SAVONIA

THESIS - **BACHELOR'S DEGREE PROGRAMME**
TECHNOLOGY, COMMUNICATION AND TRANSPORT

THE MOBILITY REVOLUTION IN THE AUTOMOBILE INDUSTRY -

ELECTRIC CARS AND BATTERY MANAGEMENT

Final Thesis

Author: Aneta Chodakowska

SAVONIA UNIVERSITY OF APPLIED SCIENCES THESIS
Abstract

Field of Study Technology, Communication and Transport			
Degree Programme Degree Programme in Industrial Engineering and Management			
Author Aneta Chodakowska			
The mobility revolution in the automobile industry - electric cars and battery management			
Date	04.05.2018	Pages/Appendices	47/0
Supervisor(s) Pertti Varis, Tiina Salli			
Client Organisation /Partners			

Abstract

The decrease of fossil fuels and the increase of available renawable energy make the electric vehicles (EV) the future of tranportation. This thesis is dedicated to analysing the electric vehicle industry and battery management systems. Different electric vehicles, battery systems and charging methods will be examined, as well as the whole market research including SWOT and PESTLE analyses and the electric vehicle situation in Finland and Norway, based on the current literature.

Various aspects including electric vehicle range, driving technique, loading problems, battery weight, dimensions and drawbacks and electrification will be discussed.To show benefits of electric vehicles, effects on environment and predictions for the future will be analysed. Some real examples of the most popular electric vehicles and battery management systems will be presented as well.

This work can be interesting and useful for everyone who wants to gain or broaden understanding of electric vehicle industry.

Keywords
automotive industry, automobile revolution, clean cars, EV, ICE, HEV, PHEV, FCEV, BEV, AC, DC, PESTLE, SWOT

CONTENTS

1 INTRODUCTION TO ELECTRIC VEHICLE

Electric vehicles are the future of transportation. Electric mobility has become an essential part of the energy transition, and will imply significant changes for vehicle manufacturers, governments, companies and individuals.The government announced in 2017 that there will be no more new petrol or diesel cars for sale after the year 2040. This relates to pure petrol and pure diesel cars. Therefore electric cars will in near future become a commonplace thanks to certain financial advantages, including government grants and the lower cost of filling up compared to a tank of petrol. Electric cars are considered better for the environment due to the fact they emit no exhaust gases. The electric car market today is about 0.2 % of all vehicles on the roads. For now, combustion cars are still cheaper and seemingly easier to use. A breakthrough in the field of energy storage is waiting for us. It should popularize technology and allow rapid sales growth. In June 2017, 28000 new electric cars were registered in Europe. This is a 54 percent growth compared to 2016.
The target of this thesis is to present electric car industry, vehicle types, battery system and charging methods, as well as market reseach, effect on environment and forecasting of the future of mobility. Different aspects will be analysed, such as electric vehicle range, driving technique, loading problems, battery weight, dimesions and drawbacks and electrification. There will be given examples to popularise electric vehicle indistry to protect environment and future generations. Market analysis will include SWOT and PESTLE analyses, as well as electric vehicle situation in Finland and Norway. In the last chapter real examples of electric vehicles and battery management will be presented.

1.1 Electric vehicle definition

Electromobility is a phenomenon that affects many areas of life. However, in the current opinion, the term refers to electric transport.

Electric vehicle is any vehicle propelled by an electric drivetrain taking power from a rechargeable battery or from a portable, refillable, electrical energy source like fuel cell or solar panels, which is manufactured for use on public roads. The electric drivetrain differentiates an electric vehicle from conventional fossil-fuelled vehicle where the drivetrain is mechanical. [1]

1.2 Electric vehicle history

The interesting fact is that the first cars in the end 19th and the early 20th century were electric. In the meanwhile, fossil fuel-powered cars with internal combustion engines became available in early 20th century. There has been an intense competition that began between the two types of vehicles. As it occured, fossil fuel powered cars won this competition due to three main reasons. The first reason was due to poor battery technology. Electric vehicles had a low range in those days and could never travel the long distances reached by a gasoline powered car. Further, charging them took much longer than refueling gasoline. The second reason was that the mass production of cars like the Ford Model-T made

gasoline cars affordable. The third reason was price of vehciles. In 1912 there were 6000 EV and 80000 Ford Model T. EV costed approximately 1110$ and Ford Model-T 590$.
With a cheap fuel, fossil fuel powered cars became the winner over electric cars. As a result, the internal combustion engine car has gradually dominated the market since then, until this day. However, decades of research and development in batteries, motor & power electronics technologies have helped bring back electric vehicles to the forefront. In 2014 numerous 100% electric and plug-in hybrid electric vehicles were introduced to the market from BMW, BYD, Cadillac, Chevy, Citroen, Ford, Fiat, Honda, Kia, Mercedes-Benz, Mia, Mitsubishi, Nissan, Opel, Peugeot, Porsche, Renault, Smart, Tesla, Toyota, Via, Volvo and Volkswagen.

Nowadays, there are affordable EVs with a 200-mile range that can be charged in less than an hour. In 2016 there were over 2 million electric cars already on the road globally. This number is expected to exponentially rise in the future. [2]

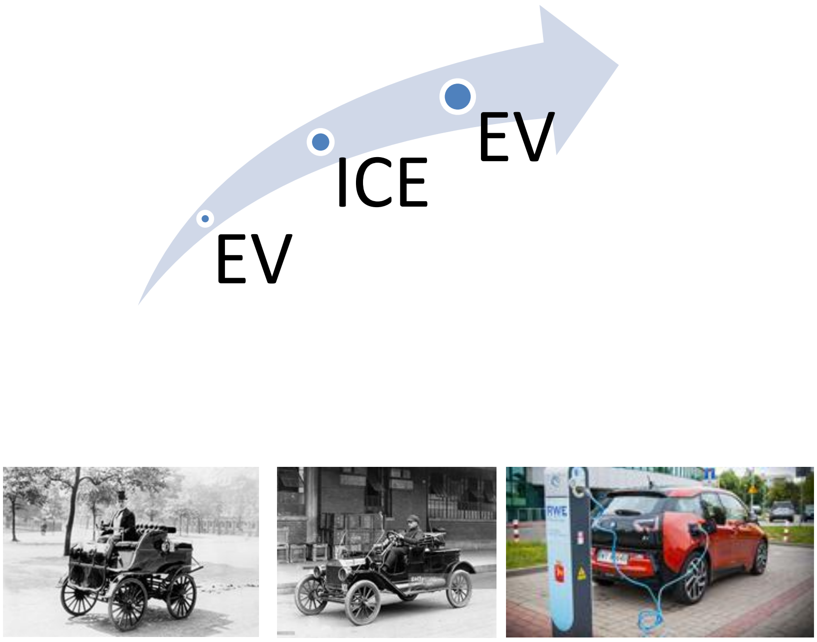


FIGURE 1. History of EV and ICE

2 TECHNOLOGY OF ELECTRIC VEHICLE

Figure 2 shows the typical electrical layout of the components in an electric car. The power is delivered from the AC grid to charge the battery via the on-board AC/DC rectifier and DC/DC battery converter. When the car is in the driving mode, the power provided by the battery goes through the battery DC/DC converter to the high voltage DC bus. Then the DC to AC inverter of the motor drive sends the power to the motor. The motor converts the electrical energy to mechanical energy, and it is forwarded to the

wheel via the transmission. Furtermore, a DC/DC uni-directional converter steps down the voltage from the high voltage DC bus to charge the auxiliary battery, which in turn powers cars' accessories.
A key role in the operation of an electric car plays the traction battery, the electric motor and the power electronics.
The power is exchanged between these components electrically using cables. This ensures great flexibility in the design of the car. On the contrary, flexibility is not possible when using cars with a mechanical drivetrain due to large size and weight of the mechanical components. [3]

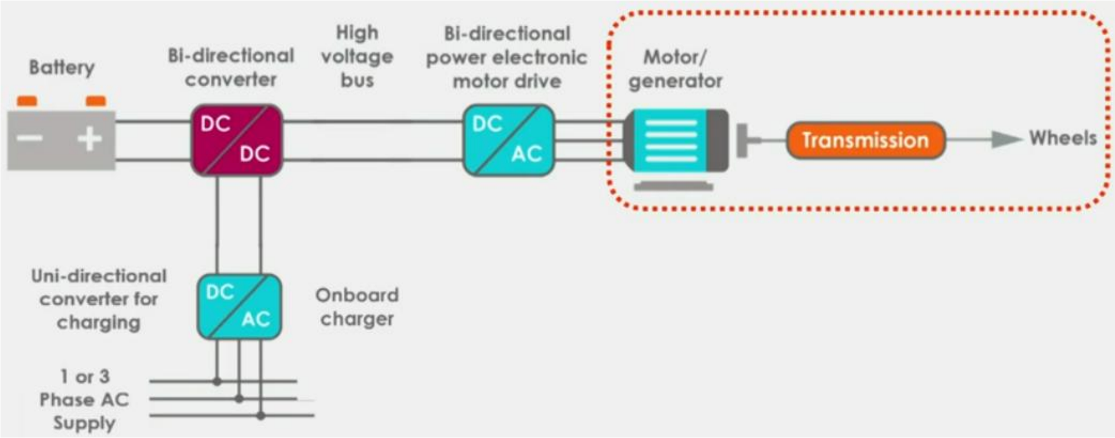


FIGURE 2. Electric car power flow (TU Delft)

2.1 Key parts of electric car

Figure 3 shows the key parts of an electric car and their function. First, there is a charging port with the connector and cable, then the high voltage traction battery and the low voltage auxiliary battery. There are electric motor and a transmission system which are used for propulsion. Finally, there are several power electronic converters that are used for battery charging, for driving the motors and for regenerative braking. Electric vehicle key parts are [4]:

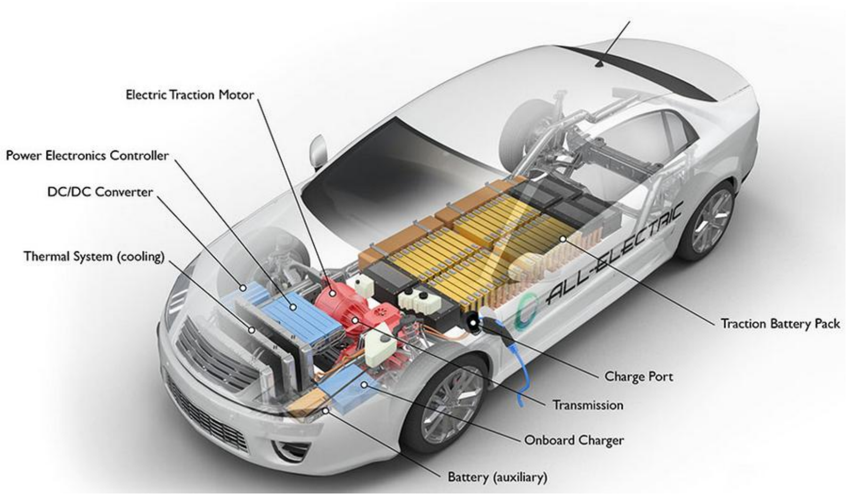


FIGURE 3. Key parts of a battery electric vehicle [4]

Charging port: It is a connector present on the electric vehicle, which allows it to be connected to an external source of electricity for charging.The charging port together with the connector and cable provides the electric car to connect to an external power supply in order to charge the traction battery pack. The charging port is often reffered as the vehicle inlet.

Power electronic converter: A power electronic converter is made of high power fast-acting semiconductor devices, which act as high-speed switches. Different switching states change the input voltage and current through the use of capacitive and inductive elements. The result is an output voltage and current, which is at a different level to the input.

On-board charger: It is an AC-to-DC power electronic converter (often referred to as a rectifier) that takes the incoming AC electricity supplied via the charge port and converts it to DC power for charging the traction battery. Using the battery management system, it regulates the battery characteristics such as voltage, current, temperature, and state of charge. It is required if the car is charged from the conventional electrictity grid.

Traction battery pack: It is a high voltage battery used to store energy in the electric car and provide power for use by the electric traction motor. It is a heart of any electric vehicle.The battery is located at the bottom of the car, but it can differ depending on the manufacturer. The role of the battery is to store energy for the propulsion of the vehicle. The battery has a battery management system, which monitors and regulates the battery charging characteristics such as voltage, current, stage of charge and temperature. The energy content in a battery is expressed is kilo-watt hours. Nowadays, electric cars have battery sizes in the range of 10-100 kWh. There are many different battery technologies, such as lead-acid.

Battery power converter: It is a DC-to-DC power electronic converter that converts the voltage of the traction battery pack to the higher-voltage of the DC-bus used for power exchange with the traction motor. When the electric car is drived then the power flows from the battery to the motor and to the vehicle accessories, such as light and audio system. A power electronic converter is used to regulate the power between these devices.

Motor drive: It is a DC-to-AC or a DC-to-DC power electronic converter, used to convert power from the high voltage DC bus to AC (or at times DC) power for the operation of motor. The converter is bidirectional. It operates both in driving and regenerative braking mode. The motor drive controls the speed, torque and rotational direction of the motor.

Traction electric motor/generator: It is the main propulsion device in an electric car that converts electrical energy from the traction battery to mechanical energy for rotating the wheels. It also generates electricity by extracting energy from the rotating wheels while braking, and transferring that energy back to the traction battery pack.

Transmission: For an electric car, usually a single gear transmission with differential is used to transfer mechanical power from the traction motor to drive the wheels.

Power electronics controller: This unit controls the flow of electrical power in the different power electronic converters in the electric car. It directly controls the different power converters and indirectly the operation of the battery, motors and the vehicle. It uses the driver accelerator and brake pedals to control the power flow and select the operating mode between driving and regenerative braking. It controls the onboard charger and the battery charging together with the battery management system.

Battery (auxiliary): In an electric drive vehicle, the auxiliary battery provides electricity to start the car before the traction battery is engaged and is also used to power the vehicle accessories. The auxiliary battery is usually 12V for current vehicles, but maybe increased to 48V for the future vehicles. [4]

2.2. Battery types

There is no clear choice which battery technology is the most suitable for all BEVs. Below all battery technologies will be discussed [5]:

Lead acid:

The possibility of using lead acid batteries in electric cars are limited. They suffer from low specific energy due to the weight of its lead collectors, low energy density, limited cycle life, high cut-off voltage, and lack of long-term storage due to low energy densities, sensitivity to temperature and life cycle. [5]

Nickel based:

Nickel-metal hydride (NiMH)

The main advantages of the Ni-MH battery include its high specific energy and energy density, which are twice that of lead-acid batteries. These batteries also offer fast recharge capacity, long cycle life, wide operation temperature ranges, and environmental friendlyness due to their recyclability [5].

Nickel-Cadium (NiCd)

Regardless of its high initial cost and low specific energy, this battery has the advantage of a lonng cycl life, as well as rapid recharge rate, excellent long-term storage, and a variety of sizes and designs. Despite the recyclability, cadmium in the battery can pollute the environment if not properly disposed of. [5]

Lithium based:

Lithium-ion (Li-ion)

Lithium-polymer (Li-poly)

Lithium batteries are classified by the type of active material into Lithium-ion liquid electrolyte and Li-ion-polymer electrolyte batteries. For electric cars applications, the Lithium-ion type are generally preferred.

20kWh Li-ion battery has a much lower weight than its competitors.

Li-ion battery technology offers very high energy density, good high-temperature performance, high specific power, high specific energy, and long cycle life. Additionally, the Li-ion battery is recyclable, and thus an environmental-friendly. The high costs and high self-discharge rates are two disadvantages of Li-ion batteries. Currently, Li-ion batteries are superior to other battery technologies in terms of applications to BEVs. [5]

Table 1. Different weight of 20KWh batteries [5].

Weight of 20KWh battery	
Lead acid	550 kg
Nickel Cadmium	500 kg
Nickel Metal Hydride	350 kg
Lithium Ion	180 kg

3 TYPES OF ELECTRIC VEHICLE [6]

3.1 Internal combustion engine car

Figure 4 presents internal combustion engine car. The purpose of a gasoline car engine is to convert gasoline into motion so that car can be moved. Currently the easiest way to create motion from gasoline is to burn the gasoline inside an engine. Therefore, a car engine is an internal combustion engine - combustion takes place internally.

There are different kinds of internal combustion engines. Diesel engines are one form and gas turbine engines are another. Based on drive-train and fuel type electric vehicles can be classified as the conventional internal combustion engine vehicle and the alternative fuel internal combustion engine vehicle, and the electric vehicle. The conventional ICE vehicle includes the gasoline and diesel vehicles. The alternative fuel ICE Vehicle refers to vehicles that run on a fuel other than gasoline or diesel like: autogas, natural gas, biofuel or hydrogen. [7]

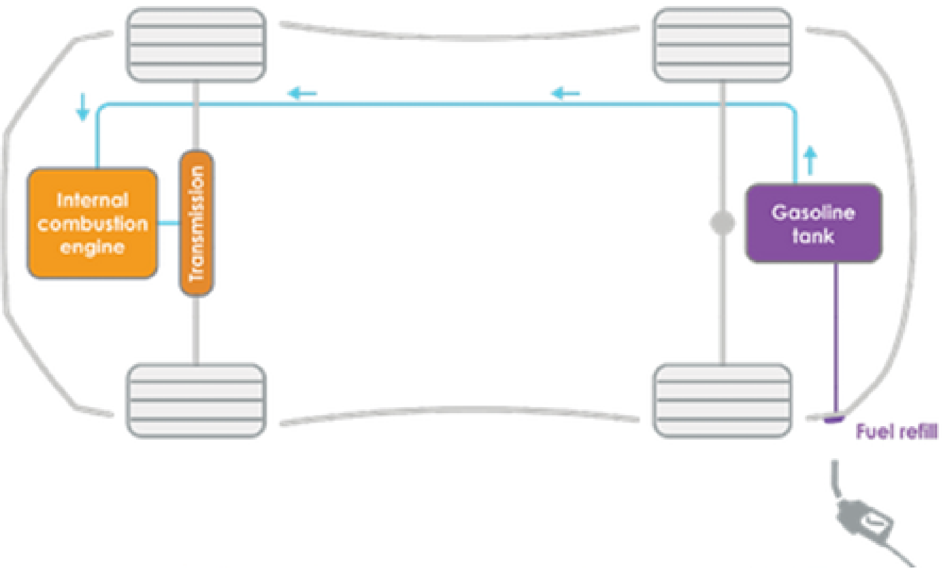


FIGURE 4. Internal Combustion engine car (TU Delft)

3.2 Hybrid electric vehicle

Figure 5 shows hybrid electric vehicle (HEV). It is a type of vehicle that uses both an electric engine and a conventional internal combustion engine. This type of vehicle is considered to have better performance and fuel economy compared to a conventional one.

An electric motor can propel the vehicle by using energy stored in the batteries. The battery is in turn charged by drawing energy from the engine by using the electric motor as an electric generator. To operate the motor and generator mode, a clever power electronic motor drive is used. The extra power provided by the electric motor allows for a smaller engine. The motor allows the engine to be operated in its optimal efficiency point, resulting in better fuel economy. Both the engine and the motor can power the wheels at the same time. [8]

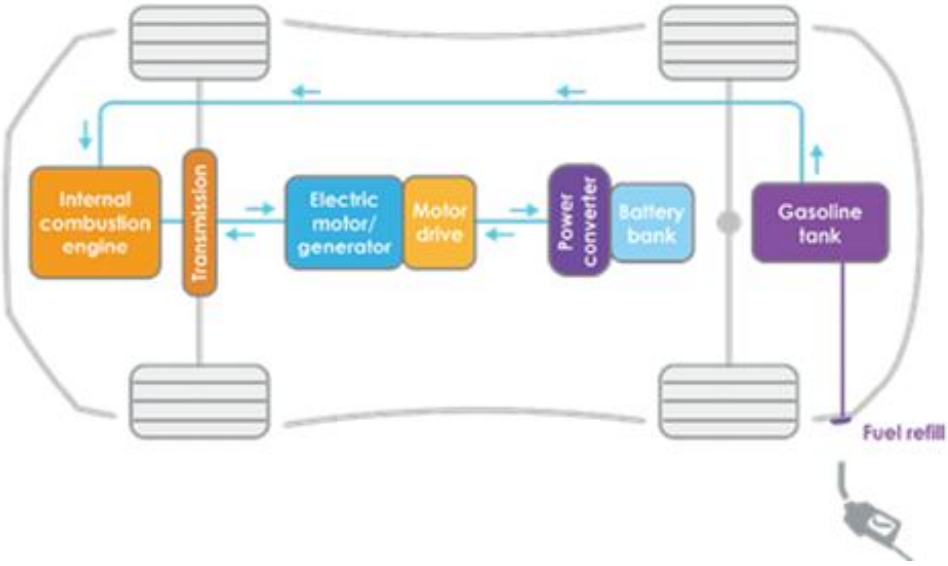


FIGURE 5. Hybrid Electric Vehicle (TU Delft)

3.3 HEV series

Series drivetrains are the simplest hybrid configuration. Figure 6 presents series hybrid. In this vehicles the electric motor is the only means of providing power to the wheels. The motor receives electric power from either the battery pack or from a generator run by a gasoline engine.
A computer determines how much of the power comes from the battery or the engine/generator. Both the engine/generator and the use of regenerative braking recharge the battery pack. Series hybrids perform at their best during stop-and-go traffic, where gasoline and diesel engines are inefficient.
The internal combustion engine is used to drive a generator and provide electrical power for the traction motors and to charge the battery. This is a common propulsion method which has been used in locomotives for many years. The traction motor is the only power supply unit with a direct connection to the wheels. The advantage is that the internal combustion engine can be operated at its most efficient point to generate the necessary current for driving the traction motor or charging the battery. [9]

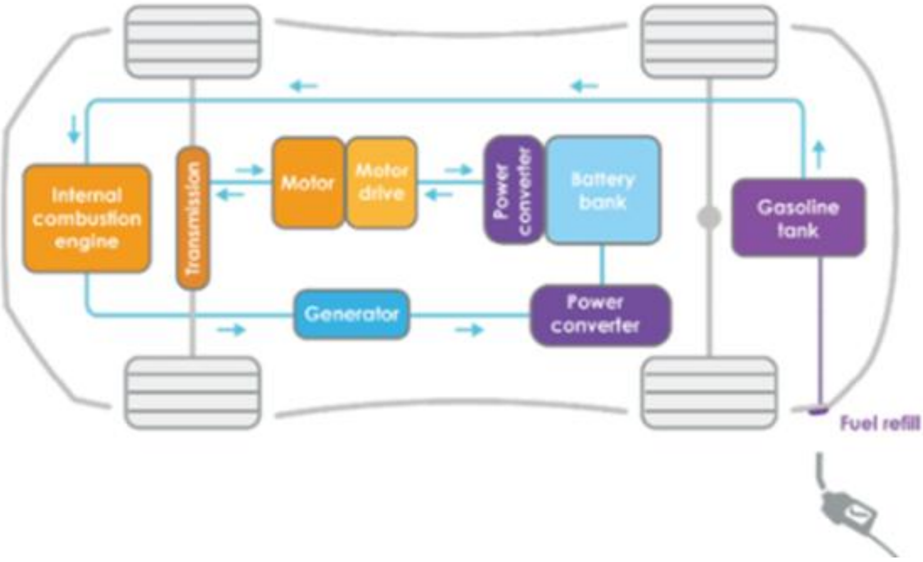


FIGURE 6. HEV series (TU Delft)

3.4 HEV series-parallel

Figure 7 presents parallel hybrid drivetrain. In this vehicles the engine and electric motor work in tandem to generate the power that drives the wheels. Parallel hybrids tend to use a smaller battery pack than series drivetrains, relying on regenerative braking to keep it recharged. When power demands are low, parallel hybrids also utilize the motor as a generator for supplemental recharging, much like an alternator in conventional cars.
This has the flexibility to operate in either series or parallel mode by using a powersplit. It has a generator to charge the battery as seen in a series hybrid.
And it has an engine and motor simultaneously powering the wheels as seen in a parallel hybrid.
Although this type of architecture is more flexible in terms of driving modes, it is also more complex and, of course, costly. The Toyota Prius is an example of a Hybrid electric vehicle based on the series-parallel architecture. [9]

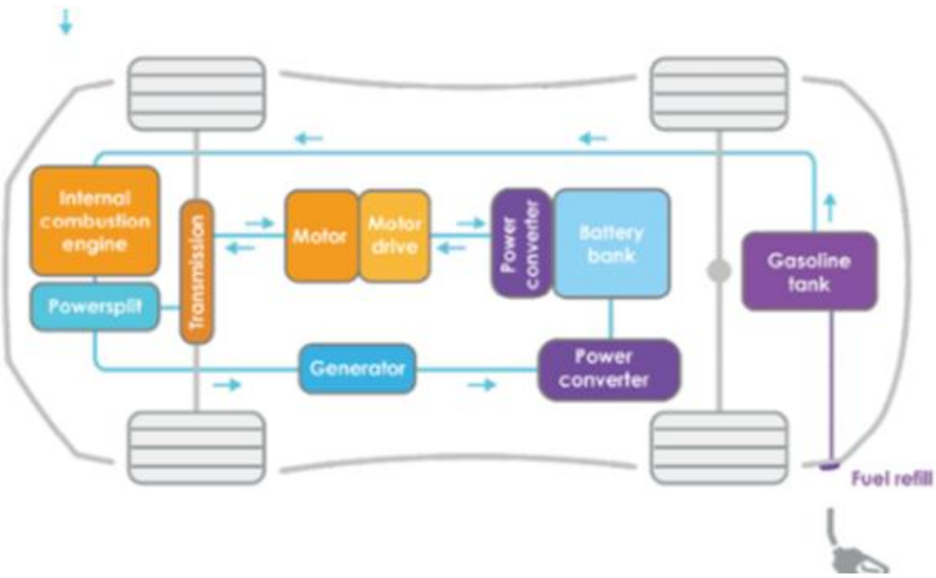


FIGURE 7. HEV series-parallel (TU Delft)

3.5 Plug-in hybrid electric vehicle

Figure 8 shows plug-in hybrid electric vehicles known as PHEVs combine a gasoline or diesel engine with an electric motor and a large rechargeable battery. Unlike conventional hybrids, PHEVS can be plugged-in and recharged from an outlet, allowing them to drive extended distances using just electricity. When the battery is emptied, the conventional engine turns on and the vehicle operates as a conventional, non-plug-in hybrid. Plug-in hybrid electric vehicles are similar to hybrid electric vehicles in that they have both an engine and motor for propulsion. The main difference lies in the fact that PHEV batteries are larger and can be externally charged using the on-board charger. The battery can be charged using the internal combustion engine while driving. This enables the PHEV to use the electric motor during larger periods of time when driving. That means for larger distances. A PHEV can drive electric for most city commutes and switch to fossil fuels for long highway rides, removing any range anxiety. A PHEV can be built based on series and series-parallel architectures as well. The Chevrolet Volt is an example of a Plug-in Hybrid electric vehicle based on the seriesparallel architecture. The disadvantage of the HEV and PHEV is that they continue to use fossil fuels and hence have tail-pipe emissions. [10]

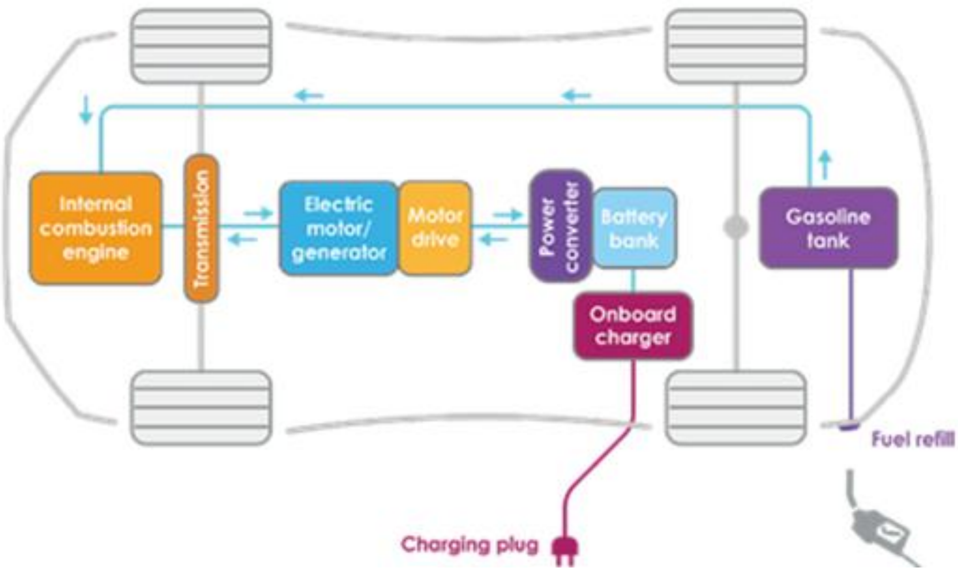


FIGURE 8. Plug-in hybrid electric vehicle (TU Delft)

3.6 Battery electric vehicle

Figure 9 shows battery electric vehicles, which run exclusively on electricity via on-board batteries that are charged by plugging into an outlet or charging station. These vehicles have no gasoline engine, longer electric driving ranges and never produce tailpipe emissions. The vehicle uses a large traction battery pack to power the electric motor and the battery must be charged from a power outlet when it is parked. The Tesla Model S is an example of a battery electric vehicle. [11]

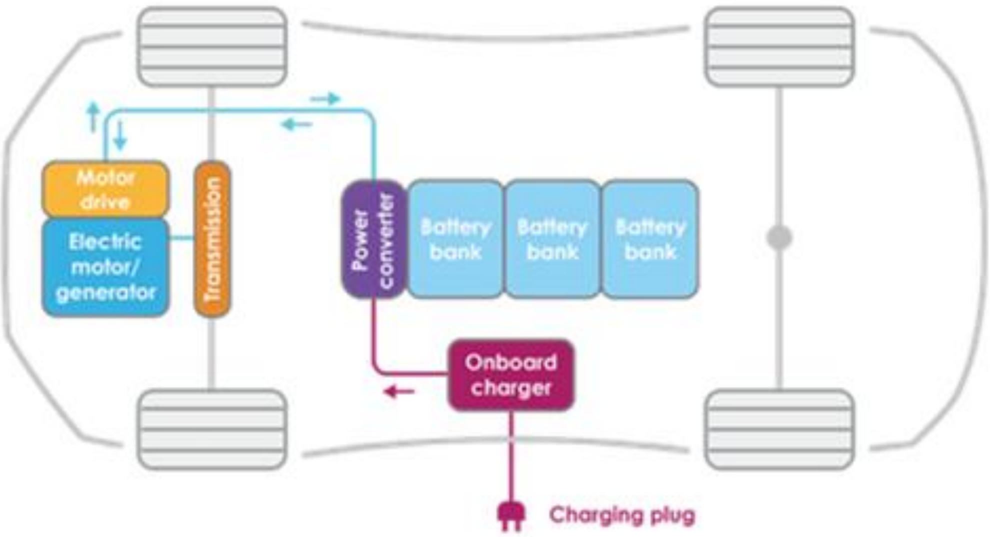


FIGURE 9. Battery electric vehicle (TU Delft)

3.7 Fuel cell electric vehicle

Figure 10 presents Fuel Cell Electric Vehicles (FCEV), which use an electric motor like a battery electric vehicle, but stores energy quite a bit differently. Instead of recharging a battery, fuel cell electric vehicle store hydrogen gas in a tank. The fuel cell in FCEVs combines hydrogen with oxygen from the air to produce electricity. The electricity from the fuel cell then powers an electric motor, which powers the vehicle just like a battery electric vehicle. There is no smog-forming or climate-changing pollution from tailpipe - the only byproduct is water. The fuel cells are recharged by refilling with hydrogen, which can take as little as 5 minutes at a filling station. A fuel cell electric vehicle substitutes the large battery of a battery electric vehicle for a fuel cell stack to generate electricity from the hydrogen fuel. A fuel cell is not a storage device, but a component that produces direct current from a chemical reaction. A small battery is still used as an energy buffer and to power the electric motor using the motor drive. A fuel cell vehicle has the advantage of short refuelling times and extended driving range when compared with battery-electric vehicles. The Hyundai Tucson and the Toyota Mirai are the examples of fuel cell electric vehicles. [12]

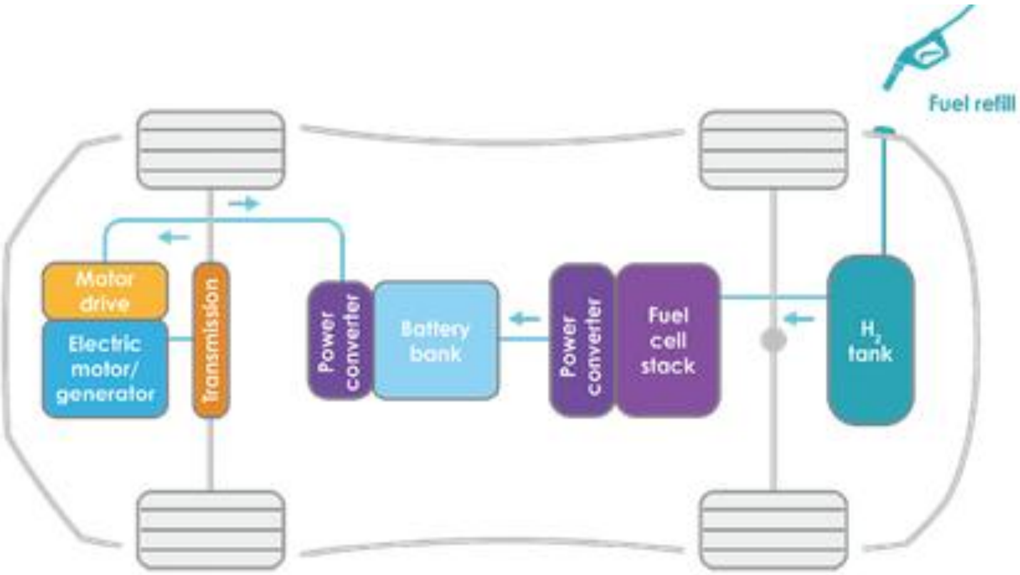


FIGURE 10. Fuel cell electric vehicle (TU Delft)

3.8 Comparison between HEV, PHEV, BEV and FCEV

Hybrid Electric Vehicles and Plug-In Hybrid Electric Vehicles are powered by both an internal combustion engine and an electric motor that uses energy stored in a battery. The battery is charged by the internal combustion engine for both. For a PHEV, the vehicle can be plugged into an electric power source to charge the battery. Battery Electric Vehicles use no fossil fuel and have zero tail-pipe emissions. Like a PHEV, the EV batteries are charged by plugging the vehicle into an electric power source. Finally, an FCEV uses fuel cell powered by hydrogen and battery to power vehicle using an electric drivetrain. [13]

Table 2. Comparison of HEV, PHEV, BEV and FCEV (TU Delft)[13]

	HEV	PHEV	BEV	FCEV
Battery size	Around 1-2 kWh	5-10 kWh	15-100 kWh	1-2 kWh
Driving with a nearly empty battery	400-700 km on fossil fuel	30 to 100 km battery electric driving range: 400-700km on fossil fuel	100-400 km battery electric driving range	400-700 km on hydrogen fuel
Charge & fuel refilling	Battery charging only during driving; refill fuel tank from fuel stations	Battery charging from the grid and during driving; Refill fuel tank from fuel stations	Battery charging only from the electricity grid	Refill hydrogen fuel tank from fuel stations
Fuel economy & efficiency	Higher fuel economy than similar ICE vehicles (ICEVs)	Higher fuel economy than ICEVs; Higher fuel economy than similar HEVs for electric driving from the battery charged from the grid.	Higher fuel economy than similar HEVs &ICEVs; Comparable fuel economy as PHEVs for electric driving from the battery charged from the grid	Higher fuel economy than similar ICEVs
Emission	Less than similar ICE vehicle	Less than similar HEV	Zero tailpipe emission	Zero harmful emission, water is by-product

4 EV CHARGING

4.1 Parts of EV Charger

To charge an electric car from the AC grid, the power has to be converted from AC to DC. An EV charging system has three main parts. The first part is the AC-DC power electronic converter. This converts the power from AC to DC. The second part is the charging cable with a connector that is used to feed power from an external power supply to the electric car via the vehicle inlet. Third part is a charge controller on the external power supply side and a battery management system on the vehicle side. These are responsible for the communication, protection, and control of the charging process. They control the charging current and stop the charging in case of overcharging, complete draining short circuit or overvoltage of the battery. It also ensures that the temperature and balancing between the cells are optimal for long battery life. To charge an electric car, AC power from the electricity grid is fed to the car via the vehicle inlet using the charging cable and connector. [14]

Figure 11 shows mode 1. This mode requires slow AC charging via a regular electrical socket. There is no connection between the vehicle and the charging point. It is needed to provide an earth wire to the EV and have an external means of protection against faults. In many countries, this form of charging is viewed to be unsafe. [14]

4.2 AC Charging

Figure 11. Mode 1 (TU Delft)

Figure 12 shows mode 2: This mode entiles for slow AC charging from a regular electricity socket. In addition, the charging cable is equipped with an In-Cable Control and Protection Device (IC-CPD), that is responsible for control, communication and protection (including residual current protection). Figure 12. Mode 2 (TU Delft) [14]

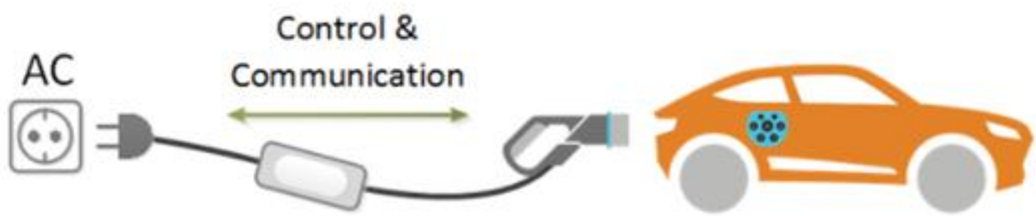


Figure 12. Mode 2 (TU Delft)

Figure 13 shows Mode 3: This mode entails both slow or semi-fast charging via a dedicated electrical socket for EV charging. The charger (or the charging station) has an EV specific socket, generally corresponding to Type 1 or Type 2. A charging cable with an EV plug on both sides is used to connect the EV to the charger. The charging station is responsible for the control, communication and protection of the charging process (including residual current protection). This mode is commonly used for public charging stations and can facilitate integration with smart grids. [14]

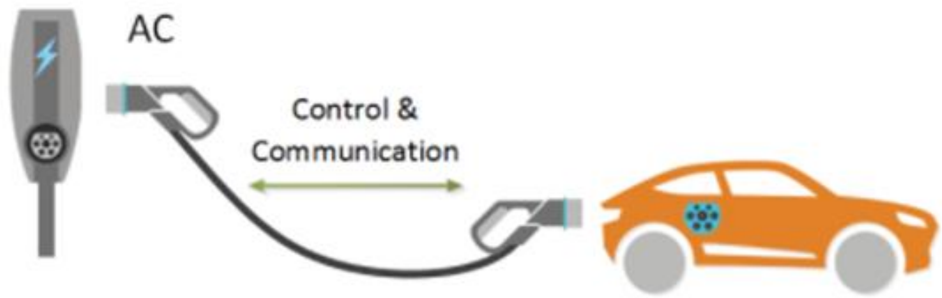


Figure 13: Mode 3 (TU Delft)

Figure 14 shows Mode 4: uses a dedicated electrical socket for EV charging like Mode 3. The charger typically has a charging cable with an EV charging plug. Mode 4 is specifically used for DC charging, which is recommended for fast charging of an electric vehicle. In the case of DC. [14]

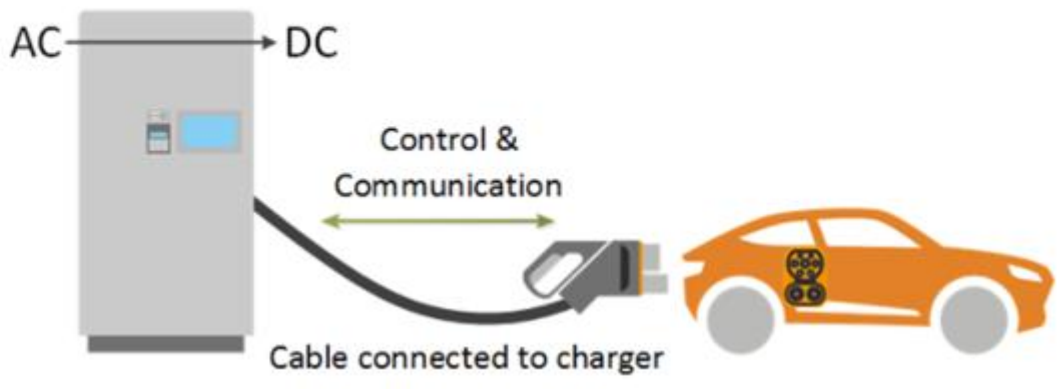
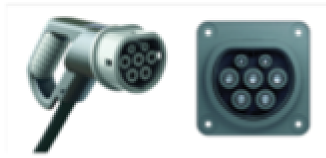


Figure 14. Mode 4 (TU Delft)

4.3 AC Connectors

AC and DC charging are characterized by the connector type and the charging power levels that can be reached. For AC charging, Type 1 connector is commonly used in USA and Japan, while the Type 2 and the less common Type 3 connectors are used in Europe. Tesla uses its proprietary connector in USA-Japan while it uses the type 2 connector in Europe. Other parts of the world are often adopting the Type 2 connector as it can work with both 230V single phase and 400V three phase connections. [15]

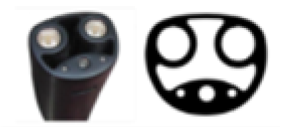
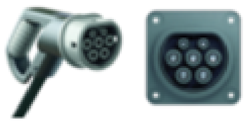
Table 3. AC Connectors (TU Delft)

USA - Japan	Europe	China
Type 1  Tesla AC 	Type 2, Tesla AC  Type 3 	Based on Type 2 

4.4 DC Connectors

In terms of DC charging, the CHAdeMO Type 4 connector is used by Japanese car manufacturers globally, while the American and European car manufacturers have adopted a combined AC/DC connector called the CCS-COMBO. Interestingly, Tesla uses the same connector meant for AC charging as well as for DC charging. In the case of China, they have their own DC connector. [15]

Table 4. DC Connectors (TU Delft)

USA- Japan	Europe	USA-Japan-Europe	China
Tesla DC 	Tesla DC 	Chademo 	GB/T 
Combo 1: Combined AC & DC 	Combo 2: Combined AC & DC 		

The main difference is that in DC charging the AC-to-DC power converter is placed outside the vehicle in an off-board charger and hence the charging power can be as high as 350kW. In case of AC charging, the onboard charger is used which is usually restricted to less than 22kW.
The conclusion is that EV industry has not agreed on one specific connector, so depending on the car brand, country and whether it is AC or DC charging, the connector varies in shape, size, and pin configuration. [15]

5 ELECTRIC VEHICLES

5.1 Driving technique

The technique of driving an electric car is the same as when moving an internal combustion vehicle with an automatic electronic transmission. Certain differences can be seen while increasing the speed. The electric motor has a maximum torque from the start. As a result, it accelerates evenly from any speed. A common mistake is to assume that all electric cars have autonomous driving systems. Technologies are interrelated only with the fact that their popularization took place at the same time. As a result, many manufacturers of electric cars use some autonomous facilities - similar to the new models of internal combustion cars. There are some indications that in the next years the service of electric cars will change significantly. One of the announcements may be a new, electric Nissan Leaf. Talking about a car controlled with only one pedal. Pressing the pedal drives the vehicle, and releasing results in braking. The system was called e-Pedal. If it is accepted by the purchasers of the Leaf model, it can be expected that in a short time it will also reach other models. [16]

5.2 Range

Many people pay attention to the low ranges of electric cars. The latest generation of Nissan Leaf can travel 380 km. The competitive Renault ZOE will travel 400 km. The slightly larger Volkswagen e-Golf will stop after traveling a maximum of 300 km. Against this background, Tesla S positively distinguishes itself with the range declared at a level exceeding 550 km. The record achieved on this model is 900 km. However, it was achieved in quite specific conditions at a speed of 40 km/h.

The results declared by producers are generally heavily inflated. However, this practice is no different from that used in internal combustion cars that are really unable to reach catalog ranges. All thanks to synthetic test conditions. In the meantime, dozens of factors influence the range of everyday driving, including driving technique, weather conditions, surface, used tires, the degree of exhaustion of the car, and even the weight of the driver. The range of electric cars can clearly decrease during severe frosts when energy consumption is higher. In addition to heating the driver's cabin, low temperatures also require reheating the batteries. Currently, when deciding to buy an electric car, one must bear in mind that it will be a vehicle created primarily for urban driving. [17]

5.3 Loading problems

A lot of emotions and questions are also raised by the issue of charging electric cars. First of all, to use this vehicle effectively, it is worth having a charging point at the house. At the same time, specialized infrastructure is not necessary. The classic 230 V electrical socket in the garage is a source of energy compatible with all electric cars. The charging time in this way mean an additional range at a level slightly exceeding 10 km. During the night it is possible to get a range of about 100 km. For most users this will be a sufficient result for commuting to work. It's definitely better if we have at least one 16A / 400V socket in the house. They can be found in many garages, workshops and industrial buildings. Its use allows to increase the efficiency of charging up to five times. Thanks to this, its possible to fully charge the batteries overnight. Sockets with 32A protection are an even better solution. They can be found at special recharging points located in city centers and on parking lots of office buildings or shopping malls. They allow to charge many models of electric cars in less than 2 hours.

Maps with marked charging points are available on the Internet. Unfortunately, such a list must be approached with reserve. Many stations offer low charging efficiency or require specific services located in the station to use the charger free of charge. In addition, some stations located on washes or gas stations may be closed when there is no qualified employee responsible for their service on site. The vision of loading the car during rain or snow arouses some anxiety. Fortunately, plugs for charging electric cars are properly protected and even heavy rain will not lead to a short circuit. [18]

5.4 Weight, dimensions and drawbacks

The batteries have slightly larger dimensions and weight than the fuel tank. It can be assumed that an electric car will usually be 200-300 kg heavier than its combustion equivalent. For example, e-Golf has a total weight of 1585 kg, of which the weight of accumulators and accessories is 318 kg. The equivalent of the 1.4 TSI engine weighs 1268-1290 kg, depending on the equipment version. Theoretically, the use of an electric motor can negatively affect the size of the vehicle or passenger cabin. However, this problem is not as severe as it may seem. Most manufacturers have already developed solutions that allow the electric drive to be deployed in places where exhaust models have exhaust system components or fluid reservoirs. Thanks to this, electric models can have identical dimensions as combustion equivalents. If the car is designed from the ground up as an electrical construction, it gives even more possibilities to arrange the vehicle. The transmission of electricity is less demanding than the hydraulics and mechanics of internal combustion cars. [19]

5.5 Service and exploitation

One of the basic questions posed in the context of electric cars is the durability of batteries. Most manufacturers provide an eight-year cell guarantee. The first brand that had to face the problem of used batteries was Nissan. New batteries for the Leaf model have been priced at over 5,500 Euro.

A slightly cheaper solution will be the replacement of batteries for regenerated cells; in this case, the costs should not exceed 2,5000 euro. The Japanese brand also took care of the processing of used elements and together with Sumitomo Corporation created the venture 4R Energy Corporation, which is the world's first factory specialized in the recycling of batteries from electric cars.

One of the concepts developed by Nissan and Sumitomo is the The Reborn Light project. Its purpose is to build public lighting in the city of Namie, which suffered as a result of a tsunami seven years ago. Batteries with Nissan Leaf will be used for independent power supply of new road lanterns. They will replace the existing, destroyed infrastructure, while protecting the network in the event of an earthquake and flood. Some brands use a different concept of battery operation. A good example is Renault, offering the purchase of a car in two options. The user can buy a vehicle with a battery or lease the batteries from the manufacturer. New links were valued at 7,000 euro, while the rent is around 100 euro per month, depending on the distance covered. [19]

5.6 Driving economies

The most often considered issue related to the economy of electric cars is fuel savings. Electric cars charged in the night tariff can cover 100 km for about 1 euro, which is the amount close to the price of a liter of fuel. This means, in fact, that even the most economical combustion cars will cost us five times more. Skeptics point out that electric cars are much more expensive to buy. For example, an electric Smart Fortwo costs about 22,600 euros. The combustion model is about 12,000 euros. Even larger price differences occur with larger models. The disproportion of purchase prices will be difficult to reduce in a few years on the fuel itself. Fortunately, the price of electricity is not the only factor generating savings. Electric cars are definitely easier to build. They do not burn, they use less fluid and mechanical elements. It is estimated that an electric motor fails 200-1000 times less often than an internal combustion equivalent. The fuel, air and oil filters replaced annually are an expense that we will not experience in an electric vehicle. In addition, for the sake of energy recovery systems, brake pads for cars on the road wear up to 10 times slower. The annual savings on repairs and exchanges can thus reach up to several thousand euros.
It is also worth paying attention to additional financial benefits flowing from driving an electric car. They can be an important asset if someone regularly travel abroad. Drivers can enjoy free parking in the city and even subsidies and tax exemptions. [20] [21]

5.7 Batteries and safety

Concerns about the dangers of using electric cars do not only apply to charging. After all, most users of conventional cars travel with a tank filled with a flammable substance, located just under the seats. Meanwhile, the most anxious situation seems to arise when the electric car suffers an accident. However, electric cars, similarly to combustion structures, are subject to homologation requirements and undergo crash tests. Following the assurance of producers, the batteries should not be ignited or spilled in the event of an accident. [19]

5.8 Superiority of electric vehicles

Many people, perhaps even most people in the world, do not realize that cars can drive "electric" instead of on petrol, oil, or gas. This is not surprising, because for decades, electric cars were on the sidelines and they did not get much attention. Unfortunately, those who know about the existence of electric cars do not always believe that they are better than currently used cars with internal combustion engines. This is also not surprising, as most people try to apply proven, well-known solutions and avoid major changes.

If only we have available electricity, the electric vehicle will be driving almost for free compared to the combustion vehicle. It is true that for decades people have been unable to store enough energy in batteries to allow electric cars to overcome long distances. This lack of knowledge, technology and materials was the main reason for the marginalization of electric cars. Currently, however, everything has changed. With the development of batteries (many varieties) that can accumulate a very large amount of energy and which can be recharged in just a few minutes, no one will stop electric cars from taking a dominant position in the market over the next several decades.

Some manufacturers of combustion cars have known for a long time about the superiority of electric cars over diesel. Initially, they implemented hybrid cars for production, which were combustion cars with an additional electric motor (the main task of the electric part of the drive was to recover energy from braking and reuse it when starting off). Today, new hybrid cars and plug-in hybrid can be recharged from an electrical outlet. Thus, there is a clear tendency to move away from the use of self-propelled internal combustion engines and the growing importance of the electric part in hybrid cars.

However, hybrid vehicles are not a target, but only an intermediate one, because they have several disadvantages. Hybrid cars are more complicated than combustion cars, and they are usually from 1.5 to 2 times more expensive. When driving a hybrid car, usually only one of the drive parts is used - electric or diesel, and the other is then a ballast. It is an indisputable fact that a hybrid car traveling for example 400 km will burn more fuel than a traditional internal combustion car (with identical diesel engine) due to its smaller mass and simpler construction. [22]

5.9 Electrification

Electrification is the most viable way to achieve clean and efficient transportation that is crucial to the sustainable development of the whole world. In the near future, electric vehicles will dominate the clean vehicle market. As shown in Table 5., the current major battery technology used in EVs in Li-ion batteries because of its mature technology. Due to the potential of obtaining higher specific energy and energy density, the adoption of Li-ion batteries is growing fast in EVs, particularly in PHEVs and BEVs. It should be noted that there are several types of Li-ion batteries based on similar but certainly different chemistry. [23]

Table 5. Batteries used in electric vehicles of selected car manufacturers. [23]

COMPANY	COUNTRY	VEHICLE MODEL	TYPES OF EV	BATTERY AND CAPACITY
Toyota	Japan	Prius PHV (Prime) Prius (fourth generation) Prius (fourth generation) Aqua (Prius C)	PHEV HEV HEV HEV	Li-ion, 8.8 kWh, Ni-MH,1.31 kWh Li-ion, 0.75 kWh Ni-MH, 0.94 kWh
Nissan	Japan	Leaf	BEV	Ni-ion, 30 kWh
Honda	Japan	Accord Hybrid Fit (Jazz) Hybrid	HEV HEV	Li-ion, 30kWH Li-ion, 1.3 kWH
Mitsubishi	Japan	i-MiEV Outlander	BEV PHEV	Li-ion, 16 kWh Li-ion, 12 kWh
BMW	Germany	i3	BEV	Li-ion, 33 kWh
Mercedes-Benz	Germany	x5 xDrive40e	PHEV	Li-ion, 9.0 kWh
Audi	Germany	B250e	HEV	Li-ion, 28 kWh
Volkswagen	Germany	e-Golf	BEV	Li-ion, 35.8 kWh
Volvo	Sweden	XC90 T8	PHEV	Li-ion, 9.0 kWh
Fiat	Italy	500e	BEV	Li-ion, 24 kWh
Tesla	The United States	Model S	BEV	Li-ion, 60-100 kWh
General Motors	The United States	Chevrolet Volt	PHEV	LI-ion, 18.4 kWh
Ford	The United States	C-MAX Energi	PHEV	Li-ion, 7.6 kWh
Hyundai	Korea	Sonata Hybrid	HEV	Li-polymer, 1.6 kWh

6 ELECTRIC VEHICLES MARKET ANALYSIS [24]

6.1 Electric vehicles in Finland

In Finland, electromobility is at an early stage of development, but it is dynamic development. In 2016 there were 1500 electric cars in the whole country (compared to 2015, this is a jump of 117.5%). The Finnish Ministry of Transport prioritizes the development of electric buses.
Passenger cars are in second place, however, tax incentives (excise reduced from 50% to 5%) are used anyway.The Finns have carefully prepared for change. The EVE program is of key importance, thanks to which the electric vehicles market and their infrastructure in Finland will grow from EUR 200 million in 2010 to EUR 2 billion in 2020. In the first phase, the car charging network will be expanded. The Finnish authorities are supposed to encourage drivers to buy vehicles.
The components of the program are research projects that are supposed to bring solutions tailored to users. In this regard, five specialized platforms are created, such as: Electrictraffic.fi, EUL-Eco Urban Living, EOV - Electric Commercial Vehicles, the national research center EVELINA and WintEVE - a platform for testing electromobility in Arctic conditions.
An important role in the development of the project is supported by IT industry. Its activities are to combine a collective transport system, mobility as a service, individual electric cars and vehicle charging systems.
Finland, like other countries with a similar climate, has a very large number of parking spaces, armed with terminals to power engine heating - which at low temperatures have problem with starting. In case of Finland, it is said that for about 3 million cars there are more than million places with terminals.
In general, the power supply of 16 A should be sufficient for free charging with power of over 3kW and for heating the interior.
The Finnish company Parkkisähkö is trying to use the niche by implementing a system that allows simple authorization and billing as well as remote control of the power supply. [25] [26]

6.2 Electric vehicle in Norway

A model example of the development of electromobility in the Nordic countries is Norway. Over 120,000 vehicles are already on the Norwegian roads powered by plug-in. Electromobility is not new anymore. Preparations for electrification transport in Norway are since 1992 and were limited not only to technology or changes in law. After subsequent crises on the fuel markets, Norwegian universities joined, among others modernization study programs in a way to educate the professions of the future electric vehicle industry. This example shows how wide the view is required in electromobility development. The Norwegian rise of electromobility was caused by huge amount of subsidies but also by access to cheap energy. Norway has been firmly in favor of the disappearance of diesel vehicles from its roads. Residents, however, expect that forcing them to give up diesel will be connected with preferential conditions for purchasing electric cars. The government in Oslo is considering limiting the previous benefits, and the strongest Norwegian organization of drivers of electric vehicles postulates their preservation. In turn, Christina Bu, secretary of the Norwegian Association Electric Vehicles, believes that the decision to buy an electric car is influenced by various factors. One of them are subsidies, but it is also important where someone lives (access to the night charging socket), how far someone gets to work every day, whether someone has access to charging points in the city. In Norway, there is no national educational program to encourage or teach Norwegians how to perceive electromobility. Recently, however, actions have been taken to integrate the environment of users of electric vehicles through rallies, trips to distant tourist attractions or joint trips. The non-governmental organization Norsk elbilforeni prepares these integration activities. [27] [28]

Norwegian Ministry of Transportation and Communication has gradually developed generous incentives to continue the development of EV market throught the country over the years.
Table 6 summarizes the national incentives and policies in Norway; Figenbaum and Kolbenstvedt [23]

Table 6. Summary of the national incentives and policies in Norway [23]

Incentives	Year
Fiscal incentives reduction of purchase price	
Exemption from registration tax	1990/1996
Exemption from VAT	2001
Reduction annual vehicle licence fee	1996/2004
Reduced company car tax	2000
Direct subsides users reducing usage costs and range challenges	
Free toll roads	1997
Exemption from paying car ferry fees	2009
Financial support for charging stations	2009
Financial support for fast charge stations	2011
Reduction of time costs and giving relative advantages	
Access to bus lanes	2003/2005
Free parking	1999

6.3 SWOT analysis

Table 7. SWOT analysis [29]

STRENGTHS	WEAKNESSES
• low cost of use and servicing • the use of the latest technology allows to reduce the cost of usege by more than half • environmentally friendly • high energy efficiency • efficiency of combustion engine ~ 35%, electric ~ 85% • zero exhaust - no emission of harmful gases • quiet, comfortable • raise social awareness about environmental protection • modern design • prestige	• higher cost of production by about 30% compared to conventional cars • limited travel range • one charge is enough to drive about 400km (fumes ~ 900km) • long charging time • battery life • no noise - danger in pedestrian traffic
OPPORTUNITIES	THREATS
• government support • tax breaks when buying electric cars • funding • free parking and charging in some countries • growing public awareness about environmental protection • technology development • faster charging • greater range • lower costs of use and service	• lack of cooperation between car manufacturers • over 7 different types of chargers • not developed charging infrastructure • battery durability • price uncertainty in the secondary market

6.4 PESTLE analysis

1) Political:

The worldwide automobile industry is an enormous, multi billion industry with several well-known brands rivaling for marketplace. It was founded in the beginning of 19th century. There are several having an impact on auto industry. In terms of revenue this sector is an essential part of the global economy. The growth and revenue of vehicle industry are influenced by several forces. Besides of manufacturing of cars globally, this sector is also engaged in the marketing and sales. The Asian market is an important market for the automotive industry. China has especially grown-up to become the world's largest market for cars. Vehicle manufacturers are concentrating more on environmental friendliness. The industry has been forced to use more pollution control systems. The major car manufacturers are trying to produce more fuel effective and low emission vehciles. The sales no emission, electric cars all over the world is growing. The European Union has rigorous regulations even it comes to gasoline engine vehciles.

2) Economical:

Economic factors are also of special significance in terms of of the automotive industry. In several markets the taxes on expensive vehicles are high. If case of good economic conditions the sales of vehicles can continue to be high. In the developed countries the sales are recorded to be superior. All countries worldwide can produce electricity themselves, so that they will not have to import increasingly expensive foreign oil. Electricity can be obtained in a variety of ways, with different fossil fuels, biomass as well as from renevable sources thanks to this the economy becomes less vulnerable. Electric cars are characterized by very high efficiency, thanks to which the distance covered is even several times cheaper than with an internal combustion car.

3) Social:

Nowadays, people are more and more aware of the envoronment and being eco-friendly. The automotive market is highly influenced by the social and cultural factors. At the moment almost every car manufacturer is releasing electric vehicle model in the market. Brands are competing for market shares. In certain cultures particular styles are liked more and in some are not accepted.

4) Technological:

In the automotive industry technology and innovation have become crucial factor. The most innovative company are dominating the market. All major car manufacturers are investing huge amounts of money in research and development, as well as in electric vehicles, which are environmental friendly and low in emission. The electric car does not have to have a gearbox or clutch, making it possible to travel comfortably (especially in a traffic jam). Sports electric cars do not require changing gears, achieving very good acceleration. Electric motors are incomparably quieter than combustion ones, which sometimes allows "noiseless" travel and comfortable listening to music. The noise that arises because of moving the electric car, reaches the level of 40 dB, the same as the operating fridge emits. For comparison, a diesel-powered car emits in urban traffic an average of 60-70 dB, bus combustion - 90 dB.

5) Legal:

Law influence the profitability and efficiency of the car brands. Law concerning pollution rates have been more strict in recent years. Vehicles, which are later exported overseas need to pass rigorous emission control tests. Laws connected to product safety have also crucial impact on vehciles.In competitive international market, car companies have to cope with several laws, such as restrictive environmental, tax and few other laws.

6) Environmental:

Worldwide the laws connected with the environment friendly and low carbon emissions are becoming more strict. All the automotive brands are focusing more on producing low emission cars. Government supports those vehicle manufacturers, which produce low emissions cars. Passing pollution test is harder and more strict. In 21st century being eco-friendly is a crucial determinant for vehicle manufacturers. Governments have made pollution control as a priority. The extraction of any fossil fuel, its delivery to the power plant and conversion to electricity, and then sending electricity to the recipient, charging the electric vehicle batteries and converting electricity into the electric vehicle is a more economical process than extracting foreign oil, delivering it to the refinery and conversion to fuel, delivery of fuel to a gas station (to the customer) and use of fuel to drive the combustion vehicle. Electric cars have no tail-pipe emissions. This factor helps in reduction of pollution due to carbon di-oxide, sulphur oxides and improves the liveability and air quality in the cities. When electric cars are charged with electricity generated from renewable energy sources such as wind turbines or solar photovoltaic panels, the emissions due to the electricity generation is zero. It is because electric vehicles can store the surplus of renawable energy by charging EV with solar energy in a day time and with wind in the night. Electric cars can recover electricity from braking, increasing their range while driving, for example, in the city or in the mountains. The use of regenerative braking results in a significant reduction in brake wear. Energy recovery also has its ecological aspect.[30]

6.5 Usage rate analysis

Statistics show that in the end of 2017 China had the largest numberof plug-ins vehicles with over 1.2 million units. When it comes plug-in electric buses China also dominates this market with stock reaching over 343, 000 units. In comparison in 2016 out of global stock in 2016 was less than 345,000 units. About 943,600 passenger vehicles had been registered in 2017 in Europe around 943,600 passenger plug-ins had been registered. Norway was a leading market with over 200,000 vehciles. In 2016 Norway had the highest market growth in the world with and over 5% of all vehicles were plug-ins. In 2017 Norway was also a world's leader when it comes to new car sales plug-in segment with 39.2%. In the end of 2017 the USA had about 765,000 plug-in cars. California was reaching about 48% of total US plug-in sales with over 365,000 vehicles. At the end of 2017 Japan had about 207,200 plug-ins, and about 2,250 EVs were registered in 2016. In 2016 the Finland's government set the goal to reach the number of 250,000 plug-in vehicles and over 50,000 biogas vehciles by 2030. In Germany there have been rise in number of plug-in electric cars with the number of 129,246 vehicles. Germany is Europe's largest passenger vehicle market and fall into category of fifth when it comes to in plug-in vehcile sales. Around 80% of the plug-ins in Germany were registered since 2014. [31]

Table 8. Passenger plug-in vehicle market share of new car sales between 2013 and 2017 for selected countries and selected regional markets [31]

Country	2017	2016	2015	2014	2013
Norway	39.2%	29.1 %	22.39 %	13.84 %	6.10 %
Iceland	14.05%	4.6%	2.93%	2.71%	0.94%
Sweden	5.2%	3.5%	2.62%	1.53%	0.71%
Belgium	2.68%	1.8 %	N/A	N/A	N/A
Netherlands	2.6%	6.7%	9.9%	3.87 %	5.55%
Finland	2.57%	1.2%	N/A	N/A	N/A
Switzerland	2.55%	1.8 %	1.98 %	0.75 %	0.44%
China	2.1%	1.31 %	0.84 %	0.23%	0.08%
Austria	2.06%	1.6 %	0.90 %	N/A	N/A
France	1.98%	1.4 %	1.19 %	0.70%	0.83%
UK	1.86%	1.37%	1.07%	0.59%	0.16%
USA	1.13%	0.90%	0.66%	0.72%	0.60%
Japan	1.1%.	0.59%	0.68%	1.06%	0.91%
Denmark	0.4%	0.6%	2.29 %	0.88%	0.29%
Estonia	0.2%	0.3%	N/A	1.57 %	0.73 %
California	4.8%	3.5%	3.1%	3.2%	2.5%
Europe	1.74%	1.3%	1.41%	0.66%	0.49%
Hong Kong	N/A	5%	4.84%	N/A	0.39%

7 ENVORONMENTAL APPLICATIONS OF ELECTRIC VEHICLES

According to research, in the tunnels, multi-level car parks and near petrol stations, the concentration of pollutants is sometimes 4 to 40 times higher than the average for the entire urban area. A research conducted in London showed that the concentration of some pollutants is several times higher inside the car than the ambient concentration. Therefore, the driver of the car after driving a given section of the city has a much higher concentration of carbon monoxide in the blood than the cyclist who crossed the same section. A bus that emits a little more exhaust than a passenger car transports as many as 70 cars in the city and 30 cars outside the city. In this way, collective transport is much less harmful to the environment than individual transport. Bicycle is even better - it does not emit any pollution. Most car journeys in cities take place on a stretch of up to 5 km - almost every bicycle can cover this distance. Part of the emitted exhaust gases and dust settles near the road. Studies have shown that, although 50 meters from the road, the level of contamination contained in the soil decreases, but even soils are contaminated even at a distance of 500 meters from the road. Automobile fumes are much more harmful to people than industrial pollutants, as automotive pollution is spreading at high concentrations at low altitudes in the immediate vicinity of people. Road transport vehicles are responsible for the following percentage of the overall emission of harmful substances:

- 63% nitrogen oxides

Nitrogen oxides are emitted into the atmosphere, where they combine with water vapor, and then return to the earth's surface in the form of acid rain. Acid rain destroys plants, causes acidification of water and soil. Nitrogen oxides are also precursors to carcinogenic compounds. They contribute to the formation of photochemical smog. In humans, they reduce the body's resistance to bacterial infections, irritate the eyes and airways, cause breathing disorders, are the cause of asthma.

- 50% of organic chemicals

- 80% carbon monoxide

It is a highly toxic gas, contributes to the formation of photochemical smog. It connects with hemoglobin, blocks the transport of oxygen in the blood. It causes respiratory problems, heart problems, headaches and dizziness, nausea and sight problems. At higher concentration it causes death. In places of high car traffic, in tunnels, in the car parks, a high concentration of this gas is found.

- 10-25% of dust suspended in the air

- 6.5% sulfur dioxide

Emitted to the atmosphere, it combines with steam to form sulfuric acid, then returns to the earth in the form of acid rain or is a component of the so-called acid fog. Acidic rains acidify the soil causing its depletion in nutrients by rinsing. Heavy metals are released from the acidified soil, which, at low pH, are dissolved and taken up by plant roots, and also pollute the water. Soil acidification is particularly harmful in forest ecosystems.

7.1 London type smog

A high concentration of flue gas in the air can lead to smog formation. There are two types: London type smog and Los Angeles type smog.

London type smog occurs in the winter period at a temperature of -3 ÷ + 5 ° C. It is mainly caused by air pollution due to emissions of sulfur dioxide and dust from the combustion of coal and petroleum products. Although coal combustion is the main cause of this type of smog, emissions from transport also contribute to this phenomenon. Contamination in combination with fog causes the formation of droplets of sulfuric acid suspended in the air. London smog reduces the visibility of up to several dozen meters, has a corrosive effect on buildings, is harmful to plants. In humans, it causes dyspnoea, irritates the eyes and skin, disrupts the work of the circulatory system.

7.2 Los Angeles type smog

Los Angeles type smog usually appears in the summer months, at temperatures above +26 ° C. It is formed in the troposphere, the lowest layer of the atmosphere, when very high concentrations of ozone, carbon monoxide, sulfur dioxide, nitrogen oxides and fine dust occur in it. Under the influence of insolation, some air pollutants undergo photochemical reactions creating toxic compounds that cause cancer and genetic mutations, e.g. acetyl peroxide nitrate (PAN). It forms in urbanized, densely populated areas. The concentrations of pollutants in photochemical smog are usually very high and exceed the air quality standards recommended by WHO (World Health Organization).

7.3 The greenhouse effect

It is caused by excessive emission of gases: carbon dioxide, methane, nitrogen oxides, freons, as well as some types of hydrocarbons. The solar radiation reaching the Earth's surface is absorbed by it (a small part is reflected) and converted into heat. The heated surface of the Earth emits heat radiation, which is largely absorbed by the greenhouse gases contained in the atmosphere. Such a situation causes a gradual warming of the Earth's climate.

According to WWF (World Wildlife Foundation), the global average temperature has risen by 0.7 ° C over the last hundred years. Scientists note increased ice melting at the poles. The cause of this phenomenon is indicated by the climate warming. Scientists warn that raising the average temperature on Earth by 2 ° C will melt the glacier covering Greenland.

Melting glaciers pose a real threat to the rise of the sea and oceans, resulting in the flooding of lower-lying lands and coastal depression. According to WWF, the rise of the Baltic Sea level may threaten the flooding of almost 2,000 km2 of the land area of Poland. This will be affected by 18 holiday resorts, five large ports and houses of 120,000 people living in threatened areas.

Researchers recognize the greenhouse effect as the cause of hurricanes, floods and drought of unprecedented proportions. The latest research results warn against a much faster rate of warming than previously thought. It is predicted that by the end of this century the temperature may rise even by 5 ° C in the tropical zone, and in the temperate zone (which includes Poland) by 8 ° C, which will cause even greater intensity of natural disasters.

According to Greenpeace, even an immediate cessation of greenhouse gas emissions will not cause a sudden improvement of the situation due to the long "life" of gases in the atmosphere. It also takes a long time for the atmosphere to absorb the accumulated heat. The Kyoto Protocol is unlikely to meet its expectations, as the reduction needs of the Intergovernmental Panel on Climate Change reach 60-70%. The protocol does not cover rapidly industrializing countries like China, India or Brazil, in which greenhouse gas emissions are growing rapidly. [32] [33] [34]

7.4 Lithium Resources

Currently, in new electric cars, different types of lithium-ion batteries are most often used, because they actually only provide vehicles with good performance. As the production of electric cars on a mass scale will in the future be associated with a significant increase in the demand for lithium-ion batteries, many people wonder if there is enough lithium available in the world to produce them. Lithium (Li) is the lightest metal that belongs to the group of alkali metals. In batteries, depending on type both lithium in metallic form and lithium compounds with other elements are used. Lithium consumption for batteries has increased significantly in recent years. In the growing market for: portable electronic, electric tools, electric vehicles, and grid storage applications, rechargeable lithium batteries are used extensively. [35]

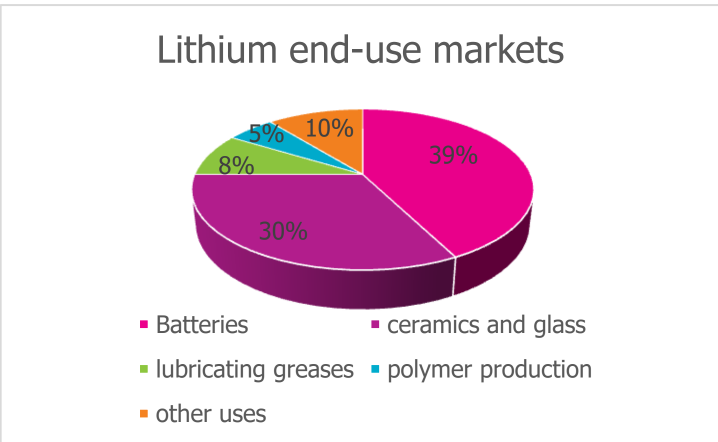


FIGURE 15. Estimated lithium resource % in the world in tonnes according to various sources. [35]

The largest producers of lithium in the world are: Chemetall (USA / Chile), SQM (Chile), Admiralty Resources (Australia and South America) and CITIC Guoan Lithium (China).

Table 9: Annual production of lithium in tonnes in 2015 and 2016 plus reserves. [35]

Country	Mine production 2015	Mine production 2016	Reserves
USA			38,000
Argentina	3,600	5,700	2,000,000
Australia	14,100	14,300	1,600,000
Brazil	200	200	48,000
Chile	10,500	12,000	7,500,000
China	2,000	2,000	3,200,000
Portugal	200	200	60,000
Zimbabwe	900	900	23,000
World total (rounded)	31,500	35,000	14,000,000

8 ELECTRIC VEHICLES EXAMPLES

8.1 Jaguar I-PACE

Jaguar I-PACE is an electric SUV presented on March 1, 2018, just before the Geneva Motor Show 2018.
The serial production will start in 2018 at the Magna Steyr plant in Graz, Austria.
The I-PACE structure is fully aluminum. A flat packet of 90 kWh batteries is placed between the axes, and 147 kW each with traction motors. In terms of charging, they were placed on a 7 kW on-board charger and a fast loading of CCS Combo with a power of up to 100 kW (0-80% in 40 minutes). The car has a heat pump that heats the cabin and a battery pack that uses engine heat loss and power electronics, improving the range in winter by up to 50 km at 0 ° C. Comfortable driving is ensured by air suspension. [36]

Figure 16. Jaguar I-Pace

WLTP -The Worldwide Harmonised Light Vehicle Test Procedure so pollutant and CO2 emissions as well as fuel consumption values would be comparable worldwide.

EPA - The United States Environmental Protection Agency maintains test methods, which are approved procedures for measuring the presence and concentration of physical and chemical pollutants. [36]

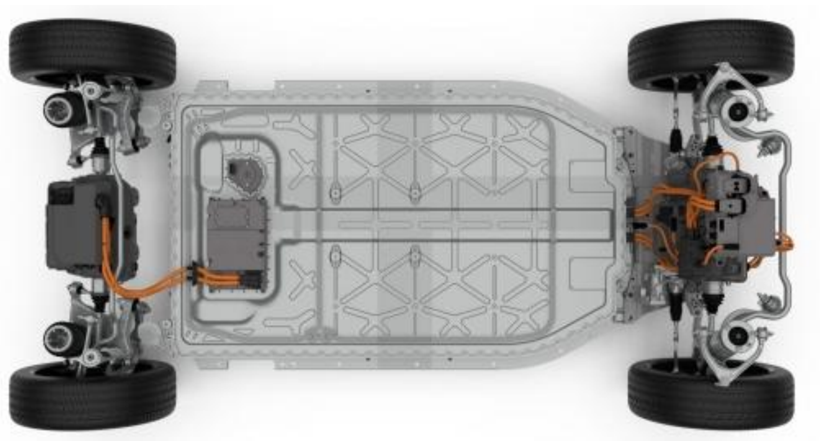


Table 10. Batteries [36]

Type:	lithium-ion, laminated, NMC (LG Chem cells)
Charging time	approx. 12.9 hours on-board charger with 7 kW
Charging time	0-80%: about 10 hours on-board charger with 7 kW
Fast charging time	0-80%: about 40 minutes with an external CCS Combo charger with 100 kW
Energy accumulated in batteries:	about 40 minutes with an external CCS Combo charger with 100 kW
Energy accumulated in batteries:	about 90 kWh
Number of modules:	36 (12 cells each)
Number of links:	432
Warranty for batteries:	160,000 km or 8 years for losing 30% of the initial capacity
Cooling / heating package:	Liquid

8.2 BMW i3s

The BMW i3s is a sporty version of the BMW i3. The car is slightly wider and lower than the standard BMW i3, has wider tires, and its drive is characterized by better performance. The differences in appearance are mainly details that emphasize the sporty style.
The power has been increased by 10 kW to 135 kW, and the torque is 20 Nm to 270 Nm, but the most important is the change in the characteristic, which gives a higher moment (acceleration) in the higher speed range. Acceleration from 80 to 120 km/h improved by 0.8 s (from 5.1 s to 4.3 s), while from 0 to 60 km/h only by 0.1 s (from 3.8 s to 3.7 s). The maximum speed is also higher (160 km/h instead of 150 km/h). [37]

Figure 17. BMW i3s

Table 11. Batteries [37]

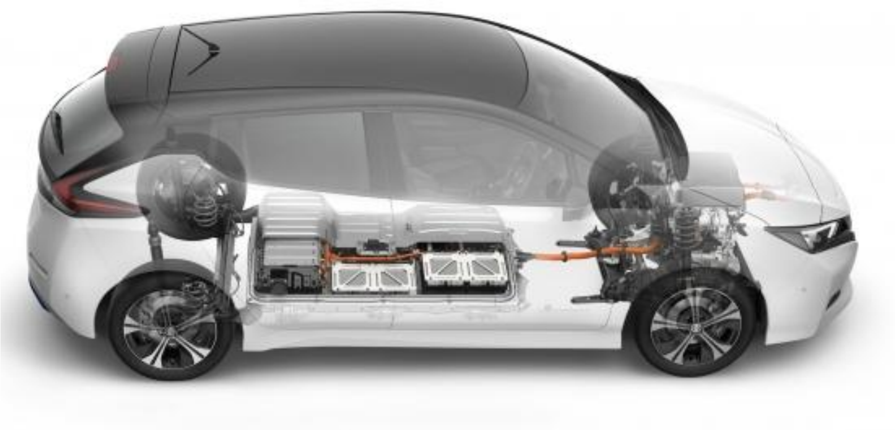
Type:	lithium-ion (cells 94 Ah from Samsung SDI)
Charging time	0-100%: approx. 7: 30h on-board charger with 3.7 kW or 3: 45h power, optional 7.4 kW charger or in Europe 2: 45h with optional 11 kW three-phase charger
Fast charging time	0-80%: about 39 minutes with an external 50 kW CCS Combo charger
Energy accumulated in batteries:	approximately 33.2 kWh (27.2 kWh available)
Nominal voltage of the package:	353 V

8.3 Nissan Leaf II

The car is a thoroughly redesigned second generation Nissan Leaf offered in 2010-2017. The new Leaf debuted in September 2017. and will be offered in Japan from October 2017, and in Europe and North America from January 2018. Ultimately, the car will be sold in more than 60 countries around the world. Leaf II is offered with a 40-kWh battery pack, which is enough for about 250 km of driving - 243 km in EPA tests. According to European tests WLTP range in a mixed cycle (with rather delicate driving) 285 km (16-inch wheels) and 270 km (17-inch wheels).
The drive uses a motor with a maximum power of 110 kW.
Leaf's prices at the time of launch are at a similar level as the previous generation Leaf prices with the 30-kWh package. [38]

Table 12. Batteries [38]

Type:	lithium-ion
Charging time	0-100%: approx. 16 h on-board charger with 3 kW, approx. 8 h on-board charger with 6 kW
Fast charging time	time 0-80%: about 40 minutes with an external CHAdeMO charger
Energy accumulated in batteries:	about 40 kWh
The nominal voltage of the package:	350 V



Nissan Leaf 2018

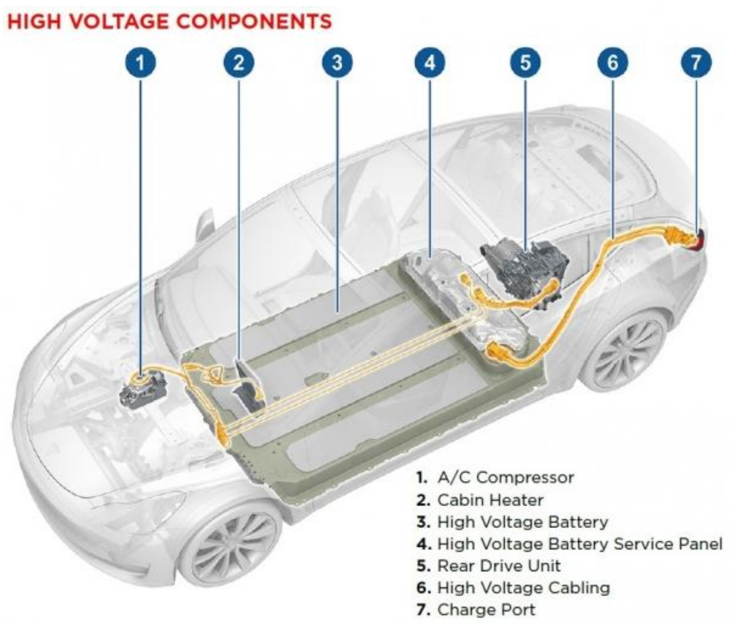
Nissan Leaf 2018 - traction drive and battery pack

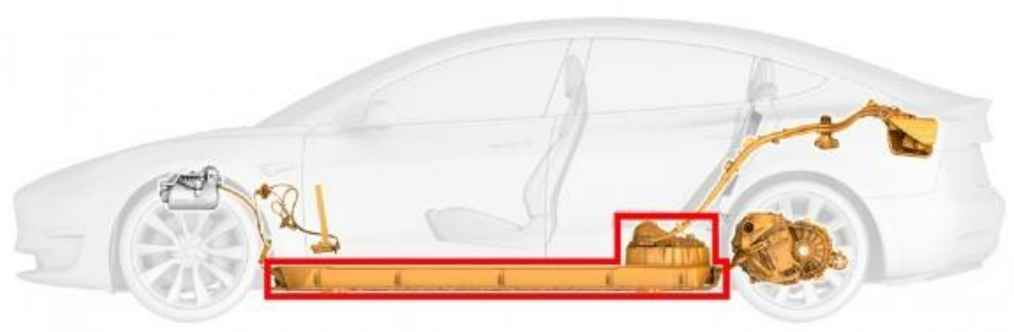
8.4 Tesla Model 3

The Tesla Model 3 is positioned 350 km (standard) and is 500 km long (Long Range Range). Tesla Model 3 brings a lot of unique solutions, ranging from authorization through the application in the phone (or a card, in size corresponding to the payment card), peculiar door handles or a 15-inch central touch screen. Model 3 is equpped with a floor-mounded 400 volt lithium-ion high voltge battery. [39]

Table 13. Batteries [39]

Type:	lithium-ion, 2170 lithium-ion cells (Tesla / Panasonic)
Charging time:	0-100%: 9.6 kW onboard charger (240 V, 40 A)
Fast charging time	0-80%: about 30 minutes charging from the Supercharger completes the 270 km range
Energy accumulated in batteries:	unofficially 70-75 kWh
Warranty:	4 years or 80,000 km per car and 8 years or 193 thousand km per battery pack





8.5 Bus Volvo 7900 Electric

Buses Volvo 7900 Electric is a 12-meter electric bus presented at the Busworld 2015 exhibition. The production and sale of the Volvo 7900 Electric began in 2016 as a complement to the Volvo 7900 Electric Hybrid buses.

The Volvo 7900 Electric is a short-reach vehicle that requires fast charging in a few minutes with a power of 300 kW for normal use. The Swedish manufacturer intends to offer this type of buses complete with Siemens or ABB quick recharging stations. Fast loading in a few minutes is enough for about 10-20 km for overcoming the route.

Among the advantages, Volvo emphasizes the aluminum body, low floor and bright interior. An interesting fact is the 2-speed gearbox. The energy consumption is supposed to be 80% lower than in the case of an internal combustion equivalent. [40]

Table 14. Batteries [40]

Type:	lithium-ion
Charging time:	full equalization 4 h, fast on route (up to 300 kW) - a few minutes (3-6 minutes is enough for about 10 km, 1 minute charging adds 5-10 minutes)
Energy accumulated in batteries:	about 76 kWh (4x 19 kWh)
Nominal voltage of the package:	600 V
Cooling / heating package:	liquid

Figure 18. Bus Volvo 7900 Electric

9 CONCLUSION

In the 21st century electrification, automation, sustainability and connectivity will be the future of the mobility. In emerging economies there will be a bigger pressure on industrialisation and urbanisation. Companies will be investing a lot of money in sustainable technologies. There is a certain rise in new technologies.[41] New era of Industry 4.0, Internet of things and digitalisation are the global trends and have a huge impact on automative industry, but also on many other. Consumers are changing their preferences, many are becoming more aware of environment and electric vehicles. Today, consumers are using their vehicles for every purpose: business, commuting to work, shopping, vacation, and leisure time. In the future they will choose an optimal mobility solution for each different specific purpose. Car sharing is a growing industry, with applications such as Uber. In the future the automative makers will be focusing on producing zero emission, zero congestion, zero energy, zero accident, zero empty and zero cost vehicles. That means that cars will be eco-friendly, more efficient using renewable electricity, using automated or autonomous cars, trucks and busses and safer. Cars will be connected to data exchange via internet of things using it to a full capacity. People will preferably share cars using big data and saving money. In recent years cars have been incrementally advancing alongside developing technologies from cruise control and GPS navigation systems, to blue-tooth connectivity and parking sensors. When talking about Intertent of things in terms of transportation smart cars and autonomous or driverless vehicles have been developed.The concept of cars being able to drive themselves without human assistance is now a reality. The number of electric cars being produced will be growing rapidly. In the coming years, more than a dozen new models of electric vehicles will appear on the market. EV could achieve another function, which is called vehicle-to-grid V2G. When the grid is overloaded in the peak time then electric car can reinforce their power to support the grid. The new era of electric car is really promising.

REFERENCES

[1] Electric vehicle definition. From Electric Vehicle News
Available from: http://electricvehiclesnews.com/Definition/description.htm

[2] Electric vehicle history. From Edison Tech center
Available from: http://orcutt.net/weblog/wp-content/uploads/2015/07/History-of-Electric-Cars.pdf

[3] Measurement of power loss during electric vehicle charging and discharging. From Elsevier
Availabe from: https://www.sciencedirect.com/science/article/pii/S0360544217303730

[4] How do all-electric cars work? From U.S department of Energy
Available from: https://www.afdc.energy.gov/vehicles/how-do-all-electric-cars-work

[5] Battery types. From Electric and hybrid vehicles by A. Khajepour, S. Fallah, A. Goodarzi, 2014

[6] Types of electric vehicle. From Ergon energy
Available from: https://www.ergon.com.au/network/smarter-energy/electric-vehicles/types-of-electric-vehicles

[7] Internal combustion car. From how stuff works
Available from: https://auto.howstuffworks.com/engine1.htm

[8] Hybrid electric vehicle. From U.S department of energy
https://www.afdc.energy.gov/vehicles/how-do-hybrid-electric-cars-work

[9] HEV series and HEV series parallel. From Union of Concerned Scientists
Available from: https://www.ucsusa.org/clean-vehicles/electric-vehicles/series-vs-parallel-drivetrains#.Wv6SA0iFNaQ

[10] Plug in Hybrid electric car. From U.S department of energy
Available from: https://www.afdc.energy.gov/vehicles/how-do-plug-in-hybrid-electric-cars-work

[11] Battery electric vehicle. From Wikipedia, the free encyclopedia
Available from: https://en.wikipedia.org/wiki/Battery_electric_vehicle

[12] Fuel cell electric vehicle. From U.S department of energy
Available from: https://www.afdc.energy.gov/vehicles/how-do-fuel-cell-electric-cars-work

[13] Comparison between HEV, PHEV, BEV and FCEV. From Union of Concerned Scientists
Available from: https://blog.ucsusa.org/josh-goldman/comparing-electric-vehicles-hybrid-vs-bev-vs-phev-vs-fcev-411

[14] Parts of EV charger. From electric vehicle charging station guidebook
Available from: https://www.driveelectricvt.com/Media/Default/docs/electric-vehicle-charging-station-guidebook.pdf

[15] Charging speeds and connectors. From zap mag
Available from: https://www.zap-map.com/charge-points/connectors-speeds/

[16] Driving technique. From Fleet carma
Available from: https://www.fleetcarma.com/training-guide-new-electric-car-drivers/

[17] Electric vehicle range. From Egon Energy

Available from: https://www.ergon.com.au/network/smarter-energy/electric-vehicles/electric-vehicle-range

[18] Electric vehicle loading problems. From Fleet carma
Available from: https://www.fleetcarma.com/impact-growing-electric-vehicle-adoption-electric-utility-grids/

[19] Electric vehicle battery. From battery university
Available from: http://batteryuniversity.com/learn/article/electric_vehicle_ev

[20] What a teardown of the latest electric vehicles reveals about the future of mass-market EVs. From McKinsey & Company Automotive & Assembly
Available from: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/what-a-teardown-of-the-latest-electric-vehicles-reveals-about-the-future-of-mass-market-evs

[21] EV maintenance. From how stuff works
Available from: https://auto.howstuffworks.com/will-electric-cars-require-more-maintenance.htm

[22] The global electric vehicle market is amped up and on the rise. From McKinsey & Company Automotive & Assembly
Available from: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-global-electric-vehicle-market-is-amped-up-and-on-the-rise

[23] Electric Vehicles. Prospectc and challenges. T. Muneer, M. Lal Kolhe, A. Doyle 2017

[24] Which countries are speeding ahead with electric cars? From world economic forum
Available from: https://www.weforum.org/agenda/2016/04/which-countries-are-doing-most-to-embrace-electric-cars/

[25] Finland is a battery powerhouse for electric vehicles. From invest in Finland
Available from: https://www.investinfinland.fi/-/finland-is-a-battery-powerhouse-for-electric-vehicles

[26] Electric cars off to a sputtering start in Finland. From Yle uutiset
Available from: https://yle.fi/uutiset/osasto/news/electric_cars_off_to_a_sputtering_start_in_finland/9610785

[27] Electric cars in Norway. From Life in Norway
Available from: https://www.lifeinnorway.net/electric-cars/

[28] Norway leads way on electric cars: 'it's part of a green taxation shift'. From The Guardian
Available from: https://www.theguardian.com/environment/2017/dec/25/norway-leads-way-electric-cars-green-taxation-shift

[29] Benefits of electric vehicle. From Ergon Energy
Available from: https://www.ergon.com.au/network/smarter-energy/electric-vehicles/benefits-of-electric-vehicles

[30] Powering the future of mobility. Deloitte Insights.
Available from: https://www2.deloitte.com/insights/us/en/focus/future-of-mobility/power-utilities-future-of-electric-vehicles.html

[31] Usage of electric car by country. Wikipedia, the free encyclopedia
Available from: https://en.wikipedia.org/wiki/Electric_car_use_by_country

[32] The rise of electric car could leave us with a big battery waste problem. From The Guardian
Available from: https://www.theguardian.com/sustainable-business/2017/aug/10/electric-cars-big-battery-waste-problem-lithium-recycling

[33] Car pollution. From Environmental protection uk
Available from: https://www.torfaen.gov.uk/en/Related-Documents/Pollution-Control/PollutionControl-IdlingVehicles/Car-Pollution-Booklet.pdf

[34] Air pollution from motor vehicles. Standards and technologies for controlling emissions.
Available from: http://www.un.org/esa/gite/iandm/faizpaper.pdf

[35] Mineral commodity Summaries 2017. From UDGS science for a changing world.
Available from:

[36] Jaguar I-Pace
Available from: https://www.jaguar.com/jaguar-range/i-pace/index.html

[37] BMW i3s
Available from: https://www.bmw.com/en/bmw-models/bmw-i3.html

[38] Nissan Leaf II
Available from: http://nissannews.com/en-US/nissan/usa/releases/overview-2018-nissan-leaf

[39] Tesla Model Available from:
https://www.tesla.com/sites/default/files/downloads/2017_Model_3_Emergency_Response_Guide_en.pdf

[40] Bus Volvo 7900 Electric
Available from: http://www.volvobuses.co.uk/en-gb/our-offering/buses/volvo-7900-electric.html

[41] The future of mobility turns electric. From ethical corporation
Available from: http://www.ethicalcorp.com/top-stories-2017-1-future-mobility-turns-electric

SAVONIA