro propulsion were racing on the road, which consisted of five sections, each one mile long (1.609 m). The winners in all five sections were electric with an average speed of 43 km/h.

Bright moment for electric vehicles in Europe was the 1899th, when on the May 1, an electric vehicle in the form of torpedo, called Jamais Contente or "dissatisfied" reference [11], reached a speed of 100 km/h. Electric vehicle weight about 1.800 kg and was constructed by Belgian Camille Jenatzy, in [12].

The next world record speed was achieved a few years later with the vehicle which had a gasoline engine and electric vehicles were never more able to develop greater speed than vehicles with internal combustion engine (**Figure 3**).

Waldemar Jungner in 1899, first patented alkaline battery in the world. In the summer 1900th he demonstrated its capacity before the wondering audience of professionals. One battery

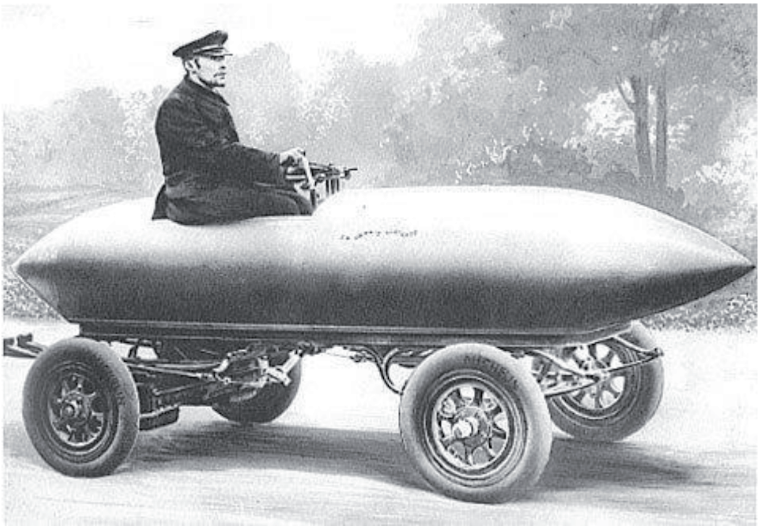

Figure 3. Electric vehicles named Jamais Contente, which in 1899, reached previously unimaginable speed of over 100 km/h.

is kept at the Waverly American Run car with which the inventor was able to drive around Stockholm in an electric vehicle for about 12 hours and with whom he went 92,3 miles (148,5 km) before the battery was discharged.

Given the fact that at the end of the 19th and early 20th century EV were moving at low speeds when the power required for handling the air resistance is negligible, the power obtained from batteries was mainly used for handling the rolling resistance, which is generally small. On the other hand, less power drain causes battery operation with a higher efficiency level so a large quantity of batteries loaded allowed a relatively large radius of movement.

3. The development of EV in 20th century

The twentieth century has been a century of change. It has been a century of unprecedented world population growth, unprecedented world economic development and unprecedented change in the earth's physical environment.

From 1900 to 2000, world population grew from 1,6 billion to 6,1 billion persons, about 85 per cent of the growth having taken place in Asia, Africa and Latin America [13].

In 1900, about 86 per cent of the world populations were rural dwellers and just 14 per cent were city dwellers, but by 2000, the share of the world population living in rural areas had declined to 53 per cent, while the number of urban-dwellers had risen to 47 per cent, in [14]. By 2030, over three fifths of the world will be living in cities. Virtually all the population growth expected during 2000–2030 will be concentrated in the urban areas of the world.

The enormous expansion in the global production of goods and services driven by technological, social and economic change has allowed the world to sustain much larger total and urban populations, and vastly higher standards of living, than ever before. For example, from 1900 to 2000, world real GDP increased 20 to 40 times, while world population increased close to 4 times and the urban population increased 13 times [13].

The first motor show held in New York 1901st was shown 23 and 58 steam electric and petrol cars were presented together. At the beginning of this century were used three types of motor vehicles with internal combustion engines that used: gasoline, steam or electricity. Statistics show that in 1900 from 8.000 cars driven on the roads in America, 38% were powered by electricity.

Almost equally, the third of the total number of vehicles, at the time was powered to electric power, steam vehicles and vehicles with internal combustion engines.

The car with the internal combustion engine has received increasing popularity due to its ease of charging, mobility, speed and autonomy, although the electric vehicle was still kept. Electric vehicles are especially favored by women, whom thought of the car with petrol as dirty and difficult to drive, and in the same time those looked like the features for which they were more preferred by men, driven by passion for the sport.

Defect of those electric vehicles then has been relatively short range between charges. In the late 19th century, the specific energy in the battery pack was about 10 Wh/kg. Already in the early 20 century, this value improved to the level of 18 Wh/kg, which would amount to only a decade later to 25 Wh/kg [10]. In addition, the charging stations were not sufficiently widespread, although the situation began to improve in the early 20th century. However, sources of oil found in that period caused the low price of gasoline and the advancement of technology in the production of internal combustion engines has created the conditions for rapid progress on these cars. Therefore, the development of electric vehicles remained on the sidelines (**Figure 4**).

Studebaker developed in 1905 five models of electric traction, using the same chassis. From 1900 to 1915 year a hundred manufacturers of electric vehicles appeared. In 1904, about a third of U.S. vehicles were produced with electro propulsion. In 1912, about 10.000 electric vehicles were produced, of which about 6.000 as passenger's vehicles and 4.000 for the transportation of goods. The total traffic had approximately 20.000 vehicles to transport people and about 10.000 for freight transport. 1913th twenty companies manufacturing electric vehicles produced about 6.000 electric cars and trucks.

In the rally ride in the long run, from Beijing to Paris 1907th, gasoline cars definitely won over steam and electricity vehicles. Wide publicity made Dey and Harry Staymez invention in 1915. Their electric car instead of the differential had motor that was designed in the way that the rotor and stator, each connected to one half of axle, were able to turn in relation to one another. Thus, power shared between the two axles was able to turn at different speeds when cornering. Upon driving on downhill, the electric motor was turning into a dynamo serving as brakes and converting mechanical energy into electrical energy.

One passenger electric vehicle in 1917 crossed the distance from Atlantic City to New York (200 km) at an average speed of 33 km per hour.

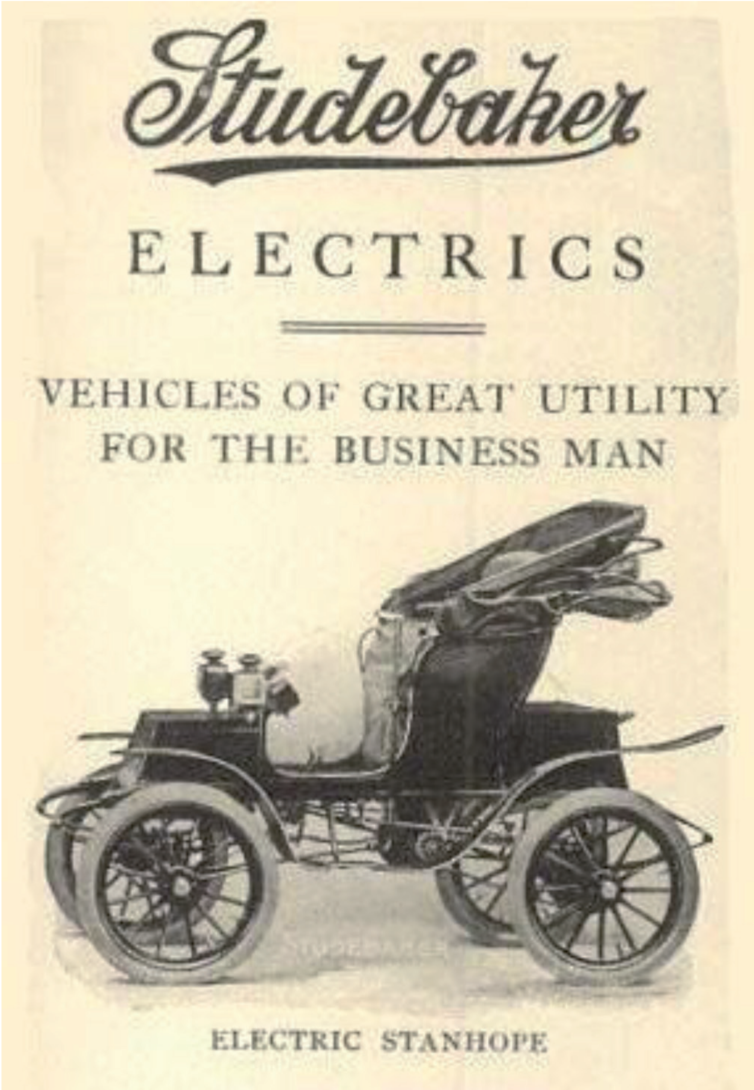

Figure 4. The external appearance of the first EV in early 20th century.

In the twenties of this century in Germany, France and Italy, electric vehicles were designed mainly for special purposes, where it did not require more speed and autonomy. Stigler from Milan, a company specialized in electric products, constructed in 1922 more one car with electric drive power of 4.5 kW (6 KS) and battery capacity of 250 Ah, which could speed up to 25 km/h to cross 100 km without recharging.

Before and after World War II many electric vehicles were on the streets of America, Western Europe and South Africa. The Last Car Show in America where a new type of electric vehicle was shown was in 1923 year.

1930 was the year when the appearance of the Fords model T, for some time, marked the dissolution of the companies that produced electric vehicles.

Soon after interest in electric vehicles was lost, even in Europe and the success of the vehicles with internal combustion engine was triumphant. The performance of electric vehicles compared to internal combustion vehicles was fairly weak. The problem of batteries that were heavy and inefficient remained unresolved. Performance of the car made for special purposes, with a short radius of movement, could not be accepted for cars that could compete with gasoline powered ones.

World War II re-emphasized in the foreground electrical traction. For convenience in the normal production some vehicles were transferred to vehicles with electro propulsion. In Italy, you could have seen the car Fiat 500 (old Topolino), accumulator battery-powered weighing over 400 kg, as well as the bigger vehicles with batteries stored in the engine and trunk space. During this period was specially designed and manufactured in a number electric Peugeot VLV. These vehicles have an advantage over the vehicles with internal combustion engines due to significantly lower maintenance costs and longer service life, making them seem more economical for exploitation.

After World War II, electric traction has remained largely reserved for special transportation and the smaller vehicles that are commonly used in the city.

3.1. Early development of drive systems

In the first EV were mostly used serious DC motors with a simple speed control solutions. In these electric motors are the excitation coil and the inductive coil connected to the serious so that the current that passes through the inductors passes through the excitation coil. This means that is in the great parts of range machine, until it comes into part of the saturation, flux is proportional to the loaded current. Only at higher loads and currents when the magnetic material enters the saturation, there is no proportionality between the magnetic flux and current, because the increase in current does not produce increase in flux.

For the operation of the serious DC motors are characteristic the great changes in flux with the load. Electric motor speed is changed in wide limits as a function of load change.

At idle load current are small and the excitation flux, so there is a risk of engine ran. Therefore, the engine should never be put into operation, under full power, without at least 20–30% rated load.

At idle, load current is small as the excitation flux, so there is a risk of electromotor over speed. Therefore, the engine should never be put into operation under full voltage without at least 20–30% rated load.

Speed regulation of DC electromotor can be making by changing the supply voltage or by load changing. Because DC electromotor has feature, that torque increase with the increasing of load and rotation speed falling, these electromotor are sometimes called traction. DC electromotor can be very hardly move in the regenerative mode and only if we make a reconnection of the winding.

- **Start-up with additional resistance**

Additional resistance is connected into the serious with a driving motor and thus lowers the voltage at the ends of the motor and reduces the starting current. With more resistance, which allows successively excluding, it is possible step-shaped voltage and speed regulator. This is a wasteful method with a low degree of usefulness.

- **Commissioning and speed control via contactors (controller)**

Relatively inexpensive and efficient method, but not enough good for regulation of electric vehicle speed. The necessary condition is that the voltages of all electric sources have to be equal, so appropriate involvement of the switches can get the basic voltages on the electric motor.

Additional regulation of the speed of rotation of electric motors can be done by additional rheostat for the step by step decreasing of flux, by which the speed increases and the torque decreases.

Former methods of starting the electric motor and speed control of the vehicle were less quality but good enough to move the EV with relatively low speeds. In addition, there were certain losses in the resistor for speed control of electric motors and did not provide recuperative braking.

3.2. The first oil crisis

Since 1869, US crude oil prices adjusted for inflation averaged 23,67 $ per barrel (1 barel = 159 l) in 2010 dollars compared to 24,58 $ for world oil prices. Fifty percent of the time prices U.S. and world prices were below the median oil price of 24,58 $ per barrel [15].

If long-term history is a guide, those in the upstream segment of the crude oil industry should structure their business to be able to operate with a profit, below 24,58 $ per barrel half of the time. The very long-term data and the post World War II data suggest a “normal” price far below the current price (**Figure 5**).

From 1948 through the end of the 1960s, crude oil prices ranged between 2,50 $ and 3,00 $. The price oil rose from 2,50 $ in 1948 to about 3,00 $ in 1957. When viewed in 2010 dollars, a different story emerges with crude oil prices fluctuating between 17 $ and 19 $ during most of the period. The apparent 20% price increase in nominal prices just kept up with inflation.

From 1958 to 1970, prices were stable near 3,00 $ per barrel, but in real terms the price of crude oil declined from 19 $ to 14 $ per barrel. Not only was price of crude lower when adjusted for inflation, but in 1971 and 1972 the international producer suffered the additional effect of a weaker US dollar.

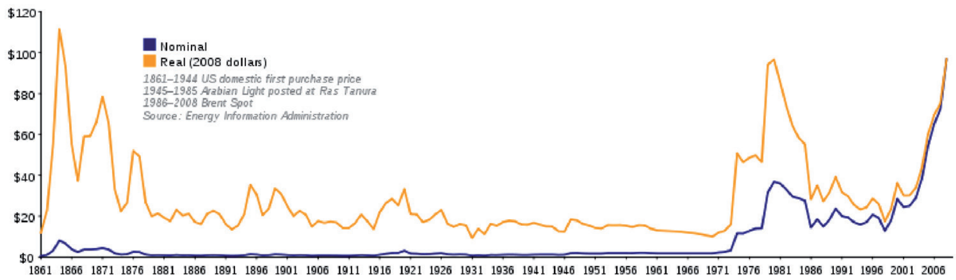

Figure 5. Long-term oil prices, 1861–2008 (orange line adjusted for inflation, blue not adjusted). Due to exchange rate fluctuations, the orange line represents the price experience of U.S. consumers only, in [16].

OPEC was established in 1960 with five founding members: Iran, Iraq, Kuwait, Saudi Arabia and Venezuela [15]. Two of the representatives at the initial meetings previously studied the Texas Railroad Commission's method of controlling price through limitations on production. By the end of 1971, six other nations had joined the group: Qatar, Indonesia, Libya, United Arab Emirates, Algeria and Nigeria. From the foundation of the Organization of Petroleum Exporting Countries through 1972, member countries experienced steady decline in the purchasing power of a barrel of oil.

Throughout the post war period exporting countries found increased demand for their crude oil but a 30% decline in the purchasing power of a barrel of oil. In March 1971, the balance of power shifted. That month the Texas Railroad Commission set proration at 100 percent for the first time. This meant that Texas producers were no longer limited in the volume of oil that they could produce from their wells. More important, it meant that the power to control crude oil prices shifted from the United States (Texas, Oklahoma and Louisiana) to OPEC. By 1971, there was no spare production capacity in the U.S. and therefore no tool to put an upper limit on prices.

A little more than two years later, OPEC through the unintended consequence of war obtained a glimpse of its power to influence prices. It took over a decade from its formation for OPEC to realize the extent of its ability to influence the world market.

In 1972, the price of crude oil was below 3,50 $ per barrel. The Yom Kippur War started with an attack on Israel by Syria and Egypt on October 5, 1973. The United States and many countries in the western world showed support for Israel. In reaction to the support of Israel, several Arab exporting nations joined by Iran imposed an embargo on the countries supporting Israel. While these nations curtailed production by five million barrels per day, other countries were able to increase production by a million barrels. The net loss of four million barrels per day extended through March of 1974. It represented 7 percent of the free world production. By the end of 1974, the nominal price of oil had quadrupled to more than 12,00 $.

Any doubt that the ability to influence and in some cases control crude oil prices had passed from the United States to OPEC was removed as a consequence of the Oil Embargo. The extreme sensitivity of prices to supply shortages, became all too apparent when prices increased 400 percent in six short months [15].

From 1974 to 1978, the world crude oil price was relatively flat ranging from 12,52 $ per barrel to 14,57 $ per barrel. When adjusted for inflation world oil prices were in a period of moderate decline. During that period OPEC capacity and production was relatively flat near 30 million barrels per day. In contrast, non-OPEC production increased from 25 million barrels per day to 31 million barrels per day.

In 1979 and 1980, events in Iran and Iraq led to another round of crude oil price increases. The Iranian revolution resulted in the loss of 2,0–2,5 million barrels per day of oil production between November 1978 and June 1979. At one point production almost halted.

The Iranian revolution was the proximate cause of the highest price in post-WWII history. However, revolution's impact on prices would have been limited and of relatively short duration had it not been for subsequent events. In fact, shortly after the revolution, Iranian production was up to four million barrels per day [15].

In September 1980, Iran already weakened by the revolution was invaded by Iraq. By November, the combined production of both countries was only a million barrels per day. It was down 6,5 million barrels per day from a year before. As a consequence, worldwide crude oil production was 10 percent lower than in 1979.

The loss of production from the combined effects of the Iranian revolution and the Iraq-Iran War caused crude oil prices to more than double. The nominal price went from 14 $ in 1978 to 35 $ per barrel in 1981 [15].

3.3. Renaissance of EV

In the seventies began the renaissance of EV. Fixed price of oil, which is less and less available, and the problems associated with its production and transport, leads to renewed interest in electric vehicles. At that time, it seemed that the coal and oil reserves would exhaust quickly, predicted at the beginning of the third millennium, so the world began to think about the "energy conservation". In addition, ongoing technical advances made with high quality and effective solutions of speed regulator for electric motor, lighter batteries and lighter materials for the body.

After 1970, environmental problems and oil crises increased the actuality of electric vehicles. Especially in the United States the interest of the citizens awoke who have acquired a habit to use widely electric vehicles for golf courses, for airports, for parks and fairs. According to some sources, one third of vehicles intended for driving on gravel roads were with electric traction. So there was a need to develop a new industry.

1974 Sebring - Vanguard began producing electric vehicles on the lane. City Car with two-seat, weighs 670 kg, and an electric voltage 48 V, 2,5 kW power only, achieved a maximum speed of 45 km/h. With an improved variant of this operation the maximum speed of 60 km/h was accomplished. The vehicle exceeded up to 75 kW with a single charge of batteries and the cost was about 3.000 US$. Only between the 1974th and 1976, about 2.000 of these vehicles was produced 1974. Copper Development Association Inc. made a prototype electric passenger vehicle. Although it used lead-acid batteries, it could develop a top speed of 55 mph (90 km/h), and could go over 100 mph (161 km/h with one battery charge at a speed of 40 mph (65 km/h).

Among the achievements of the General Motors company at the time was the GM 512 vehicle designed for drive in urban areas that are closed for classic cars. These are two types of small passenger vehicles with a carriage-body constructed partly of glass resin, but one is with pure electro propulsion and the other is a hybrid. Basic data on pure electric version are: weight 560 kg, the engine of 6 kW, a maximum speed of 70 km/h. With a 150 kg lead acid batteries could be run without charge from 50 to 70 km. It was supplied even with an air conditioning.

The largest exhibition of electric vehicles ever made till then, EV Expo 78, in [17], was held in Philadelphia. Expo displayed more than 60 electric vehicles with prices from 4.000 $ to as much as 120.000 $ (**Figures 6** and **7**).

The first electric vehicle, General Motors, a prototype car with four seats cost 6.000 $. It was planned as a second family vehicle.

Secondly there is an electric vehicle Electric Runabout Copper, who is a manufacturer of Copper Development Association Inc. said that it can be produced for 5.000 $. The vehicle mass of 950 kg, with four seats, made of fiberglass, had a top speed around 110 km/h could not move without charge to 130 km before its battery runs out of battery. It has a 10 kW electric motor that could, in one-hour mode, it delivers up to 15 kW and ups eliminates up to 22%. Weight of batteries was about 380 kg.

Most EV were relatively modestly equipped, but the Electric Car Corporation of Michigan, he believed the first luxury electric vehicle called the Silver Volt. The prototype of this five-seat EV has achieved a top speed of movement 110 km/h had a radius of 160 km between charges the battery. Silver Volt owned air conditioning and was sold for about 15.000 $ (**Tables 1** and **2**).

Some companies also produce and display luxury EV priced up to 120.000 $ the most expensive ever built passenger car of this type.

Figure 6. A typical city car (City Car) with two seats, weighs only 670 kg had a top speed of 28 mph (45 km/h) and radius of movement up to 65 km.

Figure 7. Copper City electric Car Runabouh power 15kW made on the basis of cooperation for the use components of Renault R5.

Laden vehicle total weight 1.134 kg			Empty vehicle Curb weight 934 kg
46,3%	Body	542 kg	56,1%
27,3%	Batteries	310 kg	33,2%
8,8%	Electric propulsion	100 kg	10,7%
13,2%	2 passengers	150 kg	
4,4%	Payload	50 kg	

Table 1. Percentage distribution of the reconstructed mass of the vehicle YUGO-E when it is empty and loaded.

The majority of EV is driven by a conventional lead-acid batteries that are found even 1868th years and are still the mainstay of the vehicles. But the lead-acid batteries have also already been the primary limiting factor for the development of EV. Pointed out that at least 40 million vehicles in the U.S., a total of 110 million, can be electrically driven second family vehicle as meeting the ecology and urban and suburban driving conditions. However, lead batteries and still remain a limiting factor in EV that time.

From this period, the EV was largely rebuilt vehicles from the existing series production vehicle with the drive IC. And with a maximum weight of lead acid batteries, the performances of these cars were quite limited. As an example, the percentage distribution of the reconstructed mass of the vehicle can serve example of the reconstructed vehicle YUGO-E when it is empty and loaded, reference [18, 19].

3.4. Impact of the development of power electronics on the development of EV

The invention of the transistor in 1948 revolutionized the electronics industry [20]. Semiconductor devices were first used in low power level applications for communications,

YUGO - E		Type of vehicle	Passanger
1. Body			
dimensions	3,49*1,542*1,392 m	Empty vehicle weight	934 kg
Useful load	2 persons +50 kg	drive	front-wheel
Brakes	disk, front and back	Control	over the rack
2. Direct current electric motor		Power	6,3 kW
Voltage	72 V	Rated current	113 A
Number of revolution	2.800 min^{-1}	Weight	38 kg
3. Battery		Type	traction
Total voltage	72 V	Capacity (20 h)	143 Ah
Pieces	6	Total Weight	294 kg
4. Voltage regulator		Type	transistor chopper
Current limit	180 A	Voltage drop at current of 100 A	0,7 V
Undervoltage disconnection	48 V	Weight	4 kg
5. Battery charger		Battery charger characteristic	IUUo
Voltage	72 V	Current	18 A
Power	1.800 W	Weight	38 kg
6. DC/DC converter		Type	with galvanic isolation
Output voltage	13,5 V	Maximum output currant	22,2 A
power	300 W	Weight	2 kg

Table 2. Technical data of electric drive Yugo-E, in [13].

information processing, and computers. In 1958, General Electric developed the first Tyristor, which was at that time called SCR, in [21]. Since around 1975, more turn-off power semiconductor elements were developed and implemented during the next 20 years, which have vastly improved modern electronics. Included here are improved bipolar transistors (with fine structure, also with shorter switching times), Field Effects Transistors (MOSFETs), Gate Turnoff Thyristors (GTOs) and Insulated Gate Bipolar Transistors (IGBTs) (**Figure 8**) [20].

Although they initially made Chopper with thyristors, later almost exclusively were made with transistors. The main difference is that Chopper with thyristors operates up to several hundred Hz, and the power transistors and up to several tens of kHz. For use the EV used Chopper with mutual influence (for lowering and raising the voltage), because this type of chopper allows propulsion and recuperative or regenerative braking drive motors. In this way it is possible

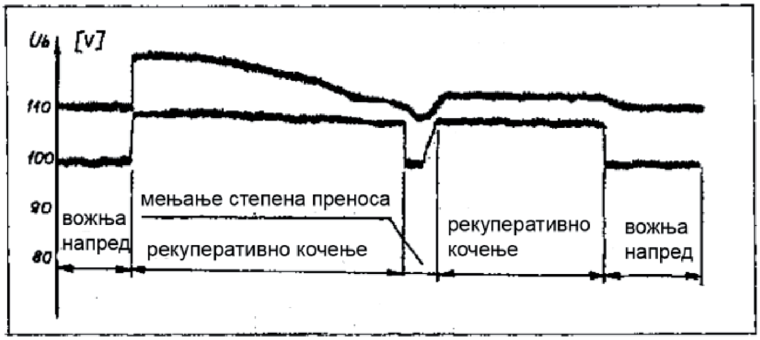

Figure 8. Change the battery voltage during DC recuperative braking in [22, 23].

to drive DC generator machine brake or braking to convert mechanical energy into electrical energy in [24].

It is well known, there are two modes of operation of electric vehicles. In the **electric motor drive mode**, in the operation is step down chopper and the average voltage on the electric motor is less then battery voltage. In the **electric braking mode**, in the operation is step up chopper, so the less voltage of the electric motor supply battery on higher level voltage and on that way there is recuperative braking.

3.5. End of the 20th century

Late 20th century contributed to an even greater exacerbation of conditions around the EV application. Scientists have become aware that environmental pollution is becoming larger, the emission of exhaust gases and particles affect climate change and that non-renewable energy sources under the influence of high demand and exploitation are becoming more expensive and slowly deplete.

Technology is certainly a double edged sword that has also created new problems such as pollution, overpopulation, the greenhouse effect, depletion of the ozone layer, and the threat of extinction from nuclear war. It has also been used to give us prosperity our ancestors could never have dreamed about. Whether it is ultimately used for our benefit or destruction is up to us and remains in the balance [2].

In 2010, the world's population reached 6,9 billion persons in [26]. It is expected to attain 9,3 billion in 2050 and 10,1 billion by the end of the century. The proportion of the population living in urban areas grew from 29 per cent in 1950 to 50 per cent in 2010. By 2050, 69 per cent of the global population, or 6,3 billion people, are expected to live in urban areas [25]. The atmospheric concentration of carbon dioxide (CO2), the main gas linked to global warming, has increased substantially in the course of economic and industrial development. CO2 emissions are largely determined by a country's energy use and production systems, its transportation system, its agricultural and forestry sectors and the consumption patterns of the population. In addition to the impact of CO2 and other greenhouse gases on the global climate, the use of carbon-based energy also affects human health through local air pollution. Currently, CO2 emissions per person are markedly higher in the more developed regions (12 metric tons per capita) than in the less developed regions (3,4 metric tons per capita) and are lowest in the least developed countries (0,3 metric tons per capita). Industrial and household activities as well as unpaved roads produce fine liquid or solid particles such as dust, smoke, mist, fumes, or smog, found in air or emissions. Protracted exposure to Particulates is detrimental to health and sudden rises of concentration may immediately result in fatalities. Concentration of particulate matter in the air of medium and large cities is inversely correlated with the level of development.

Ownership of passenger cars has increased considerably worldwide and the transportation of goods and services by road has intensified. Rising demand for roads and vehicles is associated with economic growth but also contributes to urban congestion, air and noise pollution, increasing health hazards, traffic accidents and injuries. Motor vehicle use also places pressure on the environment, since transportation now accounts for about a quarter of the world's energy use and half of the global oil consumption, and is a major contributor to greenhouse gas emissions. In the more developed regions there are more than 500 motor vehicles per 1000 population. In the less developed regions this ratio is only 70 vehicles per 1000 population, but it is increasing more rapidly than in the more developed regions [25].

Energy generated by the combustion of fossil fuels and biomass often results in air pollution, affecting the health of ecosystems and people. This type of combustion is also the main source of greenhouse gases and rising atmospheric temperatures.

However, in the late 20th century has made improvements in electric drives. Quality inverters are designed with the ability to control the voltage and frequency, enabling the use of induction motors to drive the EV in [27]. Asynchronous (induction) motor is simpler, lighter, more efficient and robust than DC motors. Despite all that, its price is considerably lower than the DC motor. Maximum speed is increased by 50–150% of maximum speed DC motor which is limited because of problems with commutation. The efficiency of induction motors is from 95–97%, and is higher than that of DC motor from 85–89% for DC motors. Inverters are power converters that convert the DC voltage alternating current, the required frequency and amplitude [28, 29].

4. Start of the 21st century

The unprecedented decrease in mortality that began to accelerate in the more developed parts of the world in the nineteenth century and expanded to all the world in the twentieth century is one of the major achievements of humanity. By one estimate, life expectancy at birth increased from 30 to 67 years between 1800 and 2005, leading to a rapid growth of the population: from 1 billion in 1810 to nearly 7 billion in 2010, in [30].

With the growth of population in the world there is a need to increase transportation of people, goods and raw materials as a prerequisite for the growth of production and consumption and the standard of living. This constant growth is natural and expected process of development of civilization and one of the most important indicators of development of society and humanity so that today a life without road traffics considered unthinkable.

Big boost for electric vehicle development was given by the developed countries where air pollution is receiving alarming values.

In cities with large population, and where there is a big environmental pollution, the city authorities have taken some steps to the special places provided for movement and recreation citizens to reduce air pollution. In places where there are a large number of urban populations, city governments often support the eco-drive vehicles.

First of all vehicles are required city services that are moving in the streets intended for pedestrians, such as travel or vehicle inspection. In addition, various types of tourist vehicles moving at pedestrian areas or in city parks. Then, various kinds of utility and delivery vehicles that work in limited areas such as rail bus stations or airports.

In order to significantly reduce oil consumption and pollution in the world that creates traffic especially in big cities it is necessary to make the transition from today's cars with internal combustion engines to electric drives. Given the poor performance of EV on the market there are fewer of these vehicles, although almost all major manufacturers of passenger vehicles operate on the development of these vehicles.

Although scientist Nikola Tesla wrote and discussed the use of EV with the alternate (induction) engine until 1904 in [31], when the EV is already contained in the traffic in the United States a decade ago founded the company bearing his name, Tesla Motors, which is producing very interesting and modern sports EV.

EV "Tesla Roadster" is a sport, the first serial built car that used lithium-ion battery in [32], and the first one which had a radius greater than 320 km on a single charge.

The vehicle has a length of 3.946 mm, 1.851 mm width and a curb weight is 1.234 kg. Useful load is for 2 persons, and the weight of batteries is 450 kg. The AC drive motor has a power 185 kW and a maximum speed of rotation 14.000 min^{-1}. Voltage Li-ion battery is a 375 V and capacity 145 Ah. Charger of the rechargeable battery is inductive (contactless). The vehicle can travel up to 231mile (372 km) in city driving with standard EPA testing procedure. Speed of 60 mph (97 km/h) can be achieved only by 3,9 s, top speed is electronically limited to 125 mph (201 km/h). This vehicle has made the largest radius of movement on single charge EV batteries 311 miles (501 km). Electricity consumption is only 145 Wh per kilometer of road traveled (**Figure 9**).

Mass production of this vehicle was started in early 2008 year. Despite the crisis that is evident and the prices of over 100,000 USD in the beginning of sales, has so far sold more than 1000 pieces of this vehicle in [33].

On the development of modern EV worked both large and small manufacturers of motor vehicles. EV still has significant problems arising from low-volume production so that these vehicles are still expensive and thus less attractive. In the first place it is air-conditioning for passengers and a relatively small possibility of storing electricity in batteries. The necessity of development of plant components specially developed for series production will be affected by

Figure 9. Tesla roadster electric car of the firm Tesla motors.

the low price of these components. Great stimulus to the occurrence of EV on the World Fair is given by Far eastern markets provide producers in [34, 35], which also made a series of large vehicles substantially at lower prices and affordable to most buyers in developed countries.

4.1 Hybrid vehicle (HV)

Oil prices value on world markets in spring 2008 exceeded 100 $/barrel, with previous analyzes have designated this value as the marginal cost of EV use. Oil prices reached a value of 147 $/barrel in early July 2008., and shortly thereafter dropped to a value of only 40 $/barrel, it is nowday stabilized at value around 100 $/barrel.

One of the objectives of the new plan, which President Obama has described as “historic”, is to replace the existing complex system of federal and state laws and regulations on exhaust emissions and fuel economy. Announcing the plan in [36], President Obama said that “the status quo is no longer acceptable,” as it creates dependency on foreign oil and contributes to climate change. Effects of new measures will be as if from the roads in America 177 million vehicles have been removed and that the state saves as much oil as in 2008 was imported from Saudi Arabia, Venezuela, Libya and Nigeria.

Since then it speeds up the development and improvement of a mostly EV batteries or “power tank” which the vehicle carries. Parallely is working on improving the use of EV which now can be used for some applications, as well as the use of HV.

Not finding the opportunity to meet the existing types of EV driving habits with conventional drive vehicles, and vehicles with conventional drive to meet certain environmental requirements, motor vehicle manufacturers have come to the medium solution, so called hybrid drive. If the hybrid has a higher capacity battery that can be recharged via connection to an external source and distribution network, then it is a “plug in” hybrid vehicle (PHV).

HV makes real breakthrough in terms of reducing consumption of fossil fuels, as well as in terms of environmental benefits, and improving air quality in cities, which is encouraged by governments in some western countries. Using PHV reduces smog emissions established in the cities, in [37].

Although PHV will never become a "zero-emission vehicles" (ZEV) due to their internal combustion engine, the first PHV which appeared on the market reduce emissions by one third to half in [38], and is expected from more modern models to reduce emissions even more.

There are several types of applications in hybrid drive vehicles. Common to all is that a shorter time in the city center, vehicle can move with the electric drive as an environmentally clean and then to aggregate that includes the IC engine that runs at the optimal point of operation. In this way the HV has minimal emissions and minimal consumption of petroleum products (**Figure 10**).

HV has two drives, and practically unlimited radius of movement. In the regime of pure electric drive with modest performance with maximum speed of 80 km/h small autonomous movement of about 80 km radius, but because of that the hybrid drive doubles the speed and radius becomes practically unlimited. Because the two types of power, HV is about 35% more expensive than the equivalent of cars with internal combustion engine, but to create habits of drivers, some states stimulated by reducing taxes for these vehicles [40].

The general conclusion is that is a positive step towards the introduction of environmental drive vehicles. However, since no definitive solution is found, experiments with pure electric

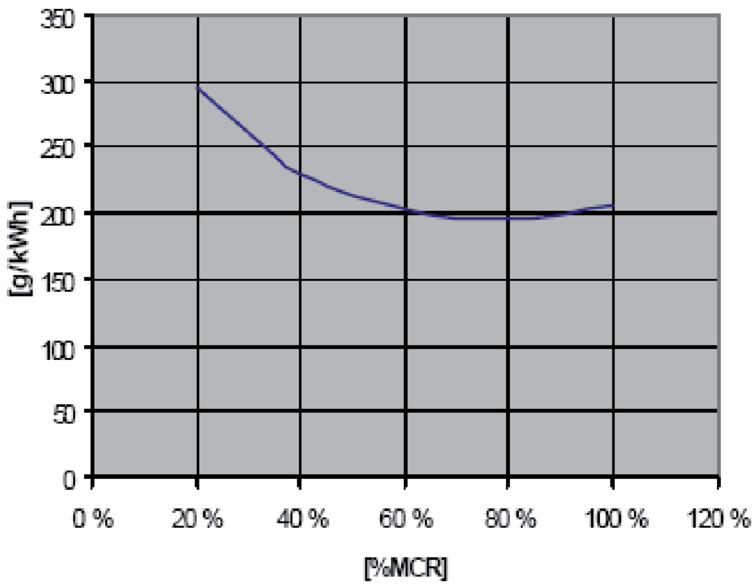

Figure 10. Diagram of the specific consumption of diesel engine as a function of maximum continuous power [31, 32].

and hybrid solutions carried out, as well as various types of technical drive solutions. Despite the turbulent development of EV and HV, some experts believe that vehicles with ICE will dominate for more 15 years, but even after that will not disappear in [41].

The main reason for the production and purchase of hybrid vehicles down to fuel economy in city driving, but are often cited and highlight information on saving energy and reducing pollution in [42, 43]. Best-selling HV Prius in [44], has a fuel-efficiency of 51 mpg (21,7 km/l) in the city and 48 mpg (20,4 km/l) on the open road. Typically, in our present data on consumption per 100 km distance traveled, so that consumption in the city is 4,6 l/100 km and on the open road is about 4,9 l/100 km.

4.2. Plug in EV (PEV)

EV with batteries still have a small market share in the sale and use of cars, but different types of EV, especially the Army, that made significant progress. This was especially favored new legislation announced by the U.S. administration.

It is known that the EV motor vehicle was powered by an electric motor fed from an electrochemical power sources. Often, an electric vehicle (EV) is called the zero vehicle emissions (ZEV), because it emits no harmful particles into the atmosphere. In the older literature, for EV use the terms electric vehicle (EM) or autonomous electric vehicle (AEV) [45].

The basic components of the EV are battery pack as a “reservoir of power” and drive electric motor with speed regulator.

	Prius PHV	**Prius HV**
Dimensions (length/width/height)	4.460/1.745/1.490 mm	←
Curb weight	1.490 kg	1.350 kg
Seats	5 persons	←
Maximum engine power	60 kW (82 KS)	←
Maximum power of the entire system	100 kW (136 KS)	←
Storage energy	Li-ion battery (5,2 kWh)	NiMH batterya (1,3kWh)
Engine Displacement / maximum power	1.797 cc / 73 kW (99 hp)	←
Fuel consumption PHV	57,0 km/l	—
Fuel consumption HV	30,6 km/l	32,6 km/l
EV range	23,4 km	around 2 km
EV top speed	100 km/h	55 km/h
Electrical energy efficiency	6,57 km/kWh	—
Battery recharge time	About 100 min. (200 V) about 180 min. (100 V)	—

Table 3. Technical characteristics comparison of the hybrid Prius “plug in” hybrid vehicles and Prius hybrid vehicles) in [39].

If someone install aggregate in the EV that has a combustion engine and generator, we get a hybrid variant of EV and then it is always possible when driving or when necessary to recharge the battery. With this solution the drive gets slightly higher consumption of oil products in long-distance driving and slightly lower performance with the drive in vehicles with internal combustion engine. But, in the city center, when the internal combustion engine is not in operation, the car behaves ecologically and uses less oil derivatives per kilometer of road vehicles then vehicle with internal combustion engine.

Hybrid vehicles are vehicles in which exists a combination of internal combustion engines (gasoline or diesel) and electric drive, but have limited features of the electric drive mode and can be supplemented from the power grid.

"Plug in" HV are vehicles that can move a distance of 15 to 60 km with a charged battery pack and then the batteries need to be supplemented from the power grid or by combustion engines. Often embedded computer determines the optimal conditions to charge.

The main differences between HV and "Plug in" HV Prius becomes obvious if one looks at the range or increase the radius of the vehicle in electric mode, approximately 2 km (Prius) to 23,4 km (PHV), in [47].

In addition, it is improved specific fuel consumption in the hybrid mode. Studies have shown that in Japan, 90% of drivers exceed the average daily distance below 50 km and 60 km and

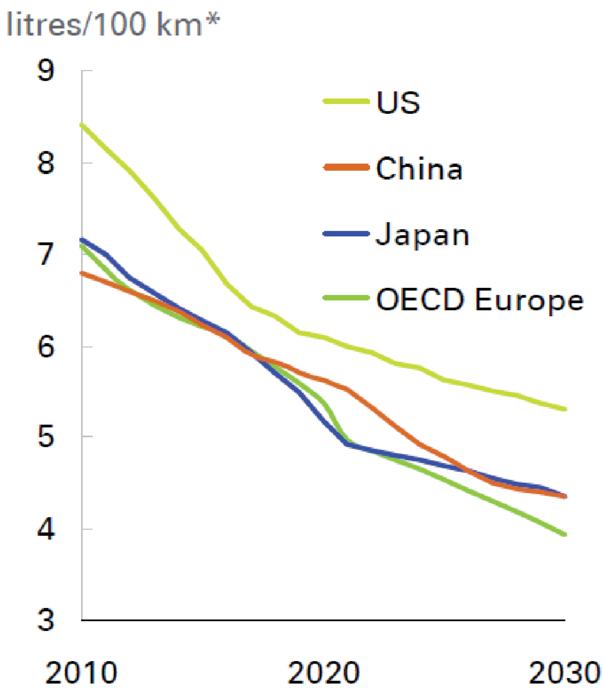

Figure 11. Experts' forecasts of consumption of hybrid vehicles by 2030 in [46].

75 in the EU and the U.S. respectively. In this case, the expected cost of vehicles greatly influences the price of electricity which during the day 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 amounts to only 5 EU cents/kWh (**Table 3**).

The best-selling hybrid car in the U.S. "Toyota Prius", has the highest demand when fuel prices rise. The state encourages the producer price of 6.400$, in [48], so that the standard model sells for just 21.610 US$). The fuel economy of this vehicle is 48 mpg (4,9 l/100 km) in city driving and 45 mpg (5,2 l/100 km) on the open road. Translated into fuel consumption per 100 km is 5,2 l/100 km in city driving and 4,9 l/100 km on the open road.

Large oil producers, such as BP33, consider that in future, up to 2030. PHV will be dominant, primarily due to a reduction in fuel consumption per kilometer of the road, **Figure 11**.

5. Factors that influence the further development of the EV

Transport in cities today is based on other petroleum derivatives. With today's technical solutions existing EV's does not have enough energy so that it can achieve a radius of movement and performance competitive with internal combustion powered vehicles. On the other hand, the absence of exhaust emissions and low noise make the EV attractive for some specific purposes such as short trips with frequent stops in which vehicles with internal combustion engines would have inefficient work.

In addition to high economic dependence on oil and oil products, is a common problem and protecting the environment, reducing emissions and greenhouse gases. It is anticipated that, due to technology development, energy consumption in production systems, despite the larger volume of production in the coming years largely be stagnant.

There are several factors that influence the development of EV:

- Growth in world population and transportation needs
- Energy demand in the world
- Crude oil as an energy source
- Pollution and global warming
- World production and consumption
- Efficiency of electric drives

5.1. The growth in world population and transportation needs

As the main means of mass transportation, cars with internal combustion engines marked the twentieth century. However, the consequences of this form of mass transportation are a large amount of harmful exhaust substances that pollute the environment. Finding alternative energy sources that would move the vehicle could solve this problem. One possible solution is EV.

The world in 2010 year, according to OICA in [49], produced 58,305,112 passenger vehicles used to transport passengers. China topped the list with almost 24% of produced cars followed by Japan, Germany and South Korea. Despite the large car manufacturers for which she is known in the world, the U.S. ranks only seventh in the world (**Table 4**).

5.2. Energy demand in the world

Population growth in the world and general technical advances cause a growing need for all types of energy. Percentage of growth energy use needs in the world is greater than the percentage of population growth. Today, more than half, or 56% of the world's energy consumed in the U.S., Japan and the European Union [10]. As these countries are relatively poor in energy resources, they represent the largest energy importers.

The statistical overview of the total consumption of primary energy in the world since 1.990 to date, as well as forecast till 2.035 years is shown in **Figure 12** and expressed in PWh in [50].

Estimates are that due to increasing consumer demands, and especially because of increasing demands for the transportation of goods and people, energy demand increased by about 1.5 to 2% per annum [10]. It is believed that in the period from 2000 to 2050. The demand for energy will be more than doubled.

The different energy sources in total or primary energy consumption in the world in the same period and forecast up until 2035, is presented in **Figure 13**. This balance includes oil, natural gas, solid fuels, nuclear energy and renewable energy sources with heat recovery lost during combustion of other fuel types. Weaker energy sources, such as wood, biomass and other sources in these considerations are not taken into account.

It may be noted that the share of nuclear 'energy significantly increases and the prediction indicate that, despite all the concern and dissatisfaction of the "green" this type of energy

Sl.no.	Country	Number of vehicles
01	China	13.897.083
02	Japan	8.307.382
03	Germany	5.552.409
04	South Korea	3.866.206
05	Brazil	2.828.273
06	India	2.814.584
07	US	2.731.105
08	France	1.922.339
09	Spain	1.913.513
10	Mexico	1.390.163

Table 4. Production of passenger cars in the world's 2010th in [49].

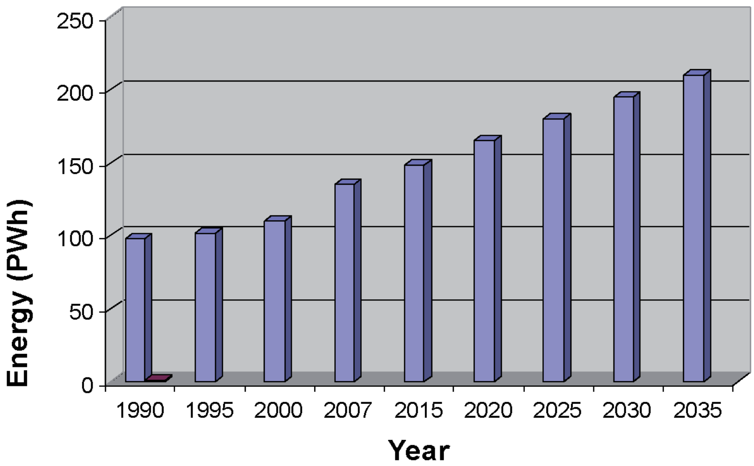

Figure 12. Consumption or total primary energy in the world since 1990 to the date and forecast till 2035.

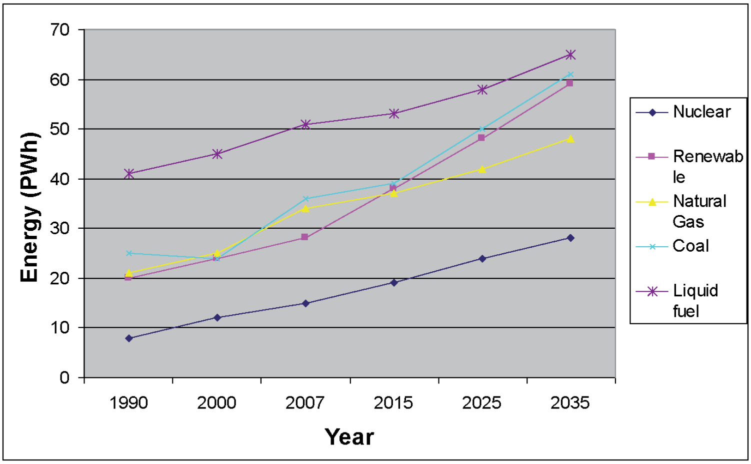

Figure 13. Types of suitable monitoring of energy in the world in the period since 1990 year to date and forecast by 2035.

will be exploited more and more. There are expectations that all types of renewable energy products and exploit all the more. Although these sources are currently produced per unit of energy even more expensive than others, it is believed that in the future primarily due to new technologies and mass production price significantly reduced.

Coal remains the main source of energy. Consumption and production of natural gas is increasing. Production of hydropower is poor because the share of water flows in the production of electricity is utilized enough.

5.3. Oil as an energy source

Although the share of oil in total primary energy percentage decreases, production, consumption of oil is generally increasing. There are opposing tendencies: on the one hand, increased daily transport of people and goods, while the second reduction of imported energy, environment and the negative economic balance. Over 97% of fuel consumed in the transport sector, U.S. in [51], is based on oil, and this represents about two-thirds of the total national oil consumption. Although the specific consumption of liquid fuels in vehicles since 1970. The steadily declining, population growth and the length of distance traveled per capita is increasing and contributing to the total consumption of liquid fuels for transport.

And if efforts are made to find new sources and new facts indicate that this type of energy is slowly decreasing and scientists expect that for some time all sources of energy will dry up.

According to a statistical review of BP (British Petroleum) [52], in 2.011. **Figure 14** shows the increase in prices of petroleum products in Rotterdam since 1993, expressed in U.S. dollars per barrel.

Forecast of production of petroleum products in the world by 2.035 year, according to the Energy Information Administration (EIA) in [50, 54] is shown in **Figure 15**. We hope to discover new oil fields, and activate the existing drain current, so that the next 25 years, production of crude oil will mainly keep the existing values. Expected to increase consumption of natural gas and non-conventional liquid fuels. At the same time certain redistribution of the consumption of liquid fuels will be made. Expected increase in consumption of liquid fuels for transport and to a lesser extent for other consumers.

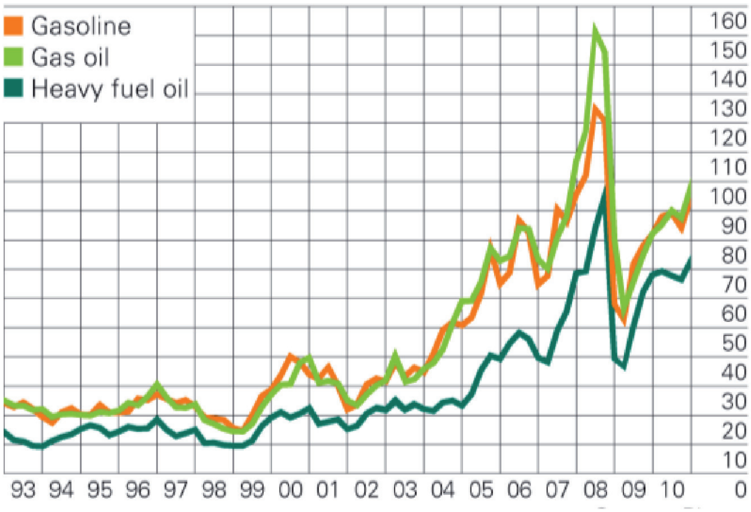

Figure 14. Prices of petroleum products on the market in Rotterdam in [52], since 1993, expressed in U.S. $ per barrel.

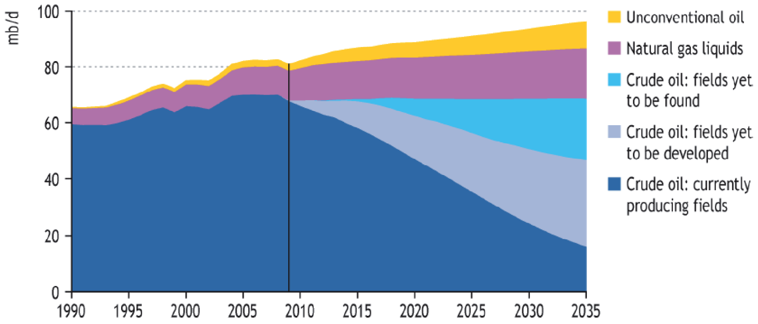

Figure 15. Forecast of global production of liquid fuels by 2035.

Taking into account today and proven preset fossil fuel reserves can be estimated that up to half of the century the transport sector and transport of energy resources was largely satisfied, but certainly not after the 2050th year, if only with today's fuel reserves appeared a new energy crisis, in [53].

5.4. Environmental pollution and global warming

Modern transport has contributed to overall economic progress but also caused problems and environmental pollution, traffic congestion and problems of energy supply - particularly in times of energy crisis.

Air pollution by burning fuel in motor vehicles becomes the most important global issue, especially in urban areas worldwide. Emission of pollutants originating from motor vehicles caused by the level of traffic, possibility of roads and weather conditions. Pollutants from the exhaust system of motor vehicles reach the atmosphere and are dependent composition, and fuel volatility (**Figure 16**) [10].

In terms of impact on global atmospheric pollution and problems associated with it, the most important effect is the increase in global mean temperature. From the standpoint of global warming the greatest danger represents carbon dioxide, an unavoidable component of the combustion products of petroleum products, in [55].

Human activities in the past two centuries have been based on the large use of hydrocarbons to obtain the necessary energy. Therefore, the amount of "greenhouse gases" in the atmosphere has increased and is expected to lead to increase in average global temperature.

In addition to air pollution in violation of the environment and space as a significant natural resource waste oils are participating, as well as uncontrolled release of oil, in [56] to contaminate surface and groundwater.

In contrast to the natural greenhouse effect, an additional effect caused by human activity contributes to global warming and may have serious consequences for humanity. Earth's average surface temperature has increased by about 0,6°C in [57], only during the twentieth century.

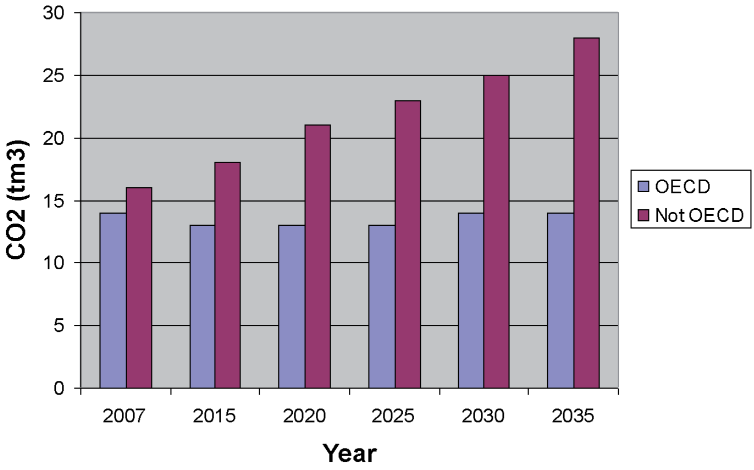

Figure 16. Forecast comparison of carbon emissions in the period since 2007 until 2035. The OECD countries and other countries.

In addition, if we cannot take any steps towards limiting emissions of greenhouse gases in the atmosphere, concentrations of carbon dioxide by 2100, can be expected to reach values between 540 and 970 million particles of the volume. This concentration of carbon dioxide is leading to global temperature increase between 1,4 and 5,8°C by the end of this century.

The temperature rise of this magnitude would also have impacted on the entire Earth's climate, and would be manifested trough the frequent rainfall, more tropical cyclones and natural disasters every year in certain regions, or on the other hand, in other regions such as long periods of drought, which would overall have a very bad effect on agriculture. Entire ecosystems could be severely threatened extinction of species that could not be fast enough to adapt to climate change.

In order to reduce air pollution from vehicles and to make more economical cars in the fight against global warming and reducing dependence on oil in the U.S. are preparing new standards for reducing automobile emissions and reduce consumption of fossil fuels. The intention of the U.S. administration is that these measures by 2016. reduce he emissions from vehicles by 30%. Under the new standards for passenger vehicles, fuel consumption must be reduced to a level of 35,5 miles/gallon (6,62 l/100 km) in [58]. It is expected that new proposals for new vehicles in the average rise in price by about 1,300 $ in 2016 Year [10].

It should be noted that the U.S. is the largest automobile market in the world with about 250 million registered vehicles

5.5. World production and consumption of electric energy in the world

A necessary precondition for economic development and growth of each country and the region is safe and reliable electricity supply. Electricity consumption per capita is highest in the Nordic countries (to a maximum of 24,677 kWh, Iceland) and in North America. Almost half of EU countries have nuclear power plants so that in France and Lithuania almost 75% of electricity is obtained from nuclear power plants in [59].

The growth and forecast growth of electricity production in the world and the total energy consumption in the period 1990–2035, according to the Energy Information Administration (EIA) is shown in **Figure 17**.

Base for observation of this comparison was taken 1990 year. It may be noted that the real growth of electricity consumption in the period since 1990 to 2006 is 59% and overall energy consumption 36%. Forecasted growth in electricity consumption by 2025 amounts to 181% and overall energy consumption 95%.

Production and consumption of electricity for years has a steady growth of around 3.3% per year. Normal for middle-income countries has a slightly higher growth. Electricity production is obtained mostly by burning solid fuel 40% and natural gases about 20%. About 16% of electricity obtained from hydropower and only slightly less, 15% from nuclear power plants. Less than 10% is obtained from petroleum.

Last few decades, the share of electricity derived from nuclear power plants have increased considerably and from hydro has declined, although the total growth in electricity production obtained from hydropower continued. It is believed that the near future will experience significant increase in production of electricity from nuclear power plants, to a lesser extent from natural gas, and later also from renewable sources.

5.6. Efficiency of electric drives

Efficiency of electric vehicles was marked several times when lead-acid batteries were used. It can be divided into two parts: the degree of usefulness in the charging and discharging the batteries.

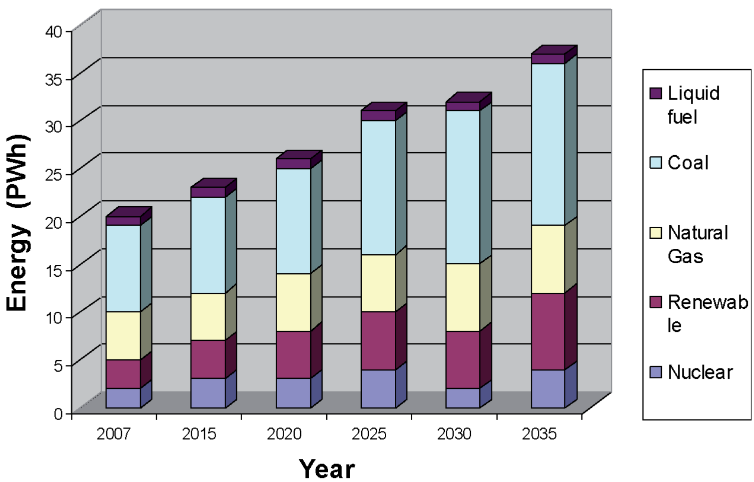

Figure 17. The share of energy in electricity generation in the world since 1971 to 2001 [59].

Batteries with a charger efficiency of 85% conditioned that 15% of the total power dissipated in heat, all for process for charging batteries or refill the tank "of electricity." Charging process is followed by the inevitable losses, so that for certain conditions and the charge current was 82%. This creates a loss of primary energy by 15,3%. This implies that already in the charging of batteries about 30% of the total electrical energy is converted into losses.

The process of discharging the battery is quite complex. How discharge current overcome five-hour discharge current and they belong to one-hour mode current to or even lower, there is a significant drop in efficiency. For example, one-hour discharge mode, discharge current is about 3,7 times higher than the five-hour, and a level of efficiency is 0,65. In discharge mode for 0,5 h, discharge current is about 5,5 times higher and the efficiency is only 0,45. In the tested vehicle we had a 45-minute discharge mode in which the utilization rate of 0,56, so that the primary energy from the power grid consumes an additional 30.7%. Practically, this much power is necessary to drive electric cars and overcoming all resistance to traction.

Assembly drive motor and voltage regulator exceeds the value of the degree of utilization of 94% with the direction of growth, regardless of whether the DC or AC powered. For these components not more than 7% is loss of electricity drawn from the power grid. Transmission along with the transmission gear has high efficiency of about 96%, so that the components of the electric drive consumes only 1,5% of primary energy.

Taking into account all the losses in transport of the electricity from the power grid to power the drive wheels of the vehicle may be test requirements for electric vehicles Yugo – E, in [60] obtain overall efficiency:

The efficiency of primary energy is much better than machines with conventional drive. Useful power is consumed in four parts and to overcoming of resistance: frictional, wind (aerodynamic), climb and acceleration. Computer data indicates that at a constant speed on flat road of 60 km/h, about 60% of output used for overcoming the friction force, and about 40% to overcoming aerodynamic drag (**Figure 18**).

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

- The efficiency of exploitation from the mine of natural fuels (fossil fuel or nuclear energy),
- Electricity production and
- The network transport.

Efficiency of electricity production can vary widely. According to European measurements, ranges from 39% for plants with coal production to 44% for power plants with natural gas, or the average value of 42%. Combined cycle power plant with natural gas can reach the level of efficiency over 58%. If we multiplied the average value of 42% by the transfer efficiency of 92%, the sources of efficiency of the reservoir of 38% is obtained. Battery charger recharges the battery, and transmission losses in the electric motor give the utility of the reservoir of

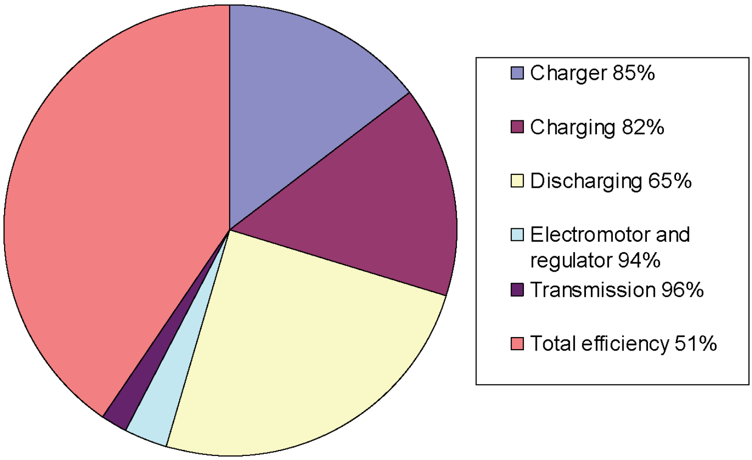

Figure 18. Diagram of losses and efficiency of electric vehicles.

	ICE	EV
From source to 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%

Table 5. The current level of utility vehicles with ICE and the EV, in [61].

energy to the wheels of 65–80%. Thus the total utility from the source to the wheels is from 25 to 30%.

Exploitation of natural fuel and transport network are dependent of the type of energy but have an average efficiency of about 92%. Together with the losses in transport and processing of getting the total level of efficiency from source to reservoir of about 83%. But the internal combustion engine is only 15–20% of energy into useful work. Thus the total utility of the source to the wheels is 12 to 17%.

Energy efficiency is extremely important information on the consumption of electricity from power grid to travel kilometer of the road. It is obtained as the ratio of distance traveled per unit of electricity consumed. Measurements have been made in Serbia, in [60, 62]. Driving a constant speed along a straight road in the hilly city driving. The results showed that the energy efficiency of a flat open road is about 5,1 km/kWh, while in the hilly city driving about 4,5 miles/kWh. The specific energy consumed, defined as the ratio of electrical energy from the power grid per unit distance traveled, or as the reciprocal of the energy economy, is on a flat open road below 0,2 km/kWh in the hilly city driving around 0,22 km/kWh (**Table 5**).

6. Problems and prospects "energy reservoir"

Development and implementation of future EV largely depend on the technical characteristics of the components of the drive. It is difficult to change established habits of drivers in the world, with the expectation from a motor vehicle to transport them quickly from one location to another. The main disadvantage of EV is in the battery pack and that they still cannot accumulate more than 200 Wh/kg energy. If compared to liquid fuels about 12.000 Wh/kg, this very fact means that the tank cars with conventional internal combustion engine, which weighs about 40 kg can store approximately 480 kWh of energy in modern Li ion battery heavy around 300 kg only about 60 kWh electricity.

Promising system Li-air batteries with 1.700 Wh/kg will be able to fully provide the comparative characteristics of the EV and to thereby make the transition to a completely pure EV.

It is interesting to note that the investigation of an aluminum-air battery has started several decades ago because of the high energy potential, because of the opportunities for quick replacement of worn out mechanical anode and the economy, in [63]. It was worked on the development of aluminum-air battery with the anode of aluminum which is alloyed with small amounts of alloying components and a neutral aqueous solution of sodium chloride NaCl as the electrolyte in [64]. The prototype battery achieved 34/39 W/kg specific power and specific energy of 170–190 Wh/kg, the optimal current density between 50 and 100 mA/cm^2, which at the present level of development of chemical power sources is a battery of exceptional quality. The lack of battery life is relatively high cost of components which are used for alloying aluminum anode.

The energy density of gasoline is 13.000 Wh/kg, which is shown as "a theoretical energy density" (**Figure 19**). 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%. 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 [10].

Oxidation of 1 kg of lithium metal, releases about 11.680 Wh/kg, which is slightly lower than gasoline. This is shown as a theoretical energy density of lithium-air batteries. However, it is expected that the real energy density of Li-ion batteries will be much smaller.

The existing metal-air batteries, such as Zn-air, usually have a practical energy density of about 40–50% of its theoretical energy density. However, it is safe to assume, that even fully developed Li-air cells will not achieve such a great relationship, because lithium is very lightweight, and therefore, the mass of the battery casing and electrolytes will have a much bigger impact.

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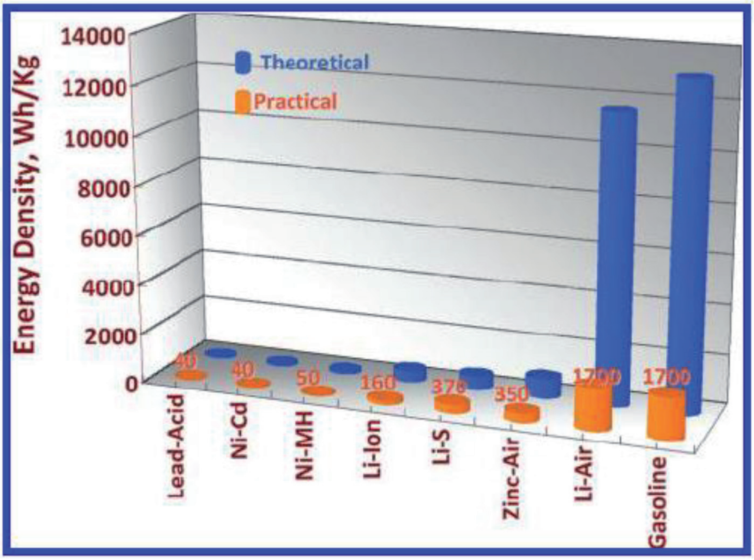

Figure 19. Energy density of different types of batteries and gasoline in [65].

Fortunately, the energy density of 1700 Wh/kg for a fully charged battery pack fits only 14.5% of the theoretical energy content of lithium metal. It is realistic to expect, achieve mint of such energy density, at the cellular level, considering the intense and long team's development in [63]. Energy density of complete batteries is only a half of density, realized at the cellular level.

It is interesting to mention, that the significant results in development this type of battery are achieved in the laboratories of the Institute of Electrochemistry ICTM and the Institute of Technical Sciences SASA, where they were working on development of aluminum-air battery with the aluminum anode alloyed with small amounts of alloying components and the neutral aqueous solution NaCl, as the electrolyte in [66]. The prototype of such batteries, had achieved a power density of 34/39 W/kg, and energy density of 170–190 Wh/kg, by optimal current density between 50 and 100 mA/cm^2.

Volumetric energy (in Wh/l) in the storage batteries is an important feature of the design considerations also. This requirement is the best expressed by condition that there is a maximum capacity of 300 dm^3 (family car) for battery pack and auxiliary systems. A driving range of 500 miles (800 km) requires that the reservoir of energy, store energy of 125 kWh (with power consumption of 250 Wh/km), so that the volume of 300 dm^3 is limiting specific gravity of the battery pack, including space for air circulation, must not be less than 0,5 kg/dm^3.

Power density: While Li-air systems imply an extremely high energy density, their power density (measured in W/kg of batteries weight) is relatively low. The prototype of Li-air cells achieves current density, in average 1 mA/cm^2, which is insufficient and is expecting significantly increase of the current density for at least 10 times. One way to achieve the required power density is the creation of a hybrid electric drive system, where a small, high power battery, for example, on the basis of Li-ion technology, would provide the power in short periods of high demand, such as it is acceleration. Supercapacitors could be used instead of these batteries.

Duration: The current Li-air cells show a possibility of full charge cycles, only about 50, with less capacity loss. Future research efforts must be directed towards improving the accumulated capacity in multiple discharges. In addition, the total number of charge cycles and discharge do not mean to be very large, due to the high energy capacity of Li-ion cells. For example, a battery, designed for duration of 250.000 km, and projected to cross the EV radius of movement of 800 km, should be charged only 300 times (Full cycle equivalent) in [67]. It is necessary to keep in mind that a lot of air will go through the battery during operation, and even a short-term accumulation of moisture, can be harmful to duration.

Safety: EV batteries will be, especially in the beginning of the application, complying with extremely high safety standards, even more strictly than at gasoline car.

Price: Design requirements of high-capacity battery for the drive EV are quite strict, but they are quite well defined. They will serve as guidelines for the scientific research, conducted on the Li-air battery system. Batteries for EV power have been just carrying out the transition from nickel metal hydride to Li-ion batteries, after years of researching and developing. Transition to the Li-ion batteries should be viewed in terms of a similar development cycle. It is known that, the price of each product, decreases with increasing mass production. It is expecting that the EV prices will decline, because of falling down prices of Li-air batteries, including the price of EV. However, support to introduction of new vehicles in traffic would be systematically addressed.

Accommodation of batteries as a power source, for vehicles with electric drive, is a big problem also depending on technological solution of batteries. As it can be seen, in **Table 6** in [68], lead-acid batteries have a low energy, per unit mass and volume and a relatively small number of charge cycles. In contrast, modern Li-ion batteries and NaNiCl, have significant

Battery types	Energy density (Wh/kg/Wh/litar)	Specific power (W/kg)	Number of rechar. Cycles	Energy efficiency	Self disch. For 24 hours	Duration (years)	Price (US$/kWh)
PbO	40/60–75	180	500	82%	1%	2,5–4	100–150
NiCd	50/50–150	150	1.350	72,5%	5%		
NiMH	70/140–300	250–1000	1.350	70,0%	2%	5–7	300–500
Li-ion	125/270	1800	1.000	90,0%	1%	5–10	> > 1000
Li-ion polymer	200/300	>3000	—	—	—		
NaNiCl (Zebra)	125/300	—	1.000	92,5%	0%		

Table 6. Characteristics of different types of batteries.

energy capacity, with a larger number of charges and are of a stable voltage. However, the latter ones are sensitive to warming and may have an energy loss up to 7,2%.

Battery duration should be, always, taken into account, when their price is consideration. The duration depends on several factors, such as how often the vehicle is in use and how many times the batteries have been filled up. In **Table 6**, there are data on duration expectancy of certain batteries types and price per unit of energy [10].

7. Conclusion

It can be concluded that the future and the past belong to the EV. Nevertheless, new sources of liquid fuels are still to be found, their exploitation is more expensive and there is less of it in the world. In addition, it is necessary to preserve oil as a resource to other industry where you cannot find an alternative. On the other hand, electricity is usually sufficient. If in the meantime renewable energy booms, the possibility of its cheap production will open. This means that, in addition to the environmental, economic and conditions for wider use of electric vehicles will gain.

Almost all the problems related to the production of EV technology are sufficiently well resolved, with high efficiency. The biggest problem is the electrical energy storage. Fuel cells, electrochemical sources, supercapacitors, or new sources that could be made sufficiently compact and inexpensive, would allow in the near future, the transition from vehicles that use liquid fuels to electric vehicles [10].

It is likely that the transition from internal combustion vehicles to EV will not be quick. Still these ones are inferior and cannot meet potential customers in all circumstances. Battery development has made great progress but still not enough.

In addition, if the battery problem will be solved, there are still many problems that need to be better addressed. Some of these problems will resolve themselves, as prices fall with the increased production, but others, supporting the introduction of new vehicle traffic will be much harder to resolve spontaneously.

So far EV's are more expensive than existing and have certain restrictions of applications you still cannot replace the existing vehicles of most vehicle owners in the world. In order to create habits of the driver for the purchase and use of EV, economically strong countries are introducing incentive funds for the EV and HV, which gives definite results. First, there are certain financial incentives for the purchase of the vehicle. In addition, the purchase of EV are not paying taxes, in the cities parking is free for them, vehicles do not pay a toll and in the cities they can move in traffic bands reserved for public transport vehicles. The most important thing is to develop a refilling station for batteries which often offer free recharge EV. EV should not be that expensive investment, especially in large-scale production. So far, the most expensive and also less than perfect for use in EV its battery. Therefore, the most intensive scientific research carried out exactly in this area.

In a situation of permanent oil price increases and increased air pollution, especially in cities, two solutions to the problem occurred.

In accordance with the statements of U.S. President, U.S. moved in the direction of energy efficiency and savings in transportation of petroleum products. This means that it is headed in the direction of HV use with the aim to reduce consumption of the average U.S. vehicle to 6,62 l/100 km. Although the U.S. made the extremely popular EV Tesla Roadster, more U.S. government supports all major car manufacturers to start producing HV.

At the same time as the major importers of oil turned to the study and making Plug in EV or pure EV. First who did it is Germany ahead of the EU, but also China and other countries.

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Nomenclature

AC	Alternating current
BP	British Petroleum
DC	Direct current
EIA	Energy Information Administration (EIA)
EU	European Union
EV	Electric Vehicle
HV	Hybrid vehicle
Li-air	Lithium- air
Li-ion	Lithium- ion
OICA	International Organization of Motor Vehicle
OPEC	Organization of Petroleum Exporting States
PHV	Plug-in Hybrid
IC	Internal combustion engine
UN	United Nations
ZEV	Zero Emissions Vehicle

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