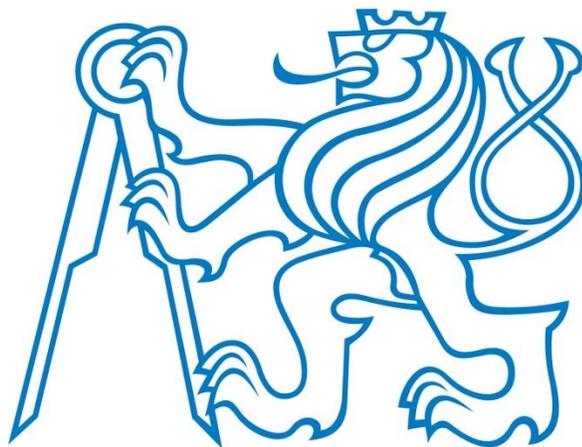


Implementation of electric vehicles as an example of clean mobility in the case of business company

Czech Technical University
Faculty of Electrical Engineering



Master Thesis

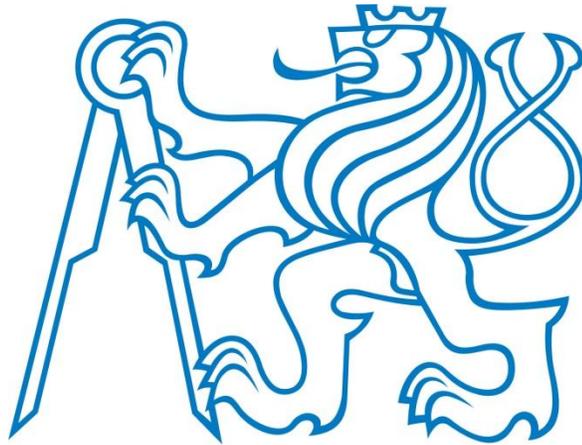
2015

Implementation of electric vehicles as an example of clean mobility in the case of business company

Czech Technical University

Faculty of Electrical Engineering

Faculty of Economics, Management and Humanities



**Implementation of electric vehicles as an example
of clean mobility in the case of Business Company**

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Pokyny pro vypracování:

- introduction – main aims of work, methodology used
- clean mobility – definition, sources, description
- technical and economic aspects of electric car utilization
- obstacles for electric car penetration
- methodology of evaluation of economic effectiveness of electrical cars utilization in company's practice
- case example of shift from classic cars to electric cars for given company – technical analysis, economic effectiveness
- conclusions and recommendation

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European Commission: Study on Urban Freight Transport, 2012
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Declaration:

I hereby declare that this master's thesis is the product of my own independent work and that I have clearly stated all information sources used in the thesis according to Methodological Instruction No. 1/2009 - On maintaining ethical principles when working on a university final project, CTU in Prague".

May 2015

Evgeny Rytov

Abstract:

This work describes the possible prospects for the use of cars with electric drive from an economic point of view at the moment. The aim of the work is to determine the method and calculation of economic efficiency purchase of electric vehicles. The practical value of this work is to develop a mechanism to assess the possibility of using vehicles with environmentally friendly fuel on an example of the business company.

Key words:

Economic evaluation, electric vehicle, EV, Prvni telefonni company, construction of electric vehicles.

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1. Introduction

1.1 Motivation

At all times and among all nations transport plays an important role. At the present stage of its value immeasurably increased. Today, the existence of any state is impossible without a powerful transport system.

Transport is integral part of human existence and its quality and performance are directly indicators of technological development. Transport is present in all areas of human activity, thus the problems associated with transport directly affect the human and his environment.

Important role played by the fact that most of the transport is concentrated in the cities so that people living in the cities suffer from pollution generated by vehicles. Of course do not forget about environmental pollution, since almost all the air and noise pollution in cities comes from transport.

Environmental contamination has become more serious and more serious but humanity is trying to find a solution to this problem is not only to improve existing technologies, such as improving the quality of engines in cars using petrol as fuel and reduce pollution emissions from these engines, but also the creation of transport use is not internal combustion engines.

One of such variants the most notable, in my opinion, it is electric vehicles. Over the last 10-15 years of technology development of electric vehicles has reached such heights that currently we can talk about electric cars as a technology capable

Implementation of electric vehicles as an example of clean mobility in the case of business company of replacing conventional cars, and in the perspective of the future, and perhaps even completely.

1.2 Main objectives

The present work is focused on the study and valuation the possibility of replacing the vehicle fleet of Czech transport company vehicles using gasoline to electric cars. Main objective is determining investment and operational costs for this kind of replacement in perspective of future, assessing the effectiveness of this kind of investment for the company and determine the technical and economic feasibility of such kind of replacement.

1.3 Specific Objectives

The following specific objectives are identified:

- Evaluation of the transport vehicle fleet companies, the number of machines, etc.
- A description of the way used for replacement vehicle fleet of transport company to electric vehicles
- Assessing the impact of replacement on the company.
- Estimation of investment costs, cash flows generated by the company transport and profitability valuation.

1.4 Methodology used

The work is structured as follows:

Chapter 2 are explained existing replacement gasoline as a fuel for cars.

Chapter 3 are explained the technology and operation of electric vehicles, types of electric machines and batteries for them and charging capabilities.

Chapter 4 describes the current situation in the EU

Chapter 5 Description of Business Company

Chapter 6 Description of costs and financial evaluation of the results arising from the replacement

Chapter 7 Sensitivity analysis

Chapter 8 conclusion

2. Alternative types of source

The growing interest in alternative fuels for cars and trucks due to three important considerations: alternative fuels, tend to give lower emissions that increase smog, air pollution and global warming, most alternative fuels produced from inexhaustible resources, the use of alternative fuels can any State to increase energy independence

1. Natural gas

Natural gas is an alternative fuel that is clean-burning combustion and is widely used in the automotive industry and in everyday situations, for example during the construction or in remote areas. When used in vehicles powered by natural gas generates less harmful substance than with an internal combustion engine.

2. Hydrogen

Hydrogen fuel can be used in electric vehicles, using fuel-cell by combining hydrogen and oxygen. More details on this topic discussed below in 3.3.

3. Propane

Propane is a by-product of natural gas or crude oil. He has been widely used as a fuel for cooking and heating, propane is also a popular alternative fuel for vehicles. When using propane produces less harmful emissions than using gasoline, in addition, there is a highly developed infrastructure for transportation, storage and distribution of propane.

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4. Biodiesel

Biodiesel is a type of alternative fuel obtained from natural waste or natural fats. There is an opportunity to upgrade your car so it will use as fuel clean biodiesel or mixed with hydrocarbon diesel. Its main advantage is the safety of use and significantly lower emissions compared to a conventional engine on gasoline or diesel.

5. Methanol

Methanol, also known as methyl alcohol, wood can be used as an alternative fuel in vehicles with universal fuel system, a mixture containing 85% methanol and 15% gasoline. But these days, do not produce vehicles with methanol engines. However, in the future, methanol could be an important alternative fuel as a source of hydrogen, which is required for the fuel cell.

6. Ethanol

Ethanol is an alternative fuel, it can be mixed with gasoline to produce fuel with a higher octane rating and lower the content of harmful substances in emissions compared to pure gasoline. Ethanol is produced by fermentation of grain products such as corn, barley and wheat, and distillation. Also, it can be made from many kinds of plants and trees, although this technology has to be more complex, in this case the ego is called bioethanol.

7. Fuels Series P

P-Series fuel is a mixture of ethanol and gas liquids metiltetragidrofurana, co-solvent, obtained from biomass. P-Series fuels are transparent alternative fuel with a high octane number, which can be used in vehicles with a universal fuel system. Fuel P series can be used in pure form or mixed with gasoline in any proportion by simply adding fuel to the tank

3. Electricity source

Electric car - a vehicle drive wheels which are driven by an electric motor fed by batteries. He first appeared in England and France in the early 80's of the nineteenth

century that is used to cars with internal combustion engines. Drive motor in such machines are powered by lead-acid batteries with very low energy consumption. Therefore, with the invention of the internal combustion engine car production was rapidly gaining momentum, and for electric forgot to serious environmental problems. First, the greenhouse effect followed by irreversible climate change and, second, reduced immunity of many people especially those living in big cities.

These problems were triggered by toxic substances that in large enough quantities contained in the exhaust gases of internal combustion engine. Solving problems is to reduce emissions, especially carbon monoxide and dioxide, despite the fact that production of cars is increasing. Scientists, made a number of studies have identified several ways to solve the above problems, one of which is the production of electric vehicles.

Why electric car can be attractive? In the first place, it almost does not release harmful substances. Toxic gases released into the atmosphere during charging and discharging of the battery, much less than the internal combustion engine (ICE). Electric to heat in the winter, they set the heater, consuming gasoline or diesel fuel. But they, of course, does not pollute the atmosphere as much as the engine.

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The second advantage is the simplicity of the device. The motor has very attractive vehicle characteristics: at low speeds it has a lot of torque, which is very important when you need to pull away or overcome a difficult stretch of road.

The third advantage comes from the second. Electric car does not require such meticulous care as regular cars: less adjustments, does not consume a lot of oil, easier operation, as fuel absent.

3.1. Types of electric vehicles

3.1.1. Hybrid electric vehicles

Hybrid electric vehicles (HEV) are made up of two main components:

1. A gasoline engine and gas tank
2. Electric motor, the battery and the controls system

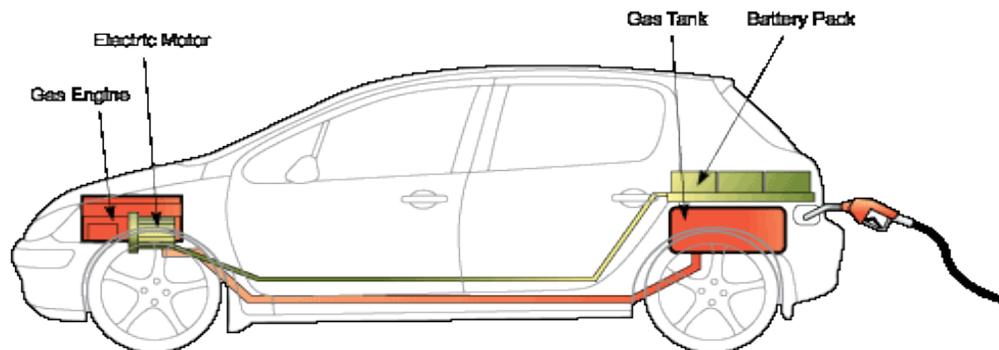


Figure 3.1.1 Hybrid Electric Vehicle¹

¹<http://www.mto.gov.on.ca/english/dandv/vehicle/electric/plan-greener-ontario/buying-and-driving.shtml>

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HEV use gasoline or diesel as a resource and can be recharged from the mains. Recharging the batteries is when you drive during deceleration and braking. Accumulated electricity is used to reduce the cost of gasoline engine, in other words, is used as a tool that saves fuel and also reduces emissions of harmful substances into the atmosphere.

In this case, the savings for the hybrid vehicle can reach 30%². Of course this index depends not only on the quality of performance HEV but also on the personal driver's qualities such as driving style and correct operation HEV.

3.1.2. Plug-In Hybrid Electric Vehicles

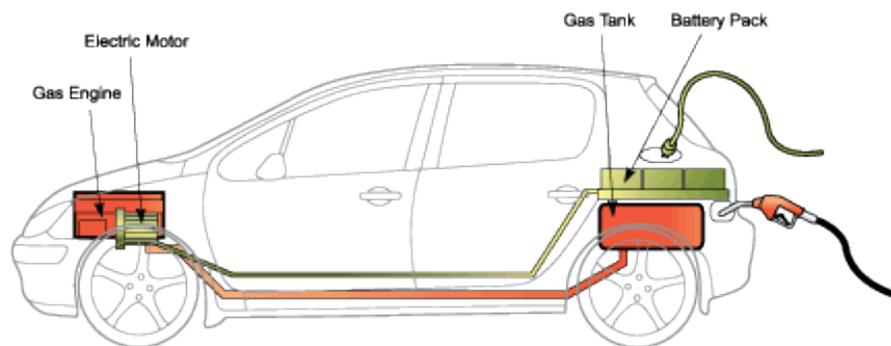


Figure 3.1.2 Plug-In Hybrid Vehicle (PHEV) ³

²Hybrid Electric Vehicle (HEV) Concepts - Fuel Savings and Costs

³<http://www.mto.gov.on.ca/english/dandv/vehicle/electric/plan-greener-ontario/buying-and-driving.shtml>

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Plug-in technology is an advanced technology of hybrid cars. The main difference is the ability to recharge the Battery from electricity grid and the increased capacity of the battery. This system makes it possible to drive car for the short distains 20 to 50 kilometers only on electricity, which is undoubtedly a great advantage of this system. In other words, no long trips in the city now do without the use of an internal combustion engine, which reduces noise and emission of harmful substance in the air to almost zero.

There are two basic PHEV configurations:

1) Extended Range Electric Vehicles (EREVs)

Combustion engine is only used to drive the generator, and the electricity generated by charging the battery and powers the electric motor, which turns the drive wheels. This eliminates the need for a transmission and clutch. To recharge the battery also used regenerative braking. The mechanical energy generated by the engine into electrical generators, and again to mechanical.

In this part of the energy is inevitably lost. Serial hybrid engine allows low-power, and he always has a range of maximum efficiency, or it can be completely disabled. When disconnecting the electric engine and battery is able to provide the necessary power for the movement. They therefore, in contrast to the internal combustion engine to be more powerful, and therefore, they do have a greater value. The most efficient sequential circuit when driving in mode Stop & Go, braking and acceleration, low speed, i.e. in the city. Therefore, use it on city buses and other forms of public transport. Work on the same principle as large mining trucks, which must pass a large torque to the wheels, and does not require high speed.

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2) Parallel or Blended PHEVs

The drive wheels are set in motion and the internal combustion engine and electric motor. For coordinating parallel operation using computer control. In this case, there remains a need in the usual transmission and engine work inefficient in transient conditions. Moment, coming from two sources, distributed according to the driving conditions: in transient conditions (start, acceleration) to assist ICE connects the motor, and in established modes and breaking it acts as a generator, charging the battery. Thus, in parallel hybrids most of the time running engine and the electric motor are used to help him. Therefore parallel hybrids can use a smaller battery, compared to sequential. Since the engine is directly connected to the wheels, then the power loss is much less than in series hybrid. Such a construction is quite simple, but the disadvantage is that the reversible parallel hybrid car cannot simultaneously drive the wheels and recharge the battery. Parallel hybrids are effective on the highway, but not very effective in the city. Despite the simplicity of this scheme, it cannot significantly improve both the environmental performance and efficiency of the engine.

Advantages Parallel PHEVs:

- 1) Use less fuel: PHEVs uses 40% - 60% less fuel than vehicles with internal combustion engines⁴. Since electricity is produced primarily from domestic resources, PHEVs reduce our dependence on oil. But cost of new PHEV vehicles would be bigger on \$ 2000 to \$ 7000 more than the room. However, in the case of buying FEB total amount of fuel will be much cheaper, because most of the costs will take the Electricity that much cheaper than petrol or diesel.

⁴<http://www.fueleconomy.gov/feg/phevtech.shtml>

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- 2) Less Emission (GHE): make less pollution compared to conventional vehicles, but this case plays an important role location and method of generating electricity. This topic will be described in more detail below.
- 3) Regenerative Braking: In conventional vehicles braking energy is lost, and no it does not use. In PHEVs regenerative braking systems capture that energy and store it in the battery, put simply generating energy every time the driver uses the brakes.
- 4) This increases the efficiency of energy use. You can also use ultracapacitors to extend the life of a hybrid vehicle's on-board battery system because in this case, better suited to capturing high power from regenerative braking and releasing it for initial acceleration

3.1.3. Battery Electric Vehicle

The essence of any motor that moving part of the motor (rotor) perform a rotational motion around a fixed part (starter) to a magnetic field, which creates electricity. The rotor drives a shaft, on which are wheels. On the motor shaft and the differential gear set to adapt the speed of the rotor to the radius of wheels.

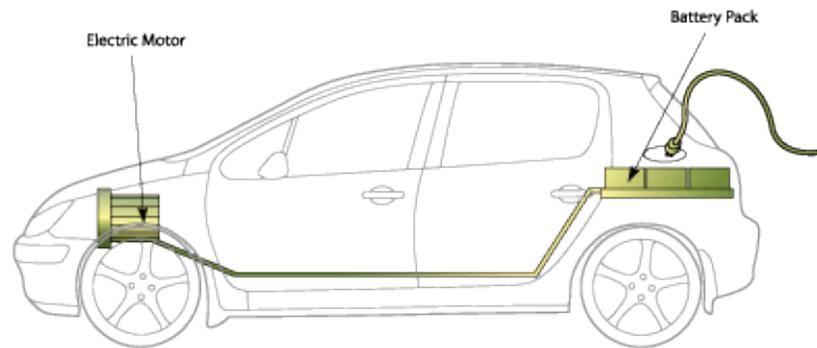


Figure 3.1.3 Battery Electric Vehicle ⁵

Electric car has no transmission, since the transition from standstill to motion is smooth high speed. When the car does not make the movement, the motor does not consume energy.

Comparison with internal combustion engines - benefits

- Absence of harmful emissions.
- The simplicity of design (simplicity of the electromotor and lack of transmission)
- Electric car - the only way use in the light vehicles cheap (compared to gasoline) energy
- The massive use of electric cars would be able to help solve the problem "Energy peak" due to charge batteries at night.
- Less quantity noise due to fewer movable parts and mechanical transmissions.
- High smoothness of moving during driving
- Recharging batteries during regenerative braking

⁵[<http://www.mto.gov.on.ca/english/dandv/vehicle/electric/plan-greener-ontario/buying-and-driving.shtml>]

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- Possibility inhibition by the electric motor (electromagnetic mode brake) without the use of mechanical brakes - no friction respectively brakes wear.

Comparison with internal combustion engines - disadvantages

- Batteries not achieved characteristics which allow an electric car to compete with the car on a stock of progress and cost, despite a significant improvement in the design. On the possibilities of Batteries for electric vehicles will be described in more detail below.
- Batteries work well when driving at a steady speed and smooth acceleration. With a sharp start losing a lot of battery power.
- The problem is the production and disposal of batteries, which are often contain toxic components (e.g., lead or lithium) and acid.
- Some of the energy is spent on batteries cool or heat the car, as well as on other energy consumers (eg, light or air compressor).
- For mass use of electric vehicles requires the creation of an appropriate infrastructure for recharging the batteries. Purchase electric vehicle is directly dependent on Number of charging station and their location and construction of the station is directly dependent on number of electric vehicles that will use the station.
- With the mass use of electric vehicles at the time of charging home network increases overload electrical networks which can lead to decreased quality of power supply and the risk of local crashes of network.

3.2. Batteries for electric vehicles

The main force driving an electric car is an electric motor that receives the necessary energy from the battery. Battery is the heart of electric vehicles and, to date, the most problematic element in the electric car. Rechargeable battery electric vehicle is a chemical power source, which is used for storage, accumulation of energy and ensuring various electrical equipment. The energy in the battery is formed by the internal properties of the reversibility of chemical processes that can produce it repeatedly.

The principle of operation of any battery is based on the properties of a reversible chemical reaction. Structurally, the battery is a vessel filled with electrolyte, which placed two metal electrodes of different chemical composition. During the interaction of the electrode with the electrolyte in the vessel occurs a potential difference. With time, as a result of chemical reactions, composition of the electrolyte and the electrodes is changed and there is a process discharging the battery. If the electrodes are supplied voltage from an extraneous power source, the processes in the battery will flow in the opposite direction, thus restoring the original chemical composition of the electrolyte and the electrodes. This process is called charging the battery.

Rechargeable batteries are available in the following types:

- Lead-acid batteries
- Lithium-ion batteries
- Sodium nickel chloride batteries
- Nickel-cadmium batteries

3.2.1. Lead-acid batteries

Today it is the most popular, practical and cheap power source for electric vehicles. Lead-acid batteries are classified by their use in transportation. For electric vehicles, we are interested in the traction subspecies of lead-acid batteries. These batteries are used as the power source of electric motors. Operating mode - cyclical, that is operated by electric transportation for the day, and at night put on the battery charge.

Advantages of lead-acid batteries:

- This battery is widespread, and therefore finds it easier, and they are inexpensive.
- The low internal battery
- do well with powerful loads
- High environmental (as compared with other types)

Disadvantages of lead-acid batteries:

- More weight than other batteries
- The relatively low energy density
- Requires continuous monitoring of the level of the electrolyte in the battery
- Bad predict possible crash of the battery

3.2.2. Lithium-ion batteries

The use of lithium-ion batteries as the traction batteries is a promising direction for electric vehicles. Technology of production of these batteries is improving from year to year: improved performance, reduced costs kW \ h. It is likely that the lithium-ion batteries will be the sole power source for electric vehicles in the near future.

The advantages of Lithium-ion batteries:

- High energy density
- The voltage on one element of the battery is 3.6 volts, which is three times higher than that of other types of batteries
- Extremely fast charge the battery up to 90-95% of capacity in 30-40 minutes
- Resource life - more than 1000 ^[4] discharge / charge cycle battery
- Self-discharge rate - 4-5% per month

Disadvantages of Lithium-ion batteries:

- May cause an explosion during charging or mechanical damage to the battery
- Terms of normal productive not more than five years
- Sufficient high cost of batteries

3.2.3. Sodium Nickel Chloride batteries (NiNaCl)

Sodium-nickel chloride batteries (ZEBRA), as they are called, have become cheaper and safer alternative to lithium-ion batteries.

In today's world, many car companies producing electric cars are increasingly installed batteries (ZEBRA), guided by their practicality and high performance.

Advantages of sodium nickel chloride batteries (NiNaCl):

- High capacity, the same as that of lithium-ion batteries
- Low cost and more accessible, which competes with lead-acid batteries
- Long Life - over 1,000 times the battery \ battery charge
- Can hold up to 5-7% of the power loss due to failure of the battery cells
- High Voltage
- Relatively high security
- Environmentally friendly

Disadvantages of sodium nickel chloride batteries (NiNaCl):

- Requires maintain high operating temperatures
- To warm cold battery may require time-consuming

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- The batteries are very sensitive to temperature changes and can withstand up to 50 cycles of heating and cooling of the battery

Use NiNaCl batteries is quite promising for electric vehicles. Today the average car kilometrage on the battery NiNaCl can reach quite a good indicator of a one battery charge. Of course prices, even for such economical battery is still very large. This is the only barrier to serial implementation in electric vehicles.

3.2.4. Operational batteries characteristics

1) *Lead-acid battery:*

Efficiency - 80-90%, operating temperature can range from -40 to +40 ° C, low battery voltage - 2 V, EMF charged battery - 2.18 volts, the voltage - 2 volts, power consumption - 30 - 60 Wh / kg. The life cycle of 1000-1500 discharge / battery.

2) *Lithium-ion battery:*

Charged cell voltage - 4.2 volts, the voltage discharged - 2.75 volts, temperature - 20 to +60 degrees Celsius, charge time - 2-4 hours. The cycle of life - over 1000 discharge / charge of the battery.

3) *Nickel chloride batteries:*

Operating Temperature - +300 ° C, power consumption - 730 Wh / kg, the voltage discharged - 2.6 volts. The cycle of life - over 1000 discharge / charge of the battery.

3.3. Fuel cells

The chemical energy fuel combusted in power plants, used to move the electric vehicle is very small. This is due to the energy losses in transmission lines, transformers, converters, battery chargers, and batteries themselves, electric machines, as in traction, and a generator, and when it is impossible to break energy recuperation. With a large spread of battery electric vehicles they simply run out of electricity generated by power plants in the world. This kind of problem can be solved with the use of fuel cells

A fuel cell directly converts chemical energy of a fuel into electrical energy during the electrochemical reaction. From a practical point of view, the fuel cell resembles an ordinary galvanic battery. The difference is that the original battery is charged. In operation, fuel consumed, and the battery is discharged. In a fuel cell to produce electrical energy using fuel supplied by an external source such as oxygen and hydrogen

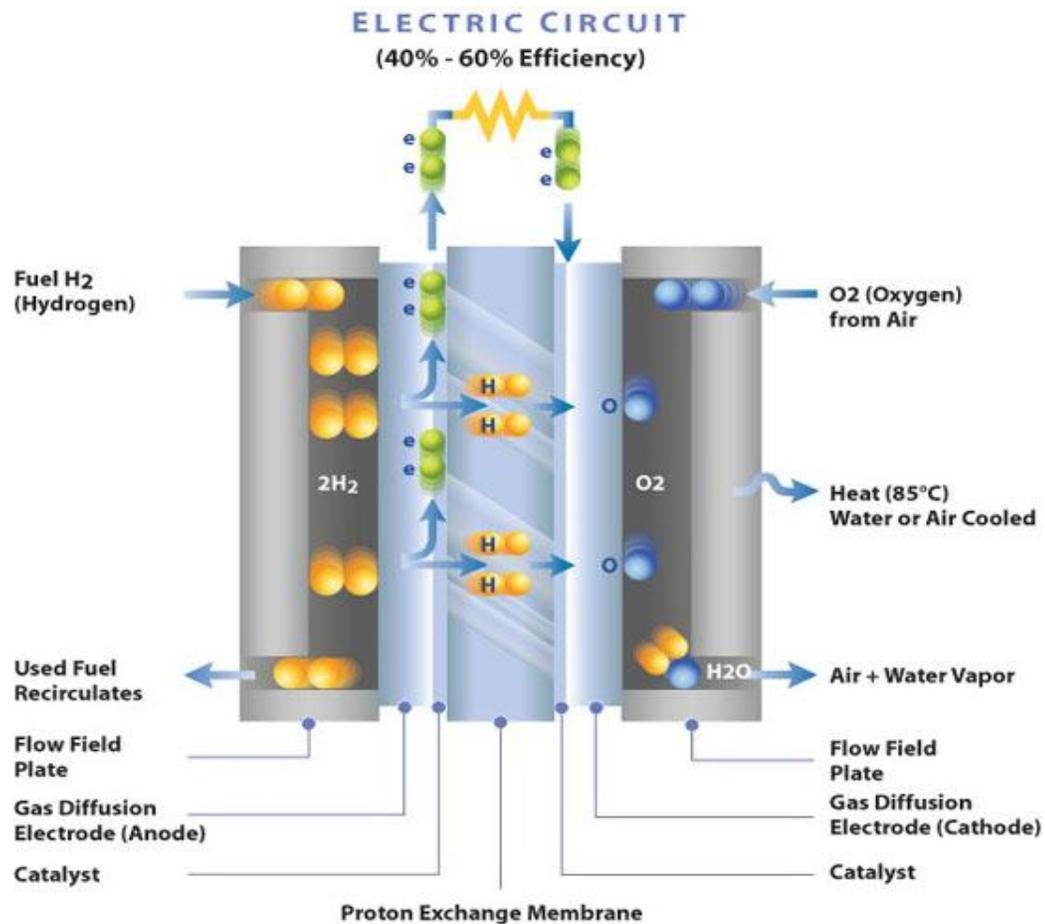


Figure 3.3 Fuel Cells⁶

By using pure hydrogen as a fuel reaction products are heat and water (or steam), ie, the atmosphere does not emit gases that cause air pollution or greenhouse effect (and of course produce electricity). If the fuel is hydrogen-containing materials, such as natural gas, a by-product of the reaction will be, and other gases, such as carbon and nitrogen oxides, but the amount is much lower than burning the same amount of natural gas.

Currently, there are several types of fuel cells, differing composition of the electrolyte used:

⁶<http://www.fuelcells.org/fuel-cells-and-hydrogen/>

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- 1) Fuel cells with ion-exchange membrane (Proton Exchange Membrane Fuel Cells) / solid-polymer fuel cells (Polymer Electrolyte Membrane Fuel Cells) - PEMFC.
- 2) Fuel cells based on phosphoric (phosphoric acid) (Phosphoric Acid Fuel Cells, PAFC).
- 3) Fuel cells based on molten carbonate (Molten Carbonate Fuel Cells, MCFC).
- 4) Solid oxide fuel cells (Solid Oxide Fuel Cells, SOFC).
- 5) Alkaline fuel cells (Alkaline Fuel Cells, AFC).
- 6) Fuel cells are direct methanol (Direct Methanol Fuel Cells, DMFC), fuel cells, direct oxidation of ethanol (Direct Ethanol Fuel Cells, DEFC).

For the automotive industry can be used PEMFC, SOFC, DMFC and DEFC.

One of the motivating factors for the development of this direction on an industrial scale is the fact that fuel cells provide more energy per unit of specific volume than traditional batteries. However, the main problem for the widespread use of fuel cells in the automotive industry is the lack of development of technology and the difficulty in determining the optimal configuration of fuel cells for use in EV.

3.4. Charging

To accept the widespread use of hybrid electric vehicles (PHEVs) and all-electric vehicles (EVS), consumers need good infrastructure of charging stations. Drivers must compatible options available for charging at home (or in the Navy means, in the case of fleets).

Level 1 charging

Level 1 provides charging via a cable to 120 volts AC. Most, if not all, PEVs come with wires to be able to charge the 1st level, so no additional equipment is required charging. On one side of the cable is a standard three-pin connector household. At the other end is a standard connector J1772, which is inserted in the car.

Level 1 is used for charging, in cases where there is only access to only the 120 V outlets and the average charging level 1 adds about 2 to about 5 km from the size of a full charge in an hour PEV charging⁷.

Level 2 charging

Level 2 charging equipment is at 240 V or 208 V power supply. To charge Level 2 requires an additional installation at home or work charger and a dedicated channel from 20 to 80 amps.

This charger has the ability to operate at speeds of up to 80 amps and 19.2 kW. However, in most homes charge level 2 will run on less power. Many of these devices operate at up to 30 amps, providing 7.2 kW of power. These devices require a special 40 A network.

Most homes have a socket 240 V so Level 2 charging can easily charge a fully electric car for the night, which is certainly a big advantage At Level 2 charging equipment uses the same connector to the vehicle and charge it at level 1. On average, Level 2 adds 10 to 20 miles ^[7] per hour. However, this figure is largely dependent on the type of vehicle and used batteries.

⁷<http://www.afdc.energy.gov>

DC Fast Charging

DC fast charging equipment (480 V AC) provides rapid charging for heavy traffic conditions and on public stations. DC fast charging can add from 60 to 80 km distance to the light PHEV or EV in 20 to 30 minutes. This has not the best influence on the battery electric vehicle but if necessary can help if you have a discharged battery or you are driving for a long time.

3.4.1. Charging stations

Public charging stations could make electric vehicles and hybrid electric vehicles more convenient to use. Public charging stations may increase the useful range of electric vehicles and reduce their consumption of gasoline in PHEVs.

Public charging stations will use the method for charging Level 2 or DC fast charging (in case you need to quickly recharge the electric car). Located charging stations should be implemented according to the location of owners of electric vehicles as well as in places such as a shopping center, city parking lots and garages, airports, hotels, government agencies and other enterprises.

3.4.2. Public charging

Ability to charge electric vehicles in the workplace can nearly double the range of the electric vehicle. At the moment a lot of organizations analyze the possibility of installing charging stations for electric vehicles at work for their employees. However, charging at work during peak electricity demand could

Implementation of electric vehicles as an example of clean mobility in the case of business company increase electricity bills so this question depends on the organization of the company, the country of location.

Currently is a huge Number application for Smartphone and other devices with which can find nearest place to charge your electric car from you. in other words, development in this direction are under way, for example, might go to <https://maps.google.com/> and just type your nearest electric charging station and the result does not take long. The result may be seen in Figure 3.4.2

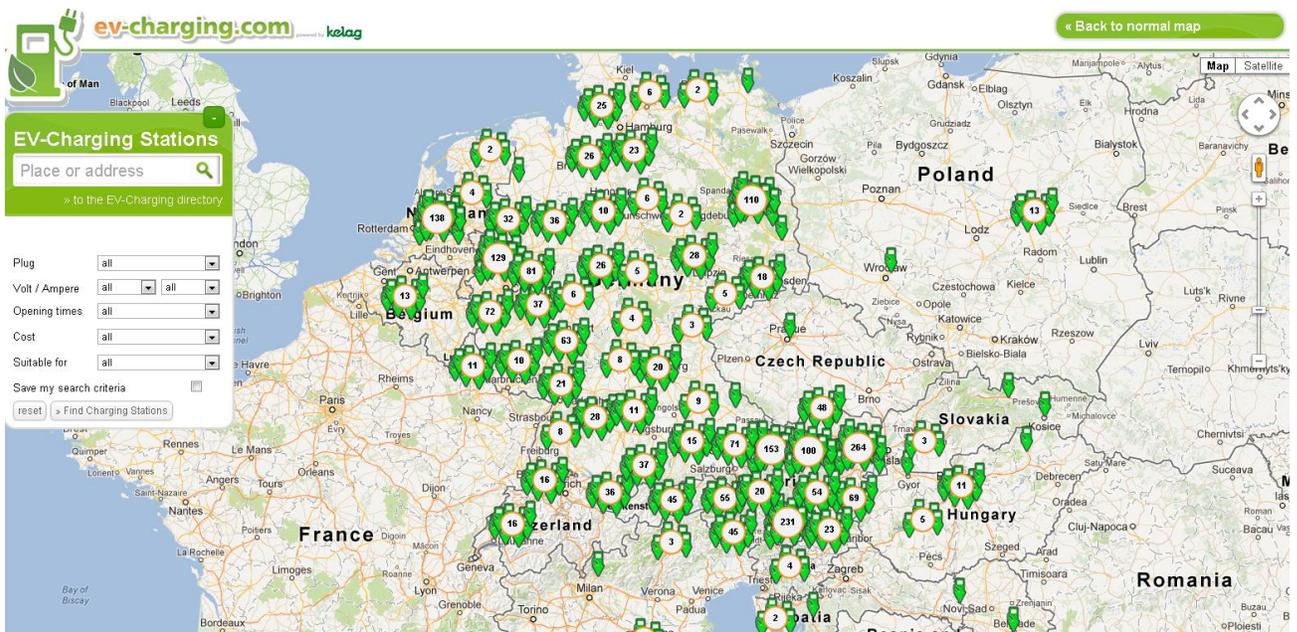


Figure 3.4.2 Map of EV charging stations⁸.

In the future, the ability to recharge the electric vehicle can reach a level that make charging would be possible at any angle. On any parking at the hotel, at work, it will be possible to recharge your electric car. And if this is achieved then the electric cars can become really transport can replace conventional machines.

⁸ <http://ev-charging.com>

4. Technical and economic aspects of electric car utilization

4.1. Situation in EU

In the countries of the European Union seriously think about the problem of environmental pollution emanating from vehicles. In all of Europe, and directly in the Czech Republic conducted a large public investment in alternative-fuel vehicles. In 2001 the European Union adopted a directive according to which the number of electric vehicles using alternative fuels in relation to vehicles using gasoline or diesel must be at least 20%⁹ of the total. As has been said all aimed at reducing greenhouse gas emissions. If we look at the European Union forwards such as Germany we see that the number of electric cars sold in 2011 was 1,020 vehicles, just incredibly small in relation to the total number of vehicles. In France, the figure is 953 cars, and it numbers for the full year. The same poor performance and show the rest of the European Union..

These numbers are so small, because at the present time in Europe more popular to use cars on TSNG, it is much cheaper than electric vehicles and vehicle performance characteristics by using liquid gas as a resource is much closer than electric vehicles compared to conventional cars.

Information about electric vehicles sold in the EU is given below¹⁰:

Country	Number of sold EV
1. Germany	1020
2. France	953

⁹<http://eon.energieplus.cz/>

¹⁰<http://www.jato.com>

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3. Norway	850
4. UK	599
5. Austria	347

6. Denmark	283
7. Netherlands	269
8. Spain	122
9. Sweden	111
10. Italy	103
11. Portugal	93
12. Belgium	85
13. Czech Republic	43

4.2. Situation in CZECH REPUBLIC

Today the situation with electric cars in the Czech Republic is not very favorable, one might even say that the negative. In 2012, the Czech Republic has sold only 43 cars, which is very small in terms of the rate of the whole country. Even in spite of the fact that since 2005, the territory of the Czech Republic introduced plan development of cars on the alternate fuel wider application received cars on natural gas¹¹. In the private sector this is easily explained by the fact that the cost of buying and fueling vehicles with natural gas is much less than electric cars.

Unfortunately the infrastructure for electric vehicles just beginning to develop. The first public charging station was opened by company E.ON Energy in Brno only in 2010 and charging in it is free for all owners of electric vehicles. This is not the only example, now you can find a parking in Prague and Brno, where it is possible to recharge your EV for free.

¹¹<http://www.cleanvehicle.eu/info-per-country-and-eu-policy/member-states/czech-republic>



Figure 4.2. Photo first charge station for EV¹².

Currently, this segment of the infrastructure is developing and possible find the charging station almost the entire territory of the Czech Republic. Moreover, in case of an emergency recharge your car is extremely fast on many stations as possible to do this with DC Fast Charging (see p. 3.4).

¹² <http://eon.energieplus.cz>

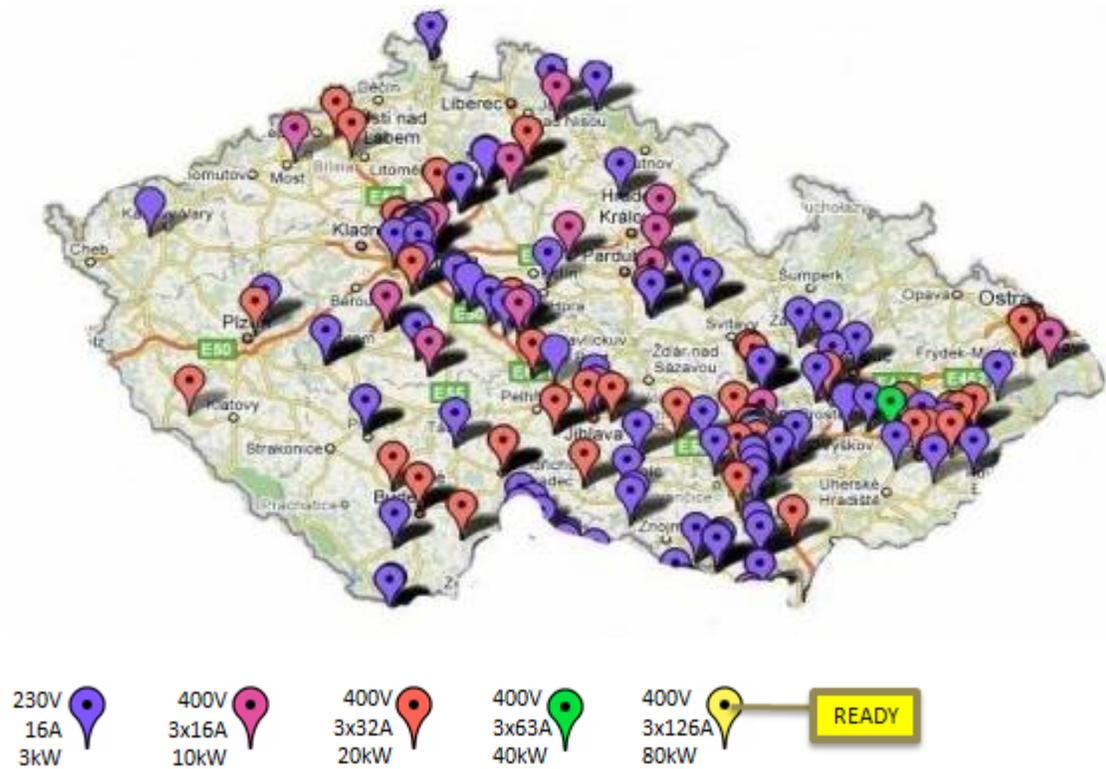


Figure 4.2.1 map of charging station in CR¹³.

If we take a look at the figure 7 we can see that the charging stations are almost uniform distribution over all the territory of the Czech Republic, with a few exceptions in the northern part. In other words, for owners of electric vehicles there any areas where life will be easier in case you need a quick recharge the car during the journey, you can follow any responses to easily pull it out, even those living far from the central cities such as Prague or Brno.

¹³ <http://www.elektromobily.org>

5. Description of Business Company

In this work considered the possibility of using electric vehicles on company Prvni telefonni a.s. (<http://www.telefonni.cz/>). The main activity of this company is a repair service and installation of telecommunication equipment. The main area of activity of the company is the city of Jihlava. However, the company has many offices throughout the Czech Republic, including the Prague. The company has existed since 2001, which shows its stability and continuous growth. The company's goals for the near future are expanding the scope of the company by installing new equipment's and finding new customers. The realization of these goals can be achieved only with the possibility of trouble-free and timely departure to the customer for the repair or installation of new equipment. Therefore, the transport component plays a huge role in the company, and the opportunity to purchase electric vehicles may have not only cost effective but also have a huge image component. This is inapplicable gives opportunity to attract new customers, people or companies who care about the environment certainly will allocate the company Prvni telefonni a.s. against other companies, if the company intends to announce this acquisition properly.



PRVNI TELEFONNI

5.1. Existing car park from the point of view of fuels

Currently the company has more than 20 cars. Most of them are using gasoline. Moreover the company has diesel car and CNG cars; this is done for reasons of economy. The cars on the electric force are absent, so it is necessary in the future to take into account

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5.2. Choice of replacement options

Some cars from the truck fleet needs to be replaced, because of old age or for some other reason. These are cars Astra Van from 1995, Astra Caravan from 1995, Astra Sedan from 2001.

Replacement of vehicles in the company will be realized through the sale of old cars and buy new cars, but for a more comprehensive review of this issue we consider three possible options:

- 1) Buy 3 diesel vehicles
- 2) Buy 3 hybrid cars
- 3) Buy 3 full electric cars

As companies need to replace the 3 car selling price is about the same, will be considered the purchase of three new vehicles, so we can easily estimate the cost of 3, 2 or 1 car respectively.

Option 1

Would provide the information about buying and maintenance diesel cars. This option needs to be able to compare it with the remaining two options, in which case we can estimate the cost of buying a car on the electric force compared to conventional cars. After estimating the costs of purchase and maintenance of diesel and gasoline vehicles choice was made in favor of diesel cars. Diesel cars, compared with gasoline, have lower costs of a liter per kilometer, and in our case, the use of cars in the city where

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the fuel consumption per kilometer is particularly high, the choice fell on diesel cars.

Option 2

Would provide the information about buying and maintenance hybrid cars. Price of hybrid cars is much more compared to petrol or diesel cars, but because of the potential use of electric power and the automatic charging while driving, the hybrid is much less fuel consumption per kilometer. Moreover hybrid car when driving in the city can only use electrical power that can allow for even more savings.

Option 3

Would provide the information about buying and maintenance full electric cars. Despite the radical difference in the design of these vehicles, subject to the conditions described in 5.1.1. will not have any problems using these vehicles in the company.

5.2.1. Skoda Roomster.

As the diesel car was chosen Skoda Roomster. Of all the possible options for diesel vehicles this option is the most preferable, because of all the possible options in the Czech Republic, it has the one of the highest performance of diesel cars, besides, it is one of the best-selling diesel car in the Czech Republic. In car can be installed 5 or 6 speed gearbox that allows is achieved maximum fuel economy while driving.



Figure 5.1.2 Skoda Roomster¹⁴

Main technical characteristics Skoda Octavia 1.9 TDI:

- *Engine capacity (l) - 1,4*
- *Power (Kw/k) - 75 / 86*
- *Fuel consumption (l/100km) - 4,7 (city) / 6,0 (out of city) / 5,0 (mix)*
- *Range of driving(km/tank) -*
- *Top speed (Km/h) - 183*
- *Price - 300 000 Czk*

¹⁴ <http://em8.ru>

5.2.2. Toyota Yaris Hybrid

As the hybrid car the Toyota Yaris Hybrid been chosen. This car has proven itself as the most reliable, economical and simple car of all available at the moment of hybrid cars on the market "middle class." This car has a "proprietary" hybrid system developed by Toyota and it proved it from every possible angle. Of course, this car has all the modern capabilities of hybrid cars, such as regenerative braking and others described in 3.1.2. This car deserved highest marks not only around the world but also in the Czech Republic, being the best-selling hybrid car in the Czech Republic¹⁵.



Figure 5.1.2 Toyota Yaris Hybrid¹⁶

¹⁵ <http://www.tipcars.com/magazin-yaris-je-nejprodavanejsi-hybrid-od-toyoty-6104.html>

¹⁶ <http://lethistorylive.com/toyota-yaris-hybrid/>

Main technical characteristics Toyota Yaris Hybrid:

- *Engine capacity (l) - 1,5*
- *Power (without an electric motor) (Kw/k) - 55 / 75*
- *Power (with an electric motor) (Kw/k) - 74 / 100*
- *Fuel consumption (l/100km) - 3,1 (city) / 3,5 (out of city)*
- *Range of driving(km/tank) - 1000*
- *Top speed (Km/h) - 145*
- *Price - 450 000 CZK*

The characteristics of the car is not inferior to the diesel Skoda, and if we do not take into accounts such factors as acceleration to 100 km / h, which for the company is the least priority, the economic performance of the car look much more attractive. Such savings allows for an electric motor using a nickel battery as a power source, the advantages and disadvantages of such a battery can be found in Section 3.2.4.

5.2.3. Skoda EVC R3

Currently, the Czech Republic is not many electric vehicles, which is possible to buy. One such is the electric vehicles Skoda Skoda EVC R3. It is a fully electric car of the Czech production. This car shows excellent performance in comparison to other electric cars "middle class" at all in this case it is almost "normal" Skoda Roomster, which has the same design and the "filling".



Figure 5.1.3 Skoda EVC R3¹⁷.

Main technical characteristics Skoda EVC R3:

- *Engine capacity (Kw) - 30*
- *Power (Kw/k) - 55 / 75*
- *Range of driving(km/full charge) - 150 - 200*
- *Top speed (Km/h) - 125*
- *Price - 800 000 CZK*

As can be seen from the characteristics of driving a car depends on the capacity of a car battery. Capacity of the car affects its price when buying, because almost 70% of the price of the car is its battery. Battery capacity varies from 16 to 50 kW.

¹⁷<http://www.hybrid.cz/elektromobily-ktere-si-dnes-muzete-koupit-v-cr>

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Each additional 5 KW capacity battery is added to the average of 100 000 CZK to the cost of the car.

According to information received from the company První telefonní a.s., the average driving rate for cars to be replaced, composes no more than 50-100 km per day, as they are used exclusively for driving around town, but in order to avoid problems and unforeseen situations over the appropriateness buy electric car with an average capacity of battery 30 KW. This does not greatly increase the cost of the car, but in this case, enable to drive a day when it's needed.

5.2.4. Obstacles for electric car penetration

In current situation, buy the charging station inexpedient, because the electric car will be used only during the day, so no problems with it charging at night. Methods for charging as well as the possible places where you can recharge the car can be found in Section 3.4. and 4.2.

A full charge the car can range from 7 to 11 hours. And all that is needed to charge the car during the night, while car is standing in the car park - it is socket. In this regard, there will be no problems, and the company can provide everything is need.

However, to ensure maximum economy in the vehicle's charging is achieved in that the charging of electric vehicles was exactly at night, but at 8-hour working day, it is possible only with the use of automated outlet that will automatically connect to the network at night, after 12 pm, when the rate of use electricity is most advantageous. An employee who leaves work to be connected to

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an electric charge, but the automatic switch will not let the current to charge up to the moment when the price of electricity consumption will not be the most profitable, i.e. at night, this is achieved in the most cost will be recharged when the car. This system is commonly used, for example on the boilers for heating the water, so its installation with no problems.

It is imperative to pay attention to the fact that all 3 cars types are needed to be replaced used exclusively for going to the client. In other words, moving cars throughout the day adds up for city driving from the office to the customer and for driving between cities or outside the city used other cars from the fleet of the company. Thus we can take into account the fact that the total number of kilometers traveled per day is no more than 150 kilometers. This is the main condition for which we can compare these 3 variant with each other, in spite of the strong difference in the cars design and their ability to drive without refueling.

6. Costs

6.1. Purchase costs

Purchasing of vehicles based on the current price list published on the website of car manufacturers Skoda and Toyota, specified in paragraphs 5.1.3., 5.1.4, 5.1.5 it is necessary to decide how it will be implemented the purchasing cars. The prices of cars are without VAT.

Several options were considered a possible purchase of vehicles. Of the options can distinguish purchasing through the own funds, bank loan and leasing, through a leasing company. Since purchasing cars through own a fund is not possible and not advisable, has been selected to take a loan to buy a car. To purchase through credit was selected GE Money Auto a.s. - a company with a huge experience in financing the purchase of both new and old cars, because at the moment, the company offers the most favorable terms of credit rate. Term of the loan 4 years and the average interest rate of 11.9%. These conditions will be the most beneficial for our circumstances.

In our case we are talking about getting a car credit to the company, which significantly reduces the interest rate to 5.5% in GE Money. To be able to obtain competitive assessment of auto loan company will take another example Ceska Sporitelna a.s. where the interest rate is 5.7%.

To resort to leasing companies is not quite rational in the circumstances. Because the company cars are used for long periods of time, which means that the car rental does not make sense. Since we are talking about buying 3 cars, it means that we cannot

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rely on what or special conditions of the bank, upon receipt of such a small loan.

Purchasing cars on credit in the future will help the company to reduce taxes because depreciation deductions will not be taxable and will be considered but as the fixed costs of the firm. However, this fact does not affect the economic efficiency of cars.

6.2. Service costs

Because all the cars are new, this means that they must be service at the official dealer. This is necessary not only by what at the official dealer to get the best possible conditions and quality of care, but also by the fact that without



this service is not impossible to get credit for cars. Credit for vehicles issued with a condition of its limited coverage, and this condition is not possible to execute if the service will not take place at an authorized dealer. These amounts may collect from official dealer's information. In this case it is necessary to add that amount as costs.

Service costs for chosen new cars (for 6 year period):

- Skoda Roomster - 120 000 Czk
- Toyota Yaris Hybrid - 160 000 Czk
- Skoda EVC R3 - 9 000 Czk

note - prices for services are based on official information available on the websites of authorized dealers. However, the overall price is provided that the car will be all the service of

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service from an authorized dealer until the end of the warranty on the car.

When comparing prices for Skoda EVC R3 with the other cars can be seen that the simplicity of the design and lack of more complex mechanisms has an effect, service costs for the car is worth much less than the other cars.

6.3. Tires costs

Best-selling portions to be replaced in the car this tire. The most popular and sold tires in the Czech Republic is a brand tires Barum. In our case, there is the need for a tire size of 15 inches for the Skoda Octavia and 14 inches size for Skoda Roomster and Skoda EVC R3. This means that at this point the cost will be minimal since these tire sizes are enough cheap. However, in all cases there is a need to purchase the summer and winter wheels it is doubling the amount for expenses.

Since the vehicles will be used exclusively for city trips, this means that one set of tires will last for 2 years of use for summer and winter versions.

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Skoda Roomster			
Period	Type	Price for 1 Pc DPH [CZK]	Total with DPH [CZK]
Summer	Barum Bravuris 2	1500	6000
Winter	Barum Polaris 2	1500	6000
Toyota Yaris Hybrid			
Period	Type	Price for 1 Pc DPH [CZK]	Total with DPH [CZK]
Summer	Barum Bravuris 2	2000	8000
Winter	Barum Polaris 2	2200	8800
Skoda EVC R3			
Period	Type	Price for 1 Pc DPH [CZK]	Total with DPH [CZK]
Summer	Barum Bravuris 2	1500	6000
Winter	Barum Polaris 2	1500	6000

Table 6.3 The prices of car tires¹⁸

6.4. Insurance

In operating costs should be included and the cost of car insurance. Of all the insurance companies was selected ČSOB. This company has one of the highest financial performances in the market. Moreover insurance from that company, and includes coverage of small damages such as scratches and damage to the windshield, which without a doubt a positive factor, as it is has a chance of damage can occur when using corporate vehicles.

¹⁸ <http://www.pneumatiky.cz/>

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Skoda Roomster	11 663 Czk
Toyota Yaris Hybrid	10 373 Czk
Skoda EVC R3	11 663 Czk

Note - All prices are according to the calculations on the site <http://www.csobpoj.cz/> to May 2014 for the city Jihlava

6.5. Purchase of electricity

Price for electricity, which will be powered electric vehicle, is based on the standard rates for Electricity Jihlava city. Skoda EVC R3 has socket for 16A and max path range 150 - 200 km on one charge. Electricity distributor for the company CEZ Distribuce and is used according to the most suitable tariff d25D. Advantages of this tariff are very low cost price for electric during the night. After the convert price for the electricity we get the value of 1.1 CZK per kW. When calculating consider the fact that the car pass 35,000 km per year. Thus the final price for the purchase of electricity for EVC R3 annually will reach 7,920 CZK per year¹⁹.

6.6. Purchase of fuel

For the possibility of finding the actual purchase price of petrol and diesel, we can use for help the analytical server and can obtain the price 32.1 CZK / liter for diesel today. Without DPH price would be 26.44 CZK / liter.

¹⁹ <http://www.cez.cz>

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But it is necessary to find the value of the growth rate for the future, for that reason we can collect data of price changes over the last 10 years, for the predict possibility.

Years	Price of gasoline in CR, CZK/liter
2005	24.82
2006	28.1
2007	26.38
2008	30.59
2009	25.28
2010	30.45
2011	33.36
2012	36.12
2013	35.5
2014	36.22
2015	32.1

Table 6.6. Changes in diesel prices in the last 10 years²⁰

After analysis of the data it is obvious that if we take into account only the data from the last 10 years we can assume growth rate not more that 2%. However, over the past year the situation with oil prices has changed greatly and in my opinion the price of oil in the near future will remain unchanged. Therefore in the calculation would be taken the growth rate 2%.

Note - Prices are listed in the table include VAT.

6.7. the loss of charge in the batteries

Batteries installed in electric vehicles are designed for 3000 charge / discharge. However, after this cycle is not necessary to

²⁰ <http://www.finance.cz>

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completely replace battery because its capacity is reduced only by 20%²¹. The price of new batteries for electric vehicles is 60% of the value electric vehicles. Thus, in the final calculations should take into account the reduction the selling price of the car for an additional 20% of the cost of new batteries or 100 000 CZK for 1 car.

6.8. Residual value of cars

For a more comprehensive calculation should take into account the residual value of cars. The residual value of cars will be the basis of the current prices for 6-year-old cars of each type's. After monitoring websites of car sales we take to the account that the cost of a diesel car Skoda Roomster will be 40% by the value of a new car. For Toyota Yaris Hybrid residual value of 6 years old car would be 60% by the value of a new car.

Unfortunately at the moment for Skoda EVC R3 such information does not exist, but if we will taking into account the similar electric vehicles can be assumed that the residual value would be 60% by the value of a new car, due to the of simplicity of the design and operation.

6.9. Methodology of evaluation of economic effectiveness of electrical car utilization in company's practice

Net Present Value

All financial options are designed for up to 6 years. The main indicator of financial performance for the investment is NPV (Net Present Value). NPV is the sum of the present (discounted) value of all cash flows of the asset (cash items of cash flows). Individual

²¹ <http://www.motoristi.cz/1066/elektromobil-skoda-uz-dnes-neni-problem/>

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elements of cash flows have been calculated in accordance with the investment and costs in each year and discounts have been converted to present value. The obtained value of the net present value is the sum of the discounted items. Due to the fact that in different versions being considered only investment costs and the costs of doing business and the account of the tax shield is not considered any income or profits of the company, in each case, the net present value is negative. The best investment is the option with the least negative NPV.

$$NPV = \sum_{t=0}^T \frac{CF_t}{(1+r)^t} = \sum_{t=1}^T \frac{CF_t}{(1+r)^t} - I_0 \quad (6.6.1)$$

t = year

T = examined the number of years

CF_t = cash flow in year t

r = discount

I₀ = investment in year 0

For the possibility of calculating NPV needed to determine the value of discount rate through the calculation of WACC:

WACC (Weighted Average Cost of Capital) is used to measure the cost of capital to a firm. It is most usually used to provide a discount rate for a financed project, because the cost of financing the capital is a fairly logical price tag to put on the investment.

$$WACC = \frac{E}{V} * Re + \frac{D}{V} * Rd * (1 - Tc) \quad (6.6.2)$$

$$WACC = 0.055 * (1 - 0.2) * 13028 / (13028 + 834) + 0.19 * 834 / (13028 + 834) = 0.0413 + 0.011 = 0.0527$$

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R_e = cost of equity; R_d = cost of debt; E = market value of the firm's equity; D = market value of the firm's debt; $V = E + D$; E/V = percentage of financing that is equity; D/V = percentage of financing that is debt; T_c = corporate tax rate

Tax shield

In our research, the only positive point in the cash amount of the tax shield CF. The principle of the tax shield is that the interest on the debt is included in the price, and thus reduces the profits that are subject to income tax. The result is a decline in profits and thereby reduces the cargo business tax. As a result is the return on equity.

Tax shield calculation at financing by cash:

$$t_{\text{cash}} = (\text{operational costs} + \text{depreciation}) * \text{income tax}$$

Tax shield calculation at financing by Bank loan:

$$t_{\text{loan}} = (\text{operational costs} + \text{depreciation} + \text{interest loan}) * \text{income tax}$$

Calculation of tax depreciation

Calculation of tax depreciation was elected to the possibility of reducing the taxable amount (tax shield). This calculation was made according to the following equation:

$$\text{depreciation in the first year} = \frac{\text{input price}}{\text{factor from Table}} \quad (6.6.3)$$

$$\text{depreciation in subsequent years} = \frac{2 * \text{net book value price}}{\text{factor from the table} - n} \quad (6.6.4)$$

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n = number of years for which has already depreciated fixed assets

Depreciation group	depreciation in the first year	depreciation in the subsequent years
1	3	4
<u>2</u>	<u>5</u>	<u>6</u>
3	10	11
4	20	21
5	30	31
6	50	51

Table 6.7 Factor for accelerated depreciation²²

²² <http://www.penize.cz/investice/17063-odpisove-doby-sazby-a-koeficienty>

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7. Case example of shift from classic cars to electric cars for given company - technical analysis, economic effectiveness

7.1.1. Financial analysis - 3 x Diesel cars

Year	2015	2016	2017	2018	2019	2020	
The cost of new cars							
Purchase price	900 000						
Depreciation	180 000	288 000	216 000	144 000	72 000	-	
loan G M							
size of the loan	630 000						
prepayment	270 000						
payment	72 064	72 064	72 064	72 064	72 064	72 064	
interest	19 800	16 925	13 893	10 693	7 318	3 757	
amortization	52 264	55 139	58 172	61 371	64 746	68 308	
loan	307 736	252 597	194 425	133 054	68 308	-	
loan CS							
size of the loan	630 000						
prepayment	270 000						
payment	72 522	72 522	72 522	72 522	72 522	72 522	
interest	20 520	17 556	14 423	11 111	7 611	3 911	
amortization	52 002	54 966	58 099	61 411	64 911	68 611	
loan	307 998	253 032	194 933	133 522	68 611	-	
operating costs							
purchase of petrol	123 480	125 950	128 469	131 038	133 659	136 332	
purchase of electricity							
service costs	60 000	60 000	60 000	60 000	60 000	60 000	
tires purchase	12 000		12 000		12 000		
insurance	11 663	11 663	11 663	11 663	11 663	11 663	
purchase by cash							
tax shield	77 429	97 123	85 626	69 340	57 864	41 599	
cash flow	- 900 000	- 207 143	-197 613	-212 132	- 202 701	- 217 322	91 578
purchase by G M							
tax shield	81 389	100 508	88 405	71 479	59 328	42 350	
cash flow	- 270 000	- 279 207	- 269 677	- 284 196	- 274 765	- 289 386	19 349
purchase by CS							
tax shield	81 532	100 633	88 510	71 562	59 386	42 381	
cash flow	- 270 000	- 279 665	- 270 135	- 284 654	- 275 223	-289 844	19 360

Table 7.1.1. Financial calculations for the purchase of 3 diesel cars (data in CZK)

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7.1.2. Financial analysis - 3 x Hybrid cars

Year	2015	2016	2017	2018	2019	2020
The cost of new cars						
Purchase price	1 350 000					
Depreciation	270 000	432 000	324 000	216 000	108 000	-
Loan G M						
size of the loan	945 000					
prepayment	405 000					
payment	108 097	108 097	108 097	108 097	108 097	108 097
interest	29 700	25 388	20 839	16 040	10 977	5 635
amortization	78 397	82 708	87 257	92 057	97 120	102 461
loan	461 603	378 895	291 638	199 581	102 461	-
Loan CS						
size of the loan	945 000					
prepayment	405 000					
payment	108 783	108 783	108 783	108 783	108 783	108 783
interest	30 780	26 334	21 634	16 667	11 416	5 866
amortization	78 003	82 449	87 149	92 116	97 367	102 917
loan	461 997	379 548	292 399	200 283	102 917	-
operating costs						
purchase of petrol	70 560	71 971	73 411	74 879	76 376	77 904
purchase of electricity						
service costs	60 000	60 000	60 000	60 000	60 000	60 000
wheels purchase	18 800		18 800		18 800	
insurance	11 663	12 013	12 373	12 744	13 127	13 521
purchase by cash						
tax shield	83 872	112 794	95 242	70 176	52 635	27 581
cash flow	- 1 350 000	- 161 023	- 143 984	-164 584	- 147 623	- 168 303
purchase by G M						
tax shield	92 145	120 274	101 885	75 933	57 456	31 412
cash flow	- 405 000	- 269 120	- 252 081	- 272 681	- 255 720	- 276 400
purchase by CS						
tax shield	92 361	120 464	102 044	76 058	57 544	31 458
cash flow	- 405 000	- 177 445	- 132 303	- 171 323	- 180 348	- 252 958

Table 7.1.2. Financial calculations for the purchase of 3 hybrid cars (data in CZK)

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7.1.3. Financial analysis - 3 x Electric cars

Year	2015	2016	2017	2018	2019	2020
The cost of new cars						
Purchase price	2 400 000					
Depreciation	480 000	768 000	576 000	384 000	192 000	
Loan G M						
size of the loan	1 680 000					
prepayment	720 000					
payment	192 172	192 172	192 172	192 172	192 172	192 172
interest	52 800	45 135	37 048	28 516	19 515	10 018
amortization	139 372	147 037	155 124	163 656	172 657	182 153
loan	820 628	673 591	518 467	354 811	182 153	-
Loan CS						
size of the loan	1 680 000					
prepayment	720 000					
payment	193 392	193 392	193 392	193 392	193 392	193 392
interest	54 720	46 816	38 461	29 630	20 295	10 429
amortization	138 672	146 576	154 931	163 762	173 096	182 963
loan	821 328	674 752	519 821	356 059	182 963	-
operating costs						
purchase of petrol						
purchase of electricity	23 760	23 760	23 760	23 760	23 760	23 760
service costs	4 500	4 500	4 500	4 500	4 500	4 500
wheels purchase	12 000		12 000		12 000	
insurance	11 663	11 663	11 663	11 663	11 663	11 663
purchase by cash						
tax shield	104 052	159 252	123 252	82 452	46 452	5 652
cash flow	- 2 400 000	- 51 923	- 39 923	- 39 923	- 51 923	833 367
purchase by G M						
tax shield	116 945	170 612	132 994	90 488	52 688	9 988
cash flow	- 720 000	- 244 095	- 232 095	- 244 095	- 244 095	642 443
purchase by CS						
tax shield	117 329	170 948	133 277	90 711	52 844	10 070
cash flow	- 720 000	- 245 315	- 233 315	- 245 315	- 245 315	641 254

Table 7.1.3. Financial calculations for the purchase of 3 electro cars (data in CZK)

7.2. Comparison of options

The following sections present the results of calculations of economic efficiency. These parameters are presented cost-effectiveness of the project Net Present Value. Unfortunately in the given situation comparison to other possible parameters evaluation described in paragraph 6.5. is not possible. The tables present not only the net value of projects currently purchase vehicles with different drive, but their confrontation with several possible ways of financing.

7.3. Comparison of the results

After applying the methods described in Section 6.7 it's possible to obtain the values of NPV having all the necessary data regarding cash flows for each year of vehicles operation.

	Diesel cars	Hybrid cars	Electric cars
NPV value by cash, CZK	- 1 885 018	- 1 796 973	- 2 097 345
NPV value by GM, CZK	<u>- 1 573 720</u>	<u>- 1 329 323</u>	<u>- 1 266 238</u>
NPV value by CS, CZK	- 1 575 471	- 1 332 346	- 1 271 614

Table 7.3. NPV results in CZK

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Normally, negative value of NPV means that the project should not be accepted. However, in our case we are talking only about the costs that would entail the purchase of cars. In this regard, possible to say that the positive component of the cash flow that the vehicles can make for the company will be the same for all options selected machines and to simplify the calculation it is possible to eliminate.

The greatest value NPV tells us about the most best-case scenario. In our case, when it is only about cost, NPV with the value closest to 0 would be better to choose.

After summing up the results it's possible to say that the most attractive and effective option is to buy a 3 electric cars and loan from GM bank. This option shows the best value of NPV.

7.4. Other factors that can may affect the choice.

During our choice of all three proposed options also need to pay special attention to the factors that either cannot be counted or counting which is extremely difficult

One such factor can be the image component of EV for the company. With good advertising and right conditions the possibility of buying more expensive EV may affect for the future clients, some of them may be people for whom the environmental pollution is not the last priority in life, and these people would consciously become customers of this company that will bring additional money and possible can be able to cover the higher purchase price of EV.

8. Sensitivity analysis

To select a suitable parameter sensitivity analysis projects were considered the most important aspect of the decision on the purchase of vehicles. As the most important factor advantages of individual decisions was chosen average number of kilometers driven per year. Depending on this parameter compared with the advantages of individual decisions to enable a more complete assessment of options.

8.1. Sensitivity analysis of variants

In this type of analysis will show the effect of kilometers traveled by cars per year on the total value of NPV. In our calculation of the value of kilometers was taken 35,000 km a year so, for clarity, we will modify the parameter with 10,000 km 50 000 km in increments of 5,000 km. This will undoubtedly have an effect on parameters such as service maintenance (which depends on the kilometer traveled) and the amount of costs associated with buying new wheels.

However, one of the main parameters of the possibility of using electric vehicles on the example of the company is its maximum cruising range on one battery charge, in this context, the comparison must take into account the fact that the value of 35 000 km per year, this number is approximate to the maximum possible distance that can be driven electric vehicle recharging only 1 time per day. For this reason, the maximum value of the range for an electric vehicle in the year will be 35,000 km per year.

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km/year, tsh	10	15	20	25	30	35	40	45	50
Diesel cars									
Cash	-1200013	-1 315 904	-1 458 183	-1 600 461	-1 742 740	-1 885 018	-2 027 297	-2 169 579	-2 311 854
Loan GM	-888 715	-1 004 606	-1 146 885	-1 289 163	-1 431 442	-1 573 720	-1 715 999	-1 858 278	-2 000 556
Loan CS	-890 465	-1 006 356	-1 148 635	-1 290 914	-1 433 192	-1 575 471	-1 717 749	-1 860 028	-2 002 306
Hybrid cars									
Cash	-1 360 605	-1 426 529	-1 519 140	-1 611 751	-1 704 362	-1 796 973	-1 889 584	-1 982 195	-2 074 806
Loan GM	-892 655	-958 879	-1 051 490	-1 144 101	-1 236 712	-1 329 323	-1 421 933	-1 514 544	-1 607 155
Loan CS	-895 679	-961 902	-1 054 513	-1 147 124	-1 239 935	-1 332 346	-1 424 957	-1 517 568	-1 610 179
Electric cars									
Cash	-2064447	-2 068 447	-2 072 447	-2 076 447	-2 086 895	-2 097 345	-2 107 795	-2 118 244	-2 122 244
Loan GM	-1233340	-1 237 340	-1 241 340	-1 245 340	-1 255 789	-1 266 238	-1 276 988	-1 287 137	-1 291 137
Loan CS	-1 238 715	-1 242 715	-1 246 715	-1 250 715	-1 261 165	-1 271 614	-1 282 063	-1 292 513	-1 296 513

Table 8.1. Sensitivity analysis of variants (CZK)

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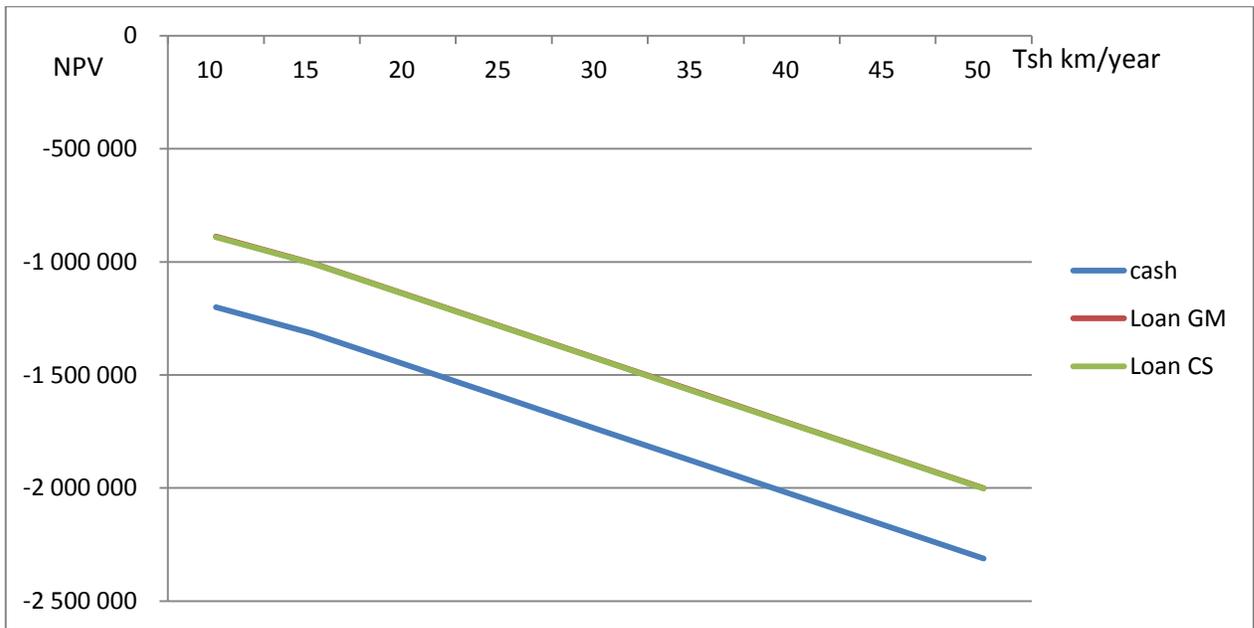


Diagram 8.1.1. Analysis of purchase diesel vehicles depending on the choice of financing (CZK)

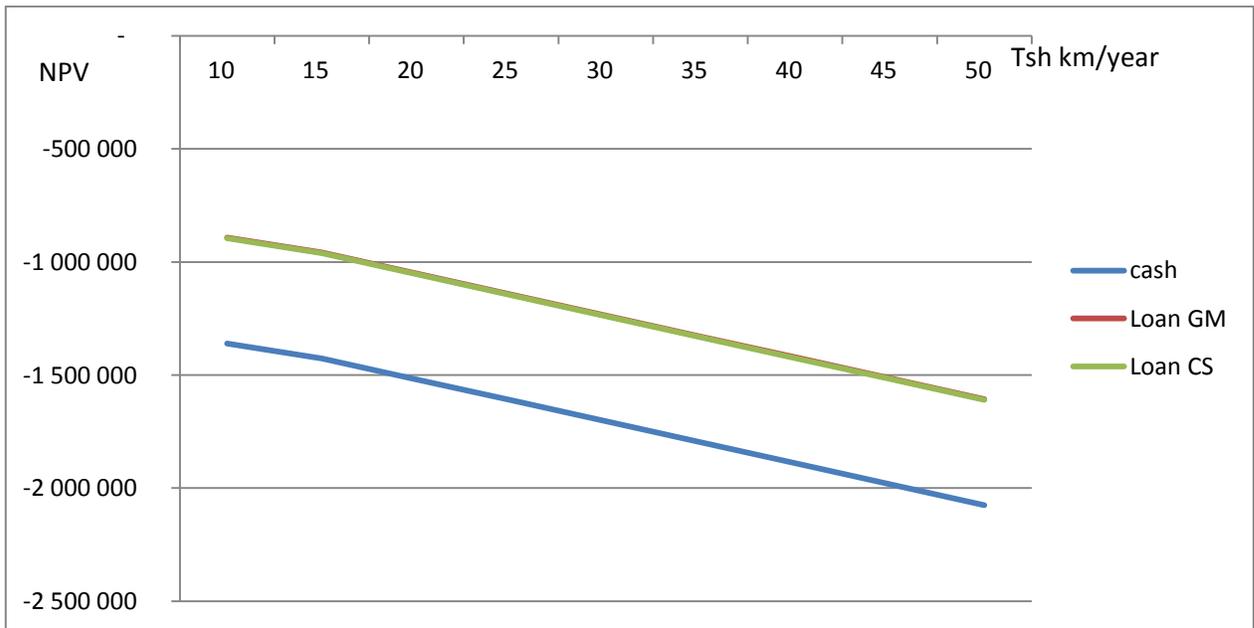


Diagram 8.1.2. Analysis of purchase hybrid vehicles depending on the choice of financing (CZK)

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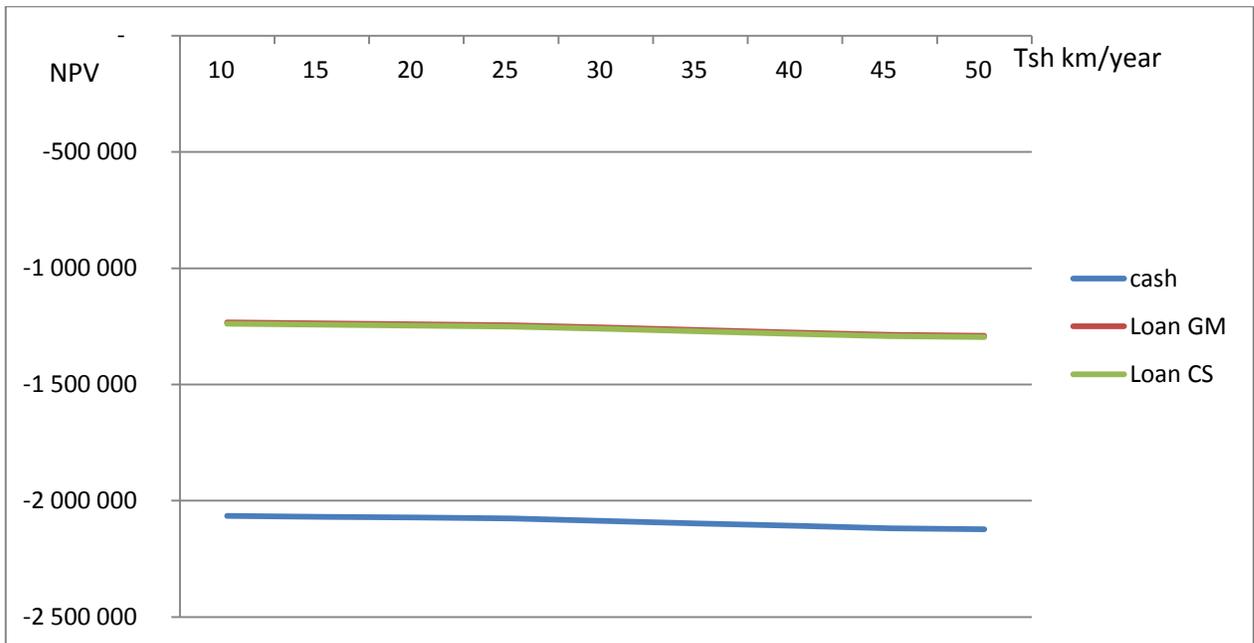


Diagram 8.1.3. Analysis of purchase electric vehicles depending on the choice of financing (CZK)

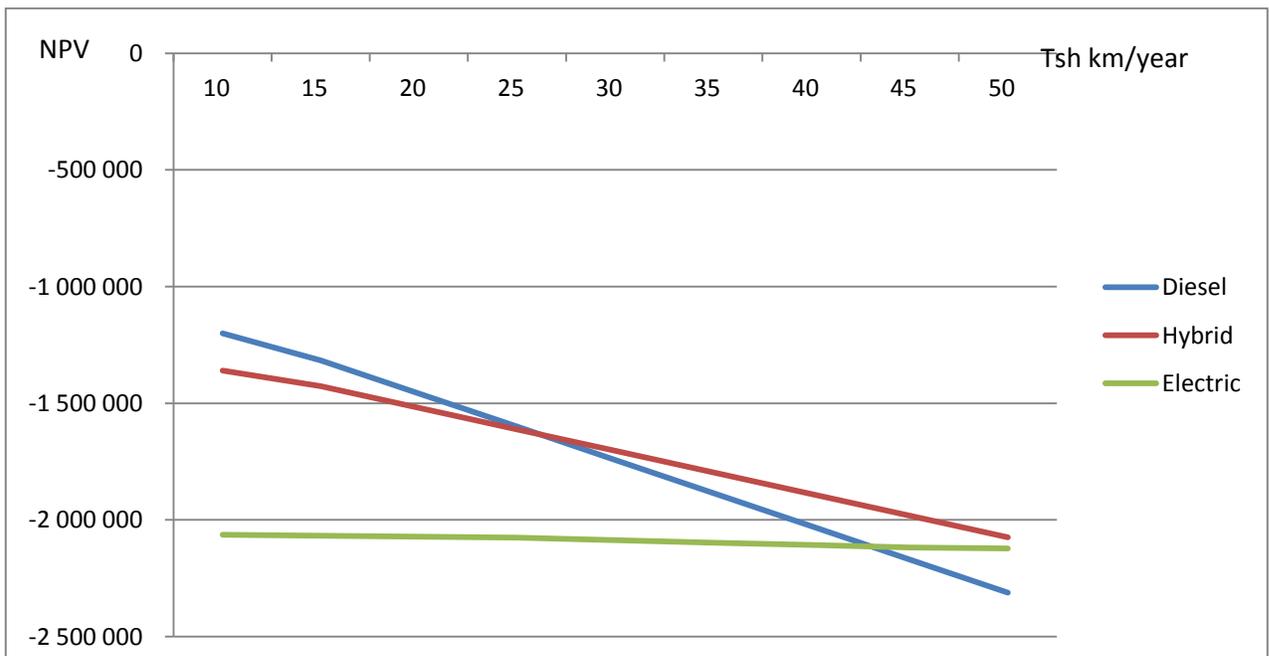


Diagram 8.1.4. Analysis of purchase cars in cash, depending on the type of vehicle (CZK)

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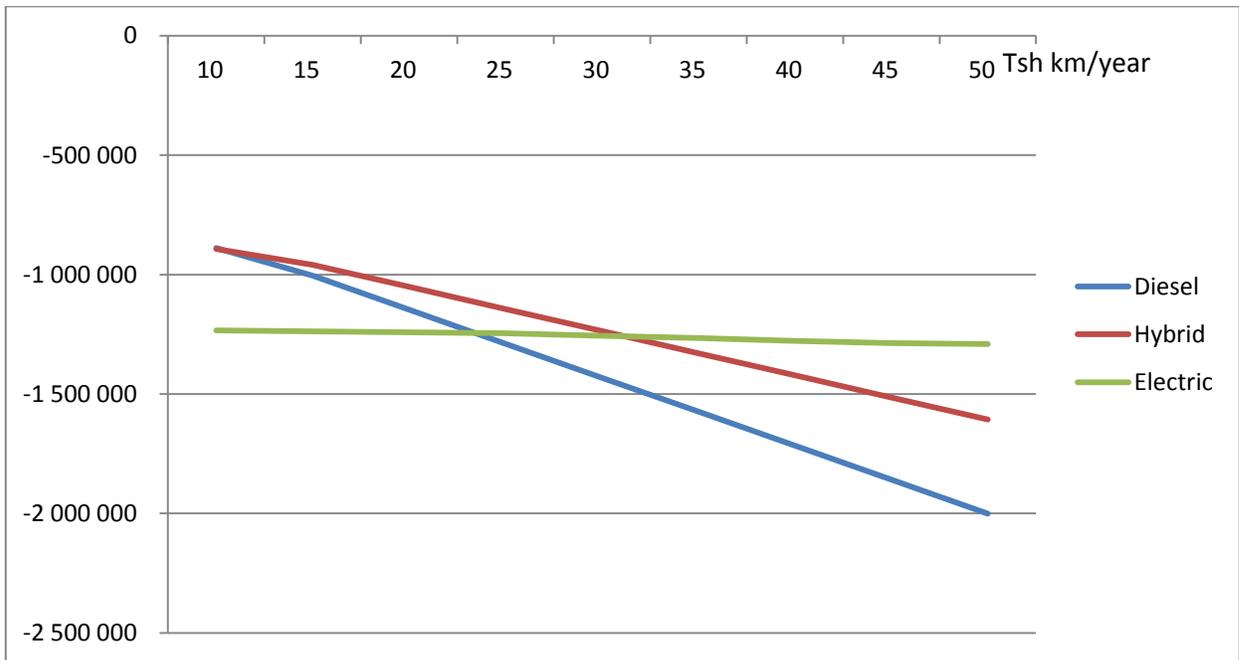


Diagram 8.1.5. Analysis of purchase cars by loan from Ge Money bank, depending on the type of vehicle (CZK)

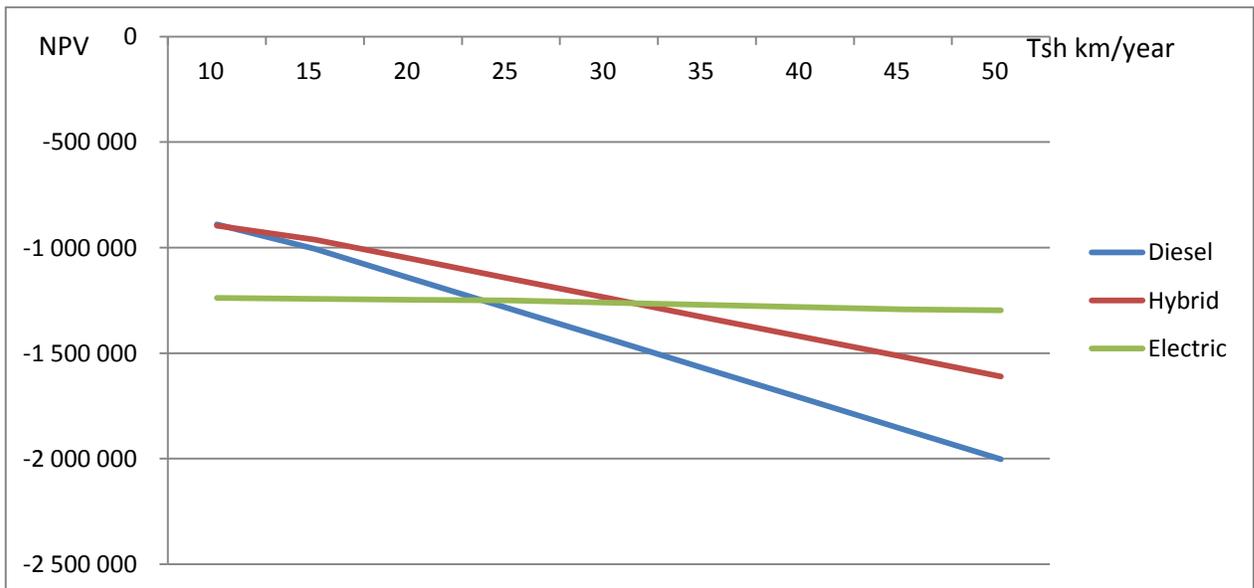


Diagram 8.1.6. Analysis of purchase cars by loan from Ceska Sporitelna bank, depending on the type of vehicle (CZK)

8.2. Break-even point analysis

For more fully analysis of the results we will do break-even point analysis. This analysis shows the dependence of the NPV depending on changes in fuel prices (For EV fuel will be considered as electricity). For calculating NPV was chosen the most favorable in all cases - NPV with loan from GE.



Diagram 8.2. Break-even point analysis in depending on cost of fuel changes to the NPV (CZK).

8.3. Sensitivity and BEP analysis outputs

On the basis of the analysis possible draw some preliminary conclusions based the point of intersection:

- For all three options for financing the purchase of cars worth considering the fact that if we want to use the car less than 15 000 km per year, more rational thinking of getting the diesel car, due to more conducive indicator NPV. The greatest influence on the result in this case is played the low price of purchase a new car but for cases with bank loan NPV values for diesel cars and hybrid cars would almost on the same level.
- Another important point of the analysis is the fact that if we are planning to buy cars by cash without bank loan in this case starting from 10 000 to 25 000 kilometers per year would be the best option to buy a diesel cars, after 25 000 kilometers per year the best NPV value will show hybrid cars because of the high fuel-efficient performance. However, in this case, electric car will be more favorable for purchasing in comparison with the diesel cars starting from 40 000 kilometers per year.
- However, when considering the options with a bank loan we get a completely different situation: between 10 000 and 30 000 kilometers per year the best results will have option with hybrid cars. But since 30 000 kilometers per year the best NPV value will show option with EV. This means that from this point on those savings on service costs and fuel for electric vehicles to become so notable that this option will be the best of all possible. It is also possible to add that the option with the purchase of electric vehicles will be the most

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favorable option than diesel car starting from 20 000 kilometers per year.

- Break-even point analysis shows us NPV dependence on fluctuations in fuel prices, according to decreasing graphs clearly shows which option the most depends of changes in fuel prices. In addition, it may be noted that the decline in fuel prices 15% and more better performance NPV will have hybrid cars. In the current situation and fluctuations in oil prices, this option is possible.

9. Conclusion

In this work was investigated by the electric force as a possible alternative replacement engines using diesel as fuel. On an example of real company was considered an example of the use of electric power as a substitute for an internal combustion engine as partially (hybrid engine) or fully electric.

At the beginning work was described all possible alternatives fuel vehicle as the driving force, were analyzing it and a description of their strengths and weaknesses.

Other section described the existing technologies of electric force for movement of vehicles, described existing versions EVs and made their direct comparison with an internal combustion engine with the description of the problems with technology and possible solutions. In this case it is necessary to take into account that, given the current situation of this technological breakthrough in this area is possible at any time. And the situation can change dramatically within the next 5 years already.

To be able to evaluate options for the immediate use of electric vehicles on the example of the business company were selected 3 replacement option; this option are based on the most common type of alternatives available in the Czech Republic and was made a reasonable choice of possible options.

The first option is due to the purchase of new diesel car to be able to compare a car with an internal combustion engine with subsequent. The second option is due to the purchase of new hybrid cars as an alternative to using an electric power as an auxiliary component of the internal combustion engine. A third option is due to the purchase of electric cars using only the electric force, this option is the most attractive not only from a technological point of view but also from the ecological. Possible maximum annual

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mileage was set at 35,000 miles per year; this figure is acceptable for all 3 options including the maximum number of kilometers traveled per day. In this case, it should be understood that the choice of car to buy based on the needs of not big company. In addition, the selection was based on the state of the infrastructure for electric vehicles in the Czech Republic. In other words, for any other company choice of cars could be different, particularly if the company would use the cars for work with clients a direct, instead for service trips.

Fuel prices (including the price of electricity) were selected on the basis of historical data obtained during the previous ten-year period. But taking into account the current state of the fuel market and taking into account the changes that followed for the past 2-3 months, rising fuel prices in the coming years can significantly slow down. In the calculation of economic efficiency the options considered several options for financing the purchase of cars. The purchase option of vehicles considered by own expense, purchase by a car loan from the GE Money bank and purchase by the loan from Ceska Sporitelna bank.

Economic efficiency was based on Net Present Value (NPV), for all methods of financing. Based on the results possible to say that the most effective option is the purchase of electric cars because of their low maintenance and services costs, which is undoubtedly a play an important role in long-term calculation and it is well seen from paragraph 6.8. In addition, it is necessary to pay attention to the fact that the difference between electric and hybrid cars with the current parameters is minimal. This means that the hybrid car with its low fuel costs not only takes the 2nd position in the list, and is practically at the level of an electric vehicle.

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For a more depth assessment has been made sensitivity analysis, which was based on the NPV on the one hand and on the number of kilometers driven per year and the method of financing on the other hand. Need to pay attention to the fact that each of the options can be most advantageous, depending on the kilometers driven per year. Based on the results it is also possible to make conclusions that the option of diesel cars would be the best option when you drive less than 10 000 Km per year. More than 10 000 Km per year would be the best option with hybrid cars but starting from the 30 000 km per year the best option for our case would be electrical cars. This is a very interesting result clearly shows that already today In case of using the not most advanced technologies in the electric automobile production we can get better results than the nearest competitor which using fuel as the driving force.

Summing up the results it's necessary to look at the situation not only from economic point of view. The basic idea of the possibilities to replace the internal combustion engine was not only to assess its economic efficiency but also the possibility of using more environmentally friendly vehicle. Therefore, I think we should base choice solely on the economic component and do not reject the possibility to use electric vehicle and to take into account an environmental and image component.

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List of abbreviations:

ICE - Internal combustion engine

HEV - Hybrid electric vehicles

PHEV - Plug-In Hybrid Vehicle

EREVs - Extended Range Electric Vehicles

NiNaCl - Sodium Nickel Chloride batteries

PEMFC - Polymer Electrolyte Membrane Fuel Cells

PAFC - Phosphoric Acid Fuel Cells

MCFC - Molten Carbonate Fuel Cells

SOFC - Solid Oxide Fuel Cells

AFC - Alkaline Fuel Cells

DMFC - Direct Methanol Fuel Cells

EV - electric vehicles

TDI - Turbo Diesel Injection

VAT - Value added tax

NPV - Net Present Value

ROI - Return of Investment

IRR - Internal Rate of Return

PP - Payback Period