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The impact of electric vehicles on the automobile industry

Bachelor thesis

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Abstract

The main aim of this bachelor thesis is to identify the current and future importance of the electric vehicles. Apart from global situation, it also investigates the development in China, Europe, Norway and the U.S. To see the future position of electric vehicles on the automotive market, trend analysis and Bass Diffusion Model were used. The results showed that in the year 2035, the share of sales of electric vehicles will slowly approach a threshold of 50% in all analysed regions. The exception is Norway where the market of electric vehicles is already developed. Next, the correlation analysis was applied to measure the relationship between the sales of electric vehicles and internal combustion engine vehicles. It was shown that the correlation is relatively strong with the same direction. The sales are influenced by similar factors. Furthermore, the correlation analysis was used to detect the relationship between the sales of electric vehicles and price of gasoline. The coefficient was positive. At the end, the regression analysis was applied to measure the cross elasticity of demand between electric and internal combustion engine vehicles. It was proved that these vehicles are substitutes. That means that the price of internal combustion engine vehicle can affect the sales of electric vehicles.

Abstrakt

Hlavním cílem této bakalářské práce je identifikovat aktuální a budoucí význam elektrických vozidel. Vedle globální situace zkoumá práce také vývoj v Číně, Evropě, Norsku a Spojených Státech. Ke zjištění budoucí pozice elektrických vozidel na automobilovém průmyslu byla použita analýza trendu a Bassův Model Difúze. Výsledky ukázaly, že v roce 2035 se podíl prodejů elektrických vozidel bude blížit hranici 50 % ve všech analyzovaných oblastí. Výjimkou je Norsko, kde je trh s elektrickými auty již rozvinut. Dále byla použita korelační analýza ke změření vztahu mezi prodeji elektrických vozidel a vozidel se spalovacím motorem. Bylo ukázáno, že korelace je relativně silná se stejným znaménkem. Prodeje jsou ovlivněny podobnými faktory. Navíc byla změřena korelace mezi prodeji elektrických vozidel a cenou benzinu. Koeficient vyšel pozitivně. Nakonec byla aplikovaná regresní analýza k vypočítání křížové elasticity poptávky mezi elektrickými vozidly a vozidly se spalovacím motorem. Bylo dokázáno, že tato vozidla jsou substituty. To znamená, že cena vozidel se spalovacím motorem ovlivňuje prodeje elektrických aut.

Klíčová slova

Elektrická vozidla, Automobilový průmysl, Bassův model difúze, Křížová elasticita poptávky, Regresní analýza, Analýza trendu, Korelační analýza

Keywords

Electric vehicles, Automotive industry, Bass Diffusion Model, Cross elasticity of demand, Regression analysis, Trend analysis, Correlation analysis

Range of thesis: 71 186 characters with spaces

Declaration of Authorship

1. The author hereby declares that he compiled this thesis independently, using only the listed resources and literature.

2. The author hereby declares that all the sources and literature used have been properly cited.

3. The author hereby declares that the thesis has not been used to obtain a different or the same degree.

Prague, May 8, 2018 Adéla Pavelková

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I would like to also express my sincere gratitude to Ing. Ivo Koubek for guiding me when choosing the topic and compiling the content, for his patience, motivation and immense knowledge.

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Institute of Economic Studies
Bachelor thesis proposal

Author: Adéla Pavelková
Supervisor: doc. PhDr. Julie Chytilová Ph.D.
Proposed topic: The impact of electric vehicles on the automobile industry

Preliminary scope of work:
Research question and motivation
The research question I will be studying in this bachelor thesis is whether the industry of EV's is able to be competitive. The industry of EV's is at its beginning, but it may have a great future ahead of itself. In this thesis, I will analyse the development of the industry, its current importance and market share of EV's nowadays. Using the methodology of the elasticity model, I will calculate the extent to which EV's can be considered as a substitute to non-electric vehicles. These results will help us to analyse whether the EV's may replace the non-electric cars or not. My thesis can also help to answer the question whether the EV's can be considered as the future of the automobile industry.

Contribution
As the industry is still in its early stages, there have been published many different articles with inconsistent opinions about the importance of this sector. The perspectives on the future of EV's vary as well. I would like to summarize the real development, as well as objectively qualify the possible importance of this industry mainly for companies. My thesis can be later used in practice for further analysis of this car segment. It could also be interesting to evaluate whether the future expectations were right. Later, the extent to which we can consider the industry of EV's as substitutes to non-electric vehicles may develop as well. This type of analysis can be beneficial for potential producers of car parts and accessories to consider adopting their program for newly growing car segment.

Methodology
To answer the question of my thesis, I will use the official data of the automobile factories. These datasets are very often published monthly. There are also many other relevant data about the car market statistics. With the knowledge of sales, I will firstly analyse the market share of EV's in comparison to the market share of non-electric cars (in percentages). These data will give us the background for the consecutive correlation analysis. The analysed question will be whether the increase in the number of EV's is directly related to the decrease in sales of non-electric vehicles. By trend analysis and Bass Diffusion Model, it will be possible to measure the presumable future of EV's. Very important part will be the question to which extent can EV's be considered as substitutes to non-electric vehicles. I will use the elasticity model based on the application of the cross elasticity of demand. This model measures the impact of change in price of one good on demanded quantity of other good.

Outline

Introduction
History and description of EV's
Percentage comparison - market share of EV's and comparison to the market share of non-electric vehicles
Correlation analysis with the application of the results computed before
Trend analysis and Bass Diffusion Model - the possible future of EV's
Application of the elasticity model - use of cross elasticity of demand to measure if we can consider the electric vehicles as substitutes to non-electric vehicles
Conclusion and answering the question whether the industry of EV's can be considered as a real competition

Bibliography

Ajanovic A. "The future of electric vehicles: prospects and impediments". WILEY INTERDISCIPLINARY REVIEWS-ENERGY AND ENVIRONMENT. November/December 2015. p521-p536.

Carley S., Graham J.D., Krause R.M., Lane B.W. "Intent to purchase a plug-in electric vehicle: A survey of early impressions in large US cites". Transportation Research Part D: Transport and Environment, January 2013. p39-45.

The Economist. "Sales of green vehicles are booming in Norway". 18. February 2017. http://www.economist.com/news/business/21717063-ever-more-electric-cars-are-road-next-step-build-charging-network-support

The Economist. "Why the future is hybrid". 2. December 2004. http://www.economist.com/node/3422941

Feng Wei, Miguel Figliozzi. "An economic and technological analysis of the key factors affecting the competitiveness of electric commercial vehicles: A case study from the USA market". Transportation Research: Part C. January 2013, Vol. 26. p135-145.

Kraft, Thomas E. "Electric Vehicles--A Historical Snapshot". Tech Directions. November 2012. 4pp.

Mealiea Wallace. "What Makes EVs Work?". Electric Perspectives. September/October 2012, Vol. 37 Issue 5. p10-10.

Russell Hensley, Stefan Knupfer, and Dickon Pinner. "Electrifying cars: How three industries will evolve". McKinsey, June 2009. http://www.mckinsey.com/industries/automotive-and-assembly/our-insights/electrifying-cars-how-three-industries-will-evolve

Contents

1 Introduction

The automobile industry may be at the threshold of a new era with the emergence of electric vehicles. The limited oil reserves, persistent noise, worsening air pollution are the most important factors favouring these vehicles. Furthermore, the desire for technological innovation is also relevant part. Nowadays, these vehicles experience great enhancement and they become more popular. An example can be the recent mission of Tesla Roadster into the space. This makes the topic of electric vehicles very interesting. In addition, some countries as for example the United Kingdom or France have decided to ban the sales of gasoline and diesel cars in the near future. Therefore, with the existing possibility that the electric vehicles will become the only allowed vehicles in the future, this topic is of high importance.

However, many impediments need to be solved firstly to make the electric vehicles a competitive market. That means high purchasing price, bad rechargeable infrastructure and unsatisfactory driving range. Nowadays, these shortcomings are compensated by appreciable government subsidies.

For producers, potential buyers and investors, it is very important to have decent knowledge about current standings, possible future and factors influencing the development of the electric vehicles. This information will help them to decide whether it is worthy investing in the electric vehicles.

As the industry is still in its early stages, the opinions on the future development are very inconsistent. Therefore, we will conduct our own analysis on the future development for the year 2035. For this purpose, I have decided to use Bass Diffusion Model. There exist researches calculating the future behaviour, but most of them have used other methods as for example agent-based model or simulation models. To my best knowledge, the Bass Diffusion Model has not been used to forecast the sales of the electric vehicles in Europe. On the U.S., Thomas A. Becker, I. Sidhu and Burghardt Tenderich (2009) have used this model to predict the future till the year 2030. On China, Ming Zeng, Fan-xiao Zeng, Xiao-li Zhu and Song Xue (2012) have predicted the development in China till the year 2022 using the Bass Diffusion Model. Therefore, in this thesis, I will complete these gaps and extend the analysis for the year 2035. Also, we will get our own result in order to compare it with so inconsistent opinions on the future in other studies. The Bass Diffusion Model was earlier used to predict the future of mobile phones or colour televisions.

Next, the impact of price of internal combustion engine vehicles on the sales of electric vehicles is certainly a relevant factor for the future development of electric vehicles. For this purpose, it is important to calculate the cross elasticity of demand and verify whether the electric and gasoline cars are substitutes. Not much attention has been paid to this problem. Therefore, we will analyse it using the regression analysis.

Furthermore, most of the studies are focused on some concrete region or country. But, some countries are more progressive than others. Therefore, we will be aimed on more regions to compare their approach and results in the field of electric vehicles. This comparison is very important to find the policy that is the best for expanding the electric vehicles. The regions of our interest are China, Europe, Norway, the U.S. and the global situation.

On a structure of this thesis, the first part will be descriptive. At the very beginning, we will go through the history and description of the electric vehicles. The next chapter will describe the current situation on the market. There, all abovementioned regions will be analysed - their current standings on the market, their diverse approach to support the electric cars, their effort to eliminate the main impediments and the attitude of population towards the adaptation of the electric cars. Later, the literature review will be provided, with the summary of studies and researches that have been made in this field.

In the methodology section, the methods used in this thesis will be described. Next, we will look at the presumable future of the electric vehicles. Firstly, we will conduct the trend analysis to see the potential future in the next couple years. Together with the trend analysis, we will precisely describe factors, which will influence the future behaviour of the market. That means, the possible development of gasoline, diesel and electricity prices, battery prices, investment to rechargeable infrastructure and many other factors will be taken into the account. We will look at their potential future development and discuss how they can affect the market of electric vehicles. Secondly, we will look to the further future with the usage of Bass Diffusion Model.

Later, the common behaviour of sales of internal combustion engine vehicles and electric vehicles will be studied. We will discover whether they behave similarly or they move the opposite way. For this purpose, we will use the correlation analysis. Very important factor influencing the future of electric vehicles is the relationship with the gasoline and electricity prices. Therefore, in the next section, this relationship will be analysed using the correlation analysis.

As abovementioned, the influence of the price of internal combustion engine vehicles on the sales of electric vehicles is very important factor. Therefore, in the next part, the cross elasticity of demand will be measured using the regression analysis to announce whether the vehicles are substitutes. Furthermore, we will discuss the forecasts on the price of internal combustion engine vehicles.

The last chapter will put these calculations together to make a result on the importance and future of the electric vehicles. These calculations will help us to make our own picture in this field of so inconsistent opinions and forecasts. Furthermore, the results will be described and compared for all analysed regions.

2 History

Although, it may seem that the concept of EVs (electric vehicles) is rather a new technology, the first attempts to build an electric car can be dated to 1830s. The big revolution in this branch took place in France. There, the first lead-acid rechargeable battery was introduced in the year 1859. During the late 19th century and the first part of the 20th century, more than 30 companies were actively working on the development of an electric car. [39]

During that time, it was not ordinary to own a car. Horses were still used for the transportation. Only the most prosperous companies were able to produce electric, steam and engine cars. Soon, steam cars were rejected, as the process of starting the engine could last up to an hour. Electric cars were much preferred in the cities, because their speed was lower than the speed of internal combustion engine (ICE) cars. [48]

At the end of 19th century, Ferdinand Porsche developed an electric car. Furthermore, he even constructed the first hybrid car, which could use either gas or electricity. [48]

Baker Motor Company was active in the turn of 19th and 20th century. It was the first company that could build an electric car, which could ride more than 100 miles per hour. At that time, there existed more electric cars, but most of them were not able to pass through the safety tests. The surprise of this new electric car was the successful fulfilling of these tests. [39]

During twenties and thirties of the 20th century, the demand for the electric cars declined. It was mainly due to the lower prices of gas, rapid construction of gas stations and the fact that still many people had better access to gas instead of the electricity. During that time, the technology stagnated.

At the end of the 20th century, General Motors constructed more than 1000 two-door electric cars. These vehicles reached a speed of 60 miles per hour in 8 seconds and were called the EV 1. However, couple of years later, General Motors announced that the public is still not ready to use the electric cars. Consequently, the company destroyed a large amount of these cars, as they did not see any possible profit in them. [39].

The EVs were later used by the National Aeronautics and Space Administration`s (NASA). The vehicles that were established to operate on the moon were electric. These lunar vehicles included satellite and could carry two astronauts. Their driving range reached 57 miles. [39]

Bob Beaumont, the leader of the company Sebring-Vanguard, was the founder of the so-called Citicar. It was an electric car that should have reduced the pollution of air. In the US, this kind of car was massively produced. The highest speed was only 38 miles per hour as it was intended being used only in cities. [39]

On Europe, the United Kingdom was the leader in the production of electric cars. In seventies, more than 150 000 electric cars were used in Britain. Among them, there existed the milk delivery trucks. Their maximum speed was only 25 miles per hour, but they were very safe and reliable. Unfortunately, these trucks were not used globally, as they were constructed for the left-hand driving only. [39]

With the beginning of the 21st century, the new revolution and rapid development has come. The first mass-produced hybrid car sold world-widely was Toyota Prius. Another great step was the establishment of the company Tesla. This company started to produce purely electric, luxury cars that could be used for long-distance trips. The success of the company motivated other globally well-known companies to start producing their own electric or hybrid cars. Unlike Tesla, the other companies saw a potential profit in producing the electric vehicles that would be financially more accessible. Among the successful companies is for example Nissan. With the higher demand for electric cars, the further development of batteries started as well. [48]

3 Description of electric vehicles

As we are looking for the replacement of ICE vehicles, we must distinguish between various possibilities of electric vehicles.

3.1.1 Hybrid Electric Vehicle

The first type is called Hybrid Electric Vehicle. As the name of this type says, these cars are equipped with the internal combustion engine as well as with the electric engine. The internal combustion engine should be used as the main source, especially for longer distances. The electric engine is considered as a supplement.

The most important is that these vehicles cannot be plugged to the electricity grid. The battery is charged during the braking. The vehicle can be powered by only the internal combustion engine or by the combination of both engines. Other alternative is that the internal combustion engine gives energy to the battery and the wheels are powered by the electricity. [1]

3.1.2 Plug-in Hybrid Electric Vehicle

The other type is Plug-in Hybrid Electric Vehicle. It is very similar to the first type. The main difference is that the battery can be recharged in the electricity stations. Furthermore, the battery is being charged during the braking as well. Here, the electric engine can be used as the principal one because the battery is larger and therefore, the vehicle can ride longer distances. [1]

3.1.3 Battery Electric Vehicle

Battery Electric Vehicles, Full Electric Vehicles or Pure Electric Vehicles are equipped with the battery. The combustion engine is not present here. To charge the battery, these vehicles are plugged into the electricity grid. Among this type are the most well-known vehicles as Tesla or Nissan Leaf. [1]

3.1.4 Range Extender Electric Vehicle

Range Extender Electric Vehicle uses the electric engine as the main source of energy. The combustion engine is also included here. Its main aim is to charge the battery during the ride to prolong the distance the car can run. Therefore, this type is only the other version of the battery electric vehicle. [1]

3.1.5 Fuel Cell Vehicle

Fuel Cell Vehicles are still under development. These vehicles use fuel cell which is powered by hydrogen. The hydrogen is loaded into the vehicle and the fuel cell electrify the hydrogen. [1]

3.2 How does electric vehicle work?

To fully understand the advantages of EVs, we should make a short description about how the EVs work. The main component are the batteries. The supplementary battery helps the car to be started. This battery is also important for other facilities in the car such as lights. Then, the traction battery is used for storing the energy and using it to power the electric engine. The regulator is used to maintain that the batteries will produce a certain amount of energy which will be used in constant rates. [62]

When the vehicle is started by usage of supplementary batteries, the so-called power electronics controller will ensure that the energy will be brought to the electric engine from the traction batteries. Before the energy enters the engine, the converter will change the higher-voltage power to lower-voltage power to manage that the engine will be able to change the electric energy to the mechanical energy. Then, the wheels are powered by the mechanical energy using the transmission. [62]

There exist three main types of batteries that are used:

Lead acid battery – these batteries are cheap and recyclable.

Lithium ion batteries – these types are more expensive as they are lighter and ensure more energy and longer distance range.

Nickel metal hydride batteries – these are the most expensive one, which ensure even higher productivity. [16]

To recharge the batteries, public or home charging stations are used. The charging cable is plugged into the vehicle. The charger changes the power from the station to the composition that can be easily accepted by the batteries. There, the energy is stored.

Depending on the charging speed, there are three main options:

Slow charging – the batteries are recharged in 7–12 hours. These stations are mainly used at homes.

Fast charging – the batteries are recharged in 3-4 hours. These stations are the most popular ones, often used at homes, garages or works.

Rapid charging – the batteries are recharged in a few minutes. These types are usually used in streets. As it is the fastest solution, it is also the most expensive one. [1]

3.3 Range of distance

The driving range is one of the most important factor when considering buying an EV. Hybrid electric vehicles and plug-in hybrid electric vehicles have the advantage of using two different engines. Thus, the driving distance when combining electric and combustion engine might climb up to 800km. Therefore, to realistically compare the distance of those vehicles, the only electric driving range is compared. The driving range is influenced by many factors, the type of road, the temperature, humidity and many others. Overall, the ranges are still not so long.

On battery electric vehicles, the average distance can move from 100 to 500 km. As the hybrid vehicles use primarily the combustion engine, the driving range of the electric engine is maximally around 100 km. [1]

4 Current situation on the market

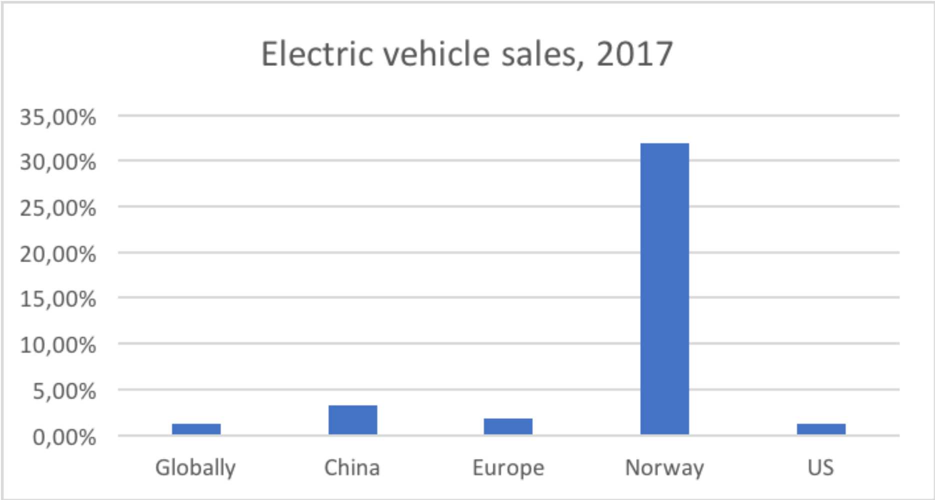
In these days, the automobile industry is going through the great change. Of course, this change includes many new technical challenges, with which the industry must learn how to operate. But, another challenge – even maybe more important – is that users of the vehicles must get used to these new technological changes. For producers, one of the most difficult barrier is that people do not have decent knowledge about the EVs. Naturally, when there is no or only rare knowledge about something new, people are afraid to use it. This situation is even more truthful when there exists an alternative to which people are used to – the ICE vehicles.

As it will be shown, the electric vehicles are experiencing a great development and every day, their number is rising. During the last months, governments of many states have decided to support this progressive process. Furthermore, some states are subsidizing the growth of electric vehicles by very strong incentives. These supportive actions include reduction of the purchase price, usage of the public parking for no fee, possibility to use the bus road lines, no road taxes and many others. To persuade the potential buyers to buy a car, it is much more effective if the price reduction can be evident at the time of purchasing the vehicle. The later advantages do not bring such a great motivation for the potential users of the electric vehicles.

In addition, some countries organize events where people can gain the knowledge about these new vehicles. This obviously includes refuting the belief that costs of EVs are much higher than the costs of ICE vehicles. People need to be informed that despite the higher initial price, the running costs of EVs are then smaller.

4.1 Global situation

Even though, the sales of electric vehicles are increasing every year, the global share is still very low. During the year 2017, 1 227 117 EVs were sold, from which 809 897 were the pure electric vehicles. This number gives us the share of EV sales, which was only 1,30%. More optimistically, in December 2017, the share of global sales ascended to almost 2,07%. However, the sales differ widely in various parts of the world. We can compare the trade in the year 2017 in more locations to see the difference.



Graph: 4.1: Electric vehicle sales, 2017, data source: [65]

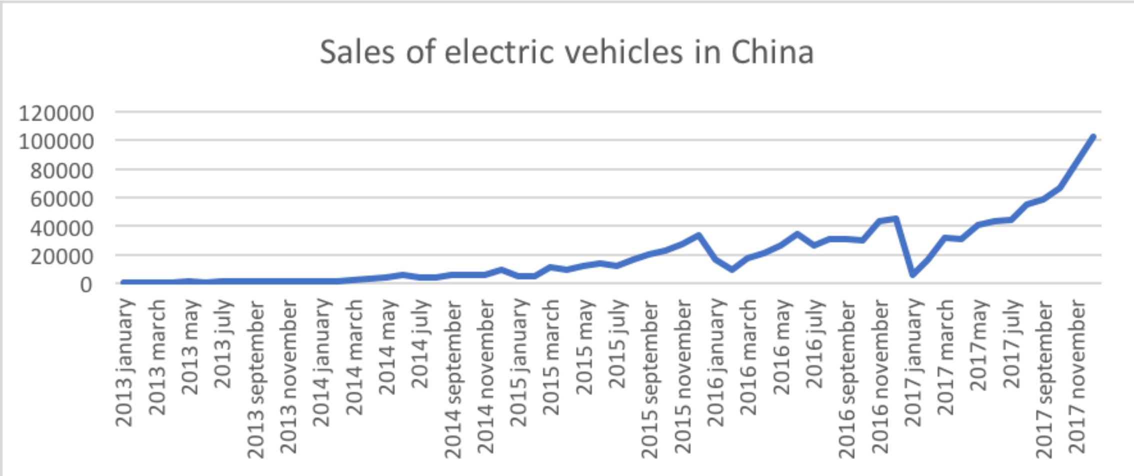
As it can be seen, the differences are quite high (graph 4.1). The reason may be in the diverse approach to the subsidies. For example, in Norway, the price of the car may be reduced to 55% of its original purchasing price by legal combination of the available subsidies [33]. Globally, the sales of EVs are not very radical. But, many countries have decided to support the development and make the EVs a competitive market. Now, we can look more precisely at some concrete locations and their individual approach.

4.2 Situation in China

China belongs to one of the most developing market in this field of electric vehicles. That is primarily caused by very strong incentives from the government. The motivation of China is not only to beat US in the number of EV sales, but among all, to become the leader in their production. The intension is clear, even nowadays, China belongs to the automobile powers and if they could become the leader in the production of EVs, their automobile brands would experience great market growth in this new era of electric vehicles.

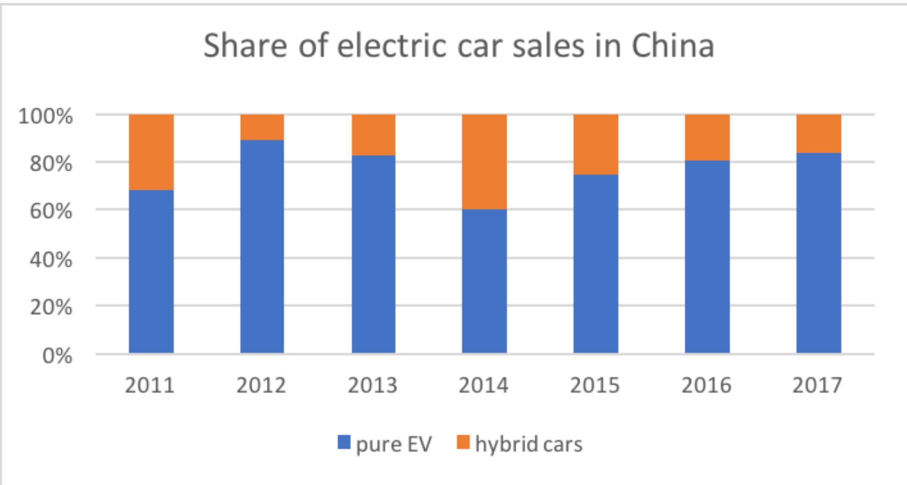
It is not any coincidence that China is now expanding so much. Already in the year 2009, China has invested 4,5 billion US dollars to the development of technology for EVs [35]. The Chinese government has decided that in the year 2030, 80% of sold cars should be electric. Therefore, the subsidies for consumers are also very advantageous. For example, receiving the driving license for EV is easier than for the ICE vehicle. Also, almost 23% of the purchasing price is financed by the state. [23]

Another interesting fact is that almost all EVs which are sold in China are produced by Chinese companies, especially by the company called BYD. This is not an accident, because Chinese government gives subsidies only for locally produced cars. Furthermore, even the producers get financial help from the state [23]. This altogether leads to a rapid growth of EV sales in China.



Graph: 4.2: Sales of electric vehicles in China, data source: [24]

During the year 2015, the strong support from the state has commenced. As it can be seen from the graph 4.2, this policy was very successful. In December 2017, the share of EV sales reached 3,95% from all sold vehicles.



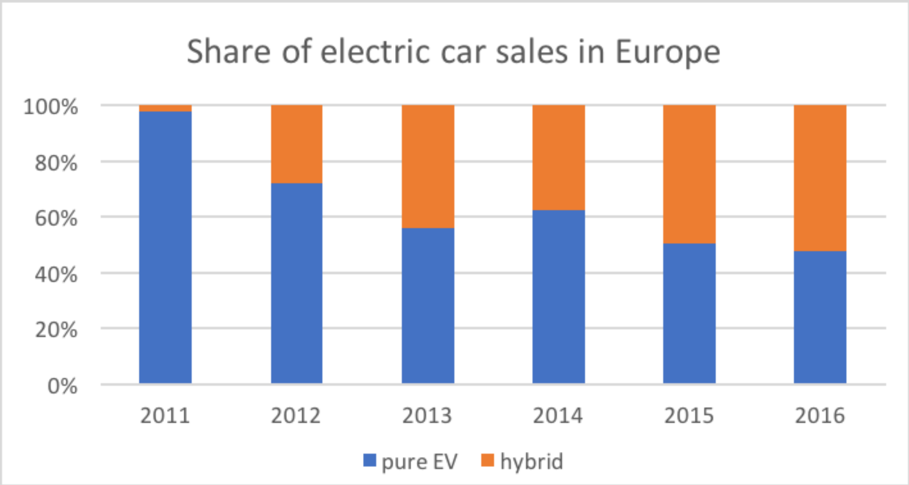
Graph: 4.3: Share of electric car sales in China, data source: [24]

Another fact is that in China, there outweighs the amount of pure electric vehicles (Graph 4.3). This is very important, because globally, the share of pure electric vehicles is around 50%. As the hybrid electric vehicles (HEV) are considered as the intermediary step between the ICE vehicles and pure electric vehicles, it gives China even higher potential for the future. The reason why in China the pure electric vehicles outweigh the HEVs is that Chinese citizens prefer small cars, which are designed for cities. The hybrid vehicles consist of an internal combustion engine and the electric battery. Therefore, it would make no sense to construct small cars with both sources of power. [51]

4.3 Situation in Europe

The current situation in Europe differs a lot from the position of China. The market is very inconsistent, which leads to many problems. According to the European Automobile Manufacturers Association, it is almost impossible for Europe to implement one general program to support the sales of EVs. Therefore, it is quite difficult for the European Union to discuss this policy as a common interest. To support this fact, during the year 2016, 32 EVs were sold in Greece in comparison to Norway, where there were sold 44888 EVs. [22]

Another problem is that the sales of HEVs are beginning to outweigh the sales of pure electric vehicles (Graph 4.4). This is because the Europeans are more careful and they are not so open for new technologies. Therefore, they need a smooth transition from the ICE vehicles to purely electric vehicles through the purchase of hybrid vehicles. However, in the future, this might lead to a problem. Most of the automobile manufacturers do not plan to produce HEVs in the future, they want to focus only on the construction of purely electric cars. Therefore, once the EVs will replace the ICE vehicles, Europe will not be as competitive as China and most likely the US.



Graph: 4.4: Share of electric car sales in Europe, data source: [23], [24]

Even though, Europe is not a leader in the sales of EVs, many countries are working hardly to motivate people to get used to these cars. For instance, Netherland has bought many pure electric vehicles to use them as a taxi service at the Schiphol Airport. [2]

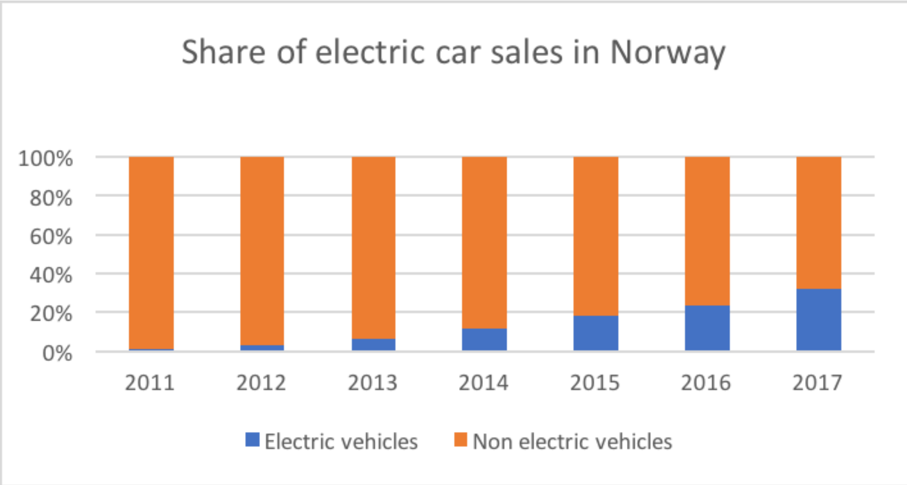
Still, Norway keeps the first position, but Germany is right behind it. Since 2016, the government of Germany has begun to actively support the sales. This resulted in the greatest growth of the sales of EVs in 2017. If this growth would continue, Germany would even outrun Norway.

Some countries acceded to tougher conditions. The United Kingdom and France have decided that from the year 2040, there will be established a ban for selling diesel and petrol cars. [57]

Generally, in all European countries the sales have progressed during 2017. The only exception was Netherland. There, the problem was in the termination of offering the subsidies for HEVs. Nowadays, consumers do not want to use the support to purchase the pure electric vehicles. It may seem as a problem for Netherland, but this step is very important for the future development on the market. Specifically, some people used the subsidies from the state to buy a hybrid vehicle, but later they used only the internal combustion engine [23]. This problem should be viewed as a warning for the whole Europe. It showed what may happen in the situation of selling more hybrid cars.

4.4 Situation in Norway

The current situation in Norway differs a lot in contrast to the other regions. Here, the sales of EVs represent a significant part of the automobile industry (Graph 4.5). On December 2017, almost 45% of car sales were EVs.



Graph: 4.5: Share of electric car sales in Norway, data source: [13]

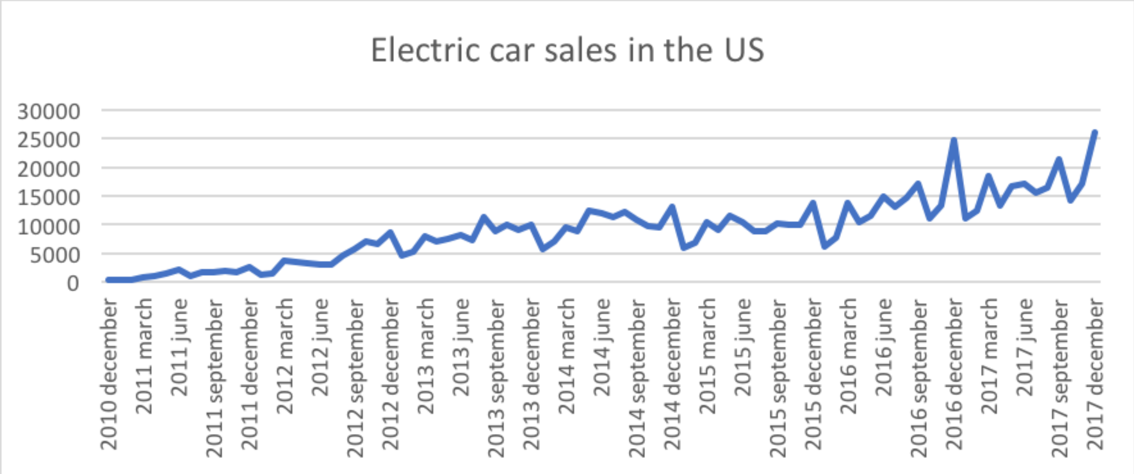
Such success in Norway is achieved thanks to the enormous incentives provided by the state. The subsidies include an elimination of vehicle fees, road taxes, purchase taxes and availability of free public parking. Therefore, the final price of an EV is the same as the price of non-electric vehicle. Furthermore, later, the running costs are even lower. This approach can be performed in Norway due to the very high vehicle taxes [10]. Obviously, this procedure cannot be applied for a long time. It is expected that when the share of EVs will reach 75%, the subsidies will start being removed. [23]

Another motivation for car buyers in Norway is that the charging infrastructure is very well developed and belongs to the best in Europe. Still, there is running a campaign that is focused on the improvement of charging stations. This means to construct the fastest charging stations.

According to the International Council on Clean Transportation, since 2050 all cars on the road should be the electric vehicles. [46]

4.5 Situation in the US

Overall in the US, the sales of EVs are not very remarkable. But, the amount is rising (Graph 4.6). In 2017, the share of EV sales was 1,16%. In December 2017, the share reached 1,63%.



Graph: 4.6: Electric car sales in the US, data source: [36]

The situation in the US is a bit similar to the situation in Europe. The support and subsidies vary around the US states and therefore, the share of EVs differs notably. For the government, it is difficult to implement one general policy, but many states are working hardly to develop the market of EVs. On the other hand, the future speaks for the US. One reason is Tesla Model 3, which should be very attractive to public because it is financially more available. The second reason are still longer distances of new vehicles, which is a very important factor for the US citizens.

As Norway is very important for Europe, the same counts for California in the US. California works actively in the programme called Zero Emission Regulation. Many incentives are also available, for example reduced sales taxes, reduced federal tax credits and permission to ride in a high occupancy vehicle lines. Sooner, California organized events which were focused on familiarization with the EVs. There, potential buyers could get a knowledge about the EVs - how they work and which subsidies and benefits they can get from the state. Furthermore, they could try to drive a car. [44]

Nowadays, California released a car sharing programme. Most of the vehicles used there are the purely electric vehicles. This makes people getting used to these cars more easily. [46]

5 Literature review

As the industry of electric vehicles is rather a new topic, there do not exist enormous number of studies. However, the topic is very important for our future development, therefore, researches are emerging quickly nowadays.

Some studies are focused on the future forecasting. The study by A. Ajanovic (December 2015) highlights that EVs should help to reduce the amount of greenhouse gas. As she stated, in Europe, vehicles create around one quarter of the total greenhouse gas. Before studying the future, she evaluates the current situation. Overall, the share of electric vehicles is very low. The main reasons are high investment costs, limited driving range and bad charging infrastructure. However, she adds that evaluating the charging infrastructure is very misleading, because many users can recharge their cars in their households.

On the future, the author has focused on two issues – batteries and government incentives. On the batteries, the main aim should be to focus on a technology that would decrease their price. In the outermost situation, the battery can create 58% of the car price. However, the price is not the only problem. The batteries are too heavy and their energy endurance is not optimal. As she stated, the future of the electric vehicles stays on the battery development. On the incentives, Norway should be seen as a proper example of combining monetary (road taxes, registration tax, fuel consumption tax) and non-monetary incentives (free parking, bus lines). Usage of only monetary incentives will not lead to such success. Combination of both is more appropriate.

Other studies do not analyse the future only on theoretical basis, but they try to calculate it. The study by C. Liu (2017) used Monte Carlo simulation to predict the future. The result is that the future of the electric vehicles is very uncertain nowadays. The author concludes that the price of EVs will still be higher than the price of ICE vehicle until 2030. The simulation has also showed that neither the decrease of battery prices nor better rechargeable infrastructure will lead to certain future of electric vehicles. The other important factor is the price sensitivity. The lower price sensitivity is important nowadays, as the price should not be the main decisive issue. The other advantages of electric vehicles should be emphasized. On the other hand, the author adds that even if the cheaper batteries will not ensure certainty, the sales will be surely higher.

The study by M. Safari (2017) is consistent with the previous researches. The author agrees that the price of electric vehicle will not be competitive with the price of ICE vehicle in the near future. However, with the support of government incentives, the price might be advantageous. On the price, G. Bauer (2018) emphasizes in his research that the situation is not so pessimistic, because the running costs of EV are lower even nowadays and the purchasing price is still diminishing.

Some studies used the Bass Diffusion Model to predict the future. T.A. Becker, I. Sidhu and B. Tenderich (2009) used this model to discover the future in the United States till 2030. They came with a result that in the year 2030, the sales of electric vehicles could range between 64% - 90% of all sold cars. Furthermore, S. Li, H. Chen, G. Zhang (2017) and A. N. Redondo, A.P. Cagigas (2015) applied the Bass Model to predict the future in China and Spain respectively. On Spain, the results showed that the share of sales could maximally reach 80% in the year 2040.

B. Lin (2017) studied the situation in China. The air pollution in China is very serious, therefore, the electric vehicles are strongly supported by the government. If the growth of electric vehicles would continue similarly, they would soon become the competitive alternative for the ICE vehicles.

Norway is often used as a case study. K.Y. Bjerkan, T.E. Norbech and M.E. Nordtomme (2016) studied Norway as a successful example of implementing the electric vehicles. They say that no country can be compared to Norway in the share of sales nowadays. The achieved success in Norway is caused by the support of government. The incentives made the electric vehicles more favourable than ICE vehicles. This approach also helped people to get used to these vehicles to such an extent that most of the cars are owned by private owners for their daily purposes.

The authors made a research among the car buyers. Most of the respondent agreed that the reduction of vehicle registration tax and value added tax are the most important incentives for them. Others are the reduction from road tolling, vehicle license, free parking, bus line access and free ferry tickets. Nonetheless, some people responded that combination of all of these factors helped them in their decision to purchase an electric car.

S. Hardman (2017) confirms the importance of the incentives in his research. In addition, he says that the incentives should be given according to the driving range of the vehicle.

The study by G. Bauer (2018) adds that government in Norway emphasizes the ecological behaviour. The sales are still increasing and they are supposed to grow further in the future. The breaking point will be the ending of subsidies. The author mentions that the prosperity in Norway may be also due to the culture of owning more cars. Therefore, a household with more cars can replace one of them with the electric car. The research shows that people who bought an electric car are more likely to drive more than before. This can cause more accidents and noise. Therefore, he recommends giving subsidies only for cars, which are bought in order to replace an ICE car. But, as he adds, higher number of kilometres driven by the EV may only replace the kilometres that would have been driven by ICE car even in the situation when the EV is bought as an additional car.

Many studies aimed at the factors which influence the sales. The research by A. Soltani-Sobh, K. Heaslip, A. Stevanovic, R. Bosworth and D. Radivojevic (2017) is focused on factors influencing the sales in the US. They used the binominal logit model. The results are not surprising – higher incentives, higher gasoline prices and income raise the sales. Furthermore, more electric vehicles are sold in the urban areas. However, on the example of Vermont and New Jersey the authors show that these factors cannot be generalized. The presumed results should favour New Jersey but the opposite is true. Therefore, the authors conclude that there exist some unobserved factors which influence each state individually.

The research by S. Carley, J.D. Graham, R.M. Krause, B.W. Lane (2013) studies the factors which influence people in their buying decision. The study was also conducted in the US. The largest problem in buying an EV is the purchasing price and charging time. What may be surprising is that the technical innovation and environmental image was not considered as big advantage. Most of the studies agreed that a typical person buying an electric car is young man with higher education and environmental behaviour. This is in line with the study by K.Y. Bjerkan, T.E. Norbech M.E. Nordtomme (2016) and also G. Bauer (2018).

6 Methodology

To calculate the importance of the EVs, we will use monthly data of sales of EVs and ICE vehicles. As we will compare different regions, we have found the global data and the data for China, Europe, Norway and the US. The choice of these regions is not coincidental. Even nowadays, these areas dominate in the manufacture of vehicles with an exception of Norway. Their intent is to establish a strong position in the industry of electric vehicles. Norway is chosen as a successful example of implementing EVs. Furthermore, it will be clearly seen how different approach cause different level of success. On the US, we have also found data for gasoline, diesel and electricity prices, average EV prices, average ICE prices and disposable income per capita.

To calculate the future behaviour, we will use two different approaches – trend analysis and Bass Diffusion Model. On trend analysis, we will work with the historic data of sales and we will approximate them with a trend line. We will find the line that describes our data the best. This will be done by comparing the R squared of each line. The functions we take into the account are linear, exponential, logarithm and power function. Later, the future growth will be computed with the function we have measured is the best one. This procedure can be accomplished by Excel, which uses the method of least squares.

In the case of linear growth, we will use the function called lintrend, in the case of exponential growth, the function loglintrend will be appropriate. On power growth, the calculations must be done according to the formula $ax\^{}b$. Therefore, firstly, we need to calculate the coefficients a and b. They can be calculated with the combination of functions: exp, index, lintrend and ln. On logarithm growth, the formula $a\ln(x)+b$ is appropriate. The coefficients can be computed with the combination of functions: index, lintrend and ln. [25]

The Bass Diffusion Model forecasts the future with the knowledge of the consumer's potential behaviour. It is a differential equation, which is very often applied to predict whether a new technology or product is likely to being adopted soon in the market. The Bass Model was introduced in the year 1969 and was widely used to predict the sales of for example colour televisions, air conditioners, mobile phones etc. The assumption is that the product is durable. [5]

The Bass Model is represented by a differential equation:

$$\frac{f(t)}{1-F(t)} = p + \frac{q}{M}[A(t)],$$

where $A(t)$ is the cumulative number of adoptions (sales) in the time t. M is the market potential. That means the maximum number of adoptions in the concrete market. The value p is the coefficient of innovation. It is the number of customers, who will buy a new product no matter what other people buy, because they want to adapt a new technology. The value q is called the coefficient of imitation. These customers will buy a product in the situation when other people are buying it as well. They are influenced by the amount of prior sales. $f(t)$ is the share of the market potential, who adapts the new technology at the time t. $F(t)$ is the share of the market potential, who has adapted a new technology until time t. There is an assumption that M is constant. [6]

We will make some algebraic computations to get better form of this equation for the consecutive calculations. For this purpose, we will need a new variable $a(t)$, which is the number of adoptions (sales) in the time t. [6]

Naturally, $a(t) = Mf(t)$ and $A(t) = MF(t)$.

Therefore,

$$\frac{f(t)}{1-F(t)} = p + \frac{q}{M}[A(t)].$$

$$\frac{\frac{a(t)}{M}}{1-\frac{A(t)}{M}} = p + \frac{q}{M}[A(t)].$$

$$\frac{a(t)}{M} = \left(1 - \frac{A(t)}{M}\right)p + \left(1 - \frac{A(t)}{M}\right)\frac{q}{M}A(t).$$

$$\frac{a(t)}{M} = p - p\frac{A(t)}{M} + \frac{A(t)}{M}q - \frac{[A(t)]^2}{M^2}q.$$

$$\frac{a(t)}{M} = p + (q - p)\frac{A(t)}{M} - \frac{[A(t)]^2}{M^2}q.$$

$$a(t) = Mp + (q - p)A(t) - \frac{q}{M}[A(t)]^2.$$

This form of equation is better for our purposes as we will calculate the sales for years, therefore, we need to calculate $a(t)$.

Another part of this thesis will use the correlation analysis. More concretely, we will use two different correlation methods. The first one is the Pearson Correlation and the second one is the Spearman's Rank Order Correlation. Pearson Correlation measures the linear relationship between the variables and the assumption of normality is necessary. The Spearman's Correlation measures the monotonic relationship between the variables. The variables need to be arranged according to their rankings, but the assumption of normality is not needed.

The Pearson Coefficient is calculated as $\frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$, where x_i and y_i are the observations, the $\bar{x}, \bar{y}$ is the mean. The number of observations is displayed by n. [17]

The Spearman's Rank Order Coefficient can be calculated as the Pearson Coefficient, but the variables must be already ranked. When the pairs (in our case the increase/decrease in sale of EV and nonelectric vehicle in one month) do not have the same value, we can use different formula $1 - \frac{6\sum d_i^2}{n(n^2\text{-}1)}$. N denotes for number of observations and d_i^2 is the difference between the variables, which are ranked. [17]

The correlations will be calculated in the software R. To detect which of these two methods will be more appropriate, firstly, we need to run the Shapiro-Wilk test in R. This test will tell us whether the distribution of the data is normal.

At the end, we will calculate whether the price of ICE vehicles affects the sales of EVs. Therefore, we need to calculate the cross elasticity of demand to find out whether the goods are substitutes or complements. To measure whether the goods are substitutes, we will use the regression analysis for calculating the elasticities [49]. This method will allow us not to measure only the point change in prices and sales, but to precisely see the development over some period. More concretely, we will use the log-log model: $\log Q_{EV} = log\alpha + \beta_1 logP_{EV} + \beta_2 logP_{ICE} + \beta_3 logY + \epsilon$, where Q_{EV} is the quantity of sales of the EVs, P_{EV} is the average price of EVs, P_{ICE} is the average price of ICE vehicles, Y is the disposable income per capita and ϵ is the error term. This equation is widely used in studies to measure different elasticities, but we will be interested only in the cross elasticity as our aim is to measure whether the goods are really substitutes. Therefore, we need to calculate β_2, because this coefficient will show us the relation [31]. We will proceed the analysis in the econometric software R.

7 The presumable future of the electric vehicles

Obviously, the market sector of the EVs is still in its early stages, but each year the number of sold cars is rising. Therefore, mainly for the producers but also for the consumers, it is very important to see how this market sector will behave in the future. Most probably, during the next ten years the ICE vehicles will still make higher profit. Later, this can change.

The expectations are rather positive. Many countries have already implemented some sort of subsidies. And even more countries are likely to implement those soon. The core reason is the protection of the environment and the improvement of the air condition mainly in cities. Another reason is the dependence on the oil supplies, which cannot last forever.

The producers also positively incline to the production of EVs. At the very beginning, the purely electric vehicles were very expensive and only small fraction of people could afford it. Nowadays, almost all automobile factories produce an EV. Therefore, the financial availability is wider. We can find EVs in almost all financial categories. The companies have also moved from the production of only luxury cars. In these days, the companies offer vans, family cars, small city cars, coupés, all of them in an electric version. According to the announcements of producers, this trend should continue and the model availability should enlarge very quickly.

Other positive factor supporting the future of EVs is the diminishing price of batteries. The producers of cars are aware of the influence of battery prices. More than one third of the car price is the battery itself. Therefore, the decreasing battery price would lead to higher demand. The economies of scale should also play very important role here. [54]

We will conduct two different analysis. Firstly, we will do the trend analysis to see the near future in the next couple years. Secondly, we will use the Bass Diffusion Model to look to the further future.

7.1 Trend analysis

To do the trend analysis, we will firstly approximate our known data by the trend line that fits most precisely. Then, we will know which function describes our data.

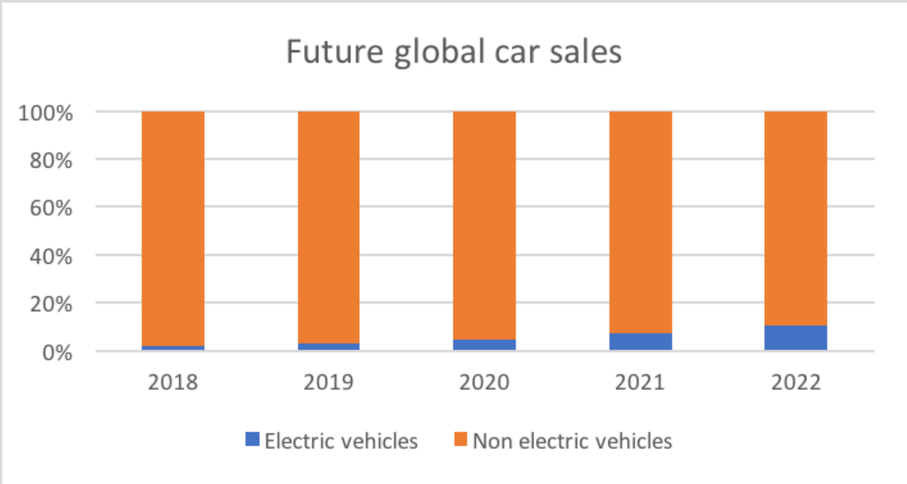
Therefore, we can later calculate the growth with the function we have measured is the most precise one. Of course, the trend analysis only shows the presumable future with the condition that the market will behave approximately similarly as till nowadays. Therefore, we will not calculate the possible sales to many consecutive years as the mistake would be higher. There are many factors which influence the development and they are not included in the analysis, therefore we will discuss them precisely later and make the result with them.

7.1.1 Future Global situation

With the knowledge of history sales, we made a graph and added a trend line. We want the trend line to fit as much as possible to our history data. In the case of global sales, the exponential trend line fits rightly, better than the linear trend. We will compare the R squared to really see which trend fits our data the most. R squared of the linear trend is only 76,9 in contrast to the exponential trend with the R squared 90,89. That means that the exponential trend explains our data very well. It is not any coincidence that the exponential trend line fits better. The market of the EVs is at the beginning and is expanding quickly. Furthermore, the arrival of new car models, availability of subsidies and lower price will help to speed the expand. This is exactly described by the exponential line. The linear trend line would rather explain long-time functioning market.

To calculate the exact values, we will use the knowledge that the exponential line fits most accurately. But, as we want to calculate not only the future sales, but also the future share, we will do the same procedure for the whole global car sales. The most accurate trend for the global sales is the linear one. As written above, the use of linear trend is presumed.

With the knowledge of future values, we can calculate the possible share of EV sales. As it was supposed to, the share of EVs would rise (Graph 7.1).



Graph: 7.1: Future global car sales, data source: [23]

If the situation would continue similarly as by now, the share of electric cars would rise significantly. According to the Electric Vehicle World Sales Database, the share of EVs should be reaching one third in the year 2025. This is very courageous estimate. We have come to the result that in the year 2022 more than 12 million electric cars would be sold. From today's point of view, this is unimaginable. On the other hand, the future looks very hopefully, but as the market contains many different components, everything would have to work smoothly. Governments would have to continue implementing subsidies, the rechargeable infrastructure would have to expand rapidly, costs of batteries would have to diminish, producers would have to invest heavily into the new technology etc.

To study it more precisely, it is important to compare the future prices of inputs, which are necessary for electric and ICE cars. According to the Annual Energy Outlook 2018, the price of the electricity should remain stable in many consecutive years. More concretely, the price should remain between 10,6 – 11,8 cents per kilowatt-hour. This is almost the same price as nowadays.

On the other hand, the prices of gasoline and diesel are likely to grow in the future. The crude oil prices should increase and gasoline and diesel prices are affected by that. According to the Annual Energy Outlook 2018, the price of gasoline could move from today's $2,5 per gallon up to $5,95 per gallon in 2050. The diesel prices could be moved from current $2,9 per gallon to $7,02 over the same period. The growth in diesel and gasoline prices is large. Together with the stable prices of electricity, this would confirm our expectations of steady increase of EVs. [3]

On batteries, according to Bloomberg New Energy Finance, the price of batteries should drop to one half till 2026 [66]. If the governments would support the car sales till the significant drop in battery prices and later the batteries would be cheap enough to not needing the subsidies anymore, the EVs would become competitive very soon.

Another important factor is the rechargeable infrastructure. Many companies as for example British Petroleum Company, Shell, Siemens, Tesla, Ford, BMW, Volkswagen Group decided to invest in the construction of charging stations heavily. Furthermore, governments of many states have the establishment of charging infrastructure as a one of their main tasks. [56] In addition, as it is spatially more accessible to construct the electric rechargeable stations, the number of them could exceed the number of gasoline stations in the future. For example, the public lighting lamps could be used as an electricity grid.

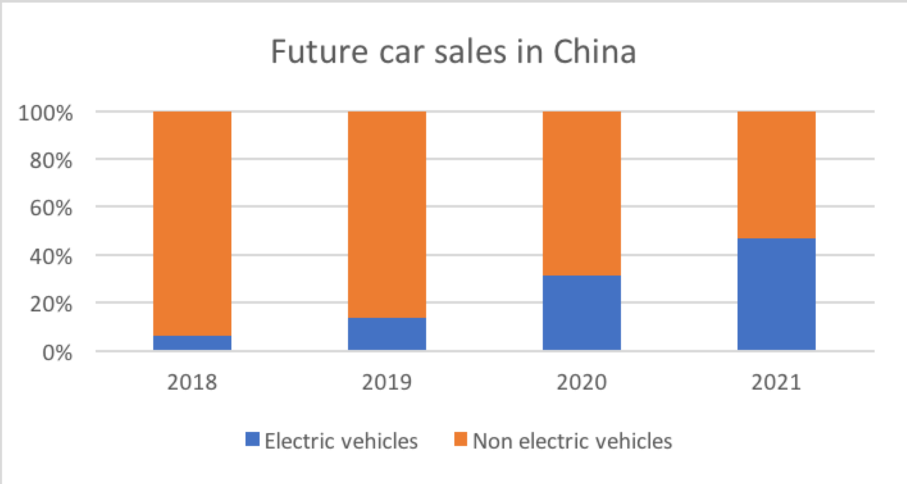
Other elements influencing the adoption of new technology are the increasing prices of raw materials for ICE vehicles (e.g. steel and aluminium) and different age of the car fleet around the globe (according to the European Automobile Manufacturers' Association, the average age of the car in Europe is around 10,5 years and in the US almost 12 years).

Overall, in the following couple years, the growth of the sales of EVs could be significant. But, it will be difficult for all of these parts to develop smoothly. The market is very fresh and the participants do not exactly know which impediments are on the way.

7.1.2 Future in China

China is working very ambitiously to become a leader in the sales of electric vehicles. Since 2015, the government is supporting both, producers and consumers. Their aim is that in the year 2030, 8 out of 10 sold cars should be electric. We will perform the same analysis as previously. The trend line that fits the data of sales of EVs most accurately is the exponential trend line. Its R squared is 90,77. The overall car sales in China are represented by the linear trend line with the R squared 78,32.

We have also calculated the concrete numbers of sales. The results are also very positive for the future of China (Graph 7.2). The government has also announced that in the year 2019, 10% of car sales should be the EVs. This goal is in their possibilities. [60].

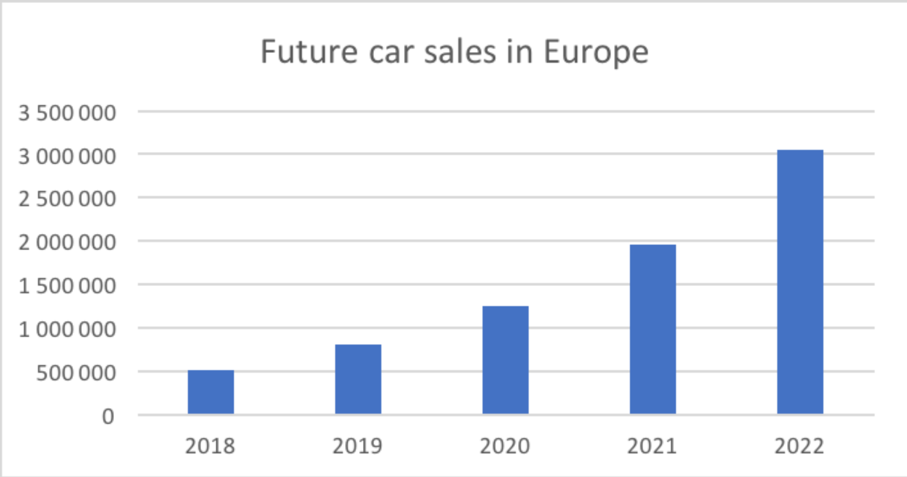


Graph: 7.2: Future car sales in China, data source: [24]

During the year 2017, the number of charging stations has grown by 51% in China. Nowadays, there is 214 000 stations and 500 000 is expected to be there till 2020. That would help the market of EVs a lot. On the other hand, we must take into account the area of China. 500 000 stations is a high number, but considering the number of sold cars it is still not enough to cover the whole country. Overall, considering the R squared and the impediments, the growth of the sales should be slightly less than exponential. [15]

7.1.3 Future in Europe

As abovementioned, the current situation in Europe is not so positive. To a large extent, this may be caused by the diversification of countries. The trend line that describes our data best is the exponential line with the R squared 80,87. Unfortunately, the highest R squared of a trend line of all car sales is very low, therefore we will look at the sales of EVs only.

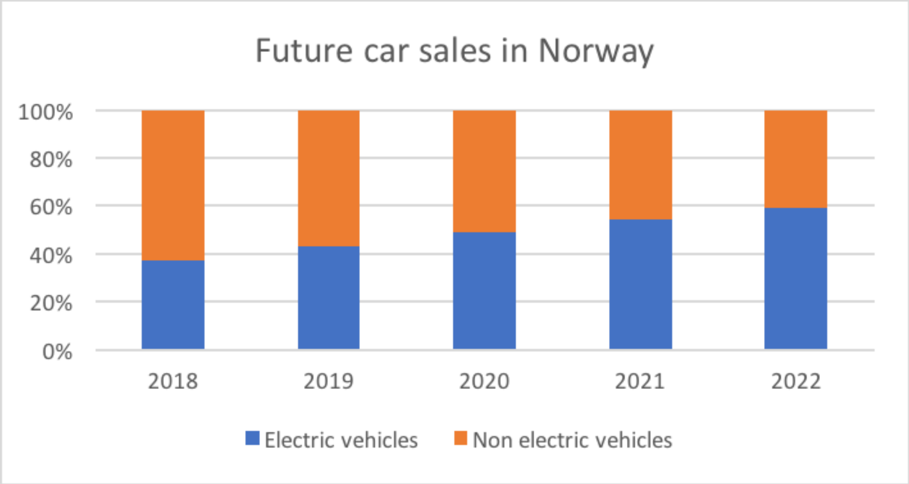


Graph: 7.3: Future car sales in Europe, data source: [23]

From the graph 7.3, it can be seen that in the year 2022, slightly more than 3 million of EVs could be sold, whereas in the year 2017, slightly less than 300 000 EVs were sold. It would be unimaginably high increase. On the other hand, many countries in Europe plan to ban the sales of ICE vehicles, therefore they will support the sales of EVs and follow Norway in its success. In addition, some countries have decided to support the sales only for limited number of years, therefore, it is expected that during this period the increase could be significant. For example, the United Kingdom will offer the subsidies from April 2018 until March 2021 only. Denmark will stop subsidising the EVs after the year 2020. [22]

7.1.4 Future in Norway

Norway has set to itself a very courageous aim. Since 2025 all sold cars should be electric [52]. By the trend analysis, we can look to the future of Norway. Unfortunately, the trend lines do not fit our data as precisely as before. Both, sales of EVs and sales of all cars are described by the linear trend line with the R squared 85,34 and 82,51 respectively.



Graph: 7.4: Future car sales in Norway, data source: [13]

The graph shows that Norway is on its way to eliminate all ICE vehicles (Graph 7.4). On shares of sold EVs, Norway will most probably keep its first place for many consecutive years. On the other hand, when the share will reach 75%, Norway wants to start eliminating the subsidies [23]. This means that after that, the sales will not probably grow as quickly as before.

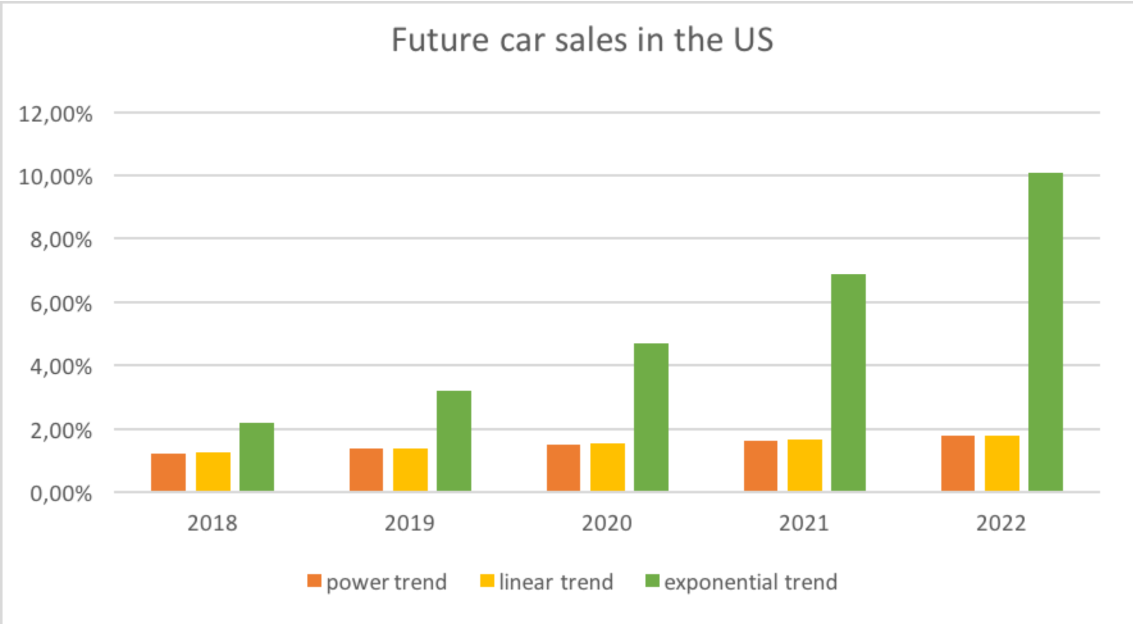
7.1.5 Future in the US

We will also look at the possible future in the US. But, as written above, the current situation in the US is not as clear as in China due to the differences among states.

Firstly, the exponential trend line does not fit as precisely as before. Its R squared is only 72,45. This is not surprising as during the last years, the growth was not so rapid. The year 2017 was worse than expected especially due to the late delivery of Tesla Model 3, which should be very successful in the US. The consecutive years should be much better because of the arrival of Tesla and new Nissan Leaf II. So, even though the trend line does not fit greatly our data, the consecutive years in the US could possibly grow according to the exponential line.

The linear trend line fits much better with the R squared 78,84. But, the power trend line describes our data most precisely. Its R squared is 90,92. As we have more trend lines that could correspond to the reality, we will do the analysis for all of them. To discover the future shares of EVs, we need to again calculate the future sales of all cars. The trend line that describes our historic data the best is the logarithm trend line with the R squared 80,06.

With the knowledge of the future sales of EVs and non-electric vehicles, we can calculate the possible share with the usage of all three trends (Graph 7.5).



Graph: 7.5: Future car sales in the US, data source: [36]

According to the LMC Automotive, in 2025, the share of EV sales should reach 2,4% [50]. This would be true, if the growth would remain similar. According to the power growth, the share in the year 2025 would be 2,2%. However, because of the higher model availability, higher incentives and decreasing battery price, the share could be higher. Bloomberg has announced that since 2010, the cost of batteries has diminished by 73%. Furthermore, price of gasoline and diesel is expected to rise in the US. Therefore, we can expect slightly higher than power or linear growth. The main reason why the exponential growth should not be reached is poor rechargeable infrastructure and the diversity of US states. On California, because of the Zero Emission Program and the effort of this state to do as maximum as possible for the development of EVs, there, the exponential growth is reachable. Unfortunately, we cannot generalize it for the whole United States.

7.2 Bass Diffusion Model

We have just discovered how the future of the electric vehicles should look in the following couple years. On the other hand, we are also curious about the further future.

To do that, we will use the Bass Diffusion Model. We will calculate how the future would look in the year 2035. The selection of this year is not random. Many studies have published their opinions about the future of the EVs right in the year 2035. But, the expectations differ extremely. We can read that in this year, almost no EVs will be on the road because the ICE vehicles will continue being the principal choice when buying a car. On the other hand, it is possible to learn that in the year 2035 only the EVs will be sold. Therefore, it is important to do our own analysis for different regions.

As written in the methodology section, the Bass Diffusion Model is widely used to predict the adoption of a new technology. It is represented by the equation

$$a(t) = Mp + (q - p)A(t) - \frac{q}{M}A(t)^2.$$

This model uses the potential behaviour of customers, which is represented by the coefficient of innovation (people, who will buy the product, because they want to support the new technology) and coefficient of innovation (customers, who are influenced by the amount of prior sales). To get the values p and q, I got inspired by the study by J. Massiani and A. Gohs called: “The choice of Bass model coefficients to forecast diffusion for innovative products: An empirical investigation for new automotive technologies”. [47]

The results are following: according to our analysis, globally in the year 2035, the share of EV sales could reach up to 41% of the car sales. This result is very similar to the result calculated by the Bloomberg New Energy Finance. They concluded that in the year 2035, the share of EV sales should be 43%. This global outcome would be very positive for the market of EVs.

On China, the Bass Model showed that the possible share should be maximally 43% in 2035. This contrasts with the announcement of the Chinese government that already in the year 2030, 8 out of 10 sold car should be electric. Of course, in China, there are huge modern cities where this is possible. But, on the other hand, still around 20 million people live in a poverty. People living in rural areas who own a car for many years and are satisfied if they can financially cover all their expenditures won't probably buy an electric car. [69]

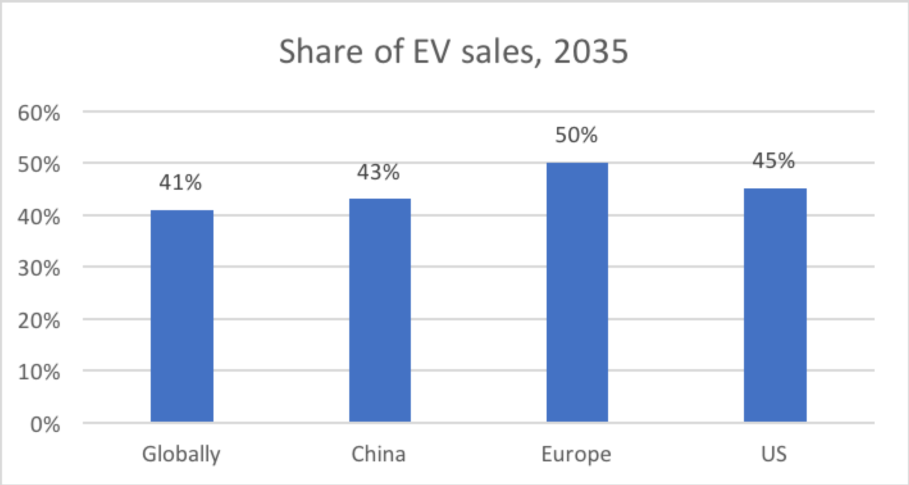
On Europe, our analysis has showed us that in 2035, 7 681 002 electric vehicles should be sold. The share would be around 45% - 50%. To compare it with the analysis by Bloomberg, according to them the share of sales in Europe will reach 50% [18]. This number corresponds to our result. On the other hand, the report by ING Economics Department concluded that in this year, the sales of EVs will reach 100% [20]. This is very courageous opinion. Europe is very dissimilar in many locations and we cannot expect all the countries to behave similarly like Norway. As mentioned at the beginning, during the year 2016, in Greece, only 32 electric cars were sold [22]. In addition, such positive outlook in the year 2035 may be caused by the behaviour of certain countries, which are the most progressive one. Later, it can be more difficult to expand further, as some states may not move from the position they are nowadays. The same idea can be applied for the situation in the US.

On Norway, the usage of Bass Model is not appropriate, because the market of electric vehicles is already developed there.

On the US, the number of sold cars in the year 2035 should achieve 7 721 202 units according to the Bass Model. This would correspond to the share of maximum 45%. According to the recent development in the US (in 2017 the share of sold electric cars was 1,16%), the value of 45% would be very favourable.

Surprisingly, according to our results, China would not lead the sales of EVs in the further future (Graph: 7.6). This is in line with the Electric Vehicle Outlook 2017 [18]. The appreciable subsidies provided by the state cannot be kept forever. Also, the country has developed during the last couple years, but not the whole country is adapted to that. It needs to fight with the surviving poverty. Such success of Europe may be caused by the fact that in our analysis we have included also HEVs.

To sum up, according to our analysis, the EVs will have an important impact on the automobile industry in the future. The beginning may be slower, but in two decades the share of EVs will start predominating over the ICE vehicles.



Graph: 7.6: Share of EV sales, 2035, data source: [23], [24], [36]

8 Correlation analysis

For the producers, it is very important to know, whether the increase in the sales of EVs is directly correlated to the decrease in the sales of non-electric vehicles. We can explore their common behaviour with the correlation analysis. Therefore, we will see whether they are correlated and whether they behave similarly or they move the opposite way.

To do that, we will use two different correlation methods - Pearson Correlation and Spearman's Rank Order Correlation. More information on their usage can be read in the methodology section.

8.1 Correlation between the sales of electric and internal combustion engine vehicles

We will measure the correlation coefficient between the global sales of EVs and non-electric vehicles. The correlations will be calculated in the software R. But, as we want to measure the increase or decrease in the sales, we will make the percentage change of sales for each month. After that, we will run the Shapiro-Wilk test in R to find out whether the distribution of our data is normal. The null hypothesis is normality.

Unfortunately, the change in sales of EVs does have the p value 0,044 which is smaller than 0,05, therefore we have to reject the null hypothesis of normality. It is not so surprising, because the market is rather new and the changes in sales are not similar in each month and they can sometimes reach high numbers. When the market is long-functioning, the changes in sales are more stable. Because of the p value, we will calculate both correlation coefficients. To calculate the Spearman's coefficient, we need to rank our data first. This is not any problem, because higher sales mean higher profit for the producers.

The results are quite similar. The Pearson's coefficient for global data is 0,69 and the Spearman's coefficient reached 0,66. The correlation is relatively high. The positive direction is clear. The market of the EVs is not as strong to make the sales of non-electric cars decreasing. The sales are influenced by the same factors – the global economic performance, introduction of new car models, willingness of people to invest in a car, income of buyers, season etc. Therefore, they move the same direction. Later, when the market of EVs will become stronger, the sales of EVs will most likely displace the sales of ICE cars.

Now, we will look on the situation in the US. Firstly, we will do the same analysis as for the global sales. We have proceeded the Shapiro-Wilk test for normality. The p values for the change in sales of EVs and non-electric vehicles are 0,079 and 0,085 respectively. Therefore, we found out that the distributions are normal. We can use the Pearson's Correlation Coefficient.

The correlation coefficient is 0,67. Therefore, the situation in the US is copying the global situation. This is not a surprise, because the market of the EVs in the US behaves in a similar way as the global market.

The correlations are quite similar in all regions we have analysed (Table 8.1). The exception is Norway where the correlation coefficient reaches only 0,25. The reason may be that in Norway, the market of EVs is stronger than in other parts of the world. There, the EVs create their own market and they may be displacing the sales of ICE vehicles. Therefore, the sales of EVs and non-electric vehicles do not behave similarly. Although, in other parts of the world the impact of the EVs on the automobile industry is not great, Norway is the exception. The calculated Pearson correlation coefficient for China is 0,34, which is also smaller than the global result.

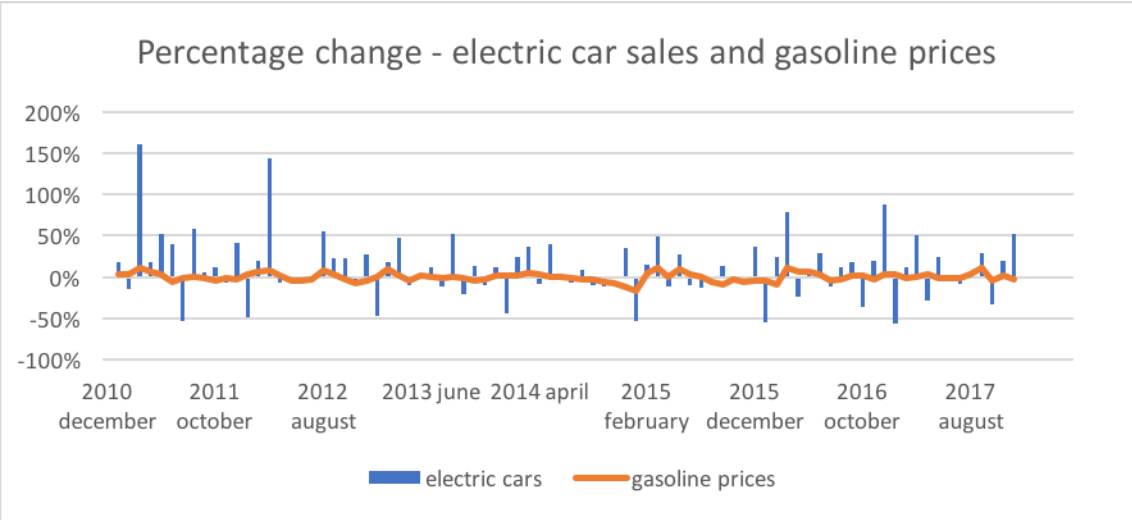
	Pearson Correlation	Spearman Correlation
Globally	0,69	0,66
China	0,34	0,36
Europe	0,66	0,63
Norway	0,25	0,28
US	0,67	0,66

Table: 8.1: Correlation between changes in sales of EV and ICE vehicles, data source: [23], [24], [36]

8.2 Correlation between electric vehicles, gasoline and electricity prices

Now, we will try to compare the sales of EVs with the price changes of gasoline and electricity. As an example, we will choose the U.S., as globally the data are not available and the situation in the U.S. is copying the global situation.

Very interesting thing is the relationship between the change of sales of the EVs and the change in the price of gasoline. From the graph 8.1, we can see that it looks like they behave analogously.



Graph: 8.1: Percentage change – EV sales and gasoline prices, data source: [63], [36]

The p value of the gasoline price change is 0,28, which means that the normality is satisfied and we can use the Pearson Coefficient. The calculated coefficient is 0,35. It is not an enormous number, but it is very interesting that higher gasoline prices correspond to higher sales of the EVs. Although, some people would buy an ICE car no matter the gasoline price, for those, who are indifferent between buying the ICE vehicle or the EV, the current gasoline price may have important meaning. Furthermore, according to the U.S. Energy Information Administration, the price of electricity should remain relatively flat, but the price of gasoline and diesel should be increasing till 2050. [3]

On the electricity prices, we have also proceeded the Shapiro-Wilk test. The p value corresponding to the electricity is 0,79. Therefore, the null hypothesis of normality is not rejected. The electricity is measured in cents per kilowatt-hour. We calculated the percentage change for each month. After that, we have proceeded the Pearson's Correlation Coefficient. The obtained coefficient is 0,26. The strength of the relationship is low. But, the direction is unexpected.

There may exist various reasons for that. Firstly, the changes in electricity price are not so large. If somebody wants to buy an electric car, the price of the car is already high and the electricity price does not cause any difference in his decision. Also, the prices of the electricity are much stable than the prices of gasoline, therefore, the consumers may rely on that. Or, the government incentives may be so advantageous that they play more important role for the buyer than the occasional growth in electricity prices.

9 Calculation of elasticity

To gain the further knowledge about the relationship between the sales of electric and ICE vehicles, we need to examine whether the price of ICE vehicles affects the sales of EVs. Therefore, we need to calculate the cross elasticity of demand. The cross elasticity of demand will exactly tell us whether the increase in the price of ICE vehicles causes the growth of sales of EVs. If it would be so, it would mean that those types of vehicles are substitutes. However, if the increase in price of ICE vehicles would cause the decrease of sales of EVs, the products would be complements. We expect the electric and ICE cars to be substitutes.

We will compute the relationship with the usage of regression analysis. We will use the monthly data of sales, average prices and average disposable income since the year 2013. Unfortunately, according to my best knowledge, such data are not available globally, therefore we will use the data from the US. This is not a problem, because as we have seen before, the situation of EVs in the US is very similar to the global situation. Therefore, we can use the data from the US for our purposes.

The results are following – the coefficient β_2 (which shows the cross elasticity of demand) is 7,1944 with the p-value 0,00014, therefore it is statistically significant (table 9.1). We needed to verify whether the coefficient will be positive and statistically significant. The adjusted R squared is 0,428, which is sufficient considering that there may be other factors, which are not included in the regression. If we would include other factors in our equation, the R squared would rise, but we would lose degrees of freedom. [49]

	Estimate	Significance
Price elasticity	-0.9901	0.01515
Cross elasticity	7.1944	0.00014
Income elasticity	2.9028	0.50165
Multiple R^2: 0.4699, Adjusted R^2: 0.428 (F-statistic: 11.23; p-value: 2.049e-05)		

Table: 9.1: Calculation of elasticity, data source: [26], [12], [37] To summarize this part, we can pronounce the electric and ICE vehicles to be substitutes. This is very important fact for the future of the EVs. During the last years, the prices of ICE vehicles were rising. This was mainly due to higher prices of raw materials, higher taxes and increase number of ecological regulations and standards. Between the December 2016 and December 2017, the average price of car has increased by 3% [4]. If the increase in prices would continue, it would surely influence the sales of the EVs in a positive way.

Conclusion

At this moment, the new industry of electric vehicles (EVs) is emerging. Therefore, it is important to discover its current and potential impact on the automobile industry. In this thesis, different calculations were computed to detect the importance. Looking at the current global situation, the share of EV sales is still very low with 1,30% in the year 2017. The position of Europe and the US corresponds with this poor outcome. Furthermore, the largest problem in Europe and the US is the diversification of locations. Therefore, it is very difficult for them to follow one general programme that would help them to expand the number of EVs. This includes the construction of rechargeable infrastructure, common support and state subsidies, investments to development and events to familiarize potential customers with pure electric vehicles.

Of course, we can find successful exemptions in these regions – e.g. California and Norway. On Norway, the share of sales is slowly approaching the threshold of 50%. The industry of the electric vehicles is already developed there. The reason is the strong support from the government, which includes monetary and nonmonetary incentives. Moreover, the state emphasizes the environmental issues connected with the usage of internal combustion engine (ICE) vehicles.

On China, the current position is slightly better than the global result. In 2017, 3,21% was the share of EV sales. The reason are the strong subsidies for consumers and producers. However, the subsidies are intended only for local producers. China is trying to become the leader in the production and therefore strongly supports its companies.

Overall, nowadays, the impact of EVs on the automobile industry is very small with some exceptions. Furthermore, the correlation analysis has showed us that the correlation between the change in sales of ICE vehicles and EVs is relatively strong and has the same direction. That means that the sales of EVs and ICE vehicles are influenced by the same factors and the sales do not displace each other.

On the other hand, the trend analysis and the Bass Diffusion Model have showed us that the future will be positive. The beginning will be rather slow, also because changing a car is not a daily issue and the age of the car fleet is relatively high. The positive factors affecting the huge potential of the EVs are diminishing price of batteries and therefore the price of the whole car, state subsidies, enlarging driving range, developing rechargeable infrastructure, wider car model availability and approach to familiarize customers with electric vehicles. Furthermore, the forecasts on the electricity price are favourably inclined, as the price should remain relatively stable over a long period. On the other hand, the price of gasoline and diesel will significantly increase. [3]

According to the Bass Diffusion Model, in the year 2035, the global share of sales should reach 41%. That would mean that the importance of EVs would rise significantly. On the US and Europe, the share could reach 45% and 50% respectively. Therefore, since that time, the number of EVs would start prevailing the sales of ICE vehicles. Surprisingly, on China, there the share would achieve maximally 43%. That would be caused by the huge area of China and the fact that still millions of people live in a poverty or they live on agriculture.

From the correlation analysis, we have showed the positive correlation among gasoline prices and EV sales. That could mean that when somebody is indifferent between purchasing an EV or ICE car, the higher price of gasoline can have significant meaning in their decision. As the price of gasoline and diesel is likely to grow in the future, it could be helpful for the development of electric vehicles.

With the calculation of the cross elasticity of demand, we have proved that EVs and ICE vehicles are substitutes. This fact also supports the positive future of the electric vehicles. Higher price of ICE vehicle would mean higher EV sales. Between the December 2016 and December 2017, the price of ICE car has risen by 3%. It is likely that the price will surge upward in further years, because of the increasing number of ecological regulations and standards and price of raw materials essential for the construction of ICE car. [4]

Overall, globally, the importance of the electric vehicles is not that significant nowadays. On the other hand, it looks that these vehicles will be competitive in the future and their importance will significantly rise. In addition, in the further future, they will probably outrun the number of ICE vehicles. As the situation in Norway shows us, the shift to electric vehicles is possible. In practice, this thesis may help potential buyers and producers to see the future development of EV market with factors that are favourably inclined. Furthermore, the comparison of different regions can help to inspire other locations to see different approaches with varying results. My thesis can be later used to evaluate whether the future expectations correspond with the reality and extend the analysis for further years. After couple years, it would be also interesting to measure the correlations and cross elasticity of demand again to see whether the EV market is stronger.

Bibliography

[1] AJANOVIC, Amela. The future of electric vehicles: prospects and impediments. *Wiley interdisciplinary Reviews-energy and Environment*. November/December 2015, Vol. 4(6), pp. 521-536.

[2] All taxi journeys from Schiphol in electric cars. *Electric Vehicle Research.* October 21, 2014. [Accessed: March 16, 2018]. Available at: <https://www.electricvehiclesresearch.com/articles/6984/all-taxi-journeys-from-schiphol-in-electric-cars>

[3] Annual Energy Outlook 2018 with projections to 2050. *Office of Energy Analysis. U.S Energy Information Administration.* February 6, 2018. [Accessed: March 24, 2018]. Available at: <https://www.eia.gov/outlooks/aeo/pdf/AEO2018.pdf>

[4] Auto sales remain strong despite record new car prices. *Chicago Tribune*. January 3, 2018. [Accessed: March 14, 2018]. Available at <http://www.chicagotribune.com/classified/automotive/ct-auto-sales-strong-record-prices-20180103-story.html>

[5] *Bar-Ilan University* [online]. Forecasting the Sales of New Products and the Bass Model. [Accessed: April 1, 2018]. Available at: <https://faculty.biu.ac.il/~fruchtg/829/lec/6.pdf>

[6] *Bass's Basement Research Institute* [online]. [Accessed: April 1, 2018]. Available at: <http://www.bassbasement.org/BassModel/Default.aspx>

[7] BAUER, Gordon. The impact of battery electric vehicles on vehicle purchase and driving behavior in Norway. *Transportation research Part D: Transport and environment.* 2018, Vol. 58, pp. 239-258.

[8] BECKER, Thomas A.; TENDERICH, Burghardt; SIDHU, Ikhlaq. Electric Vehicles in the United States A New Model with Forecasts to 2030. Center for Entrepreneurship & Technology. University of California, Berkeley. 2009.1.v.2.0 Revision Date: August 24, 2009.

[9] *Best-selling-cars* [online]. Car Sales Statistics. [Accessed: March 28, 2018]. Available at: <https://www.best-selling-cars.com/>

[10] BJERKAN, Kristin Ystmark; NORBECH, Tom E.; NORDTOMME, Marianne Elvsaas. Incentives for promoting Battery Electric Vehicle (BEV) adoption in Norway. *Transportation Research Part D: Transport and Environment*. March 2016, Vol. 43, pp. 169-180.

[11] CARLEY, Sanya; GRAHAM, John D.; KRAUSE, Rachel M.; LANE, Bradley W. Intent to purchase a plug-in electric vehicle: A survey of early impressions in large US cities. *Transportation Research Part D: Transport and Environment*. January 2013, Vol. 18, pp. 39-45.

[12] *Cars* [online]. [Accessed: March 28, 2018]. Available at: <https://www.cars.com/>

[13] *Carsalesbase* [online]. [Accessed: March 25, 2018]. Available at <http://carsalesbase.com/>

[14] *Cens* [online]. World Vehicle Sales. [Accessed: March 25, 2018]. Available at <http://www.cens.com/>

[15] China NEV public charging points increased 51 pct in 2017 - Xinhua. *Reuters*. January 21, 2018. [Accessed: March 14, 2018]. Available at: <http://www.reuters.com/article/china-autos-charging/china-nev-public-charging-points-increased-51-pct-in-2017-xinhua-idUSL4N1PG077>

[16] *Conserve Energy Future* [online]. [Accessed: March 21, 2018]. Available at: <http://www.conserve-energy-future.com/>

[17] DALININA, Ruslana. Introduction to Correlation. *Data Science.* January 31, 2017. [Accessed: March 21, 2018]. Available at: <https://www.datascience.com/blog/introduction-to-correlation-learn-data-science-tutorials/>

[18] Electric Vehicle Outlook 2017. Bloomberg New Energy Finance’s annual long-term forecast of the world’s electric vehicle market. Executive summary. *Bloomberg*

New Energy Finance. July 2017. [Accessed: April 2, 2018]. Available at: <http://data.bloomberglp.com/bnef/sites/14/2017/07/BNEF_EVO_2017_ExecutiveSummary.pdf>

[19] Electric vehicles in Europe: gearing up for a new phase? *McKinsey&Company*. April 2014. [Accessed: March 25, 2018]. Available at: <https://www.mckinsey.com/~/media/McKinsey/Locations/Europe and Middle East/Netherlands/Our Insights/Electric vehicles in Europe Gearing up for a new phase/Electric vehicles in Europe Gearing up for a new%2>

[20] ERICH, Max; WITTEVEEN, Jurjen. Breakthrough of electric vehicle threatens European car industry. *ING Economics Department*. July 2017. [Accessed: March 26, 2018]. Available at: <https://www.ing.nl/media/ING_EBZ_breakthrough-of-electric-vehicle-threatens-European-car-industry_tcm162-128687.pdf>

[21] *European Alternative Fuels Observatory* [online]. [Accessed: March 13, 2018]. Available at: < http://www.eafo.eu/>

[22] *European Automobile Manufacturers Association* [online]. [Accessed: April 2, 2018]. Available at: < https://www.acea.be/>

[23] *Ev-volumes* [online]. [Accessed: February 26, 2018]. Available at: <http://www.ev-volumes.com/>

[24] *Evobsession* [online]. [Accessed: February 21, 2018]. Available at: <https://evobsession.com/>

[25] *Exceltown* [online]. [Accessed: March 3, 2018]. Available at: <https://exceltown.com/>

[26] *Federal Reserve Bank of St. Louis* [online]. [Accessed: March 28, 2018]. Available at: <https://fred.stlouisfed.org/series/A792RC0A052NBEA>

[27] GAO, Paul; SHA, Sha; ZIPSER, Daniel; BAAN, Wouter. Finding the fast lane: Emerging trends in China's auto market. *McKinsey*. April 2016. [Accessed: March 27, 2018]. Available at: <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/finding-the-fast-lane-emerging-trends-in-chinas-auto-market>

[28] Global Overview of the Electric Vehicle Market. Coresight Research. *Electric Vehicles Global Markets.* [Accessed: March 13, 2018]. Available at: <https://www.funglobalretailtech.com/research/electric-vehicles-global-markets/>

[29] *Goodcarbadcar* [online]. [Accessed: February 26, 2018]. Available at: <http://www.goodcarbadcar.net/>

[30] HARDMAN, Scott. The effectiveness of financial purchase incentives for battery electric vehicles – A review of the evidence. *Renewable & sustainable energy reviews*. 2017, Vol. 80, pp. 1100 -1111.

[31] HAYS, Fred H.; DELURGIO, Stephen A. "Where's the Beef?": Statistical Demand Estimation Using Supermarket Scanner Data. University of Missouri—Kansas City. *Journal of Case Research in Business and Economics*. January 2009, Vol 1, pp. 1.

[32] HENSLEY, Russell; KNUPFER, Stefan; PINNER, Dickon. "Electrifying cars: How three industries will evolve". *McKinsey*. June 2009. [Accessed: March 6, 2018]. Available at: <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/electrifying-cars-how-three-industries-will-evolve>

[33] HERTZKE, Patrick; MULLER, Nicolai; SCHENK, Stephanie. China's electric-vehicle market plugs in. *McKinsey&Company*. July 2017. [Accessed: March 15, 2018]. Available at: <https://www.mckinsey.com/global-themes/china/chinas-electric-vehicle-market-plugs-in>

[34] HERTZKE, Patrick; MULLER, Nicolai; SCHENK, Stephanie. Dynamics in the global electric-vehicle market. *McKinsey&Company*. July 2017. [Accessed: March 15, 2018]. Availible at: <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/dynamics-in-the-global-electric-vehicle-market - 0>

[35] HILDERMEIER, Julia. Electric Vehicles in Europe - 2016. *Transport & Environment*. [Accessed: March 2, 2018]. Available at: <https://www.transportenvironment.org/sites/te/files/publications/TE EV Report 2016 FINAL.pdf>

[36] *Insideevs* [online]. [Accessed: February 21, 2018]. Available at: <https://insideevs.com/>

[37] *Kelley Blue Book* [online]. [Accessed: March 28, 2018]. Available at: <https://www.kbb.com/>

[38] KNUPFER, Stefan M.; HENSLEY, Russell; HERTZKE, Patrick; SCHAUFUSS, Patrick; LAVERTY, Nicholas; KRAMER, Nicolaas. Electrifying insights: How automakers can drive electrified vehicle sales and profitability. *McKinsey&Company. Advanced Industries.* January 2017. [Accessed: March 16, 2018]. Available at: <https://www.mckinsey.com/~/media/McKinsey/Industries/Automotive and Assembly/Our Insights/Electrifying insights How automakers can drive electrified vehicle sales and profitability/Electrifying insights - How auto>

[39] KRAFT, Thomas E. Electric Vehicles--A Historical Snapshot. *Tech Directions*. November 2012, Vol. 72, No. 4, p16-19.

[40] LAMBERT, Fred. BP becomes latest oil giant to invest in electric vehicle charging. *Electrek*. 30. January 2018. [Accessed: April 4, 2018]. Available at: <https://electrek.co/2018/01/30/bp-oil-giant-invest-electric-vehicle-charging/>

[41] LI, Shunxi; CHEN, Hang; ZHANG, Guofang. Comparison of the Short-Term Forecasting Accuracy on Battery Electric Vehicle between Modified Bass and Lotka-Volterra Model: A Case Study of China. *Journal of Advanced Transportation*. April 7, 2017, Vol. 2017, pp. 6.

[42] LIN, Boqiang. Why people want to buy electric vehicle: An empirical study in first-tier cities of China. *Energy policy*. 2018, Vol. 112, pp. 233-241.

[43] LIU, Changzheng; LIN, Zhenhong. How uncertain is the future of electric vehicle market: Results from Monte Carlo simulations using a nested logit model. *International journal of sustainable transportation* [1556-8318]. 2017, Vol. 11, pp. 237 -247.

[44] LUTSEY, Nic. Supporting the electric vehicle market in U.S. cities. *International Council on Clean Transportation*. October 2015. [Accessed: April 2, 2018]. Available at: <https://www.theicct.org/sites/default/files/publications/SupportEVsUScities_201510.pdf>

[45] LUTSEY, Nic. The transition to electric cars: How can policy pave the way? *The International Council on Clean Transportation*. October 25, 2017. [Accessed: April 2, 2018]. Available at: <https://www.theicct.org/blog/staff/policies-to-pave-ev-transition-20171025>

[46] LUTSEY, Nic; SLOWIK, Peter. Expanding the Electric Vehicle Market in U.S. Cities. *International Council on Clean Transportation*. July 2017. [Accessed: April 2,

2018]. Available at: <https://www.theicct.org/sites/default/files/publications/US-Cities-EVs_ICCT-White-Paper_25072017_vF.pdf>

[47] MASSIANI, Jerome; GOHS, Andreas. The choice of Bass model coefficients to forecast diffusion for innovative products: An empirical investigation for new automotive technologies. *Researchgate*. July 2015, Vol. 50, pp. 17-28.

[48] MATULKA, Rebecca. The History of the Electric Car. *Department of Energy*. September 15, 2014. [Accessed: February 27, 2018]. Available at: <https://www.energy.gov/articles/history-electric-car>

[49] MOORE, Henry L. Partial Elasticity of Demand. *The Quarterly Journal of Economics, Oxford University Press.* 1926*,* Vol. 40(3), pp. 393-401.

[50] NAUGHTON, Keith. The Near Future of Electric Cars: Many Models, Few Buyers. *Bloomberg.* December 19, 2017. [Accessed: April 3, 2018]. Available at: <https://www.bloomberg.com/news/features/2017-12-19/the-near-future-of-electric-cars-many-models-few-buyers>

[51] OU, Shiqi; LIN, Zhenhong; WU, Zhixin; ZHENG, Jihu; LYU, Renzhi; PRZESMITZKI, Steven; HE, Xin. A Study of China's Explosive Growth in the Plug-in Electric Vehicle Market. *Oak Ridge National Laboratory*. January 2017.

[52] PETROFF, Alanna. These countries want to ditch gas and diesel cars. *MoneyCNN.* July 26, 2017. [Accessed: March 29, 2018]. Available at: <http://money.cnn.com/2017/07/26/autos/countries-that-are-banning-gas-cars-for-electric/index.html>

[53] *Plug-in Hybrid & Electric Vehicle Research Center* [online]. [Accessed: February 25, 2018]. Available at: <http://phev.ucdavis.edu/>

[54] RANDALL, Tom. Here's How Electric Cars Will Cause the Next Oil Crisis. *Bloomberg*. February 25, 2016. [Accessed: March 3, 2018]. Available at: <https://www.bloomberg.com/features/2016-ev-oil-crisis/>

[55] REDONDO, Antonio N.; CAGIGAS, Alberto P. Sales Forecast of Electric Vehicles. *Journal of Engineering and Architecture*. June 2015, Vol. 3, No. 1, pp. 79-88.

[56] REID, David. Ford and Europe's auto giants to build a long-distance electric charging network. *CNBC*. November 3, 2017. [Accessed: March 26, 2018]. Available at: <https://www.cnbc.com/2017/11/03/ford-bmw-vw-daimler-building-electric-charging-network-twice-the-power-of-teslas.html>

[57] RYAN, Charlotte; SHANKLEMAN, Jess. U.K. Joins France, Says Goodbye to Fossil-Fuel Cars by 2040. *Bloomberg*. July 26, 2017. [Accessed: April 5, 2018]. Available at: <https://www.bloomberg.com/news/articles/2017-07-25/u-k-to-ban-diesel-and-petrol-cars-from-2040-daily-telegraph>

[58] SAFARI, Mohammadhosein. Battery electric vehicles: Looking behind to move forward. *Energy policy* [0301-4215]. 2018, Vol. 115, pp. 54-65.

[59] Sales of green vehicles are booming in Norway. *The Economist*. February 18, 2017. [Accessed: March 5, 2018]. Available at: <http://www.economist.com/news/business/21717063-ever-more-electric-cars-are-road-next-step-build-charging-network-support>

[60] SHIROUZU, Norihiko; JOURDAN, Adam. China sets 2019 deadline for automakers to meet green-car sales targets. *Reuters*. September 28, 2017. [Accessed: March 2, 2018]. Available at: <https://www.reuters.com/article/us-autos-china-electric/china-sets-2019-deadline-for-automakers-to-meet-green-car-sales-targets-idUSKCN1C30ZL>

[61] SOLTANI-SOBH, Ali; HEASLIP, Kevin; STEVANOVIC, Aleksandar; BOSWORTH, Ryan; RADIVOJEVIC, Danilo. Analysis of the Electric Vehicles Adoption over the United States. *Transportation Research Procedia*. May 17, 2017, Vol. 22, pp. 203-212.

[62] U.S. Department of Energy. Energy Efficiency & Renewable energy. How Do All-Electric Cars Work? *Alternative Fuels Data Center.* 2012. [Accessed: March 25, 2018]. Available at: <https://www.afdc.energy.gov/vehicles/how-do-all-electric-cars-work>

[63] *U.S Energy Information Administration* [online]. [Accessed: March 28, 2018]. Available at: <https://www.eia.gov/>

[64] WALLACE, Mealiea. What Makes EVs Work? *Electric Perspectives*. September/October 2012, Vol. 37, Issue 5, p10-10.

[65] *Wardsauto* [online]. World Vehicle Sales. [Accessed: February 24, 2018]. Available at: <http://wardsauto.com/>

[66] WATANABE, Chisaki. Why Battery Cost Could Put the Brakes on Electric Car Sales. *Bloomberg*. November 28, 2017. [Accessed: March 4, 2018]. Available at: <https://www.bloomberg.com/news/articles/2017-11-28/electric-cars-need-cheaper-batteries-before-taking-over-the-road>

[67] WEI, Feng; FIGLIOZZI, Miguel. An economic and technological analysis of the key factors affecting the competitiveness of electric commercial vehicles: A case study from the USA market. *Transportation Research: Part C.* January 2013, Vol. 26, p135-145.

[68] Why the future is hybrid. *The Economist*. December 2, 2004. [Accessed: March 5, 2018]. Available at: <http://www.economist.com/node/3422941>

[69] *Worldbank* [online]. FAQs: Global Poverty Line Update. September 30, 2015. [Accessed: April 4, 2018]. Available at: <http://www.worldbank.org/en/topic/poverty/brief/global-poverty-line-faq>

[70] ZANDT, Timothy V. Elasticity of Demand. *The Business School for the World*. August 2012. [Accessed: March 7, 2018]. Available at: <https://faculty.insead.edu/vanzandt/pm/Session07/FPM-08.pdf>

[71] ZENG, Ming; ZENG, Fan-xiao; ZHU, Xiao-li; XUE, Song. Forecast of Electric Vehicles in China Based on Bass Model. *Electric Power*. 2013, Vol. 46(1), p39.

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List of acronyms

BMW	Bayerische Motoren Werke (Bavarian Motor Works)
BYD	Build Your Dreams
EV	Electric Vehicle
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
NASA	National Aeronautics and Space Administration`s
US	United States